| *Substitute for Form 1449/PTO* | | |
|---|---|---|
| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** | Application # | To Be Determined |
| | Confirmation # | |
| | Filing Date | Concurrently Herewith |
| | First Inventor | Yuasa |
| | Art Unit | |
| | Examiner | |
| Sheet 1 of 1 | Docket # | NAGI.0003 |

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| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
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| Exam. Initial* | Country-Number-Kind Code if known | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
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| | EP 1 633 007 A2 + | 3/8/2006 | Anelva Corporation | | Yes |
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|---|---|---|---|
| Examiner Signature | | Date Considered | |

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

** Corresponds to U.S. Patent 2007/0128470, U.S. Patent 2004/0144995, WO2002/099905, and EP1 391 942, listed above.

*** Corresponds to U.S. Patent 2004/0245553, WO 2003/085750, and EP 1 494 295, listed above.

**** Corresponds to U.S. Patent 2006/0056115, listed above.

+ = Filed in Parent Application 10/591,947

DocCode - SCORE

# SCORE Placeholder Sheet for IFW Content

Application Number: **12923643** Document Date: **09/30/2010**

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Form Revision Date: December 8, 2006

PATENT APPLICATION SERIAL NO._____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

10/01/2010 AWONDAF1 00000069 12923643

| | |
|---|---|
| 01 FC:1011 | 330.00 OP |
| 02 FC:1111 | 540.00 OP |
| 03 FC:1311 | 220.00 OP |
| 04 FC:1201 | 660.00 OP |

PTO-1556
(5/87)

*U.S. Government Printing Office: 2002- 489-267/69033

PTO/SB/06 (12-04)
Approved for use through 7/31/2006. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

**Filing Date:** 09/30/10

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

## PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

12/923,643

### APPLICATION AS FILED – PART I

| FOR | (Column 1) NUMBER FILED | (Column 2) NUMBER EXTRA | SMALL ENTITY RATE ($) | SMALL ENTITY FEE ($) | OR | OTHER THAN SMALL ENTITY RATE ($) | OTHER THAN SMALL ENTITY FEE ($) |
|---|---|---|---|---|---|---|---|
| BASIC FEE (37 CFR 1.16(a), (b), or (c)) | | | | | | | 330 |
| SEARCH FEE (37 CFR 1.16(k), (l), or (m)) | | | | | | | 540 |
| EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | | | | | | | 220 |
| TOTAL CLAIMS (37 CFR 1.16(i)) | 16 minus 20 = | | X 26 = | | | X 52 = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | 6 minus 3 = | 3 | X 110 = | | | X 220 = | 660 |
| APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $270 ($135 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | | | |
| MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j)) | | | N/A | | | N/A | |
| * If the difference in column 1 is less than zero, enter "0" in column 2. | | | TOTAL | | | TOTAL | 1750 |

### APPLICATION AS AMENDED – PART II

| | | (Column 1) CLAIMS REMAINING AFTER AMENDMENT | | (Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR | (Column 3) PRESENT EXTRA | SMALL ENTITY RATE ($) | SMALL ENTITY ADDITIONAL FEE ($) | OR | OTHER THAN SMALL ENTITY RATE ($) | OTHER THAN SMALL ENTITY ADDITIONAL FEE ($) |
|---|---|---|---|---|---|---|---|---|---|---|
| AMENDMENT A | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X = | | OR | X = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X = | | OR | X = | |
| | Application Size Fee (37 CFR 1.16(s)) | | | | | | | OR | | |
| | FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | N/A | | OR | N/A | |
| | | | | | | TOTAL ADD'T FEE | | OR | TOTAL ADD'T FEE | |

| | | (Column 1) CLAIMS REMAINING AFTER AMENDMENT | | (Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR | (Column 3) PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | OR | RATE ($) | ADDITIONAL FEE ($) |
|---|---|---|---|---|---|---|---|---|---|---|
| AMENDMENT B | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X = | | OR | X = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X = | | OR | X = | |
| | Application Size Fee (37 CFR 1.16(s)) | | | | | | | OR | | |
| | FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | N/A | | OR | N/A | |
| | | | | | | TOTAL ADD'T FEE | | OR | TOTAL ADD'T FEE | |

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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15915 U.S. PTO
093010

U.S. PTO
12/923643
09/30/2010

| CUSTOMER NO. | 38327 |
|---|---|

# CONTINUATION/DIVISIONAL APPLICATION TRANSMITTAL

(Rule 53(b) Continuation or Divisional) ☐ DUPLICATE

Address to: **Assistant Commissioner of Patents**
**Box Patent Application**
**Alexandria, VA 22313-1450**

| | |
|---|---|
| Attorney Docket No.: | NAGI.0003 |
| First Named Inventor: | Yuasa |
| Total Pages: | |

This requests a ☒ Continuation or ☐ Divisional application under 37 CFR §1.53(b) of prior application:

| | | | |
|---|---|---|---|
| Appln. No.: | 10/591,947 | Group Art Unit: | 2892 |
| Filed on: | September 8, 2006 | Examiner: | Alonzo Chambliss |
| Inventors | SHINJI YUASA | | |
| Entitled: | MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME | | |

☒ 1. The entire disclosure of the pending, prior application is hereby incorporated by reference.

☐ 2. Submitted herewith is a copy of the complete prior application as filed.

☐ 3. This application is filed by fewer then all the inventors named in the prior nonprovisional application, 37 CFR 1.53(b)(1). DELETE the following inventor(s):

☒ 4. Submitted herewith is a copy of the signed Oath/Declaration from the prior application.

☐ 5. Small entity status was established in the prior application, and is still proper and desired.

☐ 6. A _____ month Petition for Extension of Time is filed concurrently in the prior application.

☒ 7. The Commissioner is authorized to credit any overpayment and charge any deficiency in any fees required under 37 CFR § 1.16 and/or 1.17 to Deposit Account No. 12-0555.

☒ 8. Credit Card Form 2038 in the amount of $ 1,790.00 for filing and Assignment Recordation fees is submitted herewith.

☐ 9. Insert before the first sentence of the specification:

☐ 10. Cancel in this application original claims _____ of the prior application before calculating filing fee.

☒ 11. The prior application is assigned of record to: Japan Science and Technology Agency and National Institute \ of Advanced Industrial Science and Technology.

☒ 12. Priority is claimed from U.S. 10/591,947 filed on September 8, 2006, which claims priority from PCT/JP2005/004720 filed on March 10, 2005, which claims priority from Japanese Application Nos. 2004-313350 and 2004-071186 filed October 28, 2004 and March 12, 2004, respectively, the content of which is hereby incorporated by reference into this application.

☐ 13. A Preliminary Amendment is enclosed.

☒ 14. Other: Information Disclosure Statement with Form PTO-1449.

| THE FILING FEE IS CALCULATED AS FOLLOWS: | | | | BASIC FEE (FILING, EXAMINATION AND SEARCH FEES): | $1,090.00 |
|---|---|---|---|---|---|
| Total Claims: | 16 | -20 = | | × $52 = | 0 |
| Independent claims: | 6 | -3 = | 3 | × $220 = | 660.00 |
| | | | | Multiple Dependent Claim (Add $360.00): | 0 |
| | | | Total Pages | 36 -100 | 0 |
| | | | | Subtotal: | 1,750.00 |
| | | | | 50% Reduction if Small Entity Status: | 0 |
| | | | | Total: | 1,750.00 |

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| Date: | Name: | Signature: | Reg. No. |
|---|---|---|---|
| September 30, 2010 | Juan Carlos A. Marquez | | 34,072 |

APPLICATION FOR
# UNITED STATES LETTERS PATENT

OF

SHINJI YUASA

FOR

# MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

WD EX1004
Western Digital v IP Bridge

# MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

## [0001] CROSS-REFERENCE TO RELATED APPLICATION

[0002] The present application is a Continuation of U.S. Application 10/591,947 filed on September 8, 2006, which is a National Stage Application of PCT/JP2005/004720 filed on March 10, 2005. Priority is claimed from U.S. 10/591,947 filed on September 8, 2006, which claims priority from PCT/JP2005/004720 filed on March 10, 2005, which claims priority from Japanese Application Nos. 2004-313350 and 2004-071186 filed October 28, 2004 and March 12, 2004, respectively, the content of which is hereby incorporated by reference into this application.

## [0003] BACKGROUND OF THE INVENTION

### [0004] Field of the Invention

[0005] The present invention relates to a magnetic tunnel junction device and a method of manufacturing the same, particularly to a magnetic tunnel junction device with a high magnetoresistance and a method of manufacturing the same.

### [0006] Description of Related Art

[0007] Magnetoresistive random access memories (MRAMs) refer to a large-scale integrated memory circuit that is expected to replace the



WD EX1004
Western Digital v IP Bridge
Page 9

currently widely used DRAM memories. Research and development of MRAM devices, which are fast and non-volatile memory devices, are being extensively carried out, and sample products of a 4Mbit MRAM have actually been delivered.

[0008] Fig. 8 shows the structure and operation principle of a magnetic tunnel junction device (to be hereafter referred to as a "MTJ device"), which is the most important part of the MRAM. As shown in Fig. 8(A), a MTJ device comprises a tunnelling junction structure in which a tunnel barrier (to be hereafter also referred to as a "barrier layer") made of an oxide is sandwiched between a first and a second electrode made of a ferromagnetic metal. The tunnel barrier layer comprises an amorphous Al-O layer (see Non-Patent Document 1). As shown in Fig. 8(A), in the case of parallel magnetization alignment where the directions of magnetizations of the first and second ferromagnetic electrodes are aligned parallel, the electric resistance of the device with respect to the direction normal to the interfaces of the tunneling junction structure decreases. On the other hand, in the case of antiparallel magnetization alignment where the directions of magnetizations of the first and second ferromagnetic electrodes are aligned antiparallel as shown in Fig. 8(B), the electric resistance with respect to the direction normal to the interfaces of the tunneling junction structure increases. The resistance value does not change in a general state, so that information "1" or "0" can be stored depending on whether the resistance value is high or not. Since the parallel and antiparallel magnetization alignments can be stored in a non-volatile fashion, the device can be used as a non-volatile memory device.



WD EX1004
Western Digital v IP Bridge
Page 10

[0009] Fig. 9 shows an example of the basic structure of the MRAM. Fig. 9(A) shows a perspective view of the MRAM, and Fig. 9(B) schematically shows a circuit block diagram. Fig. 9(C) is a cross-section of an example of the structure of the MRAM. Referring to Fig. 9(A), in an MRAM, a word line WL and a bit line BL are disposed in an intersecting manner, with an MRAM cell disposed at each intersection. As shown in Fig. 9(B), the MRAM cell disposed at the intersection of a word line and a bit line comprises a MTJ device and a MOSFET directly connected to the MTJ device. Stored information can be read by reading the resistance value of the MTJ device that functions as a load resistance, using the MOSFET. The stored information can be rewritten by applying a magnetic field to the MTJ device, for example. As shown in Fig. 9(C), an MRAM memory cell comprises a MOSFET 100 including a source region 105 and a drain region 103 both formed inside a p-type Si substrate 101, and a gate electrode 111 formed on a channel region that is defined between the source and drain regions. The MRAM also comprises a MTJ device 117. The source region 105 is grounded, and the drain is connected to a bit line BL via the MTJ device. A word line WL is connected to the gate electrode 111 in a region that is not shown.

[0010] Thus, a single non-volatile MRAM memory cell can be formed by a single MOSFET 100 and a single MTJ device 117. The MRAMs are therefore suitable where high levels of integration are required.

[0011] Non-Patent Document 1: D. Wang, et al.: Science 294 (2001) 1488.



WD EX1004
Western Digital v IP Bridge
Page 11

[0012] SUMMARY OF THE INVENTION

[0013] Although there are prospects for achieving MRAMs with capacities on the order of 64Mbits based on the current technologies, the characteristics of the MTJ device, which is the heart of MRAM, needs to be improved if higher levels of integration are to be achieved. In particular, in order to increase the output voltage of the MTJ device, the magnetoresistance must be increased and the bias voltage characteristics must be improved. Fig. 10 illustrates how the magnetoresistance in a conventional MTJ device using an amorphous Al-O as the tunnel barrier changes as a function of the bias voltage (L1). As shown, in the conventional MTJ device, the magnetoresistance is small and, notably, it tends to drastically decrease upon application of bias voltage. With such characteristics, the output voltage when operation margins are taken into consideration is too small for the device to be employed for an actual memory device. Specifically, the magnetoresistance of the current MTJ device is small at approximately 70%, and the output voltage is also small at no more than 200 mV, which is substantially half the output voltage of a DRAM. This has resulted in the problem that as the level of integration increases, signals are increasingly lost in noise and cannot be read.

[0014] It is an object of the invention to increase the output voltage of a MTJ device. It is another object of the invention to provide a memory device with a high magnetoresistance for stable operation.

[0015] In one aspect, the invention provides a magnetoresistive device comprising a magnetic tunnel junction structure comprising: a tunnel barrier



WD EX1004
Western Digital v IP Bridge
Page 12

layer; a first ferromagnetic material layer of the BCC structure formed on a first side of the tunnel barrier layer; and a second ferromagnetic material layer of the BCC structure formed on a second side of the tunnel barrier layer, wherein the tunnel barrier layer is formed by a single-crystal $MgO_x$ (001) layer or a poly-crystalline $MgO_x$ ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented.

[0016] The invention further provides a magnetoresistive device comprising a magnetic tunnel junction structure comprising: a tunnel barrier layer comprising MgO(001); a first ferromagnetic material layer comprising Fe(001) formed on a first side of the tunnel barrier layer; and a second ferromagnetic material layer comprising Fe(001) formed on a second side of the tunnel barrier layer, wherein the MgO layer is formed by a single-crystalline $MgO_x$ (001) layer or a poly-crystalline $MgO_x$ ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented. In a preferred embodiment, the band discontinuity value (the height of the tunnel barrier) between the bottom of the conduction band of the MgO(001) layer and the Fermi energy of the Fe(001) layer is smaller than an ideal value of a perfect single-crystal without defect. These features increase the magnetoresistance and thereby allow the output voltage of the MTJ device to be increased. By using any of the aforementioned MTJ devices as a load for a single transistor, a non-volatile memory can be formed.

[0017] In another aspect, the invention provides a method of manufacturing a magnetoresistive device comprising: preparing a substrate; depositing a first Fe(001) layer on the substrate; depositing a tunnel barrier layer on the



WD EX1004
Western Digital v IP Bridge
Page 13

first Fe(001) layer by electron beam evaporation under high vacuum, the tunnel barrier layer comprising a single-crystalline $MgO_x$ (001) or a poly-crystalline $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented; and forming a second Fe(001) layer on the tunnel barrier layer.

[0018] The invention furthermore provides a method of manufacturing a MTJ device comprising a first step of preparing a substrate comprising a single-crystalline $MgO_x$(001) or a poly-crystalline $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented, a second step of depositing a first Fe(001) layer on the substrate and performing an annealing process to make the surface flat, a third step of depositing a tunnel barrier layer on the first Fe(001) layer by electron beam evaporation, the tunnel barrier layer comprising a single-crystalline $MgO_x$(001) or a poly-crystalline $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented, and a fourth step of forming a second Fe(001) layer on the tunnel barrier layer. The method may further comprise the step of growing a seed layer between the first and the second steps, the seed layer comprising a single-crystalline $MgO_x$(001) or a poly-crystalline $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented. The MgO layer may be deposited using a target with the value of x in $MgO_x$ adjusted. The value of x in $MgO_x$ may be adjusted in the step of forming the MgO.

[0019] In yet another aspect, the invention provides a magnetoresistive device comprising a magnetic tunnel junction structure comprising a tunnel barrier layer comprising MgO(001), a first ferromagnetic material layer



WD EX1004
Western Digital v IP Bridge
Page 14

comprising an amorphous magnetic alloy formed on a first sideof the tunnel barrier layer, and a second ferromagnetic material layer comprising an amorphous magnetic alloy formed on a second side of the tunnel barrier layer, wherein the discontinuous value (the height of the tunnel barrier) between the bottom of the conduction band of the MgO(001) layer and the Fermi energy of the first or the second ferromagnetic material layer comprising the amorphous magnetic alloy is lower than an ideal value of a perfect single-crystal with no defect.

[0020] BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Fig. 1(B) shows the structure of a MTJ device according to a first embodiment of the invention, and Fig. 1(A) shows the energy band structure of a ferromagnetic metal Fe(001), illustrating the $E$-$E_F$ relationship with respect to the [001] direction of the momentum space.

[0022] Fig. 2(A) to Fig. 2(D) schematically show the process of manufacturing a MTJ device with a Fe(001)/MgO(001)/Fe(001) structure (to be hereafter referred to as a "Fe(001)/MgO(001)/Fe(001) MTJ device") according to an embodiment of the invention.

[0023] Fig. 3(A) shows a RHEED image of a Fe(001) lower electrode (a first electrode), and Fig. 3(B) shows a RHEED image of a MgO(001) barrier layer.

[0024] Fig. 4 shows the results of observing the quadrupole mass spectra in the deposition chamber during the MgO evaporation.



WD EX1004
Western Digital v IP Bridge
Page 15

[0025] Fig. 5 shows the film deposition rate dependency of the oxygen partial pressure during the MgO evaporation.

[0026] Fig. 6 shows typical magnetoresistance curves of the Fe(001)/MgO(001)/Fe(001) MTJ device.

[0027] Fig. 7(A) shows the bias voltage dependency of the MR ratio at room temperature, and Fig. 7(B) shows the output voltage $V_{out}$ of the MTJ device (=bias voltage × (Rap-Rp)/Rap).

[0028] Fig. 8 shows the structure of the MTJ device and its operating principle.

[0029] Fig. 9 shows an example of the basic structure of an MRAM, Fig. 9(A) showing a perspective view of the MRAM, Fig. 9(B) showing a schematic circuit diagram, and Fig. 9(C) showing a cross-sectional view of an example of its structure.

[0030] Fig. 10 shows how the magnetoresistance of a conventional MTJ device using an amorphous Al-O as the tunnel barrier changes depending on the bias voltage.

[0031] Fig. 11 shows the structure of a MTJ device according to a variation of the invention, corresponding to Fig. 1(B).



WD EX1004
Western Digital v IP Bridge
Page 16

[0032] DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0033] In the context of the present specification, because MgO has a cubic crystal structure (NaCl structure), the (001) plane, the (100) plane, and the (010) plane are all equivalent. The direction perpendicular to the film surface is herein considered to be the z-axis so that the film plane can be uniformly described as (001). Also in the context of the present specification, BCC structure, which the crystalline structure of ferromagnetic electrode layer, means body-centered cubic lattice structure. More specifically, BCC structure includes the BCC structure with no chemical ordering so-called A2-type structure, the BCC structure with chemical ordering such as B2-type structre and $L2_1$-type structure, and also the aforementioned structures with slight lattice distortion.

[0034] The term "ideal value" with regard to a perfect single-crystal without defect herein refers to a value that has been estimated from ultraviolet photoemission spectroscopy experiments (see W. Wulfhekel, et al.: Appl. Phys. Lett. 78 (2001) 509.). The term "ideal value" is used herein because the aforementioned state can be considered to be an upper limit value of the potential barrier height of the tunnel barrier of an ideal single-crystal MgO with hardly any oxygen vacancy defect or lattice defect.

[0035] Before describing the preferred embodiments of the invention, an analysis conducted by the inventors is discussed. The magnetoresistance (MR) ratio of a MTJ device can be expressed by the following equation:

[0036] $\Delta R/Rp = (Rap - Rp)/Rp$



WD EX1004
Western Digital v IP Bridge
Page 17

[0037] where Rp and Rap indicate the tunnel junction resistance in the cases of parallel and antiparallel magnetization alignments, respectively, of two electrodes. According to the Jullire's formula, the MR ratio at low bias voltage can be expressed by:

[0038] MR ratio = $(Rap - Rp)/Rp = 2P_1P_2/(1-P_1P_2)$, and

[0039] $P\alpha = (D\alpha \uparrow (E_F) - D\alpha \downarrow (E_F))/(D\alpha \uparrow (E_F) + D\alpha \downarrow (E_F)$,

[0040] where $\alpha = 1, 2$ (1)

[0041] In the above equations, $P\alpha$ is the spin polarization of an electrode, and $D\alpha \uparrow (E_F)$ and $D\alpha \downarrow (E_F)$ are the density of state (DOS) at the Fermi energy ($E_F$) of the majority-spin band and the minority-spin band, respectively. Since the spin polarization of ferromagnetic transition metals and alloys is approximately 0.5 or smaller, the Jullire's formula predicts a highest estimated MR ratio of about 70%.

[0042] Although the MR ratio of approximately 70% has been obtained at room temperature when a MTJ device was made using an amorphous Al-O tunnel barrier and polycrystalline electrodes, it has been difficult to obtain the output voltage of 200 mV, which is comparable to the output voltages of DRAMs, thereby preventing the realization of MRAM as mentioned above.

[0043] The inventors tried an approach to deposit a MTJ device in which the tunnel barrier comprises a single-crystal (001) of magnesium oxide (MgO) or a poly-crystalline MgO in which the (001) crystal plane is preferentially oriented. It is the inventors' theory that, because magnesium oxide is a



WD EX1004
Western Digital v IP Bridge
Page 18

crystal (where the atoms are arranged in an orderly fashion), as opposed to the conventional amorphous Al-O barrier, the electrons are not scattered and the coherent states of electrons are concerved during the tunneling process. Fig. 1(B) shows the MTJ device structure according to an embodiment of the invention. Fig. 1(A) shows the energy band structure of the ferromagnetic Fe(001), that is, the $E$-$E_F$ relationship with respect to the [001] direction of the momentum space. As shown in Fig. 1(B), the MTJ device structure of the present embodiment comprises a first Fe (001) layer 1, a second Fe (001) layer 5, and a single-crystalline $MgO_x$ (001) layer 3 or a poly-crystalline $MgO_x$ ($0 < x < 1$) layer 3 sandwiched therebetween, the polycrystalline layer having the (001) crystal plane preferentially oriented therein. According to the aforementioned Jullire's model, assuming that the momentum of the conduction electrons is preserved in the tunneling process, the tunneling current that passes through MgO would be dominated by those electrons with wave vector $k_z$ in the direction perpendicular to the tunnel barrier (normal to the junction interfaces). In accordance with the energy band diagram shown in Fig. 1(A) of Fe in the [001] ($\Gamma$-H) direction, the density of state (DOS) at the Fermi energy $E_F$ does not exhibit a very high spin polarization due to the fact that the sub-bands of the majority-spin and the minority-spin have states at the Fermi energy $E_F$. However, in case the coherent states of electrons are conserved in the tunneling process, only those conduction electrons that have totally symmetrical wave functions with respect to the axis perpendicular to the barrier would be coupled with the states in the barrier region and come to have a finite tunneling probability. The $\Delta 1$ band in the Fe(001) electrode has such totally symmetric wave functions. As shown in Fig. 1(A), the majority



WD EX1004
Western Digital v IP Bridge
Page 19

spin $\Delta 1$ band (solid line) has states at the Fermi energy $E_F$, whereas the minority spin $\Delta 1$ band (broken line) does not have state at the Fermi energy $E_F$. Because of such half-metallic characteristics of the Fe $\Delta_1$ band, there is the possibility that a very high MR ratio can be obtained in a coherent spin polarized tunneling. Since in an epitaxial (single-crystal, or (001) oriented poly-crystal) MTJ device the scattering of electrons is suppressed during the tunneling process, an epitaxial MTJ device is thought to be ideal for realizing the aforementioned coherent tunneling.

[0044] In the following, a MTJ device according to a first embodiment of the invention and a method of manufacturing the same will be described with reference to the drawings. Figs. 2(A) to 2(D) schematically show the method of manufacturing the MTJ device having the Fe (001)/MgO(001)/Fe(001) structure according to the embodiment (to be hereafter referred to as a "Fe(001)/MgO(001)/Fe(001) MTJ device"). Fe(001) refers to a ferromagnetic material with the BCC structure. First, a single-crystal MgO(001) substrate 11 was prepared. In order to improve the morphology of the surface of the single-crystal MgO(001) substrate 11, a MgO(001) seed layer 15 was grown by the molecular beam epitaxy (MBE) method. This was subsequently followed by the growth of an epitaxial Fe(001) lower electrode (first electrode) 17 with the thickness of 50 nm on the MgO(001) seed layer 15 at room temperature, as shown in Fig. 1(B), and then annealing was performed at 350°C under ultrahigh vacuum ($2 \times 10^{-8}$ Pa). Electron-beam evaporation conditions included an acceleration voltage of 8 kV, a growth rate of 0.02 nm/sec, and the growth temperature of room temperature (about 293K). The source material



WD EX1004
Western Digital v IP Bridge
Page 20

of the electron-beam evaporation was MgO of the stoichiometric composition (the ratio of Mg to O being 1:1), the distance between the source and the substrate was 40 cm, the base vacuum pressure was $1 \times 10^{-8}$ Pa, and the $O_2$ partial pressure was $1 \times 10^{-6}$ Pa. Alternatively, a source with oxygen vacancy defects may be used instead of the MgO of the stoichiometric composition (the ratio of Mg to O is 1:1).

[0045] Fig. 3(A) shows a RHEED image of the Fe(001) lower electrode (a first electrode). The image shows that the Fe(001) lower electrode (first electrode) 17 possesses a good crystallinity and flatness. Thereafter, a MgO(001) barrier layer 21 with the thickness of 2 nm was epitaxially grown on the Fe(001) lower electrode (first electrode) at room temperature, also using the MgO electron-beam evaporation method. Fig. 3(B) shows a RHEED image of the MgO(001) barrier layer 21. The image shows that the MgO(001) barrier layer 21 also possesses a good crystallinity and flatness.

[0046] As shown in Fig. 2(D), a Fe(001) upper electrode (a second electrode) 23 with the thickness of 10 nm was formed on the MgO(001) barrier layer 21 at room temperature. This was successively followed by the deposition of a Co layer 25 with the thickness of 10 nm on the Fe(001) upper electrode (second electrode) 23. The Co layer 25 is provided to increase the coercive force of the upper electrode 23 so as to realize the antiparallel magnetization alignment. The thus prepared sample was then processed by microfabrication techniques to obtain the Fe(001)/MgO(001)/Fe(001) MTJ device.



WD EX1004
Western Digital v IP Bridge
Page 21

[0047] The aforementioned MgO evaporation using an electron beam involved the formation of a film under ultrahigh vacuum of $10^{-9}$ Torr. It can be seen that in this method, the film, even when formed on a glass substrate to the thickness of 300 nm, was colorless and transparent, showing that a good crystal film was formed. Fig. 4 shows the results of observing the quadrupole mass spectra in the deposition chamber during the MgO growth. The results show that the partial pressures regarding the spectrum P1 of O and the spectrum P2 of $O_2$ are high. Fig. 5 shows the film deposition rate dependency of the oxygen partial pressure during MgO evaporation. It will be seen from the figure that the oxygen partial pressure itself is high, and that the oxygen partial pressure increases as the deposition rate increases. These results indicate the separation of oxygen from MgO during the deposition of MgO. Since the separated oxygen is pumped out of the deposition chamber using vacuum pumps, there is the possibility that there are oxygen vacancy defects such as $MgO_x$ ($0.9 < x < 1$). When there are oxygen vacancy defects, the potential barrier height of the MgO tunnel barrier is thought to decrease (such as in the range of 0.10 to 0.85 eV; more specifically, 0.2 to 0.5 eV), which is thought to result in an increase in the tunneling current. In the case of a typical Al-O tunnel barrier, the height of the tunnel barrier with respect to Fe(001) electrodes is considered to be 0.7 to 2.5 eV. An ideal tunnel barrier height of a MgO crystal is 3.6 eV, and experimental values of 0.9 to 3.7 eV have been obtained. Using the method according to the present embodiment of the invention, a tunnel barrier height of approximately 0.3 eV is expected, indicating that the resistance of the tunnel barrier can be lowered. However, it should be noted that other factors, such



WD EX1004
Western Digital v IP Bridge
Page 22

as the influence of the aforementioned coherent tunneling, might also be involved. The value of x in $MgO_x$ due to oxygen vacancy defects is such that $0.98 < x < 1$, and more preferably $0.99 < x < 1$. These are the ranges such that the sole presence of Mg is excluded and the characteristics of MgO can be basically maintained.

[0048] The aforementioned tunnel barrier height $\phi$ was determined by fitting the electric conductance characteristics of the MTJ device (the relationship between tunnel current density J and bias voltage V) onto the Simmons' formula (Equation (20) in a non-patent document by J. G. Simmons: J. Appl. Phys. 34, pp. 1793-1803 (1963)) based on the WKB approximation, using the least squares method. The fitting was performed using the free electron mass ($m = 9.11 \times 10^{-31}$ kg) as the electron's effective mass. When a bias voltage V (which is normally on the order of 500 mV to 1000 mV) is applied until non-linearity appears in the J-V characteristics, the height $\phi$ of the tunnel barrier and the effective thickness $\Delta s$ of the tunnel barrier can be simultaneously determined by fitting the J-V characteristics using the Simmons' formula.

[0049] The effective thickness $\Delta s$ of the tunnel barrier was determined to be smaller than the thickness of the actual MgO(001) tunnel barrier layer ($t_{MgO}$) determined from a cross-sectional transmission electron microscope image of the MTJ device by approximately 0.5 nm. This is the result of the effective thickness $\Delta s$ of the tunnel barrier having been reduced from the actual MgO(001) layer thickness by the effect of the image potential produced at the



WD EX1004
Western Digital v IP Bridge
Page 23

interface between the MgO(001) layer and the alloy layer consisting mainly of Fe and Co.

[0050] It is noted that, in the event that $t_{MgO}$ can be accurately determined using the cross-sectional transmission electron microscope (TEM) image, the height $\phi$ of the tunnel barrier can be more simply determined by the following technique. Namely, when the bias voltage V applied to the MTJ device is small (normally 100 mV or smaller), the tunnel current density J is proportional to the bias voltage V, such that the J-V characteristics become linear. In such a low-bias voltage region, the Simmons' formula can be described as follows:

[0051] $$J = [(2m\phi)^{1/2}/\Delta s](e/h)^2 \times \exp[-(4\pi\Delta s/h) \times (2m\phi)^{1/2}] \times V \qquad (2)$$

[0052] where m is the mass of the free electron ($9.11 \times 10^{-31}$ kg), e is the elementary electric charge ($1.60 \times 10^{-19}$C), and h is the Planck's constant ($6.63 \times 10^{-34}$ J·s). The effective thickness of the tunnel barrier $\Delta s$ is approximately $t_{MgO}$ – 0.5 nm. By fitting the J-V characteristics of the MTJ device in the low-bias voltage region onto Equation (2), the height $\phi$ of the tunnel barrier can be simply and yet accurately estimated.

[0053] Fig. 6 shows a typical magnetoresistance curve of the Fe(001)/MgO(001)/Fe(001) MTJ device produced by the above-described method. The MR ratio is 146% at the measurement temperature of 20K and 88% at the measurement temperature of 293K. These values represent the highest MR ratios that have so far been obtained at room temperature. Such high MR ratios cannot be explained by the spin polarization of the Fe(001)



WD EX1004
Western Digital v IP Bridge
Page 24

electrode and is thought rather to be related to a coherent spin-polarized tunneling. When 160 prototype MTJ devices were made, the variations regarding the MR ratio and tunneling resistance value were not more than 20%. The yield of the MTJ devices was 90% or more at the laboratory stage. These high values suggest the effectiveness of the approach of the invention. The resistance-area (RA) product of the MTJ device was on the order of a few $k\Omega\mu m^2$, which is suitable for MRAM.

[0054] Fig. 7(a) shows the bias voltage dependency of the MR ratio at room temperature. It will be seen that the bias voltage dependency of the MR ratio is fairly small. Although the characteristics are asymmetric, the voltage $V_{half}$ at which the MR ratio is reduced in half of the zero-bias value is 1250 mV, which is a very high value. In this connection, it is noted that the voltage $V_{half}$ at which the MR ratio is reduced in half of the zero-bias value in the conventional MTJs with Al-O tunnel barrier is 300 to 600 mV. Fig. 7(b) shows the output voltage $V_{out}$ of the MTJ device (=bias voltage × (Rap – Rp)/Rap). The maximum value of the output voltage $V_{out}$ is 380 mV with a positive bias. This value is about twice as large as that (a little less than 200 mV) in the case of the Al-O barrier. These high values in terms of both MR ratio and output voltage suggest the effectiveness of the technique according to the present embodiment.

[0055] Although in the above-described embodiment Fe(001) of BCC was employed, an Fe alloy of BCC, such as an Fe-Co alloy, Fe-Ni alloy, or Fe-Pt alloy, may be used instead. Alternatively, a layer of Co or Ni with the



WD EX1004
Western Digital v IP Bridge
Page 25

thickness of one or several monoatomic layers may be inserted between the electrode layer and the MgO(001) layer.

[0056] Hereafter, a MTJ device according to a second embodiment of the invention and a method of manufacturing the same will be described. In the method of manufacturing a Fe(001)/MgO(001)/Fe(001) MTJ device according to the present embodiment, MgO(001) is initially deposited in a poly-crystalline or amorphous state by sputtering or the like, and then an annealing process is performed such that a poly-crystal in which the (001) crystal plane is preferentially oriented or a single-crystal is obtained. The sputtering conditions were such that, for example, the temperature was room temperature (293K), a 2-inch $\phi$ MgO was used as a target, and sputtering was conducted in an Ar atmosphere. The acceleration power was 200 W and the growth rate was 0.008 nm/s. Because MgO that is deposited under these conditions is in an amorphous state, a crystallized MgO was obtained by increasing the temperature to 300°C from room temperature and maintaining that temperature for a certain duration of time.

[0057] Oxygen vacancy defects may be introduced by a method whereby oxygen vacancy defects is produced during growth, a method whereby oxygen vacancy defects is introduced subsequently, or a method whereby a state with oxygen vacancy defects is subjected to an oxygen plasma process or natural oxidation so as to achieve a certain oxygen deficit level.

[0058] As described above, in accordance with the MTJ device technology of the present embodiment, an annealing process is carried out for



WD EX1004
Western Digital v IP Bridge
Page 26

crystallization after an amorphous MgO has been deposited by sputtering, thereby eliminating the need for large-sized equipment.

[0059] Hereafter, a MTJ device according to a variation of the embodiments of the invention will be described with reference to the drawings. Fig. 11 shows the structure of the MTJ device according to the variation, which corresponds to Fig. 1(B). As shown in Fig. 11, the MTJ device of the variation is characterized in that, as in the MTJ device of the above-described embodiments, the electrodes disposed on either side of a single-crystal $MgO_x(001)$ layer 503 or an oxygen-deficit poly-crystal $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented comprises an amorphous ferromagnetic alloy, such as CoFeB layers 501 and 505. The amorphous ferromagnetic alloy can be formed by evaporation or sputtering, for example. The resultant characteristics are substantially identical to those of the first embodiment.

[0060] As the amorphous magnetic alloy, FeCoB, FeCoBSi, FeCoBP, FeZr, and CoZr may be used, for example. Although an anneal process after the preparation of the MTJ device might cause the amorphous magnetic alloy in the electrode layers to be partially or entirely crystallized, this would not lead to a significant deterioration of the MR ratio. Thus, such a crystallized amorphous magnetic alloy may be used in the electrode layers.

[0061] While the MTJ device according to various embodiments of the invention has been described, it should be apparent to those skilled in the art that the invention is not limited to those specific embodiments and various other modifications, improvements and combinations are possible. For



WD EX1004
Western Digital v IP Bridge
Page 27

example, the height of the tunnel barrier may be adjusted by doping Ca or Sr, instead of introducing an oxygen vacancy defects to the MgO layer. Further, while the MgO layer has been described to be deposited by electron-beam evaporation or sputtering, it should be obvious that other deposition methods are also possible. The term "high vacuum" refers to values on the order of no more than $10^{-6}$ Pa in the case where oxygen is not introduced, for example. In the case where oxygen is introduced, the term refers to values on the order of $10^{-4}$ Pa.

[0062] In accordance with the invention, a larger magnetoresistance than in the conventional MTJ device can be obtained, and the output voltage of the MTJ device can be increased. At the same time, the resistance value of the MTJ device can be reduced so that it is optimized for MRAM. The invention thus enables the level of integration of MRAM using the MTJ device to be readily increased. In accordance with the invention, the output voltage value of the MRAM roughly doubles over prior art, making the MTJ device of the invention suitable for very large scale integrated MRAMs of gigabit class.



WD EX1004
Western Digital v IP Bridge
Page 28

What is claimed is:

1. A method of manufacturing a magnetoresistive device, comprising:

preparing a substrate;

depositing a first ferromagnetic material layer being amorphous above the substrate;

forming an amorphous magnesium oxide layer on the first amorphous ferromagnetic material layer and then crystallizing the amorphous magnesium oxide layer by annealing so as to form a tunnel barrier layer comprising a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented; and

depositing a second ferromagnetic material layer on the tunnel barrier layer.

2. The method of manufacturing a magnetoresistive device according to claim 1, wherein the magnesium oxide layer has oxygen vacancy defects.

3. The method of manufacturing a magnetoresistive device according to claim 1, wherein the ferromagnetic material layers each comprises an Fe-based alloy.

4. The method of manufacturing a magnetoresistive device according to claim 3, wherein the alloy is CoFeB alloy.

5. The method of manufacturing a magnetoresistive device according to claim 1, wherein the method further comprises:



WD EX1004
Western Digital v IP Bridge
Page 29

annealing to partially or entirely crystallize the amorphous ferromagnetic material layer.

6. The method of manufacturing a magnetoresistive device according to claim 5, wherein the ferromagnetic material is an Fe-based alloy.

7. The method of manufacturing a magnetoresistive device according to claim 6, wherein the alloy is CoFeB alloy.

8. A half product of a magnetoresistive device comprising:

a first amorphous ferromagnetic material layer;

a tunnel barrier layer comprising a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented and which magnesium oxide layer has oxygen vacancy defects; and

a second amorphous ferromagnetic material layer.

9. A tunnel barrier layer deposited on an amorphous ferromagnetic material layer, wherein the tunnel barrier layer comprises a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented.

10. The tunnel barrier layer deposited on an amorphous ferromagnetic material layer according to claim 9,

wherein the magnesium oxide layer has oxygen vacancy defects.



WD EX1004
Western Digital v IP Bridge
Page 30

11. The tunnel barrier layer deposited on an amorphous ferromagnetic material layer according to claim 9,

wherein the ferromagnetic material is a Fe-based alloy.

12. A tunnel barrier layer comprising a magnesium oxide layer on a ferromagnetic material layer,

wherein the magnesium oxide layer comprises a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented,

the magnesium oxide layer has oxygen vacancy defects, and

the ferromagnetic material layer comprises Fe or a Fe-based alloy of the BCC structure and comprises a poly-crystalline layer in which (001) crystal plane is preferentially oriented.

13. A tunnel barrier layer comprising a magnesium oxide layer on a ferromagnetic material layer according to claim 12,

wherein the magnesium oxide layer has a potential barrier height in the range of 0.2 to 0.5 eV.

14. A magnetoresistive device having a magnetic tunnel junction structure comprising:

a first ferromagnetic material layer of the BCC structure;

a tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure;

wherein the tunnel barrier layer comprises a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented,



WD EX1004
Western Digital v IP Bridge
Page 31

the magnesium oxide layer has oxygen vacancy defects,

a magnetoresistance ratio of the device is more than 70%, and

an output voltage of the device is more than 200mV.

15. The magnetoresistive device according to claim 13,

wherein the first and second ferromagnetic material layer comprises Fe or a Fe-based alloy and comprises a poly-crystalline layer in which (001) crystal plane is preferentially oriented.

16. A magnetic multilayer film comprising :

a first ferromagnetic material layer;

a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented, the magnesium oxide layer having oxygen vacancy defects;

a second ferromagnetic material layer; and

the first and second ferromagnetic material layers comprising Fe or a Fe-based alloy of the BCC structure and comprising a poly-crystalline layer in which (001) crystal plane is preferentially oriented.



WD EX1004
Western Digital v IP Bridge
Page 32

Abstract of the Disclosure

The output voltage of an MRAM is increased by means of an Fe(001)/MgO(001)/Fe(001) MTJ device, which is formed by microfabrication of a sample prepared by the following steps. A single-crystalline MgO (001) substrate 11 is prepared. An epitaxial Fe(001) lower electrode (a first electrode) 17 with the thickness of 50 nm is grown on a MgO(001) seed layer 15 at room temperature, followed by annealing under ultrahigh vacuum ($2 \times 10^{-8}$ Pa) and at 350°C. A MgO(001) barrier layer 21 with the thickness of 2 nm is epitaxially formed on the Fe(001) lower electrode (the first electrode) at room temperature, using a MgO electron-beam evaporation. A Fe(001) upper electrode (a second electrode) with the thickness of 10 nm is then formed on the MgO(001) barrier layer 21 at room temperature. This is successively followed by the deposition of a Co layer 21 with the thickness of 10 nm on the Fe(001) upper electrode (the second electrode) 23. The Co layer 21 is provided so as to increase the coercive force of the upper electrode 23 in order to realize an antiparallel magnetization alignment.



WD EX1004
Western Digital v IP Bridge
Page 33

# MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

## [0001] CROSS-REFERENCE TO RELATED APPLICATION

[0002] The present application is a Continuation of U.S. Application 10/591,947 filed on September 8, 2006, which is a National Stage Application of PCT/JP2005/004720 filed on March 10, 2005. Priority is claimed from U.S. 10/591,947 filed on September 8, 2006, which claims priority from PCT/JP2005/004720 filed on March 10, 2005, which claims priority from Japanese Application Nos. 2004-071186 and 2004-313350 filed March 12, 2004 and October 28, 2004, respectively, the content of which is hereby incorporated by reference into this application.

## [0003] BACKGROUND OF THE INVENTION

### [0004] Field of the Invention

[0005] The present invention relates to a magnetic tunnel junction device and a method of manufacturing the same, particularly to a magnetic tunnel junction device with a high magnetoresistance and a method of manufacturing the same.

### [0006] Description of Related Art

[0007] Magnetoresistive random access memories (MRAMs) refer to a large-scale integrated memory circuit that is expected to replace the



WD EX1004
Western Digital v IP Bridge
Page 34

currently widely used DRAM memories. Research and development of MRAM devices, which are fast and non-volatile memory devices, are being extensively carried out, and sample products of a 4Mbit MRAM have actually been delivered.

[0008] Fig. 8 shows the structure and operation principle of a magnetic tunnel junction device (to be hereafter referred to as a "MTJ device"), which is the most important part of the MRAM. As shown in Fig. 8(A), a MTJ device comprises a tunnelling junction structure in which a tunnel barrier (to be hereafter also referred to as a "barrier layer") made of an oxide is sandwiched between a first and a second electrode made of a ferromagnetic metal. The tunnel barrier layer comprises an amorphous Al-O layer (see Non-Patent Document 1). As shown in Fig. 8(A), in the case of parallel magnetization alignment where the directions of magnetizations of the first and second ferromagnetic electrodes are aligned parallel, the electric resistance of the device with respect to the direction normal to the interfaces of the tunneling junction structure decreases. On the other hand, in the case of antiparallel magnetization alignment where the directions of magnetizations of the first and second ferromagnetic electrodes are aligned antiparallel as shown in Fig. 8(B), the electric resistance with respect to the direction normal to the interfaces of the tunneling junction structure increases. The resistance value does not change in a general state, so that information "1" or "0" can be stored depending on whether the resistance value is high or not. Since the parallel and antiparallel magnetization alignments can be stored in a non-volatile fashion, the device can be used as a non-volatile memory device.



WD EX1004
Western Digital v IP Bridge
Page 35

[0009] Fig. 9 shows an example of the basic structure of the MRAM. Fig. 9(A) shows a perspective view of the MRAM, and Fig. 9(B) schematically shows a circuit block diagram. Fig. 9(C) is a cross-section of an example of the structure of the MRAM. Referring to Fig. 9(A), in an MRAM, a word line WL and a bit line BL are disposed in an intersecting manner, with an MRAM cell disposed at each intersection. As shown in Fig. 9(B), the MRAM cell disposed at the intersection of a word line and a bit line comprises a MTJ device and a MOSFET directly connected to the MTJ device. Stored information can be read by reading the resistance value of the MTJ device that functions as a load resistance, using the MOSFET. The stored information can be rewritten by applying a magnetic field to the MTJ device, for example. As shown in Fig. 9(C), an MRAM memory cell comprises a MOSFET 100 including a source region 105 and a drain region 103 both formed inside a p-type Si substrate 101, and a gate electrode 111 formed on a channel region that is defined between the source and drain regions. The MRAM also comprises a MTJ device 117. The source region 105 is grounded, and the drain is connected to a bit line BL via the MTJ device. A word line WL is connected to the gate electrode 111 in a region that is not shown.

[0010] Thus, a single non-volatile MRAM memory cell can be formed by a single MOSFET 100 and a single MTJ device 117. The MRAMs are therefore suitable where high levels of integration are required.

[0011] Non-Patent Document 1: D. Wang, et al.: Science 294 (2001) 1488.



WD EX1004
Western Digital v IP Bridge
Page 36

[0012] SUMMARY OF THE INVENTION

[0013] Although there are prospects for achieving MRAMs with capacities on the order of 64Mbits based on the current technologies, the characteristics of the MTJ device, which is the heart of MRAM, needs to be improved if higher levels of integration are to be achieved. In particular, in order to increase the output voltage of the MTJ device, the magnetoresistance must be increased and the bias voltage characteristics must be improved. Fig. 10 illustrates how the magnetoresistance in a conventional MTJ device using an amorphous Al-O as the tunnel barrier changes as a function of the bias voltage (L1). As shown, in the conventional MTJ device, the magnetoresistance is small and, notably, it tends to drastically decrease upon application of bias voltage. With such characteristics, the output voltage when operation margins are taken into consideration is too small for the device to be employed for an actual memory device. Specifically, the magnetoresistance of the current MTJ device is small at approximately 70%, and the output voltage is also small at no more than 200 mV, which is substantially half the output voltage of a DRAM. This has resulted in the problem that as the level of integration increases, signals are increasingly lost in noise and cannot be read.

[0014] It is an object of the invention to increase the output voltage of a MTJ device. It is another object of the invention to provide a memory device with a high magnetoresistance for stable operation.

[0015] In one aspect, the invention provides a magnetoresistive device comprising a magnetic tunnel junction structure comprising: a tunnel barrier



WD EX1004
Western Digital v IP Bridge
Page 37

layer; a first ferromagnetic material layer of the BCC structure formed on a first side of the tunnel barrier layer; and a second ferromagnetic material layer of the BCC structure formed on a second side of the tunnel barrier layer, wherein the tunnel barrier layer is formed by a single-crystal $MgO_x$ (001) layer or a poly-crystalline $MgO_x$ ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented.

[0016] The invention further provides a magnetoresistive device comprising a magnetic tunnel junction structure comprising: a tunnel barrier layer comprising MgO(001); a first ferromagnetic material layer comprising Fe(001) formed on a first side of the tunnel barrier layer; and a second ferromagnetic material layer comprising Fe(001) formed on a second side of the tunnel barrier layer, wherein the MgO layer is formed by a single-crystalline $MgO_x$ (001) layer or a poly-crystalline $MgO_x$ ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented. In a preferred embodiment, the band discontinuity value (the height of the tunnel barrier) between the bottom of the conduction band of the MgO(001) layer and the Fermi energy of the Fe(001) layer is smaller than an ideal value of a perfect single-crystal without defect. These features increase the magnetoresistance and thereby allow the output voltage of the MTJ device to be increased. By using any of the aforementioned MTJ devices as a load for a single transistor, a non-volatile memory can be formed.

[0017] In another aspect, the invention provides a method of manufacturing a magnetoresistive device comprising: preparing a substrate; depositing a first Fe(001) layer on the substrate; depositing a tunnel barrier layer on the



WD EX1004
Western Digital v IP Bridge
Page 38

first Fe(001) layer by electron beam evaporation under high vacuum, the tunnel barrier layer comprising a single-crystalline $MgO_x$ (001) or a poly-crystalline $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented; and forming a second Fe(001) layer on the tunnel barrier layer.

[0018] The invention furthermore provides a method of manufacturing a MTJ device comprising a first step of preparing a substrate comprising a single-crystalline $MgO_x$(001) or a poly-crystalline $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented, a second step of depositing a first Fe(001) layer on the substrate and performing an annealing process to make the surface flat, a third step of depositing a tunnel barrier layer on the first Fe(001) layer by electron beam evaporation, the tunnel barrier layer comprising a single-crystalline $MgO_x$(001) or a poly-crystalline $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented, and a fourth step of forming a second Fe(001) layer on the tunnel barrier layer. The method may further comprise the step of growing a seed layer between the first and the second steps, the seed layer comprising a single-crystalline $MgO_x$(001) or a poly-crystalline $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented. The MgO layer may be deposited using a target with the value of x in $MgO_x$ adjusted. The value of x in $MgO_x$ may be adjusted in the step of forming the MgO.

[0019] In yet another aspect, the invention provides a magnetoresistive device comprising a magnetic tunnel junction structure comprising a tunnel barrier layer comprising MgO(001), a first ferromagnetic material layer



WD EX1004
Western Digital v IP Bridge
Page 39

comprising an amorphous magnetic alloy formed on a first sideof the tunnel barrier layer, and a second ferromagnetic material layer comprising an amorphous magnetic alloy formed on a second side of the tunnel barrier layer, wherein the discontinuous value (the height of the tunnel barrier) between the bottom of the conduction band of the MgO(001) layer and the Fermi energy of the first or the second ferromagnetic material layer comprising the amorphous magnetic alloy is lower than an ideal value of a perfect single-crystal with no defect.

[0020] BRIEF DESCRIPTION OF THE DRAWINGS

[0021] Fig. 1(B) shows the structure of a MTJ device according to a first embodiment of the invention, and Fig. 1(A) shows the energy band structure of a ferromagnetic metal Fe(001), illustrating the $E$-$E_F$ relationship with respect to the [001] direction of the momentum space.

[0022] Fig. 2(A) to Fig. 2(D) schematically show the process of manufacturing a MTJ device with a Fe(001)/MgO(001)/Fe(001) structure (to be hereafter referred to as a "Fe(001)/MgO(001)/Fe(001) MTJ device") according to an embodiment of the invention.

[0023] Fig. 3(A) shows a RHEED image of a Fe(001) lower electrode (a first electrode), and Fig. 3(B) shows a RHEED image of a MgO(001) barrier layer.

[0024] Fig. 4 shows the results of observing the quadrupole mass spectra in the deposition chamber during the MgO evaporation.



WD EX1004
Western Digital v IP Bridge
Page 40

[0025] Fig. 5 shows the film deposition rate dependency of the oxygen partial pressure during the MgO evaporation.

[0026] Fig. 6 shows typical magnetoresistance curves of the Fe(001)/MgO(001)/Fe(001) MTJ device.

[0027] Fig. 7(A) shows the bias voltage dependency of the MR ratio at room temperature, and Fig. 7(B) shows the output voltage $V_{out}$ of the MTJ device (=bias voltage × (Rap-Rp)/Rap).

[0028] Fig. 8 shows the structure of the MTJ device and its operating principle.

[0029] Fig. 9 shows an example of the basic structure of an MRAM, Fig. 9(A) showing a perspective view of the MRAM, Fig. 9(B) showing a schematic circuit diagram, and Fig. 9(C) showing a cross-sectional view of an example of its structure.

[0030] Fig. 10 shows how the magnetoresistance of a conventional MTJ device using an amorphous Al-O as the tunnel barrier changes depending on the bias voltage.

[0031] Fig. 11 shows the structure of a MTJ device according to a variation of the invention, corresponding to Fig. 1(B).



WD EX1004
Western Digital v IP Bridge
Page 41

[0032] DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0033] In the context of the present specification, because MgO has a cubic crystal structure (NaCl structure), the (001) plane, the (100) plane, and the (010) plane are all equivalent. The direction perpendicular to the film surface is herein considered to be the z-axis so that the film plane can be uniformly described as (001). Also in the context of the present specification, BCC structure, which the crystalline structure of ferromagnetic electrode layer, means body-centered cubic lattice structure. More specifically, BCC structure includes the BCC structure with no chemical ordering so-called A2-type structure, the BCC structure with chemical ordering such as B2-type structre and $L2_1$-type structure, and also the aforementioned structures with slight lattice distortion.

[0034] The term "ideal value" with regard to a perfect single-crystal without defect herein refers to a value that has been estimated from ultraviolet photoemission spectroscopy experiments (see W. Wulfhekel, et al.: Appl. Phys. Lett. 78 (2001) 509.). The term "ideal value" is used herein because the aforementioned state can be considered to be an upper limit value of the potential barrier height of the tunnel barrier of an ideal single-crystal MgO with hardly any oxygen vacancy defect or lattice defect.

[0035] Before describing the preferred embodiments of the invention, an analysis conducted by the inventors is discussed. The magnetoresistance (MR) ratio of a MTJ device can be expressed by the following equation:

[0036] $\Delta R/Rp = (Rap - Rp)/Rp$



WD EX1004
Western Digital v IP Bridge
Page 42

[0037] where Rp and Rap indicate the tunnel junction resistance in the cases of parallel and antiparallel magnetization alignments, respectively, of two electrodes. According to the Jullire's formula, the MR ratio at low bias voltage can be expressed by:

[0038] MR ratio = $(Rap - Rp)/Rp = 2P_1P_2/(1-P_1P_2)$, and

[0039] $P\alpha = (D\alpha \uparrow (E_F) - D\alpha \downarrow (E_F))/(D\alpha \uparrow (E_F) + D\alpha \downarrow (E_F)$,

[0040] where $\alpha = 1, 2$ (1)

[0041] In the above equations, $P\alpha$ is the spin polarization of an electrode, and $D\alpha \uparrow (E_F)$ and $D\alpha \downarrow (E_F)$ are the density of state (DOS) at the Fermi energy ($E_F$) of the majority-spin band and the minority-spin band, respectively. Since the spin polarization of ferromagnetic transition metals and alloys is approximately 0.5 or smaller, the Jullire's formula predicts a highest estimated MR ratio of about 70%.

[0042] Although the MR ratio of approximately 70% has been obtained at room temperature when a MTJ device was made using an amorphous Al-O tunnel barrier and polycrystalline electrodes, it has been difficult to obtain the output voltage of 200 mV, which is comparable to the output voltages of DRAMs, thereby preventing the realization of MRAM as mentioned above.

[0043] The inventors tried an approach to deposit a MTJ device in which the tunnel barrier comprises a single-crystal (001) of magnesium oxide (MgO) or a poly-crystalline MgO in which the (001) crystal plane is preferentially oriented. It is the inventors' theory that, because magnesium oxide is a



WD EX1004
Western Digital v IP Bridge
Page 43

crystal (where the atoms are arranged in an orderly fashion), as opposed to the conventional amorphous Al-O barrier, the electrons are not scattered and the coherent states of electrons are concerved during the tunneling process. Fig. 1(B) shows the MTJ device structure according to an embodiment of the invention. Fig. 1(A) shows the energy band structure of the ferromagnetic Fe(001), that is, the $E$-$E_F$ relationship with respect to the [001] direction of the momentum space. As shown in Fig. 1(B), the MTJ device structure of the present embodiment comprises a first Fe (001) layer 1, a second Fe (001) layer 5, and a single-crystalline $MgO_x$ (001) layer 3 or a poly-crystalline $MgO_x$ ($0 < x < 1$) layer 3 sandwiched therebetween, the polycrystalline layer having the (001) crystal plane preferentially oriented therein. According to the aforementioned Jullire's model, assuming that the momentum of the conduction electrons is preserved in the tunneling process, the tunneling current that passes through MgO would be dominated by those electrons with wave vector $k_z$ in the direction perpendicular to the tunnel barrier (normal to the junction interfaces). In accordance with the energy band diagram shown in Fig. 1(A) of Fe in the [001] ($\Gamma$-H) direction, the density of state (DOS) at the Fermi energy $E_F$ does not exhibit a very high spin polarization due to the fact that the sub-bands of the majority-spin and the minority-spin have states at the Fermi energy $E_F$. However, in case the coherent states of electrons are conserved in the tunneling process, only those conduction electrons that have totally symmetrical wave functions with respect to the axis perpendicular to the barrier would be coupled with the states in the barrier region and come to have a finite tunneling probability. The $\Delta 1$ band in the Fe(001) electrode has such totally symmetric wave functions. As shown in Fig. 1(A), the majority



WD EX1004
Western Digital v IP Bridge
Page 44

spin $\Delta 1$ band (solid line) has states at the Fermi energy $E_F$, whereas the minority spin $\Delta 1$ band (broken line) does not have state at the Fermi energy $E_F$. Because of such half-metallic characteristics of the Fe $\Delta_1$ band, there is the possibility that a very high MR ratio can be obtained in a coherent spin polarized tunneling. Since in an epitaxial (single-crystal, or (001) oriented poly-crystal) MTJ device the scattering of electrons is suppressed during the tunneling process, an epitaxial MTJ device is thought to be ideal for realizing the aforementioned coherent tunneling.

[0044] In the following, a MTJ device according to a first embodiment of the invention and a method of manufacturing the same will be described with reference to the drawings. Figs. 2(A) to 2(D) schematically show the method of manufacturing the MTJ device having the Fe (001)/MgO(001)/Fe(001) structure according to the embodiment (to be hereafter referred to as a "Fe(001)/MgO(001)/Fe(001) MTJ device"). Fe(001) refers to a ferromagnetic material with the BCC structure. First, a single-crystal MgO(001) substrate 11 was prepared. In order to improve the morphology of the surface of the single-crystal MgO(001) substrate 11, a MgO(001) seed layer 15 was grown by the molecular beam epitaxy (MBE) method. This was subsequently followed by the growth of an epitaxial Fe(001) lower electrode (first electrode) 17 with the thickness of 50 nm on the MgO(001) seed layer 15 at room temperature, as shown in Fig. 1(B), and then annealing was performed at 350°C under ultrahigh vacuum ($2 \times 10^{-8}$ Pa). Electron-beam evaporation conditions included an acceleration voltage of 8 kV, a growth rate of 0.02 nm/sec, and the growth temperature of room temperature (about 293K). The source material



WD EX1004
Western Digital v IP Bridge
Page 45

of the electron-beam evaporation was MgO of the stoichiometric composition (the ratio of Mg to O being 1:1), the distance between the source and the substrate was 40 cm, the base vacuum pressure was $1 \times 10^{-8}$ Pa, and the $O_2$ partial pressure was $1 \times 10^{-6}$ Pa. Alternatively, a source with oxygen vacancy defects may be used instead of the MgO of the stoichiometric composition (the ratio of Mg to O is 1:1).

[0045] Fig. 3(A) shows a RHEED image of the Fe(001) lower electrode (a first electrode). The image shows that the Fe(001) lower electrode (first electrode) 17 possesses a good crystallinity and flatness. Thereafter, a MgO(001) barrier layer 21 with the thickness of 2 nm was epitaxially grown on the Fe(001) lower electrode (first electrode) at room temperature, also using the MgO electron-beam evaporation method. Fig. 3(B) shows a RHEED image of the MgO(001) barrier layer 21. The image shows that the MgO(001) barrier layer 21 also possesses a good crystallinity and flatness.

[0046] As shown in Fig. 2(D), a Fe(001) upper electrode (a second electrode) 23 with the thickness of 10 nm was formed on the MgO(001) barrier layer 21 at room temperature. This was successively followed by the deposition of a Co layer 25 with the thickness of 10 nm on the Fe(001) upper electrode (second electrode) 23. The Co layer 25 is provided to increase the coercive force of the upper electrode 23 so as to realize the antiparallel magnetization alignment. The thus prepared sample was then processed by microfabrication techniques to obtain the Fe(001)/MgO(001)/Fe(001) MTJ device.



WD EX1004
Western Digital v IP Bridge
Page 46

[0047] The aforementioned MgO evaporation using an electron beam involved the formation of a film under ultrahigh vacuum of $10^{-9}$ Torr. It can be seen that in this method, the film, even when formed on a glass substrate to the thickness of 300 nm, was colorless and transparent, showing that a good crystal film was formed. Fig. 4 shows the results of observing the quadrupole mass spectra in the deposition chamber during the MgO growth. The results show that the partial pressures regarding the spectrum P1 of O and the spectrum P2 of $O_2$ are high. Fig. 5 shows the film deposition rate dependency of the oxygen partial pressure during MgO evaporation. It will be seen from the figure that the oxygen partial pressure itself is high, and that the oxygen partial pressure increases as the deposition rate increases. These results indicate the separation of oxygen from MgO during the deposition of MgO. Since the separated oxygen is pumped out of the deposition chamber using vacuum pumps, there is the possibility that there are oxygen vacancy defects such as $MgO_x$ ($0.9 < x < 1$). When there are oxygen vacancy defects, the potential barrier height of the MgO tunnel barrier is thought to decrease (such as in the range of 0.10 to 0.85 eV; more specifically, 0.2 to 0.5 eV), which is thought to result in an increase in the tunneling current. In the case of a typical Al-O tunnel barrier, the height of the tunnel barrier with respect to Fe(001) electrodes is considered to be 0.7 to 2.5 eV. An ideal tunnel barrier height of a MgO crystal is 3.6 eV, and experimental values of 0.9 to 3.7 eV have been obtained. Using the method according to the present embodiment of the invention, a tunnel barrier height of approximately 0.3 eV is expected, indicating that the resistance of the tunnel barrier can be lowered. However, it should be noted that other factors, such



WD EX1004
Western Digital v IP Bridge
Page 47

as the influence of the aforementioned coherent tunneling, might also be involved. The value of x in $MgO_x$ due to oxygen vacancy defects is such that $0.98 < x < 1$, and more preferably $0.99 < x < 1$. These are the ranges such that the sole presence of Mg is excluded and the characteristics of MgO can be basically maintained.

[0048] The aforementioned tunnel barrier height $\phi$ was determined by fitting the electric conductance characteristics of the MTJ device (the relationship between tunnel current density J and bias voltage V) onto the Simmons' formula (Equation (20) in a non-patent document by J. G. Simmons: J. Appl. Phys. 34, pp. 1793-1803 (1963)) based on the WKB approximation, using the least squares method. The fitting was performed using the free electron mass ($m = 9.11 \times 10^{-31}$ kg) as the electron's effective mass. When a bias voltage V (which is normally on the order of 500 mV to 1000 mV) is applied until non-linearity appears in the J-V characteristics, the height $\phi$ of the tunnel barrier and the effective thickness $\Delta s$ of the tunnel barrier can be simultaneously determined by fitting the J-V characteristics using the Simmons' formula.

[0049] The effective thickness $\Delta s$ of the tunnel barrier was determined to be smaller than the thickness of the actual MgO(001) tunnel barrier layer ($t_{MgO}$) determined from a cross-sectional transmission electron microscope image of the MTJ device by approximately 0.5 nm. This is the result of the effective thickness $\Delta s$ of the tunnel barrier having been reduced from the actual MgO(001) layer thickness by the effect of the image potential produced at the



WD EX1004
Western Digital v IP Bridge
Page 48

interface between the MgO(001) layer and the alloy layer consisting mainly of Fe and Co.

[0050] It is noted that, in the event that $t_{MgO}$ can be accurately determined using the cross-sectional transmission electron microscope (TEM) image, the height $\phi$ of the tunnel barrier can be more simply determined by the following technique. Namely, when the bias voltage V applied to the MTJ device is small (normally 100 mV or smaller), the tunnel current density J is proportional to the bias voltage V, such that the J-V characteristics become linear. In such a low-bias voltage region, the Simmons' formula can be described as follows:

[0051] $$J = [(2m\phi)^{1/2}/\Delta s](e/h)^2 \times \exp[-(4\pi\Delta s/h) \times (2m\phi)^{1/2}] \times V \qquad (2)$$

[0052] where m is the mass of the free electron ($9.11 \times 10^{-31}$ kg), e is the elementary electric charge ($1.60 \times 10^{-19}$C), and h is the Planck's constant ($6.63 \times 10^{-34}$ J·s). The effective thickness of the tunnel barrier $\Delta s$ is approximately $t_{MgO}$ – 0.5 nm. By fitting the J-V characteristics of the MTJ device in the low-bias voltage region onto Equation (2), the height $\phi$ of the tunnel barrier can be simply and yet accurately estimated.

[0053] Fig. 6 shows a typical magnetoresistance curve of the Fe(001)/MgO(001)/Fe(001) MTJ device produced by the above-described method. The MR ratio is 146% at the measurement temperature of 20K and 88% at the measurement temperature of 293K. These values represent the highest MR ratios that have so far been obtained at room temperature. Such high MR ratios cannot be explained by the spin polarization of the Fe(001)



WD EX1004
Western Digital v IP Bridge
Page 49

electrode and is thought rather to be related to a coherent spin-polarized tunneling. When 160 prototype MTJ devices were made, the variations regarding the MR ratio and tunneling resistance value were not more than 20%. The yield of the MTJ devices was 90% or more at the laboratory stage. These high values suggest the effectiveness of the approach of the invention. The resistance-area (RA) product of the MTJ device was on the order of a few $k\Omega\mu m^2$, which is suitable for MRAM.

[0054] Fig. 7(a) shows the bias voltage dependency of the MR ratio at room temperature. It will be seen that the bias voltage dependency of the MR ratio is fairly small. Although the characteristics are asymmetric, the voltage $V_{half}$ at which the MR ratio is reduced in half of the zero-bias value is 1250 mV, which is a very high value. In this connection, it is noted that the voltage $V_{half}$ at which the MR ratio is reduced in half of the zero-bias value in the conventional MTJs with Al-O tunnel barrier is 300 to 600 mV. Fig. 7(b) shows the output voltage $V_{out}$ of the MTJ device (=bias voltage × (Rap – Rp)/Rap). The maximum value of the output voltage $V_{out}$ is 380 mV with a positive bias. This value is about twice as large as that (a little less than 200 mV) in the case of the Al-O barrier. These high values in terms of both MR ratio and output voltage suggest the effectiveness of the technique according to the present embodiment.

[0055] Although in the above-described embodiment Fe(001) of BCC was employed, an Fe alloy of BCC, such as an Fe-Co alloy, Fe-Ni alloy, or Fe-Pt alloy, may be used instead. Alternatively, a layer of Co or Ni with the



WD EX1004
Western Digital v IP Bridge
Page 50

thickness of one or several monoatomic layers may be inserted between the electrode layer and the MgO(001) layer.

[0056] Hereafter, a MTJ device according to a second embodiment of the invention and a method of manufacturing the same will be described. In the method of manufacturing a Fe(001)/MgO(001)/Fe(001) MTJ device according to the present embodiment, MgO(001) is initially deposited in a poly-crystalline or amorphous state by sputtering or the like, and then an annealing process is performed such that a poly-crystal in which the (001) crystal plane is preferentially oriented or a single-crystal is obtained. The sputtering conditions were such that, for example, the temperature was room temperature (293K), a 2-inch $\phi$ MgO was used as a target, and sputtering was conducted in an Ar atmosphere. The acceleration power was 200 W and the growth rate was 0.008 nm/s. Because MgO that is deposited under these conditions is in an amorphous state, a crystallized MgO was obtained by increasing the temperature to 300°C from room temperature and maintaining that temperature for a certain duration of time.

[0057] Oxygen vacancy defects may be introduced by a method whereby oxygen vacancy defects is produced during growth, a method whereby oxygen vacancy defects is introduced subsequently, or a method whereby a state with oxygen vacancy defects is subjected to an oxygen plasma process or natural oxidation so as to achieve a certain oxygen deficit level.

[0058] As described above, in accordance with the MTJ device technology of the present embodiment, an annealing process is carried out for



WD EX1004
Western Digital v IP Bridge
Page 51

crystallization after an amorphous MgO has been deposited by sputtering, thereby eliminating the need for large-sized equipment.

[0059] Hereafter, a MTJ device according to a variation of the embodiments of the invention will be described with reference to the drawings. Fig. 11 shows the structure of the MTJ device according to the variation, which corresponds to Fig. 1(B). As shown in Fig. 11, the MTJ device of the variation is characterized in that, as in the MTJ device of the above-described embodiments, the electrodes disposed on either side of a single-crystal $MgO_x$(001) layer 503 or an oxygen-deficit poly-crystal $MgO_x$ ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented comprises an amorphous ferromagnetic alloy, such as CoFeB layers 501 and 505. The amorphous ferromagnetic alloy can be formed by evaporation or sputtering, for example. The resultant characteristics are substantially identical to those of the first embodiment.

[0060] As the amorphous magnetic alloy, FeCoB, FeCoBSi, FeCoBP, FeZr, and CoZr may be used, for example. Although an anneal process after the preparation of the MTJ device might cause the amorphous magnetic alloy in the electrode layers to be partially or entirely crystallized, this would not lead to a significant deterioration of the MR ratio. Thus, such a crystallized amorphous magnetic alloy may be used in the electrode layers.

[0061] While the MTJ device according to various embodiments of the invention has been described, it should be apparent to those skilled in the art that the invention is not limited to those specific embodiments and various other modifications, improvements and combinations are possible. For



WD EX1004
Western Digital v IP Bridge
Page 52

example, the height of the tunnel barrier may be adjusted by doping Ca or Sr, instead of introducing an oxygen vacancy defects to the MgO layer. Further, while the MgO layer has been described to be deposited by electron-beam evaporation or sputtering, it should be obvious that other deposition methods are also possible. The term "high vacuum" refers to values on the order of no more than $10^{-6}$ Pa in the case where oxygen is not introduced, for example. In the case where oxygen is introduced, the term refers to values on the order of $10^{-4}$ Pa.

[0062] In accordance with the invention, a larger magnetoresistance than in the conventional MTJ device can be obtained, and the output voltage of the MTJ device can be increased. At the same time, the resistance value of the MTJ device can be reduced so that it is optimized for MRAM. The invention thus enables the level of integration of MRAM using the MTJ device to be readily increased. In accordance with the invention, the output voltage value of the MRAM roughly doubles over prior art, making the MTJ device of the invention suitable for very large scale integrated MRAMs of gigabit class.



WD EX1004
Western Digital v IP Bridge
Page 53

What is claimed is:

1. A method of manufacturing a magnetoresistive device, comprising:

preparing a substrate;

depositing a first ferromagnetic material layer being amorphous above the substrate;

forming an amorphous magnesium oxide layer on the first amorphous ferromagnetic material layer and then crystallizing the amorphous magnesium oxide layer by annealing so as to form a tunnel barrier layer comprising a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented; and

depositing a second ferromagnetic material layer on the tunnel barrier layer.

2. The method of manufacturing a magnetoresistive device according to claim 1, wherein the magnesium oxide layer has oxygen vacancy defects.

3. The method of manufacturing a magnetoresistive device according to claim 1, wherein the ferromagnetic material layers each comprises an Fe-based alloy.

4. The method of manufacturing a magnetoresistive device according to claim 3, wherein the alloy is CoFeB alloy.

5. The method of manufacturing a magnetoresistive device according to claim 1, wherein the method further comprises:



WD EX1004
Western Digital v IP Bridge
Page 54

annealing to partially or entirely crystallize the amorphous ferromagnetic material layer.

6. The method of manufacturing a magnetoresistive device according to claim 5, wherein the ferromagnetic material is an Fe-based alloy.

7. The method of manufacturing a magnetoresistive device according to claim 6, wherein the alloy is CoFeB alloy.

8. A half product of a magnetoresistive device comprising:

a first amorphous ferromagnetic material layer;

a tunnel barrier layer comprising a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented and which magnesium oxide layer has oxygen vacancy defects; and

a second amorphous ferromagnetic material layer.

9. A tunnel barrier layer deposited on an amorphous ferromagnetic material layer, wherein the tunnel barrier layer comprises a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented.

10. The tunnel barrier layer deposited on an amorphous ferromagnetic material layer according to claim 9,

wherein the magnesium oxide layer has oxygen vacancy defects.



WD EX1004
Western Digital v IP Bridge
Page 55

11. The tunnel barrier layer deposited on an amorphous ferromagnetic material layer according to claim 9,

wherein the ferromagnetic material is a Fe-based alloy.

12. A tunnel barrier layer comprising a magnesium oxide layer on a ferromagnetic material layer,

wherein the magnesium oxide layer comprises a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented,

the magnesium oxide layer has oxygen vacancy defects, and

the ferromagnetic material layer comprises Fe or a Fe-based alloy of the BCC structure and comprises a poly-crystalline layer in which (001) crystal plane is preferentially oriented.

13. A tunnel barrier layer comprising a magnesium oxide layer on a ferromagnetic material layer according to claim 12,

wherein the magnesium oxide layer has a potential barrier height in the range of 0.2 to 0.5 eV.

14. A magnetoresistive device having a magnetic tunnel junction structure comprising:

a first ferromagnetic material layer of the BCC structure;

a tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure;

wherein the tunnel barrier layer comprises a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented,



WD EX1004
Western Digital v IP Bridge
Page 56

the magnesium oxide layer has oxygen vacancy defects,

a magnetoresistance ratio of the device is more than 70%, and

an output voltage of the device is more than 200mV.

15. The magnetoresistive device according to claim 13,

wherein the first and second ferromagnetic material layer comprises Fe or a Fe-based alloy and comprises a poly-crystalline layer in which (001) crystal plane is preferentially oriented.

16. A magnetic multilayer film comprising :

a first ferromagnetic material layer;

a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented, the magnesium oxide layer having oxygen vacancy defects;

a second ferromagnetic material layer; and

the first and second ferromagnetic material layers comprising Fe or a Fe-based alloy of the BCC structure and comprising a poly-crystalline layer in which (001) crystal plane is preferentially oriented.



WD EX1004
Western Digital v IP Bridge
Page 57

Abstract of the Disclosure

The output voltage of an MRAM is increased by means of an Fe(001)/MgO(001)/Fe(001) MTJ device, which is formed by microfabrication of a sample prepared by the following steps. A single-crystalline MgO (001) substrate 11 is prepared. An epitaxial Fe(001) lower electrode (a first electrode) 17 with the thickness of 50 nm is grown on a MgO(001) seed layer 15 at room temperature, followed by annealing under ultrahigh vacuum ($2 \times 10^{-8}$ Pa) and at 350°C. A MgO(001) barrier layer 21 with the thickness of 2 nm is epitaxially formed on the Fe(001) lower electrode (the first electrode) at room temperature, using a MgO electron-beam evaporation. A Fe(001) upper electrode (a second electrode) with the thickness of 10 nm is then formed on the MgO(001) barrier layer 21 at room temperature. This is successively followed by the deposition of a Co layer 21 with the thickness of 10 nm on the Fe(001) upper electrode (the second electrode) 23. The Co layer 21 is provided so as to increase the coercive force of the upper electrode 23 in order to realize an antiparallel magnetization alignment.



WD EX1004
Western Digital v IP Bridge
Page 58

Attorney's Docket No.: HIRA-0236

# DECLARATION, POWER OF ATTORNEY AND PETITION

I (We), the undersigned inventor(s), hereby declare that:
My residence, post office address and citizenship are as stated below next to my name,
I (We) believe that I am (we are) the original, first, and joint (sole) inventor(s) of the subject matter which is claimed and for which a patent is sought on the invention entitled
MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME
the specification of which

- ■ is attached hereto.
- ☐ was filed on _____ as
  Application Serial No. _____
  and amended on _____
- ■ was filed as PCT international application
  Number PCT/JP2005/004720
  on March 10, 2005
  and was amended under PCT Article 19
  on _____ (if applicable).

I (We) hereby state that I (We) have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above; that I (We) do not know and do not believe that this invention was ever known or used before my invention or discovery thereof, or patented or described in any printed publication in any country before my invention or discovery thereof, or more than one year prior to this application, or in public use or on sale in the United States for more than one year prior to this application; that this invention or discovery has not been patented or made the subject of an inventor's certificate in any country foreign to the United States on an application filed by me or my legal representatives or assigns more than twelve months before this application.

I (We) acknowledge the duty to disclose information known to be material to the patentability of this application as defined in Section 1.56 of Title 37 Code of Federal Regulations.

I (We) hereby claim foreign priority benefits under Section 119(a)-(d) of Title 35 United States Code, of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

| Application No. | Country | Filing date | Priority claimed | |
|---|---|---|---|---|
| 2004-071186 | Japan | March 12, 2004 | ■ Yes | ☐ No |
| 2004-313350 | Japan | October 28, 2004 | ■ Yes | ☐ No |
| | | | ☐ Yes | ☐ No |
| | | | ☐ Yes | ☐ No |

I hereby claim the benefit under Section 119(e) of Title 35 United States Code, of any United States application(s) listed below.

| (Application Number) | (Filing Date) |
|---|---|
| (Application Number) | (Filing Date) |

I (We) hereby claim the benefit under Section 120 of Title 35 United States Code, of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Section 112 of Title 35 United States Code, I (We) acknowledge the duty to disclose material information as defined in Section 1.56(a) of Title 37 Code of Federal Regulations, which occurred between the filing date of the prior application and national or PCT international filing date of this application:

| Application Serial No. | Filing Date | Status (pending, patented, abandoned) |
|---|---|---|
| | | |
| | | |
| | | |

And I (We) hereby appoint: Stanley P. Fisher, Registration No. 24,344 and Juan Carlos Marquez, Registration No. 34,072.

I(We) hereby request that all correspondence regarding this application be sent to the firm of Reed Smith LLP whose Post office address is: 3110 Fairview Park Drive, Suite 1400, Falls Church, Virginia 22042-4503 U.S.A.

I (We) declare further that all statements made herein of my (our) knowledge are true and that all statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Shinji YUASA
NAME OF FIRST INVENTOR

Shinji Yuasa
Signature of Inventor

August 21, 2006
Date

Residence: Ibaraki, Japan

Citizen of: Japan

Post Office Address: c/o National Institute of Advanced Industrial Science and Technology, Tsukuba Central 2, 1-1, Umezono 1-chome, Tsukuba-shi, Ibaraki 305-8568 Japan

FIG. 1 (A)

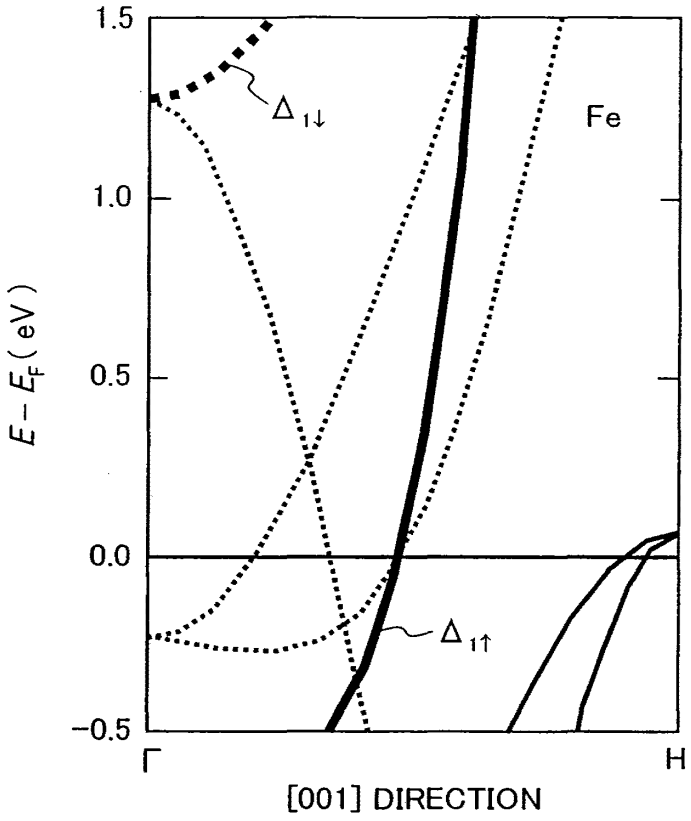
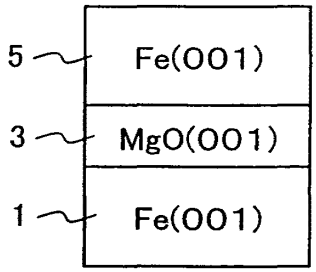



FIG. 1 (B)






WD EX1004
Western Digital v IP Bridge
Page 62

FIG. 2 (A)

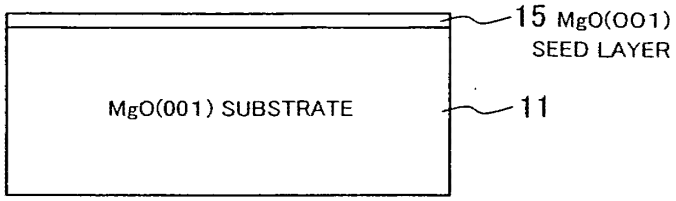



FIG. 2 (B)

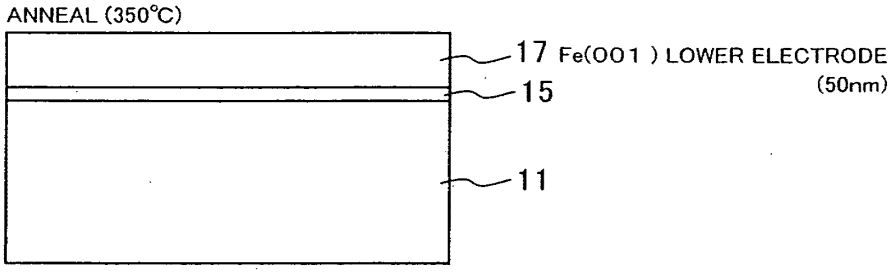



FIG. 2 (C)

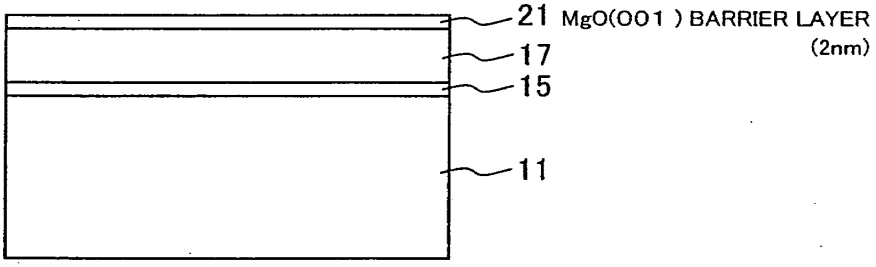
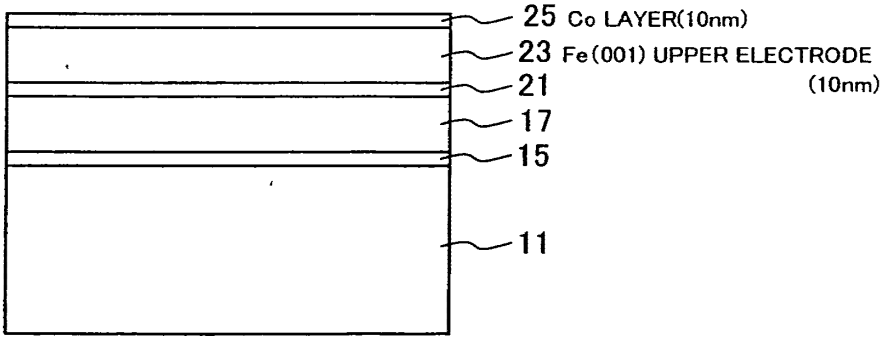



FIG. 2 (D)






WD EX1004
Western Digital v IP Bridge
Page 63

FIG. 3 (A)

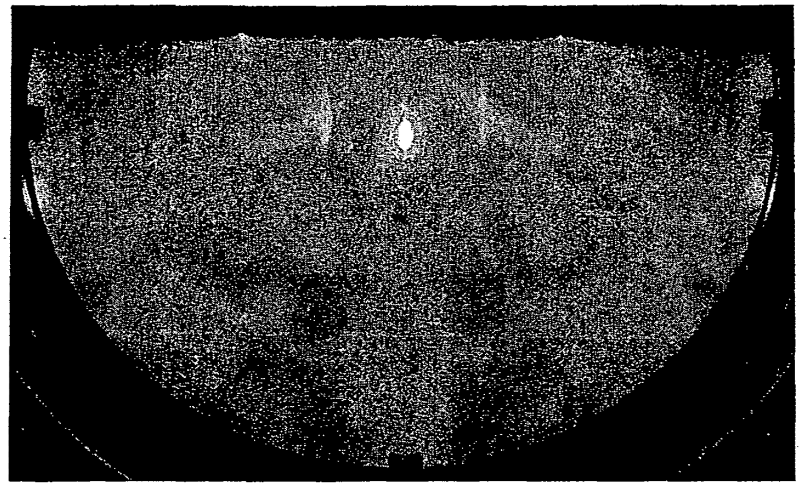
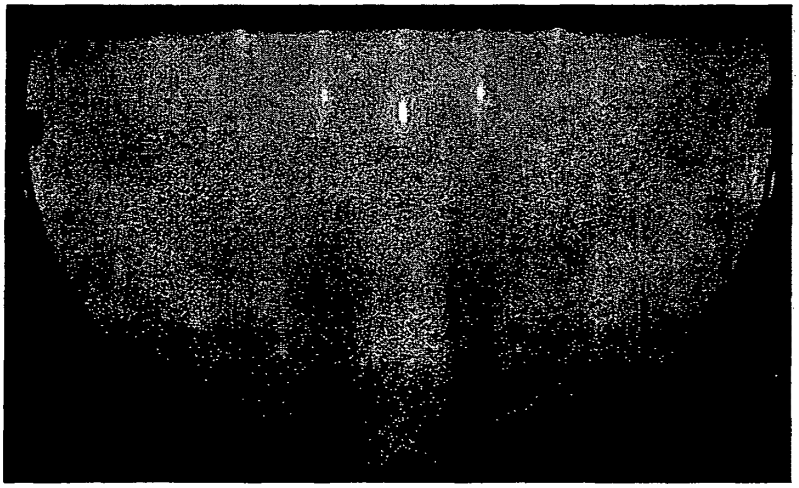


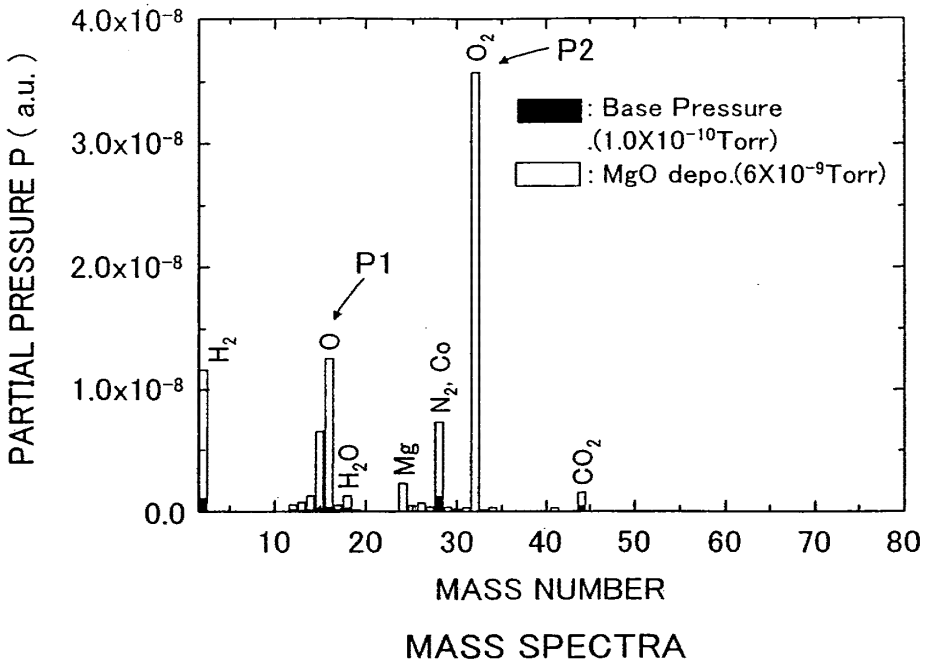
FIG. 3 (B)





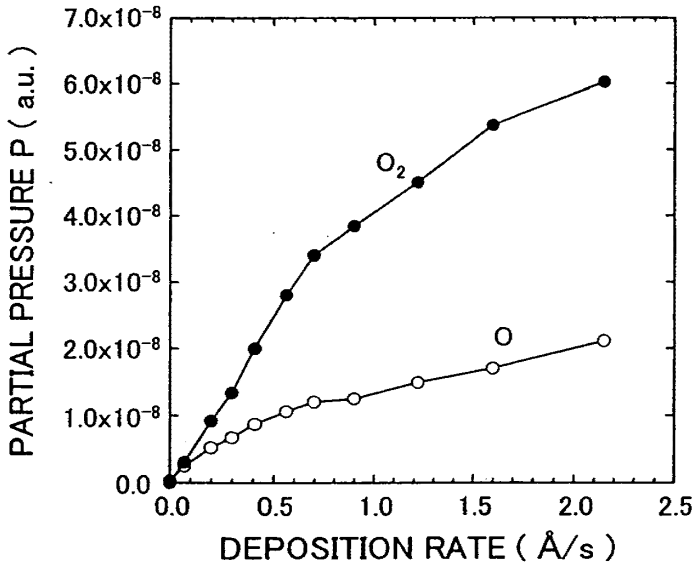
WD EX1004
Western Digital v IP Bridge
Page 64

FIG. 4




MASS SPECTRA

FIG. 5

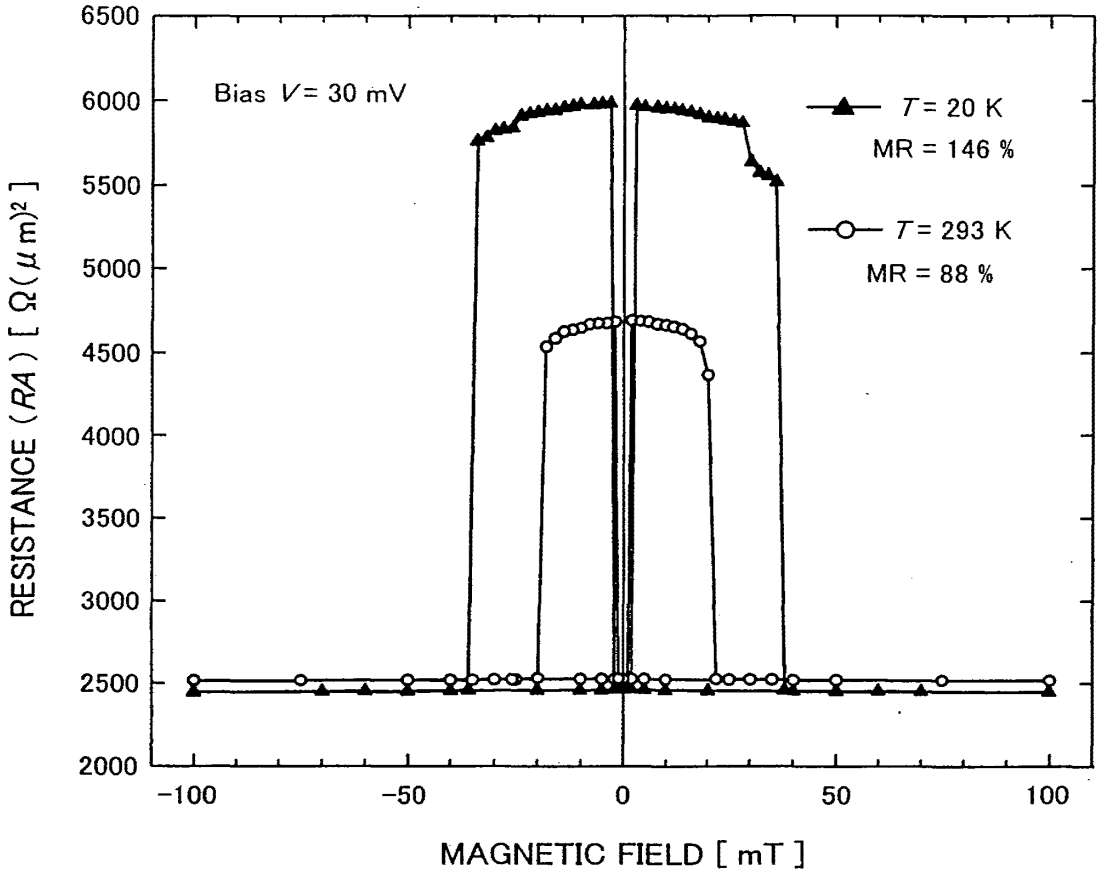



OXYGEN PARTIAL PRESSURE DURING MgO EVAPORATION



WD EX1004
Western Digital v IP Bridge
Page 65

FIG. 6






WD EX1004
Western Digital v IP Bridge
Page 66

FIG. 7 (A)

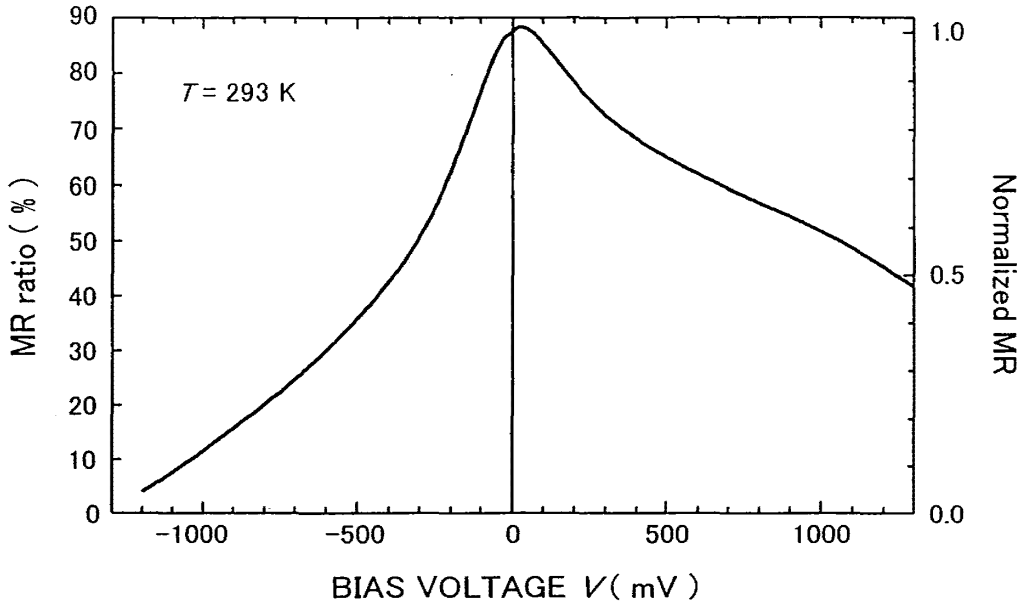
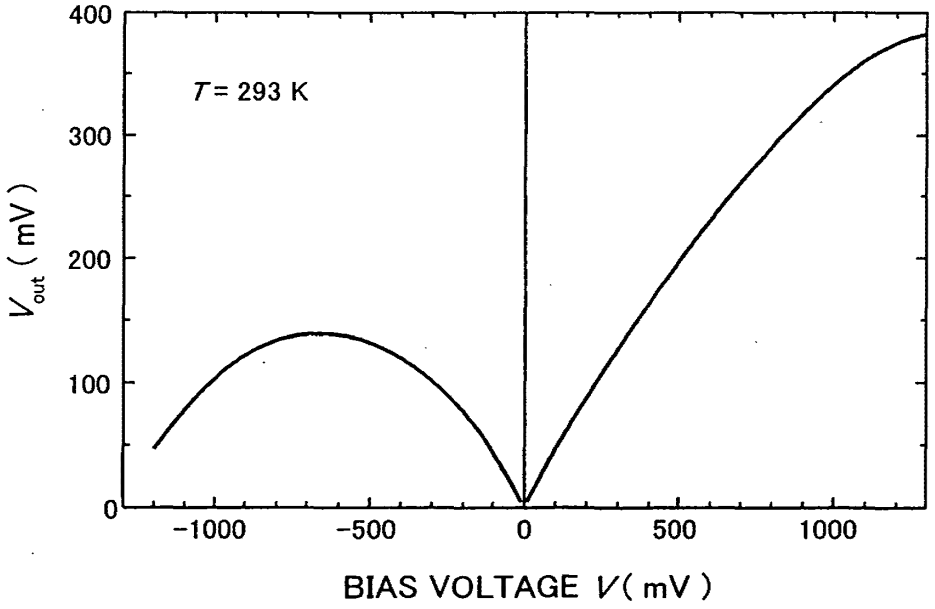


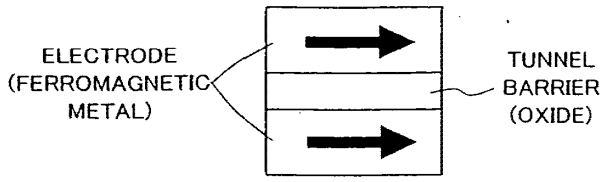

FIG. 7 (B)





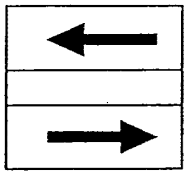

WD EX1004
Western Digital v IP Bridge
Page 67

FIG. 8 (A)




Prior Art

FIG. 8 (B)



Prior Art

FIG. 9 (A)

Prior Art

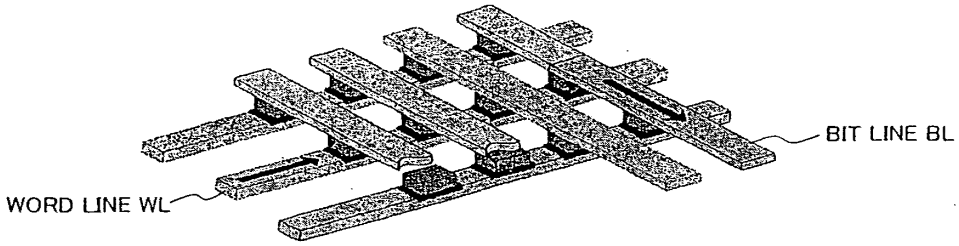



FIG. 9 (B)

Prior Art

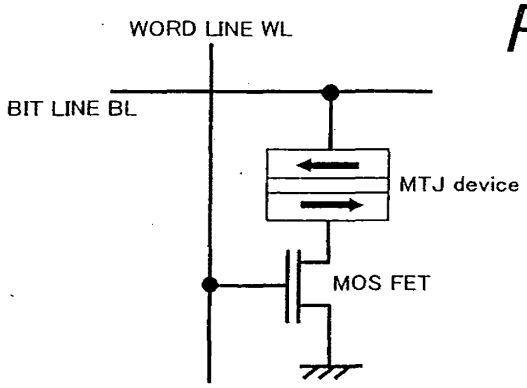



FIG. 9 (C)

Prior Art

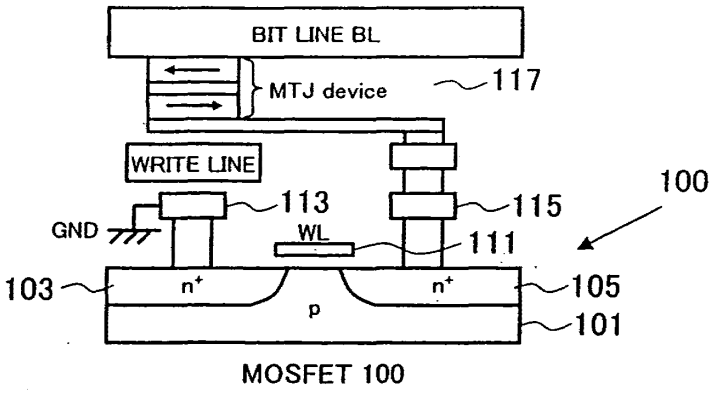
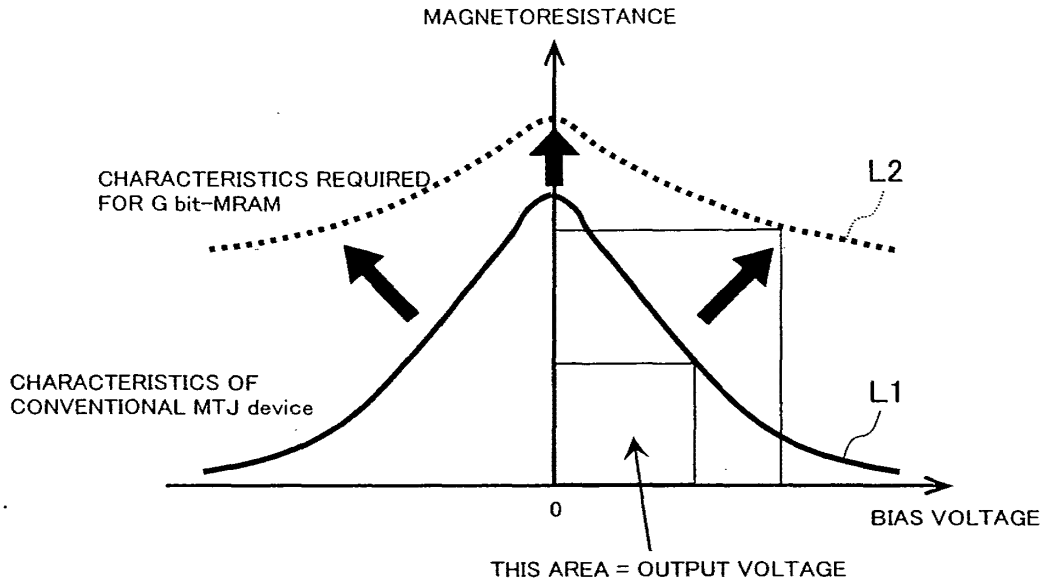


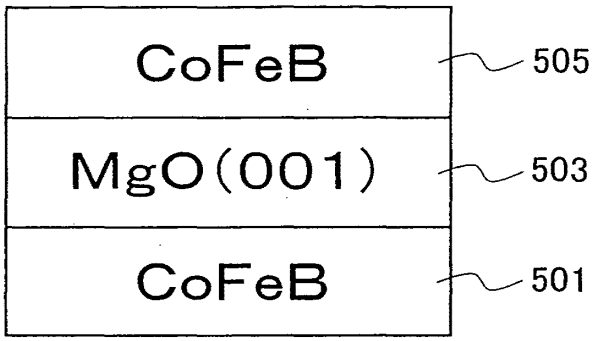
FIG. 10






WD EX1004
Western Digital v IP Bridge
Page 70

FIG. 11






WD EX1004
Western Digital v IP Bridge
Page 71

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | |
|---|---|
| **In re U.S. Patent Application of** | ) |
| | ) |
| **YUASA** . | ) |
| | ) |
| **Application Number: To Be Assigned** | ) |
| | ) |
| **Filed: Concurrently Herewith** | ) |
| | ) |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME** | ) |
| | ) |
| **ATTORNEY DOCKET NO. NAGI.0003** | ) |

**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## INFORMATION DISCLOSURE STATEMENT

Sir:

The above-referenced application is a Continuation of U.S. Application 10/591,947 filed on September 8, 2006, which is a National Stage Application of PCT/JP2005/004720 filed on March 10, 2005.

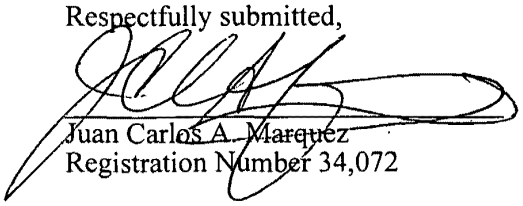
It is understood that the listed references will be considered in the examination of the application and that no separate copies of the same prior art are required to be provided since they were previously cited or transmitted in the foregoing prior application, pursuant to 37 CFR § 1.98(d). Form(s) PTO 1449 is enclosed listing references cited by the Examining Attorney and submitted by applicant in the prior applications.

This Information Disclosure Statement is submitted with the above-captioned U.S. Continuation application. Accordingly, no fee is due or payable at this time.

The Examiner is requested to acknowledge consideration of the information provided in this paper in accordance with prescribed procedures.

Please charge any additional fees or credit any overpayments in connection with this paper to Deposit Account No. 12-0555.

Respectfully submitted,



Juan Carlos A. Marquez
Registration Number 34,072

**STITES & HARBISON PLLC**
1199 N. Fairfax Street, Suite 900
Alexandria, Virginia 22314
(703) 739-4900
**September 30, 2010**



**WD EX1004**
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**Page 73**

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| APPLICATION NUMBER | FILING or 371(c) DATE | GRP ART UNIT | FIL FEE REC'D | ATTY.DOCKET.NO | TOT CLAIMS | IND CLAIMS |
|---|---|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | 2892 | 1750 | NAGI.0003 | 16 | 6 |

**CONFIRMATION NO. 8219**

38327
Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

**FILING RECEIPT**

*OC000000044258794*

Date Mailed: 11/03/2010

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

**Applicant(s)**

Shinji Yuasa, Ibaraki, JAPAN;

**Assignment For Published Patent Application**

Japan Science and Technology Agency and National Institute \ of Advanced Industrial Science and Technology

**Power of Attorney:**
Stanley Fisher--24344
Juan Carlos Marquez--34072

**Domestic Priority data as claimed by applicant**

This application is a CON of 10/591,947 09/08/2006
which is a 371 of PCT/JP2005/004720 03/10/2005

**Foreign Applications**
JAPAN 2004-071186 03/12/2004
JAPAN 2004-313350 10/28/2004

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to Retrieve Electronic Priority Application(s)** (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

**If Required, Foreign Filing License Granted:** 10/28/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/923,643**

**Projected Publication Date:** 02/10/2011

**Non-Publication Request:** No

**Early Publication Request:** No

**Title**

Magnetic tunnel junction device and method of manufacturing the same

**Preliminary Class**

257

## PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

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## Title 37, Code of Federal Regulations, 5.11 & 5.15

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This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

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# 日 本 国 特 許 庁
JAPAN PATENT OFFICE

別紙添付の書類に記載されている事項は下記の出願書類に記載されている事項と同一であることを証明する。

This is to certify that the annexed is a true copy of the following application as filed with this Office.

| | |
|---|---|
| 出 願 年 月 日<br>Date of Application: | ２００４年　３月１２日 |
| 出 願 番 号<br>Application Number: | 特願２００４－０７１１８６ |
| パリ条約による外国への出願に用いる優先権の主張の基礎となる出願の国コードと出願番号<br>The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is | ＪＰ２００４－０７１１８６ |
| 出 願 人<br>Applicant(s): | 独立行政法人科学技術振興機構<br>独立行政法人産業技術総合研究所 |

２０１０年１１月　４日

特許庁長官
Commissioner,
Japan Patent Office

岩 井 良 行

【書類名】　特許願
【整理番号】　P04-0204
【提出日】　平成16年 3月12日
【あて先】　特許庁長官　殿
【国際特許分類】　H01L 43/00
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　つくばセンター内
　【氏名】　湯浅　新治
【特許出願人】
　【識別番号】　503360115
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【特許出願人】
　【識別番号】　301021533
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【代理人】
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　【氏名又は名称】　平木　祐輔
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　【物件名】　明細書　1
　【物件名】　図面　1
　【物件名】　要約書　1

【書類名】特許請求の範囲
【請求項１】
トンネル障壁層と、該トンネル障壁層の第１面側に形成されたＢＣＣ構造を有する第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有する第２の強磁性体層と、を有する磁気トンネル接合構造であって、
前記トンネル障壁層が、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）層により形成されていることを特徴とする磁気抵抗素子。
【請求項２】
ＭｇＯ（１００）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたＦｅ（１００）からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅ（１００）からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、
前記ＭｇＯ層が、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）層により形成されていることを特徴とする磁気抵抗素子。
【請求項３】
ＭｇＯ（１００）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、
前記ＭｇＯ（１００）層の伝導帯下端と前記Ｆｅ（１００）層のフェルミ準位の間の不連続値（トンネル障壁の高さ）を単結晶における理想的な値よりも低くしたことを特徴とする磁気抵抗素子。
【請求項４】
前記不連続値は、０．２～０．５ｅＶの範囲内であることを特徴とする請求項３に記載の磁気抵抗素子。
【請求項５】
前記不連続値は、０．１０～０．８５ｅＶの範囲内であることを特徴とする請求項３に記載の磁気抵抗素子。
【請求項６】
１つのトランジスタと、該トランジスタの負荷として用いられる請求項１から５までのいずれか１項に記載の磁気抵抗素子と
を有する記憶素子。
【請求項７】
基板を準備する工程と、
該基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を堆積する工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（１００）層上に電子ビーム蒸着法により、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなるトンネル障壁層を高真空下において堆積する工程と、
該トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を形成する工程と
を有することを特徴とする磁気抵抗素子の製造方法。
【請求項８】
単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなる基板を準備する第１工程と、
該基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を堆積し、次いで、結晶化のためのアニール

を行う第２工程と、
　前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（１００）層上に電子ビーム蒸着法により単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなるトンネル障壁層を高真空下において堆積する第３工程と、
　該トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を形成する第４工程と
を有することを特徴とする磁気抵抗素子の製造方法。
【請求項９】
　前記第１工程と第２工程との間に、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなるシード層を成長する工程を有することを特徴とする請求項７又は８に記載の磁気抵抗素子の製造方法。
【請求項１０】
　前記単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなるトンネル障壁層を形成する工程中に、$MgO_x$のｘ値を調整する工程を含むことを特徴とする請求項７又は８に記載の磁気抵抗素子の製造方法。
【請求項１１】
　基板を準備する工程と、
　該基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を堆積する工程と、
　前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（１００）層上にスパッタリング法によりアモルファスＭｇＯ層を形成し、アニールにより該アモルファスＭｇＯ層を結晶化して単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなるトンネル障壁層を形成する工程と、
　該トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を形成する工程と
を有することを特徴とする磁気抵抗素子の製造方法。
【請求項１２】
　前記アモルファスＭｇＯ層を、$MgO_x$のｘ値を調整済みのターゲットを用いて堆積することを特徴とする請求項１１に記載の磁気抵抗素子の製造方法。
【請求項１３】
　前記アモルファスＭｇＯを形成する工程中に、$MgO_x$のｘ値を調整する工程を含むことを特徴とする請求項１１に記載の磁気抵抗素子の製造方法。

【書類名】明細書
【発明の名称】磁気抵抗素子及びその製造方法
【技術分野】
【０００１】
本発明は、磁気抵抗素子及びその製造方法に関し、特に、高い磁気抵抗を有する磁気抵抗素子及びその製造方法に関する。
【背景技術】
【０００２】
MRAM（Magnetoresistive Random Access Memory）は、現在広く用いられている記憶素子であるＤＲＡＭに代わる大容量向け記憶素子であり、かつ、高速な不揮発性メモリとして広く研究開発が行われており、例えば、4MbitのMRAMがサンプル出荷されたという実績がある。
【０００３】
図８は、ＭＲＡＭの心臓部であるＴＭＲ素子の構造と、その動作原理を示す図である。図８（Ａ）に示すように、ＴＭＲ素子においては、酸化物からなるトンネル障壁の両側を強磁性金属からなる第１及び第２の２つの電極により挟んだトンネル構造を有している。トンネル障壁層としては、アモルファスのＡｌ－Ｏ層が用いられている（非特許文献１参照）。図８（Ａ）に示すように、第１の強磁性電極と第２の強磁性電極との磁化の向きが平行な平行磁化の場合には、トンネル構造の界面における法線方向に関する素子の電気抵抗が小さくなる。一方、図８（Ｂ）に示すように、第１の強磁性電極と第２の強磁性電極との磁化の向きが平行な反平行磁化の場合には、トンネル構造の界面における法線方向に関する素子の電気抵抗が大きくなる。この抵抗値は、一般的な状態では変化せず、抵抗値が高いか低いかに基づいて情報“１”、“０”として記憶される。平行磁化と反平行磁化とは不揮発に記憶されるため、不揮発性メモリの基本素子として用いることができる。
【０００４】
図９は、ＭＲＡＭの基本構造例を示す図であり、図９（Ａ）はＭＲＡＭの斜視図であり、図９（Ｂ）は模式的な回路構成図であり、図９（Ｃ）は、構造例を示す断面図である。図９（Ａ）に示すように、ＭＲＡＭにおいてはワード線ＷＬとビット線ＢＬとが交差するように配置され、交差部にＭＲＡＭセルが配置されている。図９（Ｂ）に示すように、ワード線とビット線との交差部に配置されたＭＲＡＭセルは、ＴＭＲ素子と、このＴＭＲ素子と直列接続されたＭＯＳＦＥＴとを有しており、負荷抵抗として機能するＴＭＲ素子の抵抗値をＭＯＳＦＥＴにより読み取ることにより、記憶情報を読み出すことができる。尚、情報の書き換えは、例えば、ＴＭＲ素子への磁場の印加により行うことができる。図９（Ｃ）に示すように、ＭＲＡＭメモリセルは、ｐ型Ｓｉ基板１０１内に形成されたソース領域１０５とドレイン領域１０３と、その間に画定されるチャネル領域に対して形成されたゲート電極１１１とを有するＭＯＳＦＥＴ１００と、ＴＭＲ素子１１７とを有している。ソース領域１０５は接地（ＧＮＤ）され、ドレインは、ＴＭＲ素子を介してビット線ＢＬに接続されている。ワード線ＷＬはゲート電極１１１に対して図示しない領域において接続されている。
【０００５】
以上に説明したように、不揮発性メモリＭＲＡＭは、１つのＭＯＳＦＥＴ１００とＴＭＲ素子１１７とにより１つのメモリセルを形成することができるため、高集積化に適したメモリ素子ということができる。
【０００６】
【非特許文献１】D.Wang, et al.:Science 294 (2001) 1488.
【発明の開示】
【発明が解決しようとする課題】
【０００７】
現状の技術を用いることにより６４Ｍｂｉｔ程度のＭＲＡＭを実現する見通しは立っているが、それ以上の高集積化のためには、ＭＲＡＭの心臓部であるＴＭＲ素子の特性を向

上させる必要がある。特に、全素子の出力電圧を向上させるには、磁気抵抗の増大と電圧特性の改善の両方が必要である。図１０は、アモルファスＡｌ－Ｏをトンネル障壁とした従来型ＴＭＲ素子の磁気抵抗の印加電圧による変化を示す図である（Ｌ１）。図１０に示すように、従来型ＴＭＲ素子においては、磁気抵抗が小さく、特に電圧を印加することにより磁気抵抗が急激に小さくなる傾向がみられる。このような特性では、動作マージンを考慮した出力電圧が小さすぎるため、実際の記憶素子に用いるのが難しい。より具体的には、現状のＴＭＲ素子の磁気抵抗は約70％と低く、また出力電圧も200 ｍＶ以下と低いため、ＤＲＡＭの出力電圧に比べて実質的に半分であり、集積度を上げるに従い信号がノイズに埋もれて読み出せなくなってしまうという問題があった。

【０００８】

本発明は、ＴＭＲ素子における出力電圧を大きくすることを目的とする。さらに、大きな磁気抵抗により、安定に動作する記憶装置を提供することを目的とする。

【課題を解決するための手段】

【０００９】

本発明の一観点によれば、トンネル障壁層と、該トンネル障壁層の第１面側に形成されたＢＣＣ構造を有する第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有する第２の強磁性体層と、を有する磁気トンネル接合構造であって、前記トンネル障壁層が、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）層により形成されていることを特徴とする磁気抵抗素子が提供される。

【００１０】

また、ＭｇＯ（１００）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたＦｅ（１００）からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅ（１００）からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、前記ＭｇＯ層が、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）層により形成されていることを特徴とする磁気抵抗素子が提供される。前記ＭｇＯ（１００）層の伝導帯下端と前記Ｆｅ（１００）層のフェルミエネルギーの間の不連続値（トンネル障壁高さ）を単結晶における値よりも低くしたことを特徴とする。上記構成を用いると、磁気抵抗が増大しＴＭＲ素子の出力電圧を大きくすることができた。１つのトランジスタの負荷として上記磁気抵抗素子を用いると、不揮発性の記憶素子を形成することができた。

【００１１】

本発明の他の観点によれば、基板を準備する工程と、該基板上に第１のＦｅ（１００）層を堆積する工程と、前記第１のＦｅ（１００）層上に電子ビーム蒸着法により単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなるトンネル障壁層を高真空下において堆積する工程と、該トンネル障壁層上に第２のＦｅ（１００）層を形成する工程とを有することを特徴とする磁気抵抗素子の製造方法が提供される。

【００１２】

また、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなる基板を準備する第１工程と、該基板上に第１のＦｅ（１００）層を堆積し、次いで、結晶化のためのアニールを行う第２工程と、前記第１のＦｅ（１００）層上に電子ビーム蒸着法により単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなるトンネル障壁層を高真空下において堆積する第３工程と、該トンネル障壁層上に第２のＦｅ（１００）層を形成する第４工程とを有することを特徴とする磁気抵抗素子の製造方法が提供される。尚、前記第１工程と第２工程との間に、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）からなるシード層を成長する工程を有していても良い。また、前記アモルファスＭｇＯ層を、$MgO_x$のｘ値を調整済みのターゲットを用いて堆積しても良い。この際、前記アモルファスＭｇＯを形成する工程中に、$MgO_x$のｘ値を調整しても

良い。
【発明の効果】
【００１３】
本発明によれば、従来のＴＭＲ素子に比べて大きな磁気抵抗を得ることができ、ＴＭＲ素子の出力電圧を大きくすることができる。従って、ＴＭＲ素子を用いたＭＲＡＭの高集積化が容易になるという利点がある。
【発明を実施するための最良の形態】
【００１４】
本明細書において用いた単結晶における「理想的な値」との用語は、紫外線光電子分光の実験から推測した値である（参考文献：W. Wulfhekel, et al.: Appl. Phys. Lett. 78 (2001) 509.）。このような状態では、酸素欠損や格子欠陥がほとんど無い理想的な単結晶ＭｇＯのトンネル障壁の上限値と言うことができるため、理想的な値という用語を用いた。
【００１５】
発明の実施の形態について説明する前に、発明者の行った考察について説明を行う。ＭＴＪの磁気抵抗（ＭＲ）比は、以下の式で表される。
ΔＲ／Ｒｐ＝（Ｒａｐ－Ｒｐ）／Ｒｐ
ここで、Ｒｐ及びＲａｐは、２つの電極の磁化が平行と反平行の場合のトンネル接合抵抗である。Ｊｕｌｌｉｒｅの公式によれば、低バイアス電圧におけるＭＲ比は、以下のように表される。
ＭＲ比＝（Ｒａｐ－Ｒｐ）／Ｒｐ＝$2P_1P_2$／（$1-P_1P_2$）であり
ここで、Ｐα＝（Ｄα↑（$E_F$）－Ｄα↓（$E_F$））／（Ｄα↑（$E_F$）＋Ｄα↓（$E_F$））、α＝１，２　　（１）と表される。
【００１６】
ここで、Ｐαは、電子のスピン分極率であり、Ｄα↑（$E_F$）とＤα↓（$E_F$）とは、それぞれ、多数スピンバンドと少数スピンバンドのフェルミエネルギー（$E_F$）における状態密度（Ｄｅｎｓｉｔｙ　ｏｆ　ｓｔａｔｅ：ＤＯＳ）である。強磁性遷移金属及び合金のスピンの偏極は０．５以下であるため、Ｊｕｌｌｉｒｅの公式によれば、最も高い推定ＭＲ比として７０％が予測される。
【００１７】
ＭＴＪ素子をアモルファスのＡｌ－Ｏのトンネル障壁と多結晶電極とを用いて作成すると、室温でのＭＲ比として約７０％という値が得られているが、ＤＲＡＭ並の出力電圧である２００ｍＶを得るのは難しく、上述のようにＭＲＡＭ実現の対する問題点となっている。
【００１８】
発明者は、酸化マグネシウムの単結晶（１００）あるいは（１００）結晶面が優先配向した多結晶ＭｇＯをトンネル障壁として用いたＭＴＪを成長するアプローチを試みている。従来のアモルファスのアルミナ障壁とは異なり、酸化マグネシウムは結晶（原子が規則正しく配列した物質）であるため、電子が散乱されず、電子のコヒーレント状態がトンネル過程のおいて保存されることが予測される。図１は、本実施の形態によるＭＴＪ素子構造（図１（Ｂ））と、強磁性体金属であるＦｅ（１００）のエネルギーバンド構造を示す図であり、波数空間の［１００］方向に対するＥ－$E_F$の関係を示す図（図１（Ａ））である。図１（Ｂ）に示すように、本実施の形態によるＭＴＪ素子構造は、第１のＦｅ（１００）層１と、第２のＦｅ（１００）層５と、これらの間に挟まれた単結晶$MgO_x$（１００）層あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（ｘ＜１）層３と、を有して構成されている。上記Ｊｕｌｌｉｒｅのモデルによれば、伝導電子のモメンタムがトンネルプロセス中において保存されるとすると、ＭｇＯを透過するトンネル電流はトンネル障壁に垂直な方向（接合界面に対する法線方向）の波数ベクトル$k_Z$を有する電子が支配的になる。図１（Ａ）に示す［１００］（Γ－Ｈ）方向におけるＦｅのエネルギーバンド図によれば、フェルミ準位$E_F$における状態密度（ＤＯＳ）は、多数スピンと少数スピ

ンのサブバンドがフェルミ準位$E_F$において状態を有しているため、それほど高い偏極率を示さない。しかしながら、電子のコヒーレント状態がトンネル過程のおいて保存される場合には、障壁に垂直な軸に関してトータルに対称な波動関数を有する伝導電子のみが障壁領域における状態と関連し、ある一定のトンネル確率を持つことになる。図１（Ａ）に示すように、多数スピン$\Delta_1\uparrow$バンド（実線）がフェルミ準位$E_F$に状態を有するが、少数スピン$\Delta_1\downarrow$バンド（破線）はフェルミ準位$E_F$に状態を有しない。このようなＦｅ$\Delta_1\downarrow$バンドのハーフメタル的な特徴により、非常に高いＭＲ比がコヒーレントなスピン偏極トンネルにおいて得られる可能性がある。エピタキシャル（単結晶あるいは（１００）配向多結晶）のＭＴＪは、トンネル過程中における電子の散乱が抑制されるため、上記のようなコヒーレントなトンネルを実現するためには理想的であると考えられる。

【００１９】

以下、本発明の第１の実施の形態による磁気抵抗素子及びその製造方法について図面を参照しつつ説明を行う。図２（Ａ）から図２（Ｄ）までは、本発明の実施の形態によるＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）構造を有する磁気抵抗素子（以下、「Ｆｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ」と称する。）の製造工程を模式的に示す図である。Ｆｅ（１００）は、ＢＣＣ構造を有する強磁性体である。まず、単結晶ＭｇＯ（１００）基板１１を準備し、ＭＢＥ法（分子線エピタキシー法）により、単結晶ＭｇＯ（１００）基板１１の表面のモフォロジーを改善するため、ＭｇＯ（１００）シード層１５を成長する。連続して、図１（Ｂ）に示すように、５０ｎｍ厚のエピタキシャルＦｅ（１００）下部電極（第１電極）１７をＭｇＯ（１００）シード層１５上に室温で成長し、次いで、超高真空下（$2\times10^{-8}$Ｐａ）において、３５０℃でアニールを行う。尚、電子線蒸着における条件は、加速電圧が８ｋＶであり、成長速度が０．０２ｎｍ／秒、成長温度が室温（２９３Ｋ）、ソースとしては化学量論的組成のＭｇＯ（ＭｇとＯとの比が１：１）を用い、ソースと基板との距離を４０ｃｍとし、バックグラウンドの真空度が$1\times10^{-8}$Ｐａ、$O_2$分圧が$1\times10^{-6}$Ｐａである。尚、化学量論的組成のＭｇＯ（ＭｇとＯとの比が１：１）の代わりに、Ｏ欠損を有するソースを使用することも可能である。

【００２０】

図３（Ａ）は、この際のＦｅ（１００）下部電極（第１電極）１７のＲＨＥＥＤイメージを示す図である。図３（Ａ）に示すように、Ｆｅ（１００）下部電極（第１電極）１７は良好な結晶性と平坦性を有していることを示している。次いで、図２（Ｃ）に示すように、２ｎｍ厚のＭｇＯ（１００）バリア層２１をＦｅ（１００）下部電極（第１電極）１７上に室温でエピタキシャル成長する。この際も、ＭｇＯの電子ビーム蒸着法を用いた。図３（Ｂ）は、この際のＭｇＯ（１００）バリア層２１のＲＨＥＥＤイメージを示す図である。図３（Ｂ）に示すように、ＭｇＯ（１００）バリア層２１も良好な結晶性と平坦性を有していることを示している。

【００２１】

図２（Ｄ）に示すように、ＭｇＯ（１００）バリア層２１上に、室温で厚さ１０ｎｍのＦｅ（１００）上部電極（第２電極）２３を形成した。連続して、１０ｎｍ厚さのＣｏ層２５をＦｅ（１００）上部電極（第２電極）２３上に堆積した。Ｃｏ層２５は、上部電極２３の保持力を高めることによって反平行磁化配置を実現するためのものである。次いで、上記の作成試料を微細加工してＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ素子を形成する。

【００２２】

上記ＥＢによるＭｇＯ蒸着は、$10^{-9}$Ｔｏｒｒの超高真空状態で成膜を行った。この方法では、例えばガラス基板上に３００ｎｍの成膜を行った場合でも、無色透明であり、良好な単結晶膜が形成されていることがわかる。図４は、ＭｇＯ成長時における四重極Ｍａｓｓスペクトルの観測結果を示す図である。図４に示すように、ＯのスペクトルＰ１と$O_2$のスペクトルＰ２とに関する分圧が高いことがわかる。図５は、ＭｇＯ蒸着中の酸素分圧の膜堆積速度依存を示す図である。図５に示すように、酸素分圧自体がかなり高いこ

と、堆積速度とともに酸素分圧も高くなること、などは、ＭｇＯの堆積時におけるＭｇＯ単結晶からの酸素の離脱を示唆するものであり、$MgO_x$（０．９＜ｘ＜１）のように酸素欠損が生じている可能性がある。酸素欠損が生じるとＭｇＯトンネル障壁の高さが低くなると考えられ（例えば、０．１０～０．８５ｅＶ（より詳細には０．２～０．５ｅＶの範囲内））、これにより、トンネル電流が増加するものと考えられる。尚、一般的なＡｌ－Ｏトンネル障壁の場合、Ｆｅ（１００）との間のトンネル障壁の高さは、０．７～２．５ｅＶと考えられる。これに対して、ＭｇＯ結晶は理想的なトンネル障壁の高さは３．６ｅＶであり、実験値としては０．９～３．７ｅＶの値が得られている。本実施の形態による方法を用いると、０．３ｅＶ程度のトンネル障壁の高さが推定され、トンネル障壁の低抵抗化が可能であることがわかる。但し、その他の要因、例えば前述のコヒーレントなトンネルの影響も関連している可能性がある。

【００２３】

図６は、上記の方法により製造したＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ素子の典型的な磁気抵抗曲線を示す図である。測定温度２０ＫにおいてＭＲ比１４６％であり、測定温度２９３ＫにおいてＭＲ比は８８％であった。この値は、現在までに室温において得られた最も高いＭＲ比である。このような高いＭＲ比は、Ｆｅ（１００）電極のスピン分極率によって説明することはできず、むしろ、コヒーレントなスピン偏極トンネリングに関連すると考えられる。１６０のＭＴＪ素子を試作した結果、ＭＲ比とトンネル抵抗値とに関するばらつきは、２０％以内であった。ＭＴＪの歩留まりも実験室段階で９０％以上であった。このような高い値は、本アプローチの有効性を示唆している。ＭＴＪの抵抗－エリア積（ＲＡ）は、数$k\Omega\mu m^2$であり、この値は、ＭＲＡＭに適した値である。

【００２４】

図７（ａ）は、室温におけるＭＲ比のバイアス電圧依存性を示す図である。図７（ａ）に示すように、ＭＲ比のバイアス電圧依存性はかなり低いことがわかる。非対称な特性を示すが、ＭＲ比が半減する電圧$V_{half}$は１２５０ｍＶという非常に高い値が得られている。尚、従来のＡｌ－Ｏ系におけるＭＲ比の半減する電圧$V_{half}$は３００～６００ｍＶである。図７（ｂ）に、ＭＴＪの出力電圧$V_{out}$は（＝バイアス電圧×（Ｒａｐ－Ｒｐ）／Ｒａｐ）を示す。出力電圧$V_{out}$の最大値は順バイアスにおいて３８０ｍＶの値が得られている。この値は、Ａｌ－Ｏバリアの場合の値（２００ｍＶ）の約２倍の値である。このように、ＭＲ比と出力電圧との両方で高い値が得られたことは、本実施の形態による技術の有効性を示している。

【００２５】

尚、上記実施の形態においては、ＢＣＣのＦｅ（１００）を用いたが、代わりにＢＣＣのＦｅ系合金、例えば、Ｆｅ－Ｃｏ合金、Ｆｅ－Ｎｉ合金、Ｆｅ－Ｐｔ合金を用いることもできる。或いはＦｅ（１００）層とＭｇＯ（１００）層との間に、１原子層又は数原子層程度の厚さのＣｏ、Ｎｉなどを挿入しても良い。

【００２６】

次に、本発明の第２の実施の形態による磁気抵抗素子及びその製造方法について説明を行う。本実施の形態によるＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＴＭＲ素子の製造方法では、まずスパッタリング法などによりＭｇＯ（１００）を多結晶またはアモルファス状態で堆積し、その後にアニール処理を行うことにより（１００）結晶面が配向した多結晶または単結晶化する点を特徴とする。スパッタリング条件は、例えば。温度が室温（２９３Ｋ）であり、ターゲットとしては２インチφのＭｇＯを用い、Ａｒ雰囲気中でスパッタリングを行った。加速電力は２００Ｗであり、成長速度は０．００８ｎｍ／ｓである。この条件で堆積したＭｇＯはアモルファス状態であるため、室温から３００℃まで温度を上昇させ、３００℃において一定時間保持をすることにより、結晶化されたＭｇＯを得ることが出来る。

【００２７】

尚、Ｏ欠損の導入方法としては、成長時にＯ欠損が生じる条件で成長を行う方法、Ｏ欠

損を後から導入する方法、Ｏ欠損のある状態から例えば酸素プラズマ処理又は自然酸化などにより酸化を行ってある程度のＯ欠陥まで調整する方法のいずれを用いても良い。

【００２８】

以上、本実施の形態による磁気抵抗素子技術によれば、スパッタリング法を用いてアモルファスＭｇＯを堆積した後にアニール処理により結晶化するため、それほど大がかりな装置が必要ないという利点がある。

【００２９】

以上、本実施の形態による磁気抵抗素子について説明したが、本発明はこれらに制限されるものではない。その他、種々の変更、改良、組み合わせが可能なことは当業者に自明であろう。例えば、ＭｇＯ層に酸素欠陥を導入する代わりに、例えばＣａやＳｒをドーピングすることでトンネル障壁の高さを調整する方法を用いても良い。また、ＭｇＯ層の堆積方法として、電子ビーム蒸着法又はスパッタリング法を例にして説明したが、その他の堆積法も適用可能であることは言うまでもない。また、高真空との用語は、例えば酸素を導入しない場合において、概ね１０－６Ｐａ以下の値を指し、一方、酸素を積極的に導入する場合でも、１０－４Ｐａ程度の値を指す。

【産業上の利用可能性】

【００３０】

ＭＲＡＭの出力電圧値が従来の約２倍に向上し、ギガビット級の超高集積ＭＲＡＭに適した構造となっている。

【図面の簡単な説明】

【００３１】

【図１】本発明の第１の実施の形態によるＭＴＪ素子構造（図１（Ｂ））と、強磁性体金属であるＦｅ（１００）のエネルギーバンド構造を示す図であり、波数空間の［１００］方向に対するＥ－$Ｅ_Ｆ$の関係を示す図（図１（Ａ））である。

【図２】図２（Ａ）から図２（Ｄ）までは、本発明の実施の形態によるＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）構造を有する磁気抵抗素子（以下、「Ｆｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ」と称する。）の製造工程を模式的に示す図である。

【図３】図３（Ａ）は、Ｆｅ（１００）下部電極（第１電極）のＲＨＥＥＤイメージを示す図であり、図３（Ｂ）は、この際のＭｇＯ（１００）バリア層のＲＨＥＥＤイメージを示す図である。

【図４】ＭｇＯ成長時における四重極Ｍａｓｓスペクトルの観測結果を示す図である。

【図５】ＭｇＯ蒸着中の酸素分圧の膜堆積速度依存を示す図である。

【図６】Ｆｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ素子の典型的な磁気抵抗曲線を示す図である。

【図７】図７（Ａ）は、室温におけるＭＲ比のバイアス電圧依存性を示す図である。図７（Ｂ）は、ＭＴＪの出力電圧$Ｖ_{ｏｕｔ}$は（＝バイアス電圧×（Ｒａｐ－Ｒｐ）／Ｒａｐ）を示す図である。

【図８】ＴＭＲ素子の構造と、その動作原理を示す図である。

【図９】ＭＲＡＭの基本構造例を示す図であり、図９（Ａ）はＭＲＡＭの斜視図であり、図９（Ｂ）は模式的な回路構成図であり、図９（Ｃ）は、構造例を示す断面図である。

【図１０】アモルファスＡｌ－Ｏをトンネル障壁とした従来型ＴＭＲ素子の磁気抵抗の印加電圧による変化を示す図である

【符号の説明】

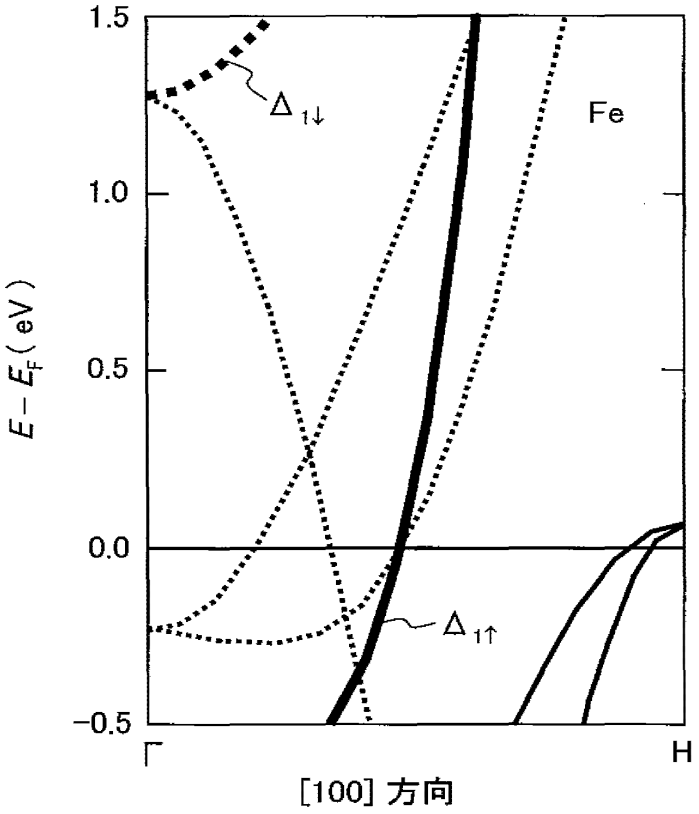
【００３２】

１…第１のＦｅ（１００）層、３…単結晶$ＭｇＯ_ｘ$（１００）あるいは（１００）結晶面が優先配向した多結晶$ＭｇＯ_ｘ$層（ｘ＜１）、５…第２のＦｅ（１００）層、１１…単結晶$ＭｇＯ_ｘ$（１００）あるいは（１００）結晶面が優先配向した多結晶$ＭｇＯ_ｘ$基板（

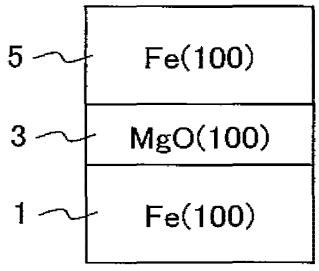
ｘ＜１）、１５…ＭｇＯ（１００）シード層、１７…エピタキシャルＦｅ（１００）下部電極（第１電極）、２１…ＭｇＯ（１００）バリア層、２３…エピタキシャルＦｅ（１００）上部電極（第２電極）。

【書類名】図面
【図１】

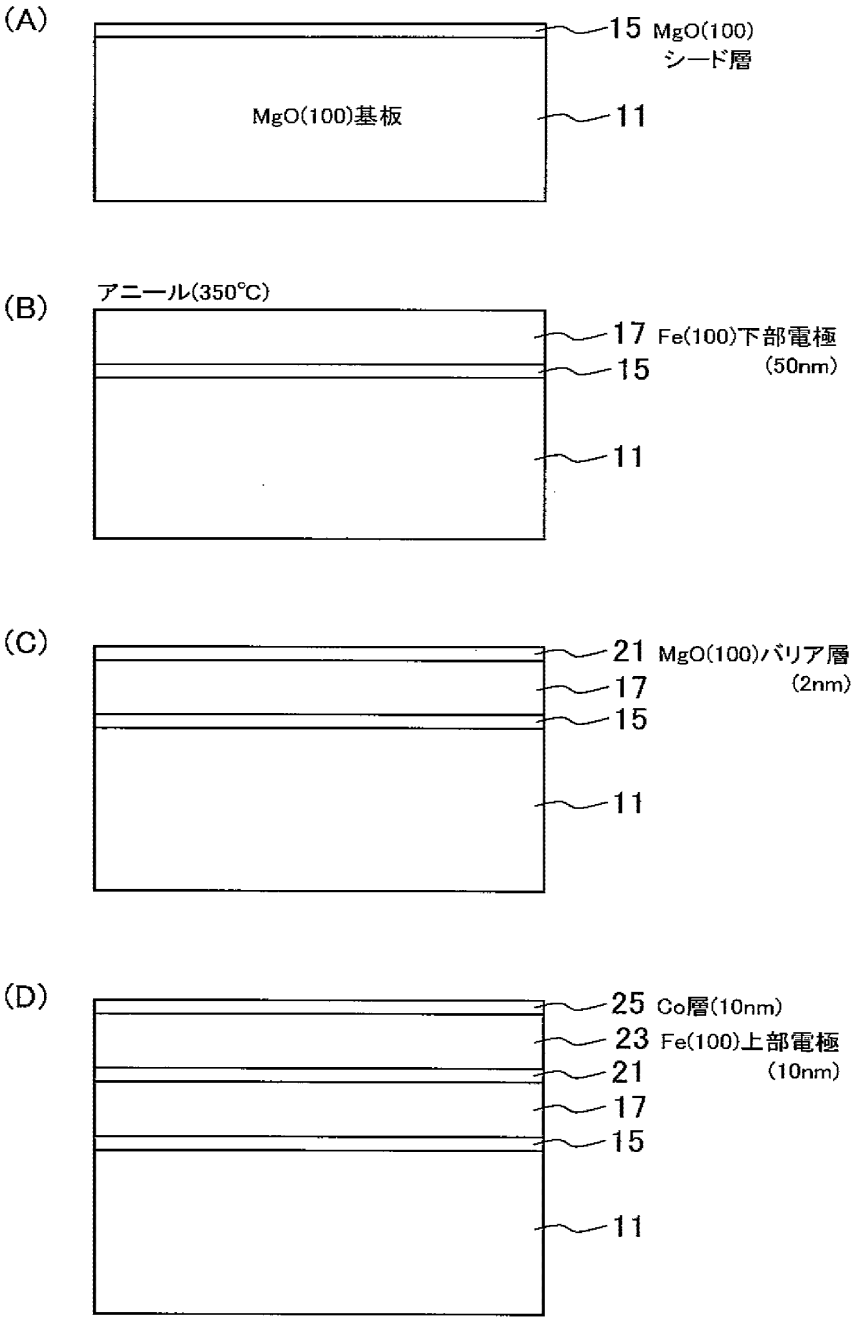
(A)




(B)

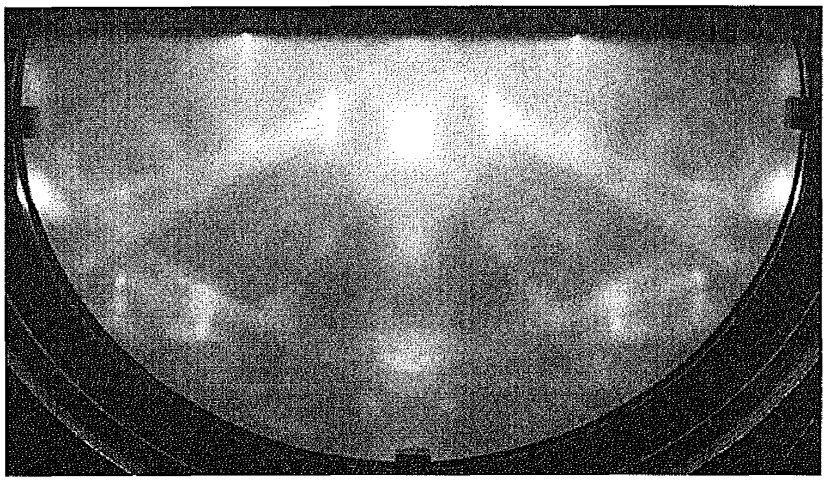


【図２】

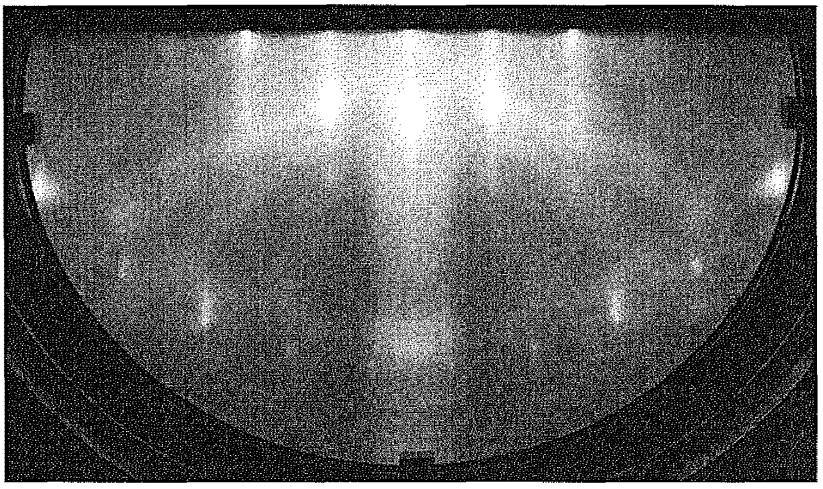

(A)
15 MgO(100)
シード層
MgO(100)基板
11
(B)
アニール(350℃)
17 Fe(100)下部電極
(50nm)
15
11
(C)
21 MgO(100)バリア層
(2nm)
17
15
11
(D)
25 Co層(10nm)
23 Fe(100)上部電極
(10nm)
21
17
15
11

【図３】

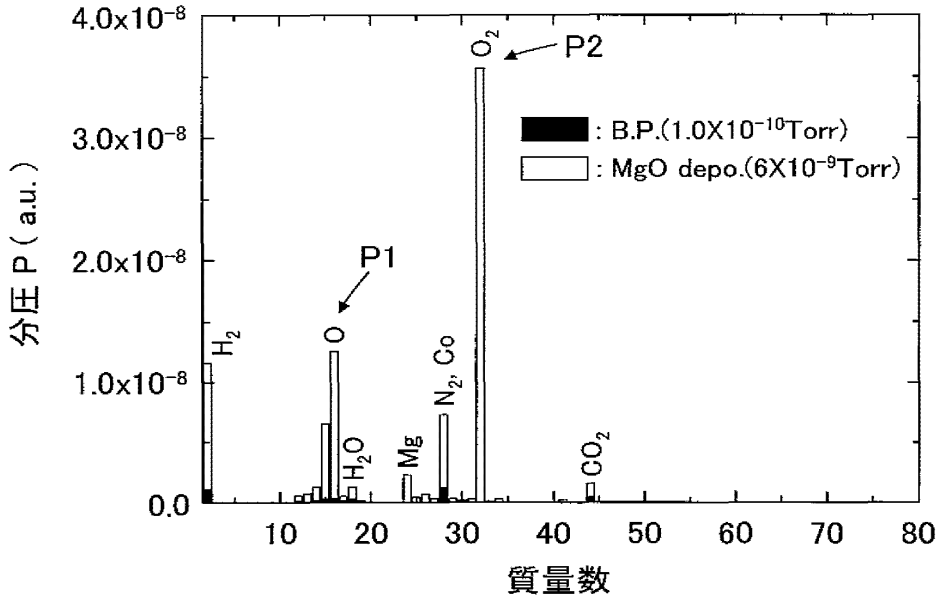
(a)



(b)

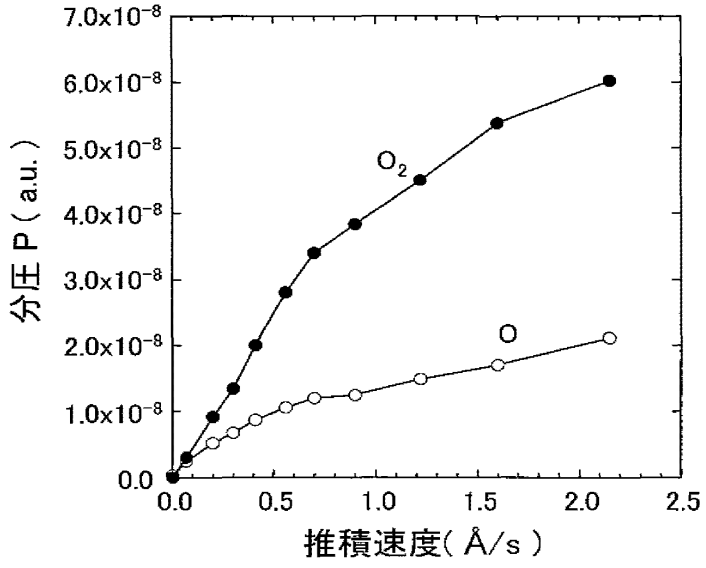


【図４】



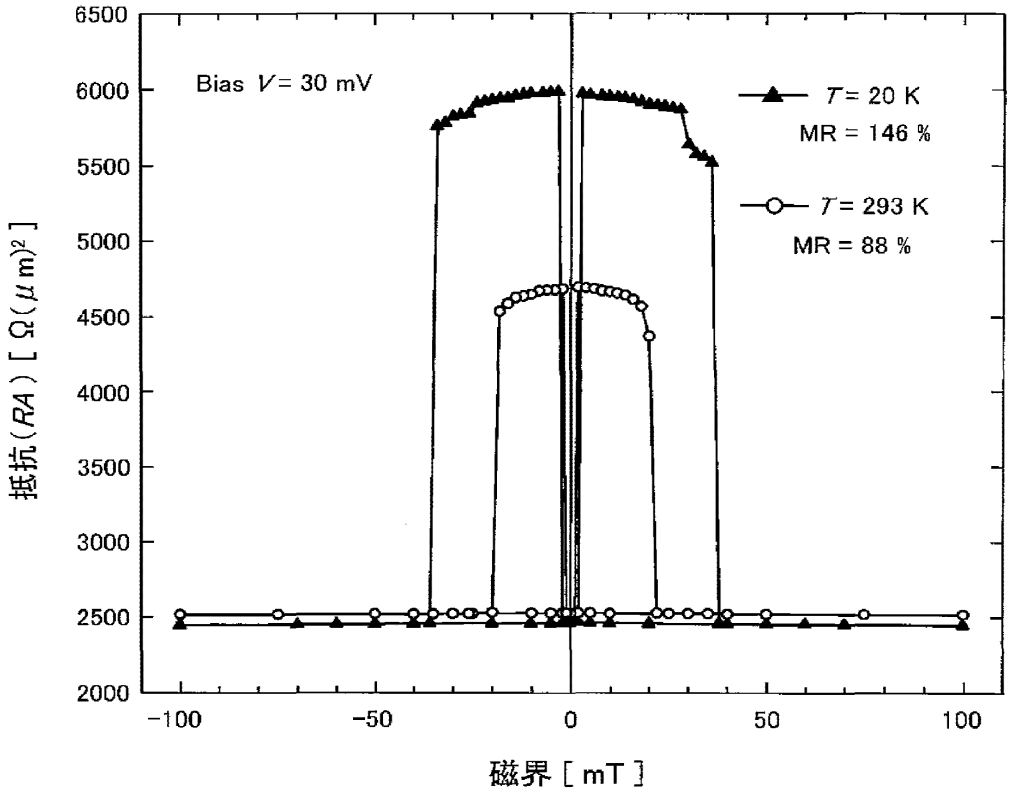

Massスペクトル

【図５】

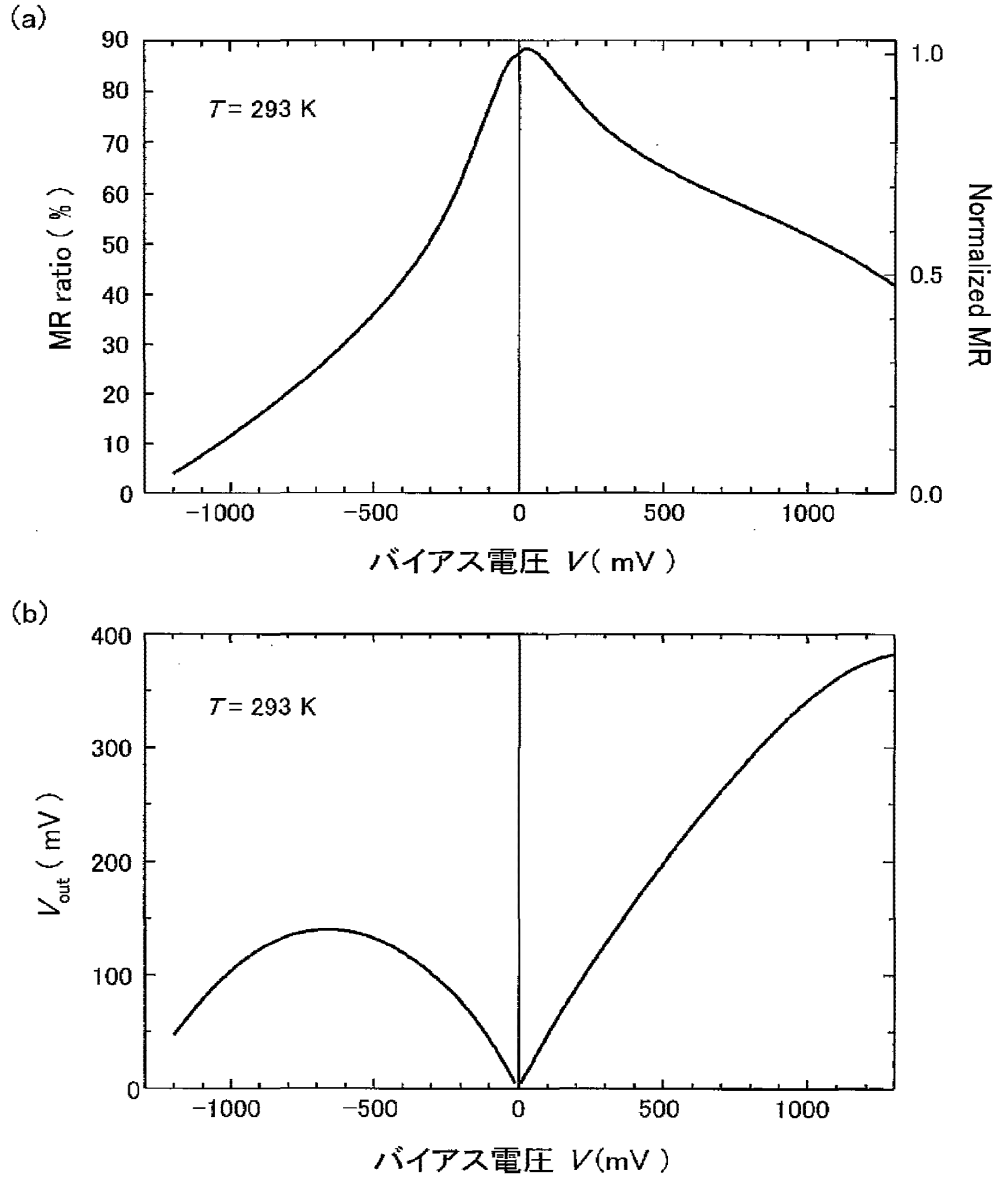



MgO蒸着中の酸素分圧

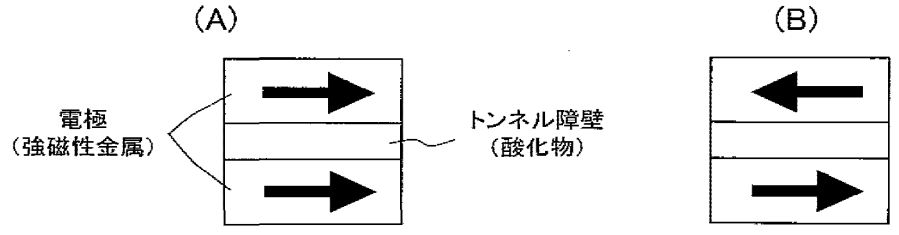
【図６】


Bias V = 30 mV
T = 20 K
MR = 146 %
T = 293 K
MR = 88 %
抵抗(RA)[Ω(μm)²]
磁界[mT]
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
−100
−50
0
50
100

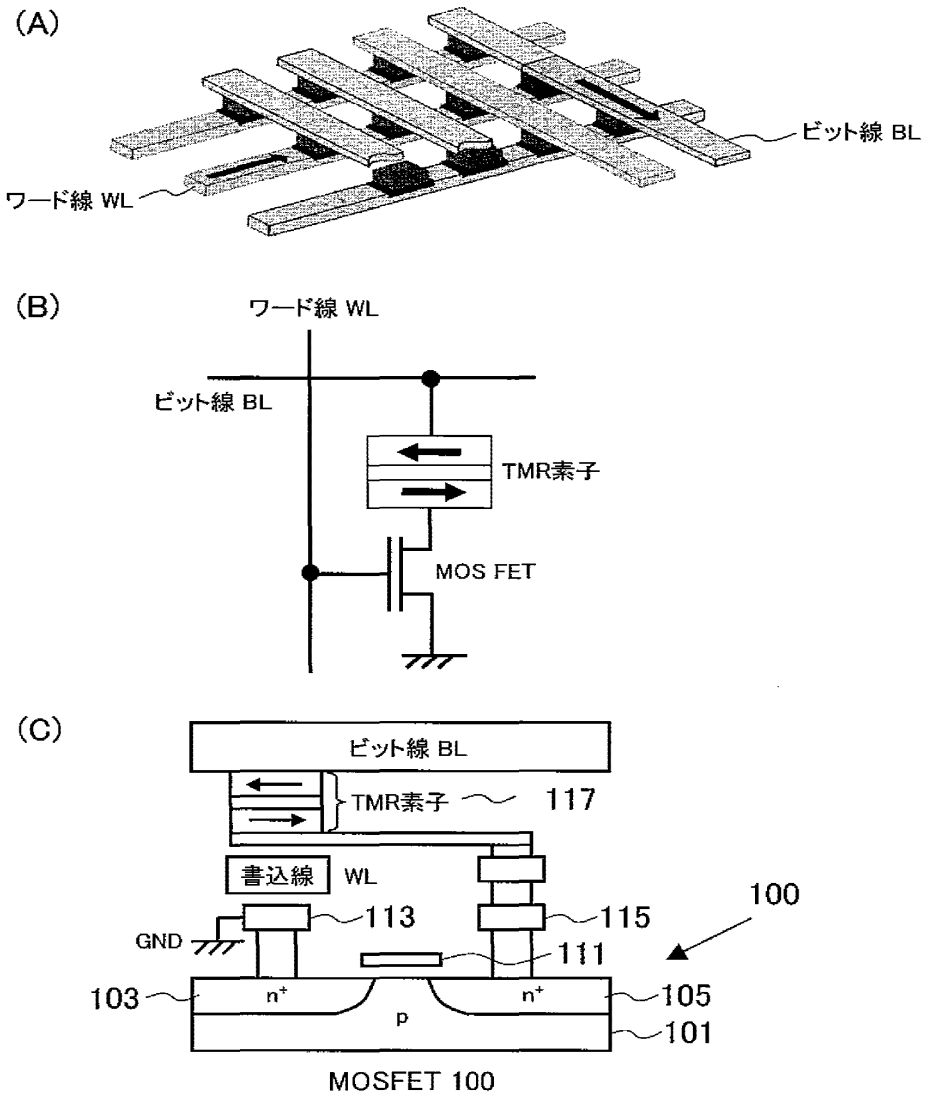
【図７】


(a)
T = 293 K
MR ratio ( % )
Normalized MR
90
80
70
60
50
40
30
20
10
0
1.0
0.5
0.0
−1000
−500
0
500
1000
バイアス電圧 V( mV )
(b)
T = 293 K
V_out ( mV )
400
300
200
100
0
−1000
−500
0
500
1000
バイアス電圧 V(mV )

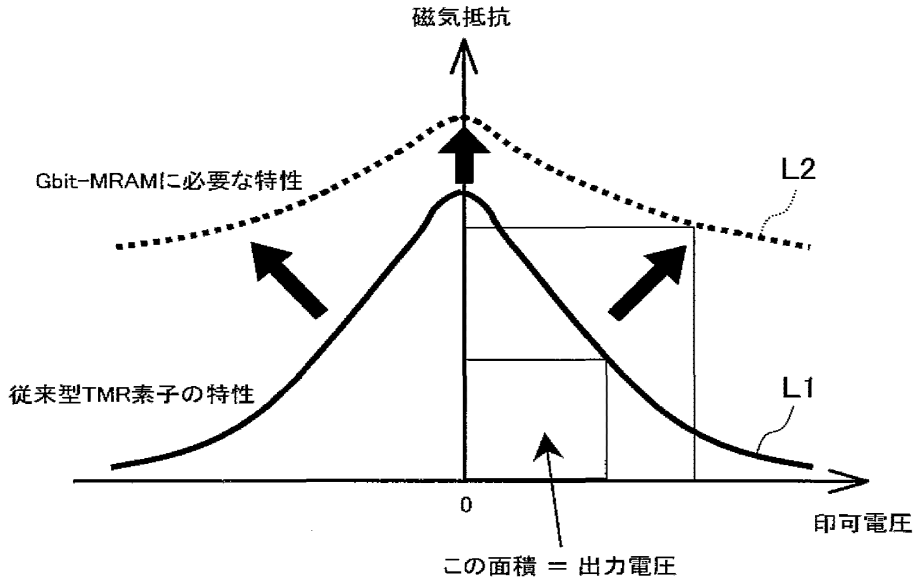
【図８】


(A)
(B)
電極
（強磁性金属）
トンネル障壁
（酸化物）

【図９】


(A)
ビット線 BL
ワード線 WL
(B)
ワード線 WL
ビット線 BL
TMR素子
MOS FET
(C)
ビット線 BL
TMR素子
117
書込線
WL
113
115
100
GND
111
103
n+
n+
105
p
101
MOSFET 100

【図１０】



【書類名】要約書
【要約】
【課題】　ＭＲＡＭの出力電圧値を高める。
【解決手段】　単結晶ＭｇＯ（１００）基板１１を準備し、５０ｎｍ厚のエピタキシャルＦｅ（１００）下部電極（第１電極）１７をＭｇＯ（１００）シード層１５上に室温で成長し、次いで、超高真空（２×１０$^{-8}$Ｐａ）において、３５０℃でアニールを行う。２ｎｍ厚のＭｇＯ（１００）バリア層２１をＦｅ（１００）下部電極（第１電極）１７上に室温でエピタキシャル成長する。この際、ＭｇＯの電子ビーム蒸着を用いた。ＭｇＯ（１００）バリア層２１上に室温で、厚さ１０ｎｍのＦｅ（１００）上部電極（第２電極）２３を形成した。連続して、１０ｎｍ厚さのＣｏ層２１をＦｅ（１００）上部電極（第２電極）２３上に堆積した。Ｃｏ層２１は、上部電極２３の強制的な磁界をエンハンスするための反平行磁化配置を実現するためのものである。次いで、上記の作成試料を微細加工してＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ素子を形成する。
【選択図】　図２

【書類名】　　手続補正書
【整理番号】　　P04-0204
【提出日】　　平成16年 4月 8日
【あて先】　　特許庁長官　殿
【事件の表示】
　【出願番号】　　特願2004- 71186
【補正をする者】
　【識別番号】　　503360115
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　【弁理士】
　【氏名又は名称】　平木　祐輔
【手続補正1】
　【補正対象書類名】　特許願
　【補正対象項目名】　提出物件の目録
　【補正方法】　　追加
　【補正の内容】
　　【提出物件の目録】
　　【物件名】　　知的財産権持分契約書　1

【物件名】　知的財産権持分契約書

【添付書類】

# 知的財産権持分契約書

独立行政法人産業技術総合研究所理事長　吉川　弘之（以下「甲」という。）及び独立行政法人科学技術振興機構理事長　沖村　憲樹（以下「乙」という。）は、乙の戦略的創造研究推進事業において、共同で行った発明等に係る知的財産権（以下「本知的財産権」という。）の持分及び取り扱いに関し次のとおり契約する。

（知的財産権の持分）

第１条　甲及び乙は、持分を以下のとおり所有する。

発明等の名称　：磁気抵抗素子及びその製造方法
整理番号等　：Ｐ０４－０２０４
持　　分　：甲　５０％　、乙　５０％

（知的財産権の管理費用）

第２条　甲及び乙は、管理（取得に係る費用を含む。）に要する費用を、持分に応じて負担するものとする。

（協議）

第３条　この契約で定めるもののほか、その取り扱い及びその他必要な事項については、甲乙が協議して定める。

この契約の締結を証するため、本契約書を３通作成し、双方記名押印の上、甲及び乙それぞれ１通を保有するとともに、１通を出願の手続きのために使用する。

平成１６年３月１２日

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　　理事長　吉川弘之

乙　住所　埼玉県川口市本町四丁目１番８号
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　　理事長　沖村憲樹

出願人履歴

５０３３６０１１５

20031001

新規登録

埼玉県川口市本町４丁目１番８号

独立行政法人　科学技術振興機構

５０３３６０１１５

20040401

名称変更

埼玉県川口市本町４丁目１番８号

独立行政法人科学技術振興機構

５０３３６０１１５

20090820

住所変更

東京都千代田区四番町５－３　サイエンスプラザ５Ｆ

独立行政法人科学技術振興機構

５０３３６０１１５

20091008

住所変更

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独立行政法人科学技術振興機構

３０１０２１５３３

20010402

新規登録

５０３０６３７６６

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独立行政法人産業技術総合研究所

# 日 本 国 特 許 庁
JAPAN PATENT OFFICE

別紙添付の書類に記載されている事項は下記の出願書類に記載されている事項と同一であることを証明する。

This is to certify that the annexed is a true copy of the following application as filed with this Office.

| | |
|---|---|
| 出 願 年 月 日<br>Date of Application: | ２００４年１０月２８日 |
| 出 願 番 号<br>Application Number: | 特願２００４－３１３３５０ |
| パリ条約による外国への出願に用いる優先権の主張の基礎となる出願の国コードと出願番号<br>The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is | ＪＰ２００４－３１３３５０ |
| 出 願 人<br>Applicant(s): | 独立行政法人科学技術振興機構<br>独立行政法人産業技術総合研究所 |

２０１０年１１月 ４日

特許庁長官
Commissioner,
Japan Patent Office

岩 井 良 行

【書類名】　特許願
【整理番号】　P04-1160
【提出日】　平成16年10月28日
【あて先】　特許庁長官　殿
【国際特許分類】　H01L 43/00
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　【連絡先】　担当
【先の出願に基づく優先権主張】
　【出願番号】　特願2004- 71186
　【出願日】　平成16年 3月12日
【手数料の表示】
　【予納台帳番号】　015244
　【納付金額】　16,000円
【提出物件の目録】
　【物件名】　特許請求の範囲　1
　【物件名】　明細書　1
　【物件名】　図面　1
　【物件名】　要約書　1

【書類名】特許請求の範囲
【請求項１】
トンネル障壁層と、該トンネル障壁層の第１面側に形成されたＢＣＣ構造を有する第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有する第２の強磁性体層と、を有する磁気トンネル接合構造であって、
前記トンネル障壁層が、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）層により形成されていることを特徴とする磁気抵抗素子。
【請求項２】
ＭｇＯ（１００）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたＦｅ（１００）からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅ（１００）からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、
前記ＭｇＯ層が、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）層により形成されていることを特徴とする磁気抵抗素子。
【請求項３】
ＭｇＯ（１００）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、
前記ＭｇＯ（１００）層の伝導帯下端と前記Ｆｅ（１００）層のフェルミ準位の間の不連続値（トンネル障壁の高さ）を単結晶における理想的な値よりも低くしたことを特徴とする磁気抵抗素子。
【請求項４】
前記不連続値は、０．２～０．５ｅＶの範囲内であることを特徴とする請求項３に記載の磁気抵抗素子。
【請求項５】
前記不連続値は、０．１０～０．８５ｅＶの範囲内であることを特徴とする請求項３に記載の磁気抵抗素子。
【請求項６】
１つのトランジスタと、該トランジスタの負荷として用いられる請求項１から５までのいずれか１項に記載の磁気抵抗素子と
を有する記憶素子。
【請求項７】
基板を準備する工程と、
該基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を堆積する工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（１００）層上に、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるトンネル障壁層を高真空下において堆積する工程と、
該トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を形成する工程と
を有することを特徴とする磁気抵抗素子の製造方法。
【請求項８】
単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなる基板を準備する第１工程と、
該基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を堆積し、次いで、結晶化のためのアニール

を行う第２工程と、
　前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（１００）層上に単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるトンネル障壁層を高真空下において堆積する第３工程と、
　該トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を形成する第４工程と
を有することを特徴とする磁気抵抗素子の製造方法。
【請求項９】
　前記第１工程と第２工程との間に、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるシード層を成長する工程を有することを特徴とする請求項７又は８に記載の磁気抵抗素子の製造方法。
【請求項１０】
　前記単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるトンネル障壁層を形成する工程中に、$MgO_x$のｘ値を調整する工程を含むことを特徴とする請求項７又は８に記載の磁気抵抗素子の製造方法。
【請求項１１】
　基板を準備する工程と、
　該基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を堆積する工程と、
　前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（１００）層上にアモルファスＭｇＯ層を形成し、アニールにより該アモルファスＭｇＯ層を結晶化して単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるトンネル障壁層を形成する工程と、
　該トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（１００）層または（１００）結晶面が優先配向した多結晶層を形成する工程と
を有することを特徴とする磁気抵抗素子の製造方法。
【請求項１２】
　前記アモルファスＭｇＯ層をスパッタリング法により、$MgO_x$のｘ値を調整済みのターゲットを用いて堆積することを特徴とする請求項１１に記載の磁気抵抗素子の製造方法。
【請求項１３】
　前記アモルファスＭｇＯを形成する工程中に、$MgO_x$のｘ値を調整する工程を含むことを特徴とする請求項１１に記載の磁気抵抗素子の製造方法。
【請求項１４】
　トンネル障壁層と、該トンネル障壁層の第１面側に形成されたアモルファス磁性合金からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたアモルファス磁性合金からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、
　前記トンネル障壁層が、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）層により形成されていることを特徴とする磁気抵抗素子。
【請求項１５】
　ＭｇＯ（１００）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたアモルファス磁性合金からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたアモルファス磁性合金からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、
　前記ＭｇＯ（１００）層の伝導帯下端と前記アモルファス磁性合金からなる第１又は第２の強磁性体層とのフェルミ準位の間の不連続値（トンネル障壁の高さ）を単結晶における理想的な値よりも低くしたことを特徴とする磁気抵抗素子。
【請求項１６】
　前記不連続値は、０．２～０．５ｅＶの範囲内であることを特徴とする請求項１４又は

１５に記載の磁気抵抗素子。
【請求項１７】
前記不連続値は、０．１０～０．８５ｅＶの範囲内であることを特徴とする請求項１４又は１５に記載の磁気抵抗素子。
【請求項１８】
１つのトランジスタと、該トランジスタの負荷として用いられる請求項１４から１７までのいずれか１項に記載の磁気抵抗素子と
を有する記憶素子。
【請求項１９】
基板を準備する工程と、
該基板上にアモルファス磁性合金からなる第１の強磁性体層を堆積する工程と、
該第１の強磁性体層上にアモルファスＭｇＯ層を形成し、アニールにより該アモルファスＭｇＯ層を結晶化して単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるトンネル障壁層を形成する工程と、
該トンネル障壁層上にアモルファス磁性合金からなる第２の強磁性体層を堆積する工程を有することを特徴とする磁気抵抗素子の製造方法。
【請求項２０】
前記単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるトンネル障壁層を形成する工程中は、スパッタリング法により$MgO_x$のｘ値を調整済みのターゲットを用いて堆積することを特徴とする磁気抵抗素子の製造方法。

【書類名】明細書
【発明の名称】磁気抵抗素子及びその製造方法
【技術分野】
【０００１】
本発明は、磁気抵抗素子及びその製造方法に関し、特に、高い磁気抵抗を有する磁気抵抗素子及びその製造方法に関する。
【背景技術】
【０００２】
MRAM（Magnetoresistive Random Access Memory）は、現在広く用いられている記憶素子であるＤＲＡＭに代わる大容量向け記憶素子であり、かつ、高速な不揮発性メモリとして広く研究開発が行われており、例えば、4MbitのMRAMがサンプル出荷されたという実績がある。
【０００３】
図８は、ＭＲＡＭの心臓部であるＴＭＲ素子の構造と、その動作原理を示す図である。図８（Ａ）に示すように、ＴＭＲ素子においては、酸化物からなるトンネル障壁の両側を強磁性金属からなる第１及び第２の２つの電極により挟んだトンネル構造を有している。トンネル障壁層としては、アモルファスのＡｌ－Ｏ層が用いられている（非特許文献１参照）。図８（Ａ）に示すように、第１の強磁性電極と第２の強磁性電極との磁化の向きが平行な平行磁化の場合には、トンネル構造の界面における法線方向に関する素子の電気抵抗が小さくなる。一方、図８（Ｂ）に示すように、第１の強磁性電極と第２の強磁性電極との磁化の向きが平行な反平行磁化の場合には、トンネル構造の界面における法線方向に関する素子の電気抵抗が大きくなる。この抵抗値は、一般的な状態では変化せず、抵抗値が高いか低いかに基づいて情報“１”、“０”として記憶される。平行磁化と反平行磁化とは不揮発に記憶されるため、不揮発性メモリの基本素子として用いることができる。
図９は、ＭＲＡＭの基本構造例を示す図であり、図９（Ａ）はＭＲＡＭの斜視図であり、図９（Ｂ）は模式的な回路構成図であり、図９（Ｃ）は、構造例を示す断面図である。図９（Ａ）に示すように、ＭＲＡＭにおいてはワード線ＷＬとビット線ＢＬとが交差するように配置され、交差部にＭＲＡＭセルが配置されている。図９（Ｂ）に示すように、ワード線とビット線との交差部に配置されたＭＲＡＭセルは、ＴＭＲ素子と、このＴＭＲ素子と直列接続されたＭＯＳＦＥＴとを有しており、負荷抵抗として機能するＴＭＲ素子の抵抗値をＭＯＳＦＥＴにより読み取ることにより、記憶情報を読み出すことができる。尚、情報の書き換えは、例えば、ＴＭＲ素子への磁場の印加により行うことができる。図９（Ｃ）に示すように、ＭＲＡＭメモリセルは、ｐ型Ｓｉ基板１０１内に形成されたソース領域１０３とドレイン領域１０５と、その間に画定されるチャネル領域に対して形成されたゲート電極１１１とを有するＭＯＳＦＥＴ１００と、ＴＭＲ素子１１７とを有している。ソース領域１０３はソース電極１１３を介して接地（ＧＮＤ）され、ドレイン領域１０５は、ドレイン電極１１５とＴＭＲ素子とを介してビット線ＢＬに接続されている。ワード線ＷＬはゲート電極１１１に対して図示しない領域において接続されている。
【０００４】
以上に説明したように、不揮発性メモリＭＲＡＭは、１つのＭＯＳＦＥＴ１００とＴＭＲ素子１１７とにより１つのメモリセルを形成することができるため、高集積化に適したメモリ素子ということができる。
【０００５】
【非特許文献１】D.Wang, et al.:Science 294 (2001) 1488.
【発明の開示】
【発明が解決しようとする課題】
【０００６】
現状の技術を用いることにより６４Ｍｂｉｔ程度のＭＲＡＭを実現する見通しは立っているが、それ以上の高集積化のためには、ＭＲＡＭの心臓部であるＴＭＲ素子の特性を向上させる必要がある。特に、ＴＭＲ素子の出力電圧を向上させるには、磁気抵抗の増大と電

圧特性の改善の両方が必要である。図１０は、アモルファスＡｌ－Ｏをトンネル障壁とした従来型ＴＭＲ素子の磁気抵抗の印加電圧による変化を示す図である（Ｌ１）。図１０に示すように、従来型ＴＭＲ素子においては、磁気抵抗が小さく、特に電圧を印加することにより磁気抵抗が急激に小さくなる傾向がみられる。このような特性では、動作マージンを考慮した出力電圧が小さすぎるため、実際の記憶素子に用いるのが難しい。より具体的には、現状のＴＭＲ素子の磁気抵抗は約70％と低く、また出力電圧も200 ｍＶ以下と低いため、ＤＲＡＭの出力電圧に比べて実質的に半分であり、集積度を上げるに従い信号がノイズに埋もれて読み出せなくなってしまうという問題があった。

【０００７】

本発明は、ＴＭＲ素子における出力電圧を大きくすることを目的とする。さらに、大きな磁気抵抗により、安定に動作する記憶装置を提供することを目的とする。

【課題を解決するための手段】

【０００８】

本発明の一観点によれば、トンネル障壁層と、該トンネル障壁層の第１面側に形成されたＢＣＣ構造を有する第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有する第２の強磁性体層と、を有する磁気トンネル接合構造であって、前記トンネル障壁層が、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）層により形成されていることを特徴とする磁気抵抗素子が提供される。

【０００９】

また、ＭｇＯ（１００）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたＦｅ（１００）からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅ（１００）からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、前記ＭｇＯ層が、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）層により形成されていることを特徴とする磁気抵抗素子が提供される。前記ＭｇＯ（１００）層の伝導帯下端と前記Ｆｅ（１００）層のフェルミエネルギーの間の不連続値（トンネル障壁高さ）を単結晶における値よりも低くしたことを特徴とする。上記構成を用いると、磁気抵抗が増大しＴＭＲ素子の出力電圧を大きくすることができた。１つのトランジスタの負荷として上記磁気抵抗素子を用いると、不揮発性の記憶素子を形成することができた。

【００１０】

本発明の他の観点によれば、基板を準備する工程と、該基板上に第１のＦｅ（１００）層を堆積する工程と、前記第１のＦｅ（１００）層上に電子ビーム蒸着法により単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるトンネル障壁層を高真空下において堆積する工程と、該トンネル障壁層上に第２のＦｅ（１００）層を形成する工程とを有することを特徴とする磁気抵抗素子の製造方法が提供される。

【００１１】

また、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなる基板を準備する第１工程と、該基板上に第１のＦｅ（１００）層を堆積し、次いで、結晶化のためのアニールを行う第２工程と、前記第１のＦｅ（１００）層上に電子ビーム蒸着法により単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるトンネル障壁層を高真空下において堆積する第３工程と、該トンネル障壁層上に第２のＦｅ（１００）層を形成する第４工程とを有することを特徴とする磁気抵抗素子の製造方法が提供される。尚、前記第１工程と第２工程との間に、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）からなるシード層を成長する工程を有していても良い。また、前記アモルファスＭｇＯ層を、$MgO_x$のｘ値を調整済みのターゲットを用いて堆積しても良い。この際、前記アモルファスＭｇＯを形成する工程中に、$MgO_x$のｘ値を調整しても良い。

【００１２】
本発明のさらに別の観点によれば、ＭｇＯ（１００）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたアモルファス磁性合金からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたアモルファス磁性合金からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、前記ＭｇＯ（１００）層の伝導帯下端と前記アモルファス磁性合金からなる第１又は第２の強磁性体層とのフェルミ準位の間の不連続値（トンネル障壁の高さ）を単結晶における理想的な値よりも低くしたことを特徴とする磁気抵抗素子が提供される。

【発明の効果】

【００１３】
本発明によれば、従来のＴＭＲ素子に比べて大きな磁気抵抗を得ることができ、ＴＭＲ素子の出力電圧を大きくすることができる。従って、ＴＭＲ素子を用いたＭＲＡＭの高集積化が容易になるという利点がある。

【発明を実施するための最良の形態】

【００１４】
本明細書において用いた単結晶における「理想的な値」との用語は、紫外線光電子分光の実験から推測した値である（参考文献：W. Wulfhekel, et al.: Appl. Phys. Lett. 78 (2001) 509.）。このような状態では、酸素欠損や格子欠陥がほとんど無い理想的な単結晶ＭｇＯのトンネル障壁の上限値と言うことができるため、理想的な値という用語を用いた。

【００１５】
発明の実施の形態について説明する前に、発明者の行った考察について説明を行う。ＭＴＪの磁気抵抗（ＭＲ）比は、以下の式で表される。

ΔＲ／Ｒｐ＝（Ｒａｐ－Ｒｐ）／Ｒｐ

ここで、Ｒｐ及びＲａｐは、２つの電極の磁化が平行と反平行の場合のトンネル接合抵抗である。Ｊｕｌｌｉｒｅの公式によれば、低バイアス電圧におけるＭＲ比は、以下のように表される。

ＭＲ比＝（Ｒａｐ－Ｒｐ）／Ｒｐ＝$2P_1P_2/(1-P_1P_2)$であり、

$P_\alpha=(D_\alpha\uparrow(E_F)-D_\alpha\downarrow(E_F))/(D_\alpha\uparrow(E_F)+D_\alpha\downarrow(E_F))$、α＝１，２　（１）

と表される。

【００１６】
ここで、Ｐαは、電子のスピン分極率であり、$D_\alpha\uparrow(E_F)$と$D_\alpha\downarrow(E_F)$とは、それぞれ、多数スピンバンドと少数スピンバンドのフェルミエネルギー（$E_F$）における状態密度（Ｄｅｎｓｉｔｙ　ｏｆ　ｓｔａｔｅ：ＤＯＳ）である。強磁性遷移金属及び合金のスピンの偏極は０．５以下であるため、Ｊｕｌｌｉｒｅの公式によれば、最も高い推定ＭＲ比として７０％が予測される。

ＭＴＪ素子をアモルファスのＡｌ－Ｏのトンネル障壁と多結晶電極とを用いて作成すると、室温でのＭＲ比として約７０％という値が得られているが、ＤＲＡＭ並の出力電圧である２００ｍＶを得るのは難しく、上述のようにＭＲＡＭ実現の対する問題点となっている。

【００１７】
発明者は、酸化マグネシウムの単結晶（１００）あるいは（１００）結晶面が優先配向した多結晶ＭｇＯをトンネル障壁として用いたＭＴＪを成長するアプローチを試みている。従来のアモルファスのアルミナ障壁とは異なり、酸化マグネシウムは結晶（原子が規則正しく配列した物質）であるため、電子が散乱されず、電子のコヒーレント状態がトンネル過程のおいて保存されることが予測される。図１は、本実施の形態によるＭＴＪ素子構造（図１（Ｂ））と、強磁性体金属であるＦｅ（１００）のエネルギーバンド構造を示す図であり、波数空間の［１００］方向に対するＥ－$E_F$の関係を示す図（図１（Ａ））である。図１（Ｂ）に示すように、本実施の形態によるＭＴＪ素子構造は、第１のＦｅ（１

００）層１と、第２のＦｅ（１００）層５と、これらの間に挟まれた単結晶$MgO_x$（１００）層あるいは（１００）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）層３と、を有して構成されている。上記Ｊｕｌｌｉｒｅのモデルによれば、伝導電子のモメンタムがトンネルプロセス中において保存されるとすると、ＭｇＯを透過するトンネル電流はトンネル障壁に垂直な方向（接合界面に対する法線方向）の波数ベクトル$k_Z$を有する電子が支配的になる。図１（Ａ）に示す［１００］（Γ－Ｈ）方向におけるＦｅのエネルギーバンド図によれば、フェルミ準位$E_F$における状態密度（ＤＯＳ）は、多数スピンと少数スピンのサブバンドがフェルミ準位$E_F$において状態を有しているため、それほど高い偏極率を示さない。しかしながら、電子のコヒーレント状態がトンネル過程のおいて保存される場合には、障壁に垂直な軸に関してトータルに対称な波動関数を有する伝導電子のみが障壁領域における状態と関連し、ある一定のトンネル確率を持つことになる。図１（Ａ）に示すように、多数スピンΔ１バンド（実線）がフェルミ準位$E_F$に状態を有するが、少数スピンΔ１バンド（破線）はフェルミ準位$E_F$に状態を有しない。このようなＦｅ$\Delta_1$バンドのハーフメタル的な特徴により、非常に高いＭＲ比がコヒーレントなスピン偏極トンネルにおいて得られる可能性がある。エピタキシャル（単結晶あるいは（１００）配向多結晶）のＭＴＪは、トンネル過程中における電子の散乱が抑制されるため、上記のようなコヒーレントなトンネルを実現するためには理想的であると考えられる。

【００１８】

以下、本発明の第１の実施の形態による磁気抵抗素子及びその製造方法について図面を参照しつつ説明を行う。図２（Ａ）から図２（Ｄ）までは、本発明の実施の形態によるＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）構造を有する磁気抵抗素子（以下、「Ｆｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ」と称する。）の製造工程を模式的に示す図である。Ｆｅ（１００）は、ＢＣＣ構造を有する強磁性体である。まず、単結晶ＭｇＯ（１００）基板１１を準備し、ＭＢＥ法（分子線エピタキシー法）により、単結晶ＭｇＯ（１００）基板１１の表面のモフォロジーを改善するため、ＭｇＯ（１００）シード層１５を成長する。連続して、図１（Ｂ）に示すように、５０ｎｍ厚のエピタキシャルＦｅ（１００）下部電極（第１電極）１７をＭｇＯ（１００）シード層１５上に室温で成長し、次いで、超高真空下（２×１０$^{-8}$Ｐａ）において、３５０℃でアニールを行う。尚、電子線蒸着における条件は、加速電圧が８ｋＶであり、成長速度が０．０２ｎｍ／秒、成長温度が室温（２９３Ｋ）、ソースとしては化学量論的組成のＭｇＯ（ＭｇとＯとの比が１：１）を用い、ソースと基板との距離を４０ｃｍとし、バックグラウンドの真空度が１×１０$^{-8}$Ｐａ、$O_2$分圧が１×１０$^{-6}$Ｐａである。尚、化学量論的組成のＭｇＯ（ＭｇとＯとの比が１：１）の代わりに、Ｏ欠損を有するソースを使用することも可能である。

【００１９】

図３（Ａ）は、この際のＦｅ（１００）下部電極（第１電極）１７のＲＨＥＥＤイメージを示す図である。図３（Ａ）に示すように、Ｆｅ（１００）下部電極（第１電極）１７は良好な結晶性と平坦性を有していることを示している。次いで、図２（Ｃ）に示すように、２ｎｍ厚のＭｇＯ（１００）バリア層２１をＦｅ（１００）下部電極（第１電極）１７上に室温でエピタキシャル成長する。この際も、ＭｇＯの電子ビーム蒸着法を用いた。図３（Ｂ）は、この際のＭｇＯ（１００）バリア層２１のＲＨＥＥＤイメージを示す図である。図３（Ｂ）に示すように、ＭｇＯ（１００）バリア層２１も良好な結晶性と平坦性を有していることを示している。

【００２０】

図２（Ｄ）に示すように、ＭｇＯ（１００）バリア層２１上に、室温で厚さ１０ｎｍのＦｅ（１００）上部電極（第２電極）２３を形成した。連続して、１０ｎｍ厚さのＣｏ層２５をＦｅ（１００）上部電極（第２電極）２３上に堆積した。Ｃｏ層２５は、上部電極２３の保持力を高めることによって反平行磁化配置を実現するためのものである。次いで、上記の作成試料を微細加工してＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ素子を形成する。

【００２１】
上記ＥＢによるＭｇＯ蒸着は、１０－９Ｔｏｒｒの超高真空状態で成膜を行った。この方法では、例えばガラス基板上に３００ｎｍの成膜を行った場合でも、無色透明であり、良好な単結晶膜が形成されていることがわかる。図４は、ＭｇＯ成長時における四重極Ｍａｓｓスペクトルの観測結果を示す図である。図４に示すように、ＯのスペクトルＰ１と$O_2$のスペクトルＰ２とに関する分圧が高いことがわかる。図５は、ＭｇＯ蒸着中の酸素分圧の膜堆積速度依存を示す図である。図５に示すように、酸素分圧自体がかなり高いこと、堆積速度とともに酸素分圧も高くなること、などは、ＭｇＯの堆積時におけるＭｇＯ単結晶からの酸素の離脱を示唆するものであり、$MgO_x$（０．９＜ｘ＜１）のように酸素欠損が生じている可能性がある。酸素欠損が生じるとＭｇＯトンネル障壁の高さが低くなると考えられ（例えば、0.10～0.85ｅＶ、より詳細には0.2～0.5ｅＶの範囲内）、これにより、トンネル電流が増加するものと考えられる。尚、一般的なＡｌ－Ｏトンネル障壁の場合、Ｆｅ（１００）との間のトンネル障壁の高さは、０．７～２．５ｅＶと考えられる。これに対して、ＭｇＯ結晶は理想的なトンネル障壁の高さは３．６ｅＶであり、実験値としては０．９～３．７ｅＶの値が得られている。本実施の形態による方法を用いると、０．３ｅＶ程度のトンネル障壁の高さが推定され、トンネル障壁の低抵抗化が可能であることがわかる。但し、その他の要因、例えば前述のコヒーレントなトンネルの影響も関連している可能性がある。尚、酸素欠損に基づく$MgO_x$のｘの値としては、０．９８＜ｘ＜１、より好ましくは０．９９＜ｘ＜１程度であり、Ｍｇ単体のようなものは含まれず、ＭｇＯの特性が基本的には維持される範囲である。
【００２２】
図６は、上記の方法により製造したＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ素子の典型的な磁気抵抗曲線を示す図である。測定温度２０ＫにおいてＭＲ比１４６％であり、測定温度２９３ＫにおいてＭＲ比は８８％であった。この値は、現在までに室温において得られた最も高いＭＲ比である。このような高いＭＲ比は、Ｆｅ（１００）電極のスピン分極率によって説明することはできず、むしろ、コヒーレントなスピン偏極トンネリングに関連すると考えられる。１６０のＭＴＪ素子を試作した結果、ＭＲ比とトンネル抵抗値とに関するばらつきは、２０％以内であった。ＭＴＪの歩留まりも実験室段階で９０％以上であった。このような高い値は、本アプローチの有効性を示唆している。ＭＴＪの抵抗－エリア積（ＲＡ）は、数$k\Omega\mu m^2$であり、この値は、ＭＲＡＭに適した値である。
【００２３】
図７（ａ）は、室温におけるＭＲ比のバイアス電圧依存性を示す図である。図７（ａ）に示すように、ＭＲ比のバイアス電圧依存性はかなり低いことがわかる。非対称な特性を示すが、ＭＲ比が半減する電圧$V_{half}$は１２５０ｍＶという非常に高い値が得られている。尚、従来のＡｌ－Ｏ系におけるＭＲ比の半減する電圧$V_{half}$は３００～６００ｍＶである。図７（ｂ）に、ＭＴＪの出力電圧$V_{out}$は（＝バイアス電圧×（Ｒａｐ－Ｒｐ）／Ｒａｐ）を示す。出力電圧$V_{out}$の最大値は順バイアスにおいて３８０ｍＶの値が得られている。この値は、Ａｌ－Ｏバリアの場合の値（２００ｍＶ）の約２倍の値である。このように、ＭＲ比と出力電圧との両方で高い値が得られたことは、本実施の形態による技術の有効性を示している。
【００２４】
尚、上記実施の形態においては、ＢＣＣのＦｅ（１００）を用いたが、代わりにＢＣＣのＦｅ系合金、例えば、Ｆｅ－Ｃｏ合金、Ｆｅ－Ｎｉ合金、Ｆｅ－Ｐｔ合金を用いることもできる。或いはＦｅ（１００）層とＭｇＯ（１００）層との間に、１原子層又は数原子層程度の厚さのＣｏ、Ｎｉなどを挿入しても良い。
【００２５】
次に、本発明の第２の実施の形態による磁気抵抗素子及びその製造方法について説明を行う。本実施の形態によるＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＴＭＲ素子の製造方法では、まずスパッタリング法などによりＭｇＯ（１００）を多結晶またはア

モルファス状態で堆積し、その後にアニール処理を行うことにより（１００）結晶面が配向した多結晶または単結晶化する点を特徴とする。スパッタリング条件は、例えば。温度が室温（２９３Ｋ）であり、ターゲットとしては２インチφのＭｇＯを用い、Ａｒ雰囲気中でスパッタリングを行った。加速電力は２００Ｗであり、成長速度は０．００８ｎｍ／ｓである。この条件で堆積したＭｇＯはアモルファス状態であるため、室温から３００℃まで温度を上昇させ、３００℃において一定時間保持をすることにより、結晶化されたＭｇＯを得ることが出来る。

【００２６】

尚、Ｏ欠損の導入方法としては、成長時にＯ欠損が生じる条件で成長を行う方法、Ｏ欠損を後から導入する方法、Ｏ欠損のある状態から例えば酸素プラズマ処理又は自然酸化などにより酸化を行ってある程度のＯ欠陥まで調整する方法のいずれを用いても良い。

【００２７】

以上、本実施の形態による磁気抵抗素子技術によれば、スパッタリング法を用いてアモルファスＭｇＯを堆積した後にアニール処理により結晶化するため、それほど大がかりな装置が必要ないという利点がある。

【００２８】

次に、本発明の実施の形態の変形例による磁気抵抗素子について図面を参照しつつ説明を行う。図１１は、本発明の実施の形態の変形例によるＭＴＪの素子構造を示す図であり、図１（Ｂ）に対応する図である。図１１に示すように、本実施の形態による磁気抵抗素子は、上記実施の形態による磁気抵抗素子と同様に、単結晶$MgO_x$（１００）あるいは（１００）結晶面が優先配向した酸素欠損多結晶$MgO_x$（$0<x<1$）層５０３に対して設けられる電極として、アモルファス強磁性合金、例えばＣｏＦｅＢ層５０１、５０５を用いた点に特徴がある。アモルファス強磁性合金は、例えば蒸着法或いはスパッタリング法を用いて形成可能である。得られた特性等は第１の実施の形態の場合とほぼ同様である。

【００２９】

尚、アモルファス磁性合金については、例えば、FeCoB、FeCoBSi、FeCoBP、FeZr、CoZrなどを用いることもできる。

【００３０】

以上、本実施の形態による磁気抵抗素子について説明したが、本発明はこれらに制限されるものではない。その他、種々の変更、改良、組み合わせが可能なことは当業者に自明であろう。例えば、ＭｇＯ層に酸素欠陥を導入する代わりに、例えばＣａやＳｒをドーピングすることでトンネル障壁の高さを調整する方法を用いても良い。また、ＭｇＯ層の堆積方法として、電子ビーム蒸着法又はスパッタリング法を例にして説明したが、その他の堆積法も適用可能であることは言うまでもない。また、高真空との用語は、例えば酸素を導入しない場合において、概ね$10^{-6}$Ｐａ以下の値を指し、一方、酸素を積極的に導入する場合でも、$10^{-4}$Ｐａ程度の値を指す。

【産業上の利用可能性】

【００３１】

ＭＲＡＭの出力電圧値が従来の約２倍に向上し、ギガビット級の超高集積ＭＲＡＭに適した構造となっている。

【図面の簡単な説明】

【００３２】

【図１】本発明の第１の実施の形態によるＭＴＪ素子構造（図１（Ｂ））と、強磁性体金属であるＦｅ（１００）のエネルギーバンド構造を示す図であり、波数空間の［１００］方向に対する$E-E_F$の関係を示す図（図１（Ａ））である。

【図２】図２（Ａ）から図２（Ｄ）までは、本発明の実施の形態によるＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）構造を有する磁気抵抗素子（以下、「Ｆｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ」と称する。）の製造工程を模式的に示す図である。

【図３】図３（Ａ）は、Ｆｅ（１００）下部電極（第１電極）のＲＨＥＥＤイメージを示す図であり、図３（Ｂ）は、この際のＭｇＯ（１００）バリア層のＲＨＥＥＤイメージを示す図である。

【図４】ＭｇＯ成長時における四重極Ｍａｓｓスペクトルの観測結果を示す図である。

【図５】ＭｇＯ蒸着中の酸素分圧の膜堆積速度依存を示す図である。

【図６】Ｆｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ素子の典型的な磁気抵抗曲線を示す図である。

【図７】図７（Ａ）は、室温におけるＭＲ比のバイアス電圧依存性を示す図である。図７（Ｂ）は、ＭＴＪの出力電圧$Ｖ_{out}$は（＝バイアス電圧×（Ｒａｐ－Ｒｐ）／Ｒａｐ）を示す図である。

【図８】ＴＭＲ素子の構造と、その動作原理を示す図である。

【図９】ＭＲＡＭの基本構造例を示す図であり、図９（Ａ）はＭＲＡＭの斜視図であり、図９（Ｂ）は模式的な回路構成図であり、図９（Ｃ）は、構造例を示す断面図である。

【図１０】アモルファスＡｌ－Ｏをトンネル障壁とした従来型ＴＭＲ素子の磁気抵抗の印加電圧による変化を示す図である。

【図１１】本発明の実施の形態の変形例によるＭＴＪの素子構造を示す図であり、図１（Ｂ）に対応する図である。

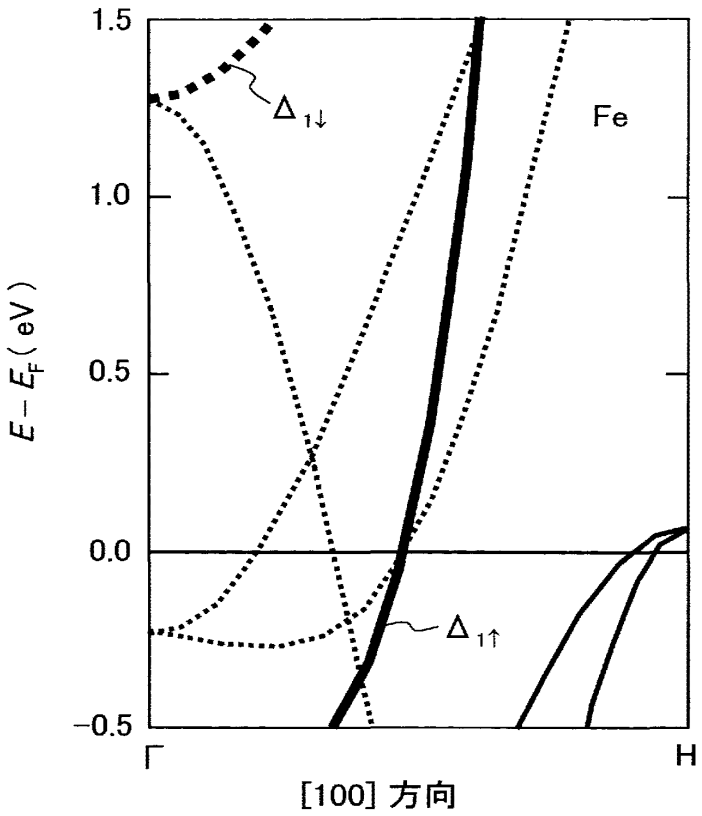
【符号の説明】

【００３３】

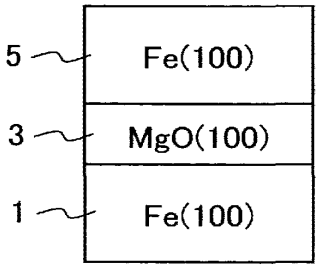
１…第１のＦｅ（１００）層、３…単結晶$ＭｇＯ_{x}$（１００）あるいは（１００）結晶面が優先配向した多結晶$ＭｇＯ_{x}$層（０＜ｘ＜１）、５…第２のＦｅ（１００）層、１１…単結晶$ＭｇＯ_{x}$（１００）あるいは（１００）結晶面が優先配向した多結晶$ＭｇＯ_{x}$基板（０＜ｘ＜１）、１５…ＭｇＯ（１００）シード層、１７…エピタキシャルＦｅ（１００）下部電極（第１電極）、２１…ＭｇＯバリア層（１００）、２３…エピタキシャルＦｅ（１００）上部電極（第２電極）、５０３…単結晶$ＭｇＯ_{x}$（００１）あるいは（００１）結晶面が優先配向した多結晶$ＭｇＯ_{x}$層（０＜ｘ＜１）、５０１…アモルファス強磁性体による下部電極（第１電極）、５０３…ＭｇＯバリア層、５０５…アモルファス強磁性体による上部電極（第２電極）。

【書類名】図面
【図１】

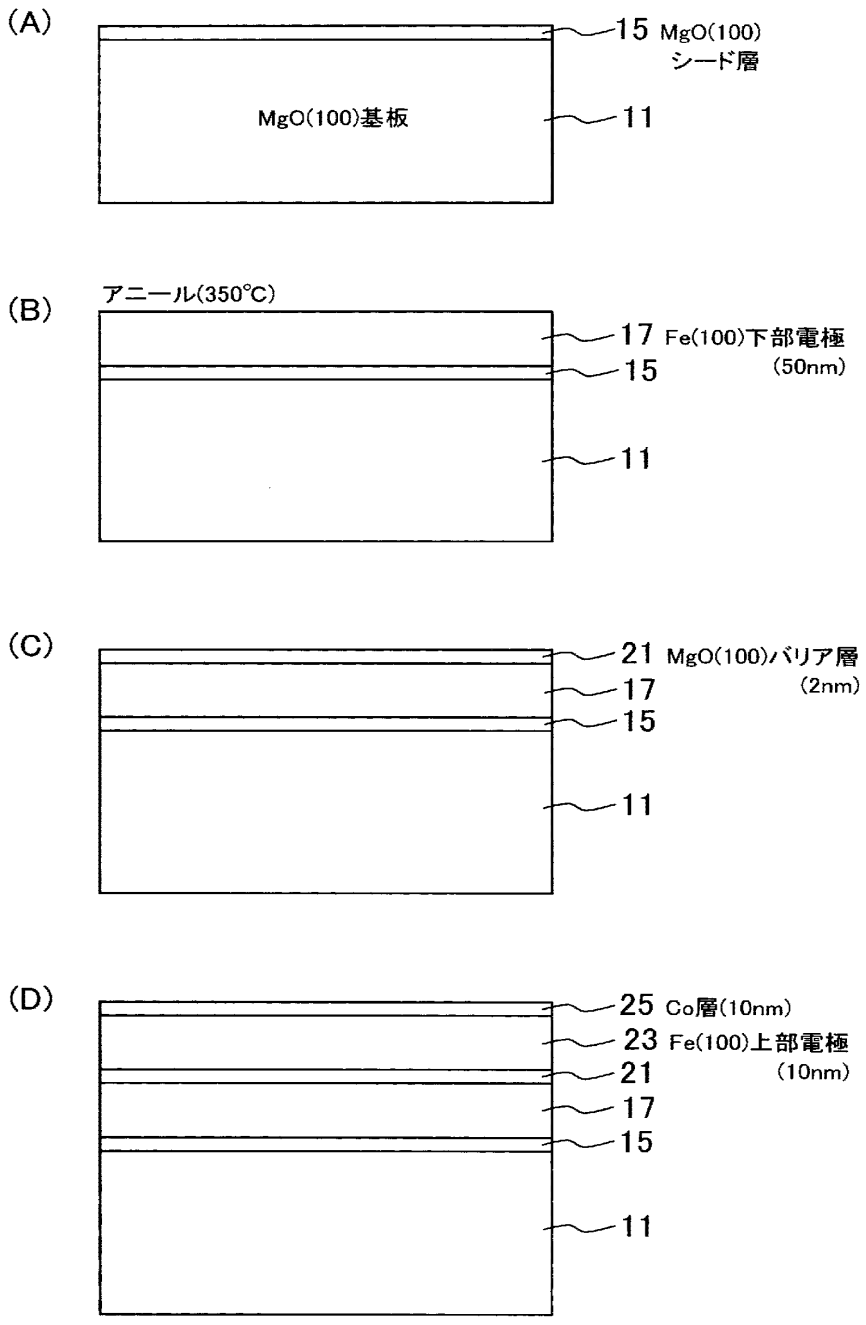
(A)


1.5
1.0
0.5
0.0
−0.5
$E - E_F$ ( eV )
$\Delta_{1\downarrow}$
$\Delta_{1\uparrow}$
Fe
Γ
H
[100] 方向

(B)

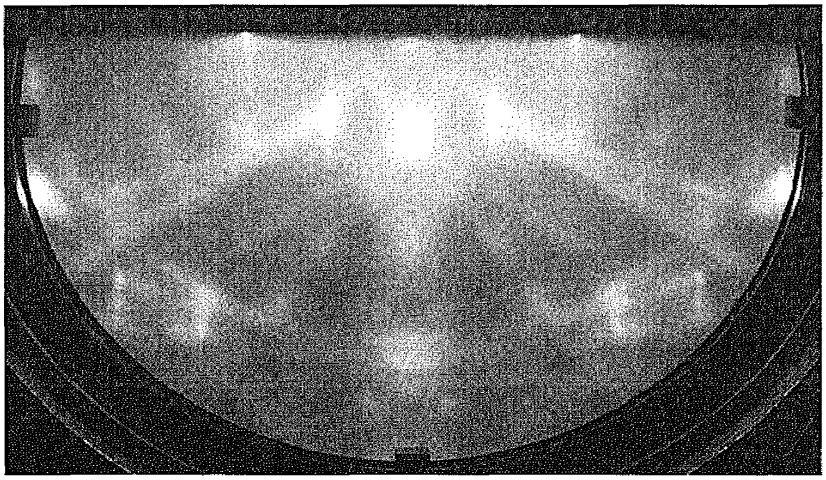

5
Fe(100)
3
MgO(100)
1
Fe(100)

【図２】

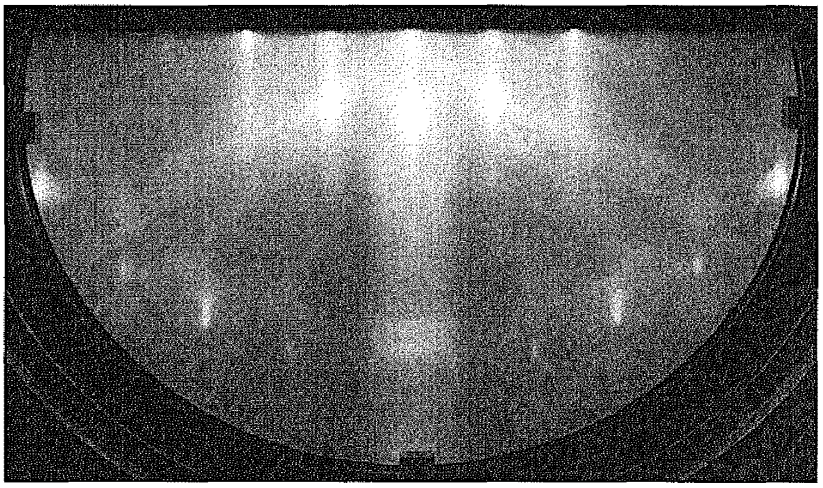

(A)
15 MgO(100)
シード層
MgO(100)基板
11
(B)
アニール(350℃)
17 Fe(100)下部電極
(50nm)
15
11
(C)
21 MgO(100)バリア層
(2nm)
17
15
11
(D)
25 Co層(10nm)
23 Fe(100)上部電極
(10nm)
21
17
15
11

【図３】

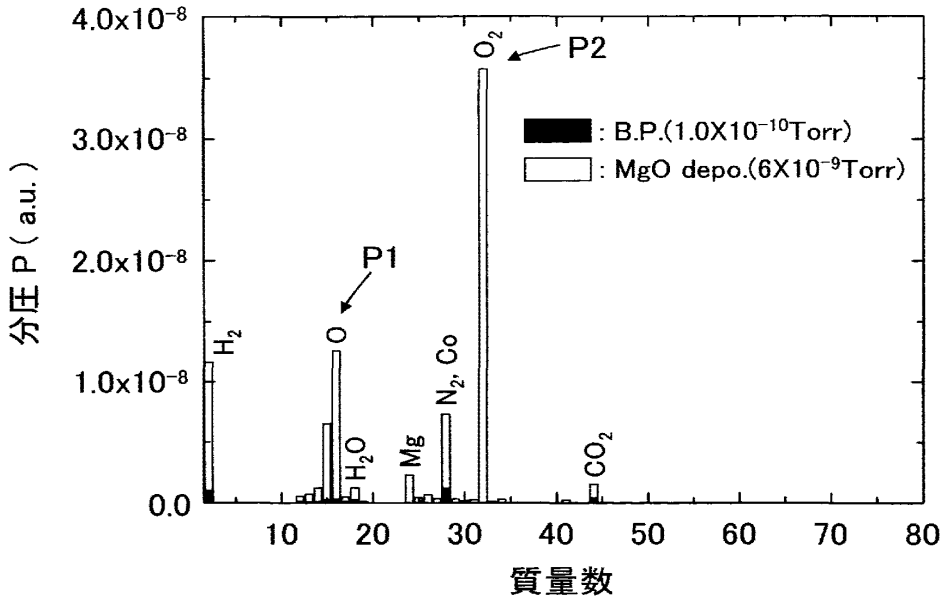
(a)



(b)

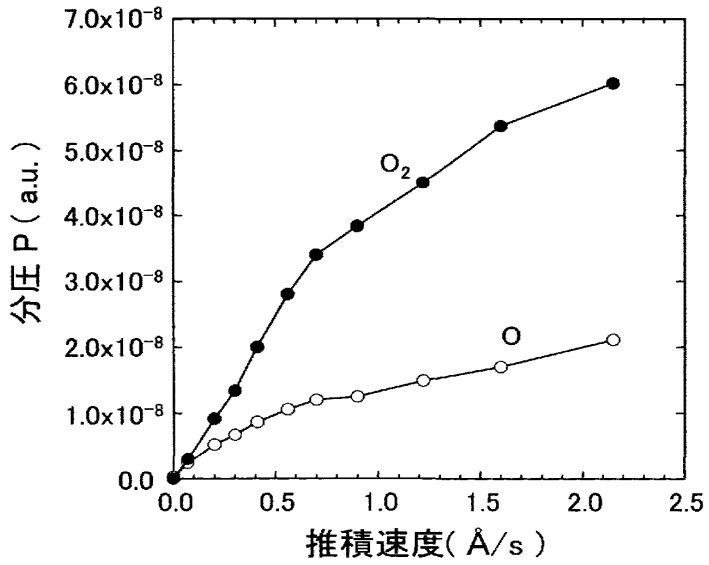


【図４】



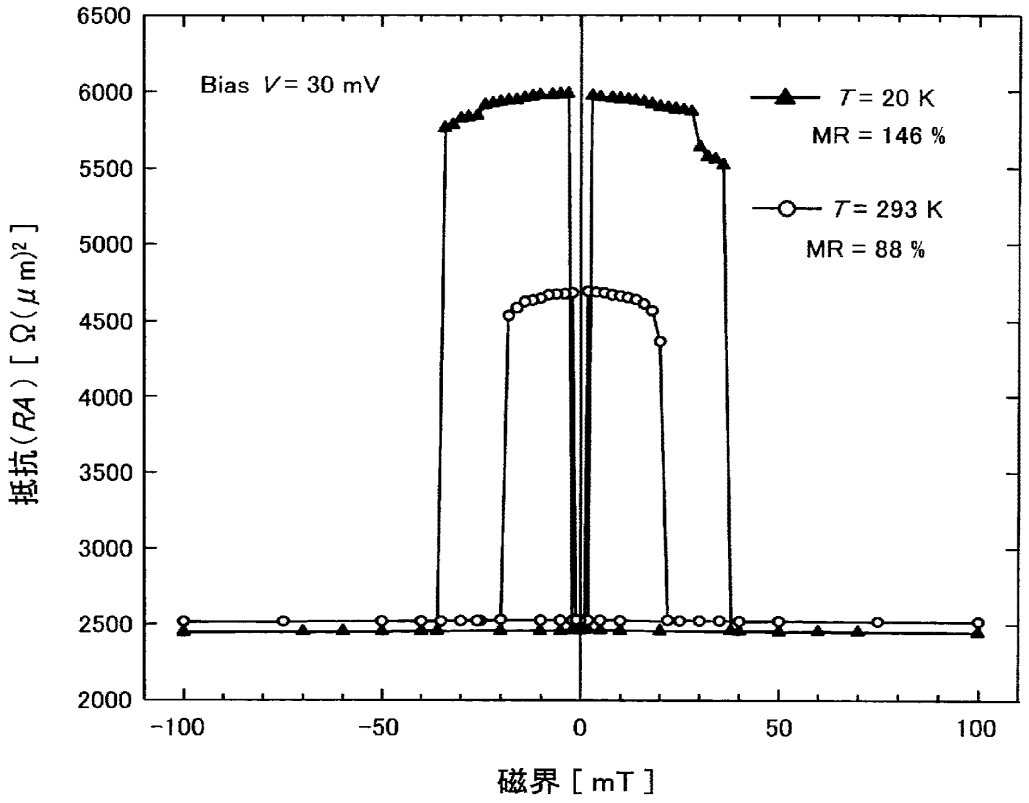

Massスペクトル

【図５】

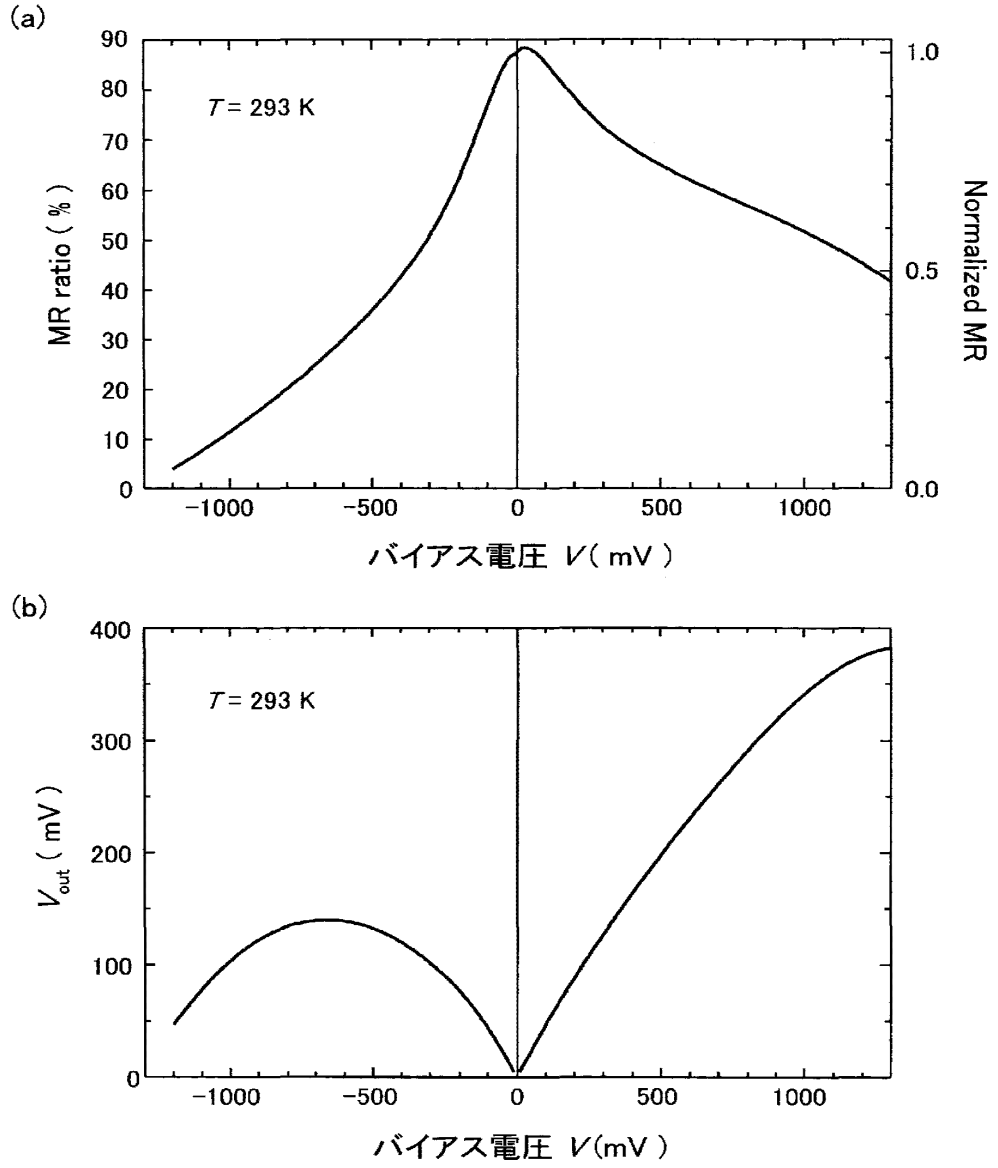



MgO蒸着中の酸素分圧

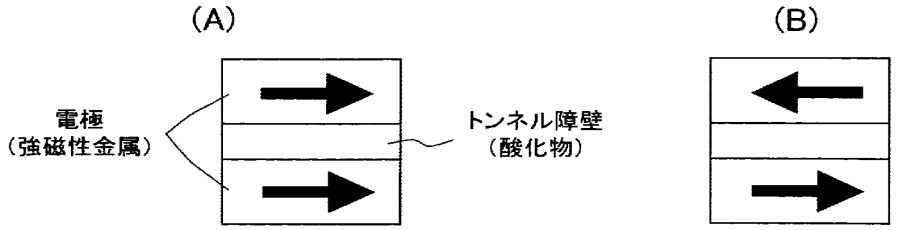
【図６】


Bias V = 30 mV
T = 20 K
MR = 146 %
T = 293 K
MR = 88 %
抵抗(RA)[Ω(μm)²]
磁界[mT]
6500
6000
5500
5000
4500
4000
3500
3000
2500
2000
-100
-50
0
50
100

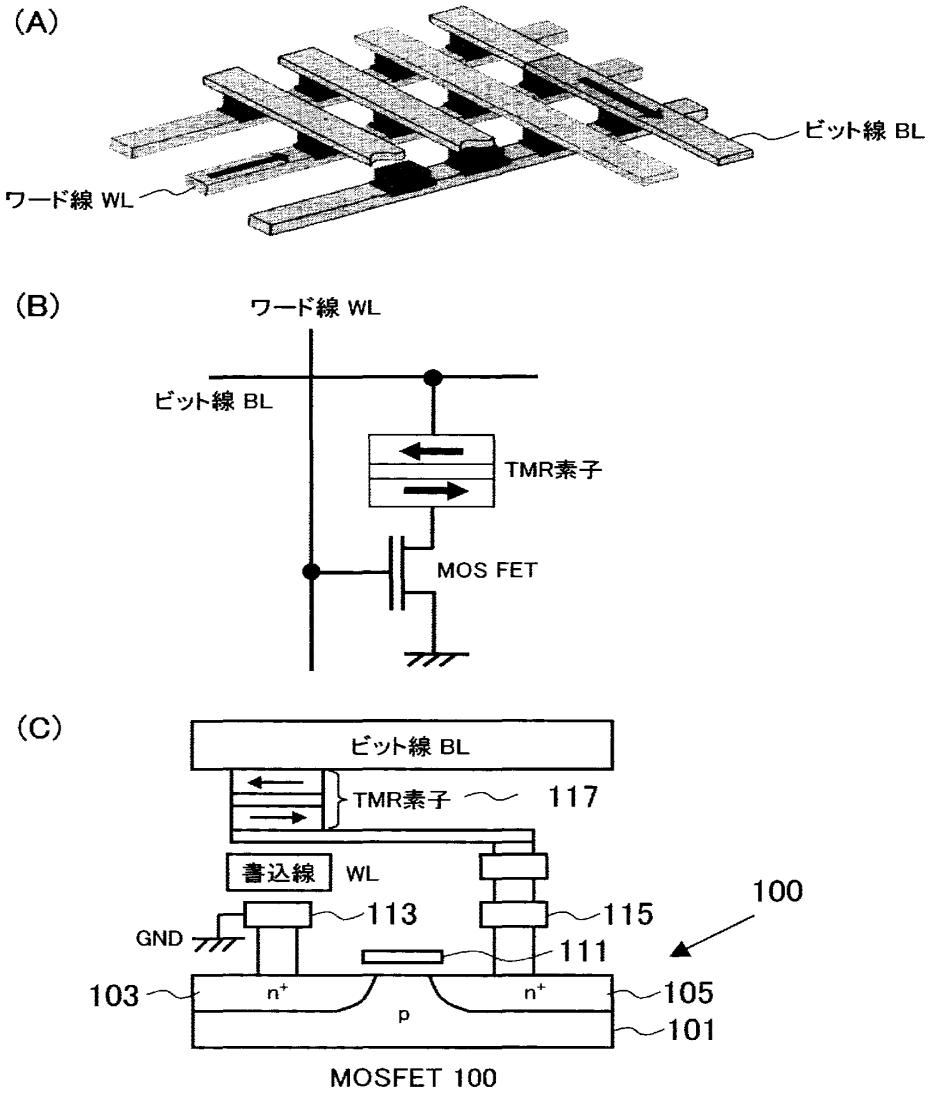
【図７】


(a)
T = 293 K
MR ratio ( % )
Normalized MR
90
80
70
60
50
40
30
20
10
0
1.0
0.5
0.0
−1000
−500
0
500
1000
バイアス電圧 V( mV )
(b)
T = 293 K
$V_{out}$ ( mV )
400
300
200
100
0
−1000
−500
0
500
1000
バイアス電圧 V(mV )

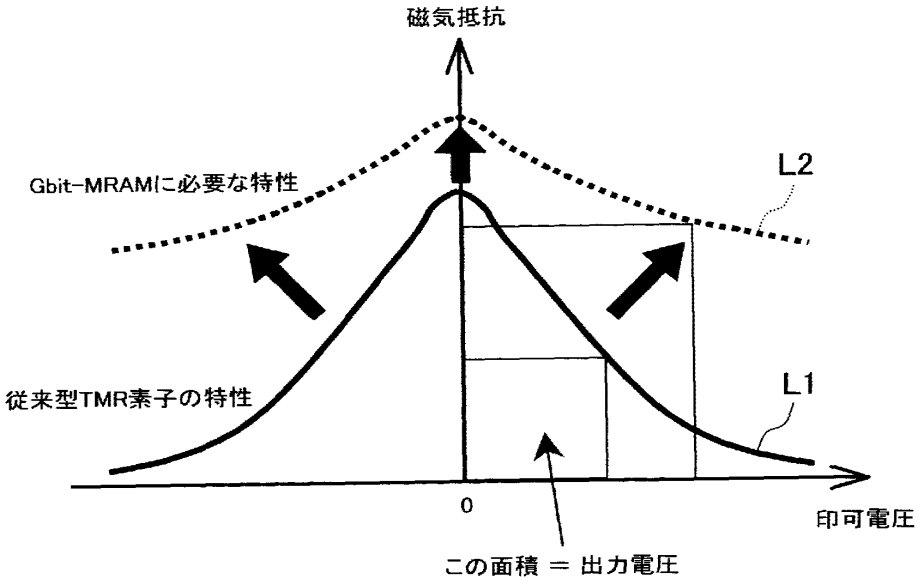
【図８】



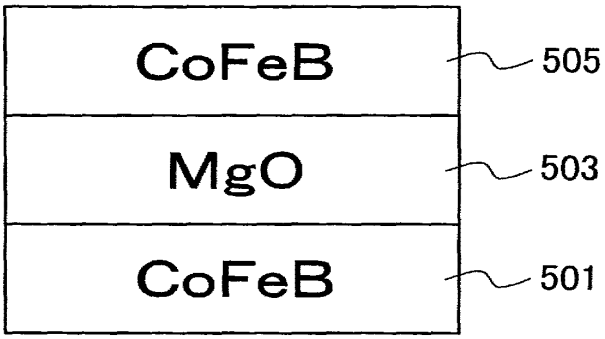
【図９】


(A)
ビット線 BL
ワード線 WL
(B)
ワード線 WL
ビット線 BL
TMR素子
MOS FET
(C)
ビット線 BL
TMR素子
117
書込線
WL
100
113
115
GND
111
103
n+
n+
105
p
101
MOSFET 100

【図１０】


磁気抵抗
Gbit-MRAMに必要な特性
L2
従来型TMR素子の特性
L1
0
印可電圧
この面積 ＝ 出力電圧

【図１１】


CoFeB
505
MgO
503
CoFeB
501

【書類名】要約書
【要約】
【課題】　ＭＲＡＭの出力電圧値を高める。
【解決手段】単結晶ＭｇＯ（１００）基板１１を準備し、５０ｎｍ厚のエピタキシャルＦｅ（１００）下部電極（第１電極）１７をＭｇＯ（１００）シード層１５上に室温で成長し、次いで、超高真空（２×１０－８Ｐａ）において、３５０℃でアニールを行う。２ｎｍ厚のＭｇＯ（１００）バリア層２１をＦｅ（１００）下部電極（第１電極）１７上に室温でエピタキシャル成長する。この際、ＭｇＯの電子ビーム蒸着を用いた。ＭｇＯ（１００）バリア層２１上に室温で、厚さ１０ｎｍのＦｅ（１００）上部電極（第２電極）２３を形成した。連続して、１０ｎｍ厚さのＣｏ層２１をＦｅ（１００）上部電極（第２電極）２３上に堆積した。Ｃｏ層２１は、上部電極２３の強制的な磁界をエンハンスするための反平行磁化配置を実現するためのものである。次いで、上記の作成試料を微細加工してＦｅ（１００）／ＭｇＯ（１００）／Ｆｅ（１００）ＭＴＪ素子を形成する。
【選択図】　図２

【書類名】　　手続補正書
【整理番号】　　P04-1160
【提出日】　　平成16年11月11日
【あて先】　　特許庁長官　殿
【事件の表示】
　【出願番号】　　特願2004-313350
【補正をする者】
　【識別番号】　　503360115
　【氏名又は名称】　独立行政法人科学技術振興機構
【補正をする者】
　【識別番号】　　301021533
　【氏名又は名称】　独立行政法人産業技術総合研究所
【代理人】
　【識別番号】　　100091096
　【弁理士】
　【氏名又は名称】　平木　祐輔
【発送番号】　　115102
【手続補正1】
　【補正対象書類名】　特許願
　【補正対象項目名】　提出物件の目録
　【補正方法】　　追加
　【補正の内容】
　　【提出物件の目録】
　　【物件名】　　委任状　2

【物件名】　委任状

【添付書類】

# 委　任　状

平成 16 年 10 月 28 日

私は、識別番号　100091096　100105463　100102576　100108394　弁理士　平木　祐輔　関谷　三男　渡辺　敏章　今村　健一　氏を以って

代理人として下記事項を委任します。

記

1．特　許　出　願

に関する一切の件並びに本件に関する出願の放棄、若しくは取下げ、出願変更、拒絶査定不服及び補正却下の決定に対する審判の請求及びその取下げ

1．特願２００４－０７１１８６に基づく特許法第４１条第１項又は実用新案法第８条第１項の規定による優先権の主張及びその取下げ

1．上記出願に基づく特許法第４１条第１項又は実用新案法第８条第１項の規定による優先権の主張及びその取下げ

1．　に関する出願の変更

1．上記出願に係る特許権、実用新案権、意匠権、商標権又は防護標章登録に基づく権利及びこれらの権利に関する手続き並びにこれらの権利の放棄

1．上記出願に関する特許法第６４条の２第１項の規定による出願公開の請求

1．上記出願に係る特許に対する特許異議の申立て又は商標（防護標章）登録に対する登録異議の申立てに関する手続

1．上記出願に係る特許、特許権の存続期間の延長登録、意匠登録、商標登録、防護標章登録又は商標（防護標章）更新登録に対する無効審判の請求に関する手続

1．上記出願に係る特許権に関する訂正の審判の請求及びその取下げ

1．上記出願に係る商標登録に対する取消しの審判の請求に関する手続

1．上記各項の手続に関する請求の取下げ、申請の取下げ又は申立ての取下げ

1．上記各項に関し行政不服審査法に基づく諸手続をなすこと

1．上記各項の手続を処理するため、復代理人を選任及び解任すること

住　所　埼玉県川口市本町四丁目１番８号

名　称　独立行政法人科学技術振興機構

代表者

理事長　沖　村　憲　樹

# 委　任　状

平成16年10月28日

私は、識別番号 100091096 100105463 100102576 100108394 弁理士 平木 祐輔 関谷 三男 渡辺 敏章 今村 健一 氏を以って代理人として下記事項を委任します。

記

1．特　許　出　願

に関する一切の件並びに本件に関する出願の放棄、若しくは取下げ、出願変更、拒絶査定不服及び補正却下の決定に対する審判の請求及びその取下げ

1．特願２００４－０７１１８６に基づく特許法第４１条第１項又は実用新案法第８条第１項の規定による優先権の主張及びその取下げ

1．上記出願に基づく特許法第４１条第１項又は実用新案法第８条第１項の規定による優先権の主張及びその取下げ

1．　　に関する出願の変更

1．上記出願に係る特許権、実用新案権、意匠権、商標権又は防護標章登録に基づく権利及びこれらの権利に関する手続き並びにこれらの権利の放棄

1．上記出願に関する特許法第６４条の２第１項の規定による出願公開の請求

1．上記出願に係る特許に対する特許異議の申立て又は商標（防護標章）登録に対する登録異議の申立てに関する手続

1．上記出願に係る特許、特許権の存続期間の延長登録、意匠登録、商標登録、防護標章登録又は商標（防護標章）更新登録に対する無効審判の請求に関する手続

1．上記出願に係る特許権に関する訂正の審判の請求及びその取下げ

1．上記出願に係る商標登録に対する取消しの審判の請求に関する手続

1．上記各項の手続に関する請求の取下げ、申請の取下げ又は申立ての取下げ

1．上記各項に関し行政不服審査法に基づく諸手続をなすこと

1．上記各項の手続を処理するため、復代理人を選任及び解任すること

住　所　東京都千代田区霞が関1丁目3番1号
名　称　独立行政法人 産業技術総合研究所
代表者　理事長　吉　川　弘　之

WD EX1004
Western Digital v IP Bridge
Page 125

出願人履歴

５０３３６０１１５

20040401

名称変更

埼玉県川口市本町４丁目１番８号

独立行政法人科学技術振興機構

５０３３６０１１５

20090820

住所変更

東京都千代田区四番町５－３　サイエンスプラザ５Ｆ

独立行政法人科学技術振興機構

５０３３６０１１５

20091008

住所変更

埼玉県川口市本町四丁目１番８号

独立行政法人科学技術振興機構

３０１０２１５３３

20010402

新規登録

５０３０６３７６６

東京都千代田区霞が関１－３－１

独立行政法人産業技術総合研究所

| LETTER – REQUEST FOR CORRECTED FILING RECEIPT | | |
|---|---|---|
| | Application # | 12/923,643 |
| | Confirmation # | 8219 |
| | Filing Date | September 30, 2010 |
| | First Inventor | YUASA, Shinji |
| | Art Unit | 2892 |
| | Examiner | |
| | Docket # | NAGI-0003/JCM |

Commissioner for Patents
Office of Initial Patent Examination
Customer Service Center
P.O. Box 1450
Alexandria, Virginia 22313

S I R:

Correction of the Filing Receipt is requested.

Submitted herewith is a copy of the Filing Receipt for the above-identified application showing the requested corrections in boldface type. The corrections are readily apparent from the application papers.

It is respectfully requested that the records of the Patent Office be corrected and that a Corrected Filing Receipt be sent to the undersigned.

Respectfully submitted,

Date: November 12, 2010

Signed By Douglas E. Jackson
Registration No.: 28,518

On Behalf Of Attorney of Record Juan Carlos A. Marquez
Registration No.: 34,072

**STITES & HARBISON PLC** ◆ 1199 North Fairfax Street ◆ Suite 900 ◆ Alexandria, VA 22314
TELEPHONE: 703-739-4900 ◆ FAX: 703-739-9577 ◆ CUSTOMER NO. 38327

186057:1:ALEXANDRIA

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
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| APPLICATION NUMBER | FILING or 371(c) DATE | GRP ART UNIT | FIL FEE REC'D | ATTY.DOCKET.NO | TOT CLAIMS | IND CLAIMS |
|---|---|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | 2892 | 1750 | NAGI.0003 | 16 | 6 |

**CONFIRMATION NO. 8219**

**FILING RECEIPT**

38327
Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

RECEIVED
NOV 03 2010
STITES & HARBISON, PLLC

*OC000000044258794*

Date Mailed: 11/03/2010

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

**Applicant(s)**

Shinji Yuasa, Ibaraki, JAPAN;

**Assignment For Published Patent Application**

~~Japan Science and Technology Agency and National Institute \ of Advanced Industrial Science and Technology~~

**(1) Japan Science and Technology Agency**
**(2) National Institute of Advanced Industrial Science and Technology**

**Power of Attorney:**
Stanley Fisher--24344
Juan Carlos Marquez--34072

**Domestic Priority data as claimed by applicant**

This application is a CON of 10/591,947 09/08/2006
which is a 371 of PCT/JP2005/004720 03/10/2005

**Foreign Applications**
JAPAN 2004-071186 03/12/2004
JAPAN 2004-313350 10/28/2004

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to Retrieve Electronic Priority Application(s)** (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

**If Required, Foreign Filing License Granted:** 10/28/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/923,643**



Incorrect

# Electronic Acknowledgement Receipt

| | |
|---|---|
| **EFS ID:** | 8827503 |
| **Application Number:** | 12923643 |
| **International Application Number:** | |
| **Confirmation Number:** | 8219 |
| **Title of Invention:** | Magnetic tunnel junction device and method of manufacturing the same |
| **First Named Inventor/Applicant Name:** | Shinji Yuasa |
| **Customer Number:** | 38327 |
| **Filer:** | Juan Carlos A. Marquez/Victoria Shockey |
| **Filer Authorized By:** | Juan Carlos A. Marquez |
| **Attorney Docket Number:** | NAGI-0003 |
| **Receipt Date:** | 12-NOV-2010 |
| **Filing Date:** | 30-SEP-2010 |
| **Time Stamp:** | 15:26:31 |
| **Application Type:** | Utility under 35 USC 111(a) |

## Payment information:

| | |
|---|---|
| Submitted with Payment | no |

## File Listing:

| Document Number | Document Description | File Name | File Size(Bytes)/ Message Digest | Multi Part /.zip | Pages (if appl.) |
|---|---|---|---|---|---|
| 1 | Request for Corrected Filing Receipt | NAGI-0003-Request-Corrected-FR.pdf | 110133<br>58f84d44c9aee93944cc81175fb1f47cbfaa2cfd | no | 2 |

| | |
|---|---|
| **Warnings:** | |
| **Information:** | |

| | |
|---|---|
| **Total Files Size (in bytes):** | 110133 |

**This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.**

**New Applications Under 35 U.S.C. 111**
**If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.**

**National Stage of an International Application under 35 U.S.C. 371**
**If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.**

**New International Application Filed with the USPTO as a Receiving Office**
**If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.**

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

| APPLICATION NUMBER | FILING or 371(c) DATE | GRP ART UNIT | FIL FEE REC'D | ATTY.DOCKET.NO | TOT CLAIMS | IND CLAIMS |
|---|---|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | 2892 | 1750 | NAGI-0003 | 16 | 6 |

**CONFIRMATION NO. 8219**

**CORRECTED FILING RECEIPT**

38327
Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

*OC000000044534756*

Date Mailed: 11/19/2010

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

**Applicant(s)**

Shinji Yuasa, Ibaraki, JAPAN;

**Assignment For Published Patent Application**

Japan Science and Technology Agency
National Institute of Advanced Industrial Science and Technology

**Power of Attorney:**
Stanley Fisher--24344
Juan Carlos Marquez--34072

**Domestic Priority data as claimed by applicant**

This application is a CON of 10/591,947 09/08/2006 PAT 7,847,327
which is a 371 of PCT/JP2005/004720 03/10/2005

**Foreign Applications**
JAPAN 2004-071186 03/12/2004
JAPAN 2004-313350 10/28/2004

Request to Retrieve - This application either claims priority to one or more applications filed in an intellectual property Office that participates in the Priority Document Exchange (PDX) program or contains a proper **Request to Retrieve Electronic Priority Application(s)** (PTO/SB/38 or its equivalent). Consequently, the USPTO will attempt to electronically retrieve these priority documents.

**If Required, Foreign Filing License Granted:** 10/28/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/923,643**

**Projected Publication Date:** 02/10/2011

**Non-Publication Request:** No

**Early Publication Request:** No

**Title**

Magnetic tunnel junction device and method of manufacturing the same

**Preliminary Class**

257

## PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

## LICENSE FOR FOREIGN FILING UNDER

## Title 35, United States Code, Section 184

## Title 37, Code of Federal Regulations, 5.11 & 5.15

**GRANTED**

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

**NOT GRANTED**

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

OPAP IAP24
DEC 07 2010
PATENT AND TRADEMARK OFFICE

*Customized* PTO/SB/08a+b (07-09)

| | | |
|---|---|---|
| *Substitute for Form 1449/PTO* **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** | Application # | 12/923,643 |
| | Confirmation # | 8219 |
| | Filing Date | September 30, 2010 |
| | First Inventor | YUASA |
| | Art Unit | 2892 |
| | Examiner | |
| Sheet 1 of 1 | Docket # | NAGI.0003 |

***U.S. PATENT DOCUMENTS***

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
| | 2009/0324814A1 | 12-31-2009 | Parkin | |
| | | | | |
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***FOREIGN PATENT DOCUMENTS***

| Exam. Initial* | Country-Number-Kind Code If known | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Translation |
|---|---|---|---|---|---|
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***NON PATENT LITERATURE DOCUMENTS***

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
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| Examiner Signature | | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

OPAP
DEC 07 2010
IAP24
PATENT & TRADEMARK OFFICE

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | | |
|---|---|---|
| **In re U.S. Patent Application of** | ) | |
| | ) | |
| **YUASA** | ) | |
| | ) | **Art Unit: 2892** |
| **Application Number: 12/923,643** | ) | |
| | ) | |
| **Filed: September 30, 2010** | ) | |
| | ) | |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME** | ) | |
| | ) | |
| **ATTORNEY DOCKET NO. NAGI.0003** | ) | |

**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

**LETTER**

Sir:

The below-identified communications are submitted in the above-captioned application or proceeding:

(x) Information Disclosure Statement with Form-1449 and references
( ) Credit card form for $.

☒ The Commissioner is hereby authorized to charge payment of any fees associated with this communication, including fees under 37 C.F.R. § 1.16 and 1.17 or credit any overpayment to **Deposit Account Number 12-0555.**

Respectfully submitted,

**STITES & HARBISON PLLC**
1199 N. Fairfax Street, Suite 900
Alexandria, Virginia 22314
Telephone: (703) 739-4900
Facsimile: (703) 739-9577
Customer No.: 38327
**December 7, 2010**

Juan Carlos A. Marquez
Registration Number 34,072

2355LT:00003:188612:1:ALEXANDRIA

OPAP
DEC 07 2010
IAP24
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | |
|---|---|
| **In re U.S. Patent Application of** | |
| **YUASA .** | |
| | **Art Unit: 2892** |
| **Application Number: 12/923,643** | |
| **Filed: September 30, 2010** | |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME** | |
| **ATTORNEY DOCKET NO. NAGI.0003** | |

**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## INFORMATION DISCLOSURE STATEMENT

Sir:

Pursuant to 37 C.F.R. §§ 1.56 and 1.97, this Information Disclosure Statement is submitted in the above-identified patent application. A listing of documents to be published on the face of any patent granted from this application is submitted herewith on Form PTO-1449. Any other documents or information submitted for consideration by the Examiner are listed in this paper. A copy of each foreign patent, or each publication or portion thereof listed or herein identified, is submitted herewith.

### CERTIFICATION

This Information Disclosure Statement is submitted before three months of the filing date and prior to the mailing date of the first Office Action in the above-captioned U.S. patent application on the merits of the above-identified application. Accordingly, no fee is due or payable at this time.

However, it is also hereby certified that each item of information contained in this statement was cited in an Office Action of a co-pending U.S. Application (No. 12/659,827).

The Examiner is requested to acknowledge consideration of the information provided in this paper in accordance with prescribed procedures.

Please charge any additional fees or credit any overpayments in connection with this paper to Deposit Account No. 12-0555.

Respectfully submitted,

Juan Carlos A. Marquez
Registration No. 34,072

**STITES & HARBISON PLLC**
1199 N. Fairfax Street
Suite 900
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Facsimile: (703) 739-9577
Customer No.: 38327
**December 7, 2010**

182674:1:ALEXANDRIA

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

38327 7590 01/05/2011

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER | |
|---|---|
| CHAMBLISS, ALONZO | |
| ART UNIT | PAPER NUMBER |
| 2892 | |

| NOTIFICATION DATE | DELIVERY MODE |
|---|---|
| 01/05/2011 | ELECTRONIC |

**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

iplaw@stites.com

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 12/923,643 | YUASA, SHINJI | |
| | Examiner | Art Unit | |
| | Alonzo Chambliss | 2892 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

1)☒ Responsive to communication(s) filed on *30 September 2010*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) *1-16* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *1-16* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

9)☐ The specification is objected to by the Examiner.

10)☒ The drawing(s) filed on *9/30/10* is/are: a)☐ accepted or b)☒ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date *9/30/10, 12/7/10*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

## DETAILED ACTION

### *Information Disclosure Statement*

1. The information disclosure statement (IDS) submitted on 9/30/10 and 12/7/10 were filed before the mailing date of the notice of allowance on 12/17/10. The submission is in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner.

### *Drawings*

2. The drawings are objected to as failing to comply with 37 CFR 1.84(p)(5) because they include the following reference character(s) not mentioned in the description: **113**. Corrected drawing sheets in compliance with 37 CFR 1.121(d), or amendment to the specification to add the reference character(s) in the description in compliance with 37 CFR 1.121(b) are required in reply to the Office action to avoid abandonment of the application. Any amended replacement drawing sheet should include all of the figures appearing on the immediate prior version of the sheet, even if only one figure is being amended. Each drawing sheet submitted after the filing date of an application must be labeled in the top margin as either “Replacement Sheet” or “New Sheet” pursuant to 37 CFR 1.121(d). If the changes are not accepted by the examiner, the applicant will be notified and informed of any required corrective action in the next Office action. The objection to the drawings will not be held in abeyance.

***Claim Rejections - 35 USC § 112***

3. Claims 1-13 are rejected under 35 U.S.C. 112, second paragraph, as being incomplete for omitting essential steps, such omission amounting to a gap between the steps. See MPEP § 2172.01. The omitted steps are: forming a first and second ferromagnetic material layers having a BCC structure.

4. Claims 9-13 and 15 are rejected under 35 U.S.C. 112, second paragraph, as being incomplete for omitting essential steps, such omission amounting to a gap between the steps. See MPEP § 2172.01. The omitted steps are: forming a first and second ferromagnetic material layers on a poly-crystalline magnesium oxide layer.

5. Claims 14 and 16 are rejected under 35 U.S.C. 112, second paragraph, as being incomplete for omitting essential structural cooperative relationships of elements, such omission amounting to a gap between the necessary structural connections. See MPEP § 2172.01. The omitted structural cooperative relationships are: between the first and second ferromagnetic material layers and the tunnel barrier layer.
matches the coefficient of thermal expansion gradient of the substrate.

The prior art made of record and not relied upon is cited primarily to show the process or product of the instant invention.

## *Conclusion*

6. Any inquiry concerning the communication or earlier communications from the examiner should be directed to Alonzo Chambliss whose telephone number is (571) 272-1927.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thao Le can be reached on (571) 272-1708. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system Status information for published applications may be obtained from either Private PMR or Public PMR. Status information for unpublished applications is available through Private PMR only. For more information about the PMR system see http://pair-dkect.uspto.gov. Should you have questions on access to the Private PMR system contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free) or EBC_Support@uspto.gov.

**AC**/December 17, 2010

/Alonzo Chambliss/
Primary Examiner, Art Unit 2892

| Notice of References Cited | Application/Control No. 12/923,643 | Applicant(s)/Patent Under Reexamination YUASA, SHINJI | |
|---|---|---|---|
| | Examiner Alonzo Chambliss | Art Unit 2892 | Page 1 of 1 |

**U.S. PATENT DOCUMENTS**

| * | | Document Number Country Code-Number-Kind Code | Date MM-YYYY | Name | Classification |
|---|---|---|---|---|---|
| * | A | US-2009/0324814 | 12-2009 | Parkin, Stuart Stephen Papworth | 427/131 |
| | B | US- | | | |
| | C | US- | | | |
| | D | US- | | | |
| | E | US- | | | |
| | F | US- | | | |
| | G | US- | | | |
| | H | US- | | | |
| | I | US- | | | |
| | J | US- | | | |
| | K | US- | | | |
| | L | US- | | | |
| | M | US- | | | |

**FOREIGN PATENT DOCUMENTS**

| * | | Document Number Country Code-Number-Kind Code | Date MM-YYYY | Country | Name | Classification |
|---|---|---|---|---|---|---|
| | N | | | | | |
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| | P | | | | | |
| | Q | | | | | |
| | R | | | | | |
| | S | | | | | |
| | T | | | | | |

**NON-PATENT DOCUMENTS**

| * | | Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages) |
|---|---|---|
| | U | |
| | V | |
| | W | |
| | X | |

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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# BIB DATA SHEET

**CONFIRMATION NO. 8219**

| SERIAL NUMBER | FILING or 371(c) DATE | CLASS | GROUP ART UNIT | ATTORNEY DOCKET NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010<br>RULE | 257 | 2892 | NAGI-0003 |

**APPLICANTS**
Shinji Yuasa, Ibaraki, JAPAN;

**** CONTINUING DATA **************************
This application is a CON of 10/591,947 09/08/2006
which is a 371 of PCT/JP2005/004720 03/10/2005

**** FOREIGN APPLICATIONS **************************
JAPAN 2004-071186 03/12/2004
JAPAN 2004-313350 10/28/2004

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****
10/28/2010

| Foreign Priority claimed ☑ Yes ☐ No<br>35 USC 119(a-d) conditions met ☑ Yes ☐ No<br>Verified and Acknowledged /ALONZO CHAMBLISS/ Examiner's Signature | ☐ Met after Allowance<br>Initials | STATE OR COUNTRY | SHEETS DRAWINGS | TOTAL CLAIMS | INDEPENDENT CLAIMS |
|---|---|---|---|---|---|
| | | JAPAN | 10 | 16 | 6 |

**ADDRESS**

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437
UNITED STATES

**TITLE**

Magnetic tunnel junction device and method of manufacturing the same

| FILING FEE RECEIVED | | |
|---|---|---|
| 1750 | FEES: Authority has been given in Paper No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following: | ☐ All Fees<br>☐ 1.16 Fees (Filing)<br>☐ 1.17 Fees (Processing Ext. of time)<br>☐ 1.18 Fees (Issue)<br>☐ Other _____<br>☐ Credit |

| *Index of Claims* | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| *1292364 3* | 12923643 | YUASA, SHINJI |
| | **Examiner** | **Art Unit** |
| | Alonzo Chambliss | 2892 |

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|---|---|---|---|---|---|---|---|
| ✓ | Rejected | - | Cancelled | N | Non-Elected | A | Appeal |
| = | Allowed | ÷ | Restricted | I | Interference | O | Objected |

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

| CLAIM | | DATE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Final | Original | 12/17/2010 | | | | | | | | |
| | 1 | ✓ | | | | | | | | |
| | 2 | ✓ | | | | | | | | |
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| | 11 | ✓ | | | | | | | | |
| | 12 | ✓ | | | | | | | | |
| | 13 | ✓ | | | | | | | | |
| | 14 | ✓ | | | | | | | | |
| | 15 | ✓ | | | | | | | | |
| | 16 | ✓ | | | | | | | | |



WD EX1004
Western Digital v IP Bridge
Page 146

| *Search Notes* | **Application/Control No.** | **Applicant(s)/Patent Under Reexamination** |
|---|---|---|
| *12923643* | 12923643 | YUASA, SHINJI |
| | **Examiner** | **Art Unit** |
| | Alonzo Chambliss | 2892 |

| SEARCHED | | | |
|---|---|---|---|
| **Class** | **Subclass** | **Date** | **Examiner** |
| | | | |

| SEARCH NOTES | | |
|---|---|---|
| **Search Notes** | **Date** | **Examiner** |
| East text search only - see attach printout | 12/16/10 | AC |

| INTERFERENCE SEARCH | | | |
|---|---|---|---|
| **Class** | **Subclass** | **Date** | **Examiner** |
| | | | |

*Customized* PTO/SB/08a+b (07-09)

| *Substitute for Form 1449/PTO* | | |
|---|---|---|
| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** | Application # | To Be Determined |
| | Confirmation # | |
| | Filing Date | Concurrently Herewith |
| | First Inventor | Yuasa |
| | Art Unit | |
| | Examiner | |
| Sheet 1 of 1 | Docket # | NAGI.0003 |

## U.S. PATENT DOCUMENTS

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
| | 2007/0128470 + | 6/7/2007 | Nagahama et al. | |
| | 2004/0144995 + | 7/29/2004 | Nagahama et al. | |
| | 2004/0245553 + | 12/9/2004 | Hosomi et al. | |
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| | 2002/0159203 A1 + | 10/31/2002 | Saito et al. | |
| | 2005/0207071 A1 + | 9/22/2005 | Sato et al. | |
| | 2002/0191355 A1 + | 12/19/2002 | Hiramoto et al. | |
| | 2002/0149962 A1 + | 10/17/2002 | Horiguchi | |
| | 2007/0195592 A1 + | 8/23/2007 | Yuasa | |

## FOREIGN PATENT DOCUMENTS

| Exam. Initial* | Country-Number-Kind Code if known | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
|---|---|---|---|---|---|
| | JP 2003-318465** + | 11/7/2003 | | | Abstract |
| | JP 2002-204004 + | 7/19/2002 | | | Abstract |
| | JP 2002-289943 + | 10/4/2002 | | | |
| | JP 2003-304010*** + | 10/24/2003 | Sony Corp | | Abstract |
| | WO 2002/099905 + | 5/24/2002 | National Institute of Advanced Industrial Science and Technology | | Abstract |
| | EP 1 391 942 + | 5/24/2002 | National Institute of Advanced Industrial Science and Technology; Japan Science and Technology Agency | | Yes |
| | WO 2003/085750 + | 10/16/2003 | Sony Corp | | Abstract |
| | EP 1 494 295 + | 1/5/2005 | Sony Corp | | Yes |
| | JP 2006-080116**** + | 3/23/2006 | | | Abstract |
| | EP 1 633 007 A2 + | 3/8/2006 | Anelva Corporation | | Yes |
| | EP 1 633 007 A3 + | 3/8/2006 | Anelva Corporation | | Yes |
| | EP 1 085 586 A2 + | 3/21/2001 | Kabushiki Kaisha Toshiba | | Yes |
| | JP 2000-030236 + | 1/28/2000 | Hitachi Ltd. | | Yes |
| | JP 2001-101645 + | 4/13/2001 | Akita Prefecture | | Yes |
| | JP 2004-022599 + | 1/22/2004 | Sony Corp | | Yes |
| | JP 2002-270921 + | 9/20/2002 | Toshiba Corp | | Abstract |
| | JP 2002-319722 + | 10/31/2002 | Matsushita Electric Ind Co Ltd | | Abstract |
| | WO 2004/025744 A1 + | 3/25/2004 | Fujitsu Limited | | Abstract |
| | JP 2003-283001 + | 10/3/2003 | Toshiba Corp | | Yes |

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

| | | | | | |
|---|---|---|---|---|---|
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| | JP 11-097766 + | 4/9/1999 | Res Inst Electric Magnetic Alloys | | Abstract & ¶22 & 23 |

| NON PATENT LITERATURE DOCUMENTS | | |
|---|---|---|
| **Exam. Initial*** | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | **Translation** |
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| | | |

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|---|---|---|---|
| Examiner Signature | /Alonzo Chambliss/ (12/17/2010) | Date Considered | |

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

** Corresponds to U.S. Patent 2007/0128470, U.S. Patent 2004/0144995, WO2002/099905, and EP1 391 942, listed above.

*** Corresponds to U.S. Patent 2004/0245553, WO 2003/085750, and EP 1 494 295, listed above.

**** Corresponds to U.S. Patent 2006/0056115, listed above.

+ = Filed in Parent Application 10/591,947

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

Receipt date: 12/07/2010

OPAP IAP24 DEC 07 2010 PATENT AND TRADEMARK OFFICE

12923643 - GAU: 2892

*Customized* PTO/SB/08a+b (07-09)

| *Substitute for Form 1449/PTO* **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** | | |
|---|---|---|
| | Application # | 12/923,643 |
| | Confirmation # | 8219 |
| | Filing Date | September 30, 2010 |
| | First Inventor | YUASA |
| | Art Unit | 2892 |
| | Examiner | |
| Sheet 1 of 1 | Docket # | NAGI.0003 |

**U.S. PATENT DOCUMENTS**

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
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| | | | | |
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**FOREIGN PATENT DOCUMENTS**

| Exam. Initial* | Country-Number-Kind Code If known | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Translation |
|---|---|---|---|---|---|
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**NON PATENT LITERATURE DOCUMENTS**

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
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| Examiner Signature | /Alonzo Chambliss/ (12/17/2010) | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

## EAST Search History

### EAST Search History (Prior Art)

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 213 | amorphous near5 (magnessium oxide MgO) and (MRAM MTJ magnetic adj3 tunnel adj3 junction) and Fe | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2010/12/17 14:11 |
| L2 | 4 | poly adj3 crystal$4 adj2 (MgO magnesium adj3 oxide) and (MRAM MTJ magnetic adj2 tunnel adj2 junction) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2010/12/17 14:12 |
| L3 | 49 | amorphous near5 (MgO magnesium adj3 oxide) same (heat anneal$3) and (MRAM MTJ magnetic adj2 tunnel adj2 junction) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2010/12/17 14:12 |

**12/17/2010 2:13:00 PM**

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| APPLICATION NUMBER | FILING OR 371(C) DATE | FIRST NAMED APPLICANT | ATTY. DOCKET NO./TITLE |
|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 |

CONFIRMATION NO. 8219

38327
Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

PUBLICATION NOTICE

*OC000000045933658*

**Title:**Magnetic tunnel junction device and method of manufacturing the same

**Publication No.**US-2011-0031570-A1
**Publication Date:**02/10/2011

## NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

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Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

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APR 05 2011
PATENT & TRADEMARK OFFICE

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | |
|---|---|
| **In re U.S. Patent Application of** | |
| **YUASA** | **Art Unit 2892** |
| **Application Number: 12/923,643** | **Examiner: Alonzo Chambliss** |
| **Filed: September 30, 2010** | |
| **For: MAGNETIC MULTILAYER FILM (as amended)** | |
| **Attorney Docket No. NAGI.0003** | |

**Mail Stop Amendment**
**Commissioner for Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

**RESPONSE AND AMENDMENT UNDER 37 C.F.R. § 1.111**

Sir:

This is in response to the Office Action mailed on January 5, 2011, the period of response to which is set to expire on April 5, 2011. Please amend the above-referenced application as follows:

**IN THE DRAWINGS**

Please amend/replace Figure 9(C) with the substitute Figure 9(C) provided in the replacement sheet of drawings submitted herewith. The Examiner objected to Figure 9(C) of the drawings, stating that the reference character "113" included therein is not mentioned within the specification. Accordingly, a replacement sheet of corrected drawings in which the reference character "113" is being removed from Figure 9(C) is being submitted herewith, thereby rendering moot and/or obviating this objection.



WD EX1004
Western Digital v IP Bridge
Page 155

**IN THE SPECIFICATION**

Please amend/replace the Title of the Invention for the instant application as follows:

MAGNETIC MULTILAYER FILM ~~TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME~~



**WD EX1004**
**Western Digital v IP Bridge**
**Page 156**

**IN THE CLAIMS**

Claims 16-19 are pending in this application, wherein claims 1-15 are being canceled without prejudice or disclaimer, wherein claim 16 is being amended to improve form, and wherein claims 17-19 are being newly added, all as follows:

1-15. (Canceled).

16. (Currently Amended) A magnetic multilayer film comprising:

a first amorphous ferromagnetic material layer;

~~a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented, the magnesium oxide layer having oxygen vacancy defects;~~

a second amorphous ferromagnetic material layer; and

a poly-crystalline magnesium oxide layer located between the first and second amorphous ferromagnetic material layers that includes magnesium oxide having oxygen vacancy defects.

~~the first and second ferromagnetic material layers comprising Fe or a Fe-based alloy of the BCC structure and comprising a poly-crystalline layer in which (001) crystal plane is preferentially oriented.~~

17. (New) A magnetic multilayer film comprising:

a first amorphous ferromagnetic material layer;

a second amorphous ferromagnetic material layer; and

a poly-crystalline magnesium oxide layer located between the first and second amorphous ferromagnetic material layers that includes magnesium oxide having oxygen vacancy defects and in which (001) crystal plane is preferentially oriented.

18. (New) The magnetic multilayer film according to claim 16, wherein the first amorphous ferromagnetic material layer comprises CoFeB alloy.

19. (New) The magnetic multilayer film according to claim 17, wherein the first amorphous ferromagnetic material layer comprises CoFeB alloy.



**WD EX1004**
**Western Digital v IP Bridge**
**Page 157**

## REMARKS

The above amendments to the above-captioned application along with the following remarks are being submitted as a full and complete response to the Office Action dated January 5, 2011 (U.S. Patent Office Paper No. 20101216). In view of the above amendments and the following remarks, the Examiner is respectfully requested to give due reconsideration to this application, to indicate the allowability of the claims, and to pass this case to issue.

Status of the Claims

As outlined above, claims 16-19 stand for consideration in this application, wherein claims 1-15 are being canceled without prejudice or disclaimer, wherein claim 16 is being amended to improve form, and wherein claims 17-19 are being newly added.

All amendments to the application are fully supported therein. For example, the amendments to the claims are supported by paragraphs [0050]-[0051] of the present application as originally filed. Applicants hereby submit that no new matter is being introduced into the application through the submission of this response.

Formality Objections/Rejections

The Examiner objected to Figure 9(C) of the drawings, stating that the reference character "113" included therein is not mentioned within the specification. As set forth above, a replacement sheet of corrected drawings in which the reference character "113" is being removed from Figure 9(C) is being submitted herewith, thereby rendering moot and/or obviating this objection.

The Examiner rejected claims 1-16 under 35 U.S.C. §112, second paragraph, as being incomplete. In particular, the Examiner stated that the step of "forming first and second ferromagnetic material layers having a BCC structure" is omitted from but essential to claims 1-13, that the step of "forming first and second ferromagnetic material layers on a poly-crystalline magnesium oxide layer" is omitted from but essential to claims 9-13 and 15, and that the structural relationship that "the thermal expansion gradient of the substrate between the first and second ferromagnetic material layers and the tunnel barrier layer" is omitted from but essential to claims 14 and 16. (Office Action, p. 3).

As outlined above, claims 16-19 remain of record. According to section 2172.01 of the U.S. Manual of Patent Examining Procedure, "essential matter may include missing elements, steps or necessary structural cooperative relationships of elements described by the



WD EX1004
Western Digital v IP Bridge
Page 158

applicant(s) as necessary to practice the invention....[A] claim which fails to interrelate essential elements of the invention as defined by applicant(s) in the specification may be rejected under 35 U.S.C. 112, second paragraph, for failure to point out and distinctly claim the invention." (Citations omitted). Nevertheless, "[a] claim does not necessarily fail to comply with 35 U.S.C. 112, second paragraph where the various elements do not function simultaneously, are not directly functionally related, do not directly intercooperate, and/or serve independent purposes." MPEP 2172.01. Moreover, "[f]eatures which are merely preferred are not to be considered critical." MPEP 2164.08(c).

In this regard, Applicants respectfully submit that any necessary structural relationships between the first and second ferromagnetic material layers and the poly-crystalline magnesium oxide layer are sufficiently recited in claim 16 as presently amended. With respect to the assertion that the structural relationship of "the thermal expansion gradient of the substrate between the first and second ferromagnetic material layers and the tunnel barrier layer" is omitted from but essential to claim 16 on page 3 of the Office Action, Applicants respectfully submit that it is not clear what is meant by this assertion and therefore withhold comments thereon.

Accordingly, Applicants respectfully submit that the present invention as claimed is definite and request reconsideration and withdrawal of the rejection of claim 16 under 35 U.S.C. §112, second paragraph. For at least these reasons, Applicants further respectfully submit that the present invention is now in condition for allowance.



WD EX1004
Western Digital v IP Bridge
Page 159

Conclusion

Favorable reconsideration of this application as amended is respectfully solicited. Should there be any outstanding issues requiring discussion that would further the prosecution and allowance of the above-captioned application, the Examiner is invited to contact the Applicants' undersigned representative at the address and phone number indicated below.

Respectfully submitted,

Nicholas B. Trenkle
Registration Number 54,500

Juan Carlos A. Marquez
Registration Number 34,072

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**April 5, 2011**

200604:1:ALEXANDRIA



**WD EX1004**
**Western Digital v IP Bridge**
**Page 160**

FIG. 9 (A)

Prior Art

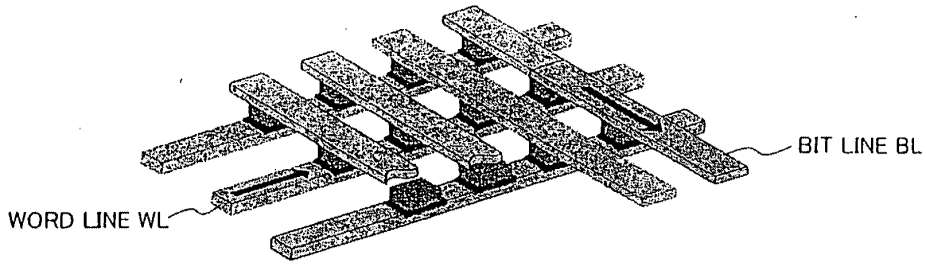



FIG. 9 (B)

Prior Art

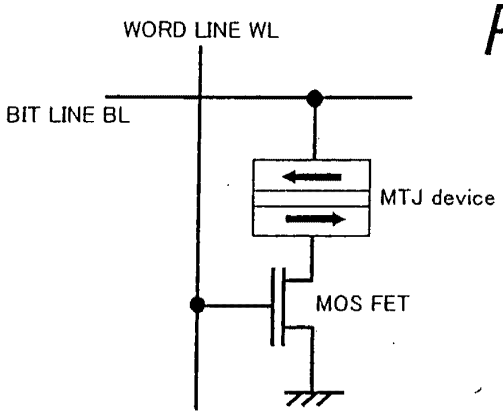
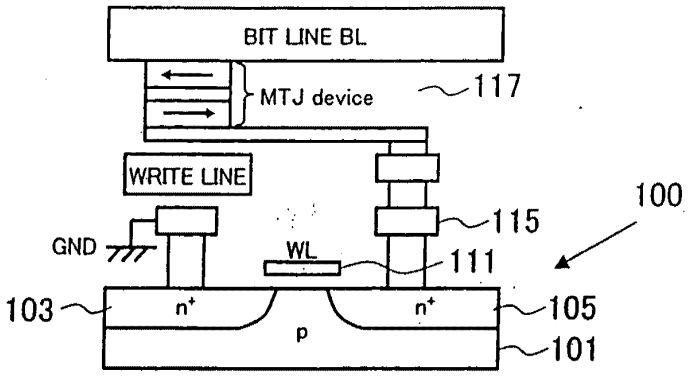



FIG. 9 (C)

Prior Art




MOSFET 100

DocCode - SCORE

# SCORE Placeholder Sheet for IFW Content

Application Number: **12923643** Document Date: **04/05/2011**

The presence of this form in the IFW record indicates that the following document type was received in paper and is scanned and stored in the SCORE database.

- Drawings

Images of the original documents are scanned in gray scale or color and stored in SCORE. Bi-tonal images are also stored in IFW. Defects visible in both IFW and SCORE are indicative of defects in the original paper documents.

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Form Revision Date: December 8, 2006

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PATENT & TRADEMARK OFFICE

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**In re U.S. Patent Application of**

**YUASA**

**Application Number: 12/923,643**

**Filed: September 30, 2010**

**For: MAGNETIC MULTILAYER FILM (as amended)**

**Attorney Docket No. NAGI.0003**

**Art Unit 2892**

**Examiner**
**Alonzo Chambliss**

**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## COVER LETTER

Sir:

[x ] The fee for submission of claims is calculated as shown below:

| FOR | TOTAL WITH NEW CLAIMS ADDED | TOTAL CURRENTLY ON FILE | CLAIMS ALREADY PAID | RATE | CALCULATION |
|---|---|---|---|---|---|
| Total Claims | 4 | 16 | (Over 20) | x $52 | 0 |
| Independent Claims | 2 | 6 | (Over 3) | x $220 | 0 |
| MULTIPLE DEPENDENT CLAIM(S) | | | | + $390 | 0 |
| REDUCTION FOR FILING BY SMALL ENTITY (note 37 C.F.R. §§ 1.9, 1.27, 1.28). | | | | x ½ | |
| | | | TOTAL | | $0 |

In addition, the below-identified communications are submitted in the above-captioned application or proceeding:

[ x ] Response and Amendment to Office Action (with claim amendments)
[ ] Substitute Abstract
[ ] Preliminary Amendment
[ ] Information Disclosure Statement
[ x ] 1 sheet of replacement drawings
[ ] RCE
[ ] Other: _____

[ ] Applicant(s) hereby request and petition that the time for taking action in this case be extended pursuant to 37 C.F.R. § 1.136(a) for:
**[ ] one (1) month [ ] two (2) months [ ] three (3) months**

The fee set in 37 C.F.R. § 1.17 for the extension of time is **$**_____ for a large/small entity.

[ ] Credit card information for **$**_____ to cover the fee associated with this filing is enclosed.

[ ] Please charge my **Deposit Account Number** _____ in the amount of _____ to cover the fees for _____.

[ x ] The Commissioner is hereby authorized to charge any additional fees associated with this communication, including fees under 37 C.F.R. § 1.16 and 1.17, or credit any overpayment to **Deposit Account Number 12-0555**.

Respectfully submitted,

Juan Carlos A. Marquez
Registration No. 34,072

**STITES & HARBISON PLLC**
1199 North Fairfax Street, Suite 900
Alexandria, VA 22314
Telephone: (703) 739-4900
Facsimile: (703) 739-9577
Customer No. 38327

**April 5, 2011**

200502:1:ALEXANDRIA

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

| **PATENT APPLICATION FEE DETERMINATION RECORD**<br>Substitute for Form PTO-875 | Application or Docket Number<br>12/923,643 | Filing Date<br>09/30/2010 | ☐ To be Mailed |
|---|---|---|---|

## APPLICATION AS FILED – PART I

| | (Column 1) | (Column 2) | SMALL ENTITY ☐ | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|
| FOR | NUMBER FILED | NUMBER EXTRA | RATE ($) | FEE ($) | | RATE ($) | FEE ($) |
| ☐ BASIC FEE (37 CFR 1.16(a), (b), or (c)) | N/A | N/A | N/A | | | N/A | |
| ☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | N/A | N/A | | | N/A | |
| ☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | N/A | N/A | | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | minus 20 = | * | X $ = | | OR | X $ = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | minus 3 = | * | X $ = | | | X $ = | |
| ☐ APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | | | |
| ☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j)) | | | | | | | |
| * If the difference in column 1 is less than zero, enter "0" in column 2. | | | TOTAL | | | TOTAL | |

## APPLICATION AS AMENDED – PART II

| | | (Column 1) | | (Column 2) | (Column 3) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **04/05/2011** | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * 4 | Minus | ** 20 | = 0 | X $ = | | OR | X $52= | 0 |
| | Independent (37 CFR 1.16(h)) | * 2 | Minus | ***3 | = 0 | X $ = | | OR | X $220= | 0 |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | **0** |

| | | (Column 1) | | (Column 2) | (Column 3) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X $ = | | OR | X $ = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X $ = | | OR | X $ = | |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | |

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/KIM WATSON SAUNDERS/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

PTO/SB/06 (07-06)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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| **PATENT APPLICATION FEE DETERMINATION RECORD**<br>Substitute for Form PTO-875 | Application or Docket Number<br>12/923,643 | Filing Date<br>09/30/2010 | ☐ To be Mailed |
|---|---|---|---|

## APPLICATION AS FILED – PART I

| | (Column 1) | (Column 2) | SMALL ENTITY ☐ | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|
| FOR | NUMBER FILED | NUMBER EXTRA | RATE ($) | FEE ($) | | RATE ($) | FEE ($) |
| ☐ BASIC FEE (37 CFR 1.16(a), (b), or (c)) | N/A | N/A | N/A | | | N/A | |
| ☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | N/A | N/A | | | N/A | |
| ☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | N/A | N/A | | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | minus 20 = | * | X $ = | | OR | X $ = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | minus 3 = | * | X $ = | | | X $ = | |
| ☐ APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | | | |
| ☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j)) | | | | | | | |
| * If the difference in column 1 is less than zero, enter "0" in column 2. | | | TOTAL | | | TOTAL | |

## APPLICATION AS AMENDED – PART II

| | | (Column 1) | | (Column 2) | (Column 3) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **04/05/2011** | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * 4 | Minus | ** 20 | = 0 | X $ = | | OR | X $52= | 0 |
| | Independent (37 CFR 1.16(h)) | * 2 | Minus | ***6 | = 0 | X $ = | | OR | X $220= | 0 |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | **0** |

| | | (Column 1) | | (Column 2) | (Column 3) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X $ = | | OR | X $ = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X $ = | | OR | X $ = | |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | |

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/CHRISTINE MOLLISH/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

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APR 28 2011
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | |
|---|---|
| **In re U.S. Patent Application of** | |
| **YUASA** | **Art Unit 2892** |
| **Application Number: 12/923,643** | **Examiner: Alonzo Chambliss** |
| **Filed: September 30, 2010** | |
| **For: MAGNETIC MULTILAYER FILM (AS AMENDED)** | |
| **Attorney Docket No. NAGI.0003** | |

**Mail Stop Amendment**
**Commissioner for Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## SUPPLEMENTAL RESPONSE AND AMENDMENT UNDER 37 C.F.R. § 1.111

Sir:

This is being submitted to replace the Response that was submitted on April 5, 2011 in reply to the Office Action mailed on January 5, 2011. The Response filed on April 5, 2011 was submitted with a typographical error corresponding to a quotation of a portion of the Office Action mailed on January 5, 2011. Accordingly, Applicant respectfully requests consideration of the present Supplemental Response in place of the previous Response filed on April 5, 2011 that is now being superseded by the present Supplemental Response. Please amend the above-referenced application as follows:

**IN THE DRAWINGS**

Please amend/replace Figure 9(C) with the substitute Figure 9(C) provided in the replacement sheet of drawings submitted herewith. The Examiner objected to Figure 9(C) of the drawings, stating that the reference character "113" included therein is not mentioned within the specification. Accordingly, a replacement sheet of corrected drawings in which the reference character "113" is being removed from Figure 9(C) is being submitted herewith, thereby rendering moot and/or obviating this objection.



WD EX1004
Western Digital v IP Bridge
Page 168

**IN THE SPECIFICATION**

Please amend/replace the Title of the Invention for the instant application as follows:

MAGNETIC MULTILAYER FILM ~~TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME~~



WD EX1004
Western Digital v IP Bridge
Page 169

**IN THE CLAIMS**

Claims 16-19 are pending in this application, wherein claims 1-15 are being canceled without prejudice or disclaimer, wherein claim 16 is being amended to improve form, and wherein claims 17-19 are being newly added, all as follows:

1-15. (Canceled).

16. (Currently Amended) A magnetic multilayer film comprising:

a first amorphous ferromagnetic material layer;

~~a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented, the magnesium oxide layer having oxygen vacancy defects;~~

a second amorphous ferromagnetic material layer; and

a poly-crystalline magnesium oxide layer located between the first and second amorphous ferromagnetic material layers that includes magnesium oxide having oxygen vacancy defects.

~~the first and second ferromagnetic material layers comprising Fe or a Fe-based alloy of the BCC structure and comprising a poly-crystalline layer in which (001) crystal plane is preferentially oriented.~~

17. (New) A magnetic multilayer film comprising:

a first amorphous ferromagnetic material layer;

a second amorphous ferromagnetic material layer; and

a poly-crystalline magnesium oxide layer located between the first and second amorphous ferromagnetic material layers that includes magnesium oxide having oxygen vacancy defects and in which (001) crystal plane is preferentially oriented.

18. (New) The magnetic multilayer film according to claim 16, wherein the first amorphous ferromagnetic material layer comprises CoFeB alloy.

19. (New) The magnetic multilayer film according to claim 17, wherein the first amorphous ferromagnetic material layer comprises CoFeB alloy.



**WD EX1004**
**Western Digital v IP Bridge**
**Page 170**

## REMARKS

The above amendments to the above-captioned application along with the following remarks are being submitted as a full and complete response to the Office Action dated January 5, 2011 (U.S. Patent Office Paper No. 20101216). In view of the above amendments and the following remarks, the Examiner is respectfully requested to give due reconsideration to this application, to indicate the allowability of the claims, and to pass this case to issue.

Status of the Claims

As outlined above, claims 16-19 stand for consideration in this application, wherein claims 1-15 are being canceled without prejudice or disclaimer, wherein claim 16 is being amended to improve form, and wherein claims 17-19 are being newly added.

All amendments to the application are fully supported therein. For example, the amendments to the claims are supported by paragraphs [0050]-[0051] of the present application as originally filed. Applicant hereby submits that no new matter is being introduced into the application through the submission of this response.

Formality Objections/Rejections

The Examiner objected to Figure 9(C) of the drawings, stating that the reference character "113" included therein is not mentioned within the specification. As set forth above, a replacement sheet of corrected drawings in which the reference character "113" is being removed from Figure 9(C) is being submitted herewith, thereby rendering moot and/or obviating this objection.

The Examiner rejected claims 1-16 under 35 U.S.C. §112, second paragraph, as being incomplete. In particular, the Examiner stated that the step of "forming first and second ferromagnetic material layers having a BCC structure" is omitted from but essential to claims 1-13, and that the step of "forming first and second ferromagnetic material layers on a poly-crystalline magnesium oxide layer" is omitted from but essential to claims 9-13 and 15. Furthermore, the Examiner also stated that the structural cooperative relationships of "between the first and second ferromagnetic material layers and the tunnel barrier layer" and that "matches the coefficient of thermal expansion gradient of the substrate" are omitted from but essential to claims 14 and 16. (Office Action, p. 3).

As outlined above, claims 16-19 remain of record. According to section 2172.01 of the U.S. Manual of Patent Examining Procedure, "essential matter may include missing



WD EX1004
Western Digital v IP Bridge
Page 171

elements, steps or necessary structural cooperative relationships of elements described by the applicant(s) as necessary to practice the invention....[A] claim which fails to interrelate essential elements of the invention as defined by applicant(s) in the specification may be rejected under 35 U.S.C. 112, second paragraph, for failure to point out and distinctly claim the invention." (Citations omitted). Nevertheless, "[a] claim does not necessarily fail to comply with 35 U.S.C. 112, second paragraph where the various elements do not function simultaneously, are not directly functionally related, do not directly intercooperate, and/or serve independent purposes." MPEP 2172.01. Moreover, "[f]eatures which are merely preferred are not to be considered critical." MPEP 2164.08(c).

With respect to the statement in paragraph 5 on page 3 of the Office Action that "[t]he omitted structural cooperative relationships are: between the first and second ferromagnetic material layers and the tunnel barrier layer. matches the coefficient of thermal expansion gradient of the substrate," Applicant respectfully submits that the language used here is unclear, as the phrase "matches the coefficient of thermal expansion gradient of the substrate" appears to be incomplete. However, Applicant respectfully submits that any necessary structural relationships between the first and second ferromagnetic material layers and the poly-crystalline magnesium oxide layer are sufficiently recited in claim 16 as presently amended.

Accordingly, Applicant respectfully submits that the present invention as claimed is definite and request reconsideration and withdrawal of the rejection of claim 16 under 35 U.S.C. §112, second paragraph. For at least these reasons, Applicant further respectfully submits that the present invention is now in condition for allowance.



WD EX1004
Western Digital v IP Bridge
Page 172

Conclusion

Favorable reconsideration of this application as amended is respectfully solicited. Should there be any outstanding issues requiring discussion that would further the prosecution and allowance of the above-captioned application, the Examiner is invited to contact the Applicant's undersigned representative at the address and phone number indicated below.

Respectfully submitted,

Nicholas B. Trenkle
Registration Number 54,500

Juan Carlos A. Marquez
Registration Number 34,072

**STITES & HARBISON PLLC**
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437
(703) 739-4900 Voice
(703) 739-9577 Fax
Customer No. 38327
**April 28, 2011**

202421:1:ALEXANDRIA



**WD EX1004**
**Western Digital v IP Bridge**
**Page 173**

OPAP IAP3 APR 28 2011 PATENT & TRADEMARK OFFICE

DW

# IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | | |
|---|---|---|
| **In re U.S. Patent Application of** | ) | |
| | ) | |
| **YUASA** | ) | |
| | ) | **Art Unit 2892** |
| **Application Number: 12/923,643** | ) | |
| | ) | **Examiner:** |
| **Filed: September 30, 2010** | ) | **Alonzo Chambliss** |
| | ) | |
| **For: MAGNETIC MULTILAYER FILM (AS AMENDED)** | ) | |
| | ) | |
| **Attorney Docket No. NAGI.0003** | ) | |

**Mail Stop Amendment**
**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## COVER LETTER

Sir:

[ x ] The fee for submission of claims is calculated as shown below:

| FOR | TOTAL WITH NEW CLAIMS ADDED | TOTAL CURRENTLY ON FILE | CLAIMS ALREADY PAID | RATE | CALCULATION |
|---|---|---|---|---|---|
| Total Claims | 4 | 4 | (Over 20) | x $52 | 0 |
| Independent Claims | 2 | 2 | 3 (Over 3) | x $220 | 0 |
| MULTIPLE DEPENDENT CLAIM(S) | | | | + $390 | 0 |
| REDUCTION FOR FILING BY SMALL ENTITY (note 37 C.F.R. §§ 1.9, 1.27, 1.28). | | | | x ½ | |
| | | | TOTAL | | 0 |

In addition, the below-identified communications are submitted in the above-captioned application or proceeding:

[ x ] Supplemental Response and Amendment to Office Action (with claim amendments)
[ ] Substitute Abstract
[ ] Terminal Disclaimer
[ ] Information Disclosure Statement
[ x ] 1 sheet of replacement drawings
[ ] RCE
[ ] Other:

::ODMA\PCDOCS\ALEXANDRIA\202545\1




[ ] Applicant(s) hereby request and petition that the time for taking action in this case be extended pursuant to 37 C.F.R. § 1.136(a) for:
[ ] **one (1) month** [ ] **two (2) months** [ ] **three (3) months**

The fee set in 37 C.F.R. § 1.17 for the extension of time is **$**_____ for a large/small entity.

[ ] Credit card information for **$**_____ to cover the fee associated with this filing is enclosed.

[ ] Please charge my **Deposit Account Number** _____ in the amount of _____ to cover the fees for _____.

[ x ] The Commissioner is hereby authorized to charge any additional fees associated with this communication, including fees under 37 C.F.R. § 1.16 and 1.17, or credit any overpayment to **Deposit Account Number 12-0555.**

Respectfully submitted,

Juan Carlos A. Marquez
Registration No. 34,072

**STITES & HARBISON, PLLC**
1199 North Fairfax Street, Suite 900
Alexandria, VA 22314
Telephone: (703) 739-4900
Facsimile: (703) 937-9577
Customer No. 38327
**April 28, 2011**

J60073:00712:123855:1:ALEXANDRIA

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PTO/SB/06 (07-06)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

| **PATENT APPLICATION FEE DETERMINATION RECORD**<br>Substitute for Form PTO-875 | Application or Docket Number<br>12/923,643 | Filing Date<br>09/30/2010 | ☐ To be Mailed |
|---|---|---|---|

## APPLICATION AS FILED – PART I

| | (Column 1) | (Column 2) | SMALL ENTITY ☐ | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|
| FOR | NUMBER FILED | NUMBER EXTRA | RATE ($) | FEE ($) | | RATE ($) | FEE ($) |
| ☐ BASIC FEE (37 CFR 1.16(a), (b), or (c)) | N/A | N/A | N/A | | | N/A | |
| ☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | N/A | N/A | | | N/A | |
| ☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | N/A | N/A | | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | minus 20 = | * | X $ = | | OR | X $ = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | minus 3 = | * | X $ = | | | X $ = | |
| ☐ APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | | | |
| ☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j)) | | | | | | | |
| * If the difference in column 1 is less than zero, enter "0" in column 2. | | | TOTAL | | | TOTAL | |

## APPLICATION AS AMENDED – PART II

| | | (Column 1) | | (Column 2) | (Column 3) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **04/28/2011** | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * 4 | Minus | ** 20 | = 0 | X $ = | | OR | X $52= | 0 |
| | Independent (37 CFR 1.16(h)) | * 2 | Minus | ***3 | = 0 | X $ = | | OR | X $220= | 0 |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | **0** |

| | | (Column 1) | | (Column 2) | (Column 3) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X $ = | | OR | X $ = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X $ = | | OR | X $ = | |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | |

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/SHIRELL M. CARMICHAEL/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

38327 7590 07/22/2011

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER | |
|---|---|
| CHAMBLISS, ALONZO | |
| ART UNIT | PAPER NUMBER |
| 2892 | |

| NOTIFICATION DATE | DELIVERY MODE |
|---|---|
| 07/22/2011 | ELECTRONIC |

**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

iplaw@stites.com

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 12/923,643 | YUASA, SHINJI | |
| | Examiner | Art Unit | |
| | ALONZO CHAMBLISS | 2892 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

1)☒ Responsive to communication(s) filed on *28 April 2011*.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

4)☒ Claim(s) *16-19* is/are pending in the application.

4a) Of the above claim(s) _____ is/are withdrawn from consideration.

5)☐ Claim(s) _____ is/are allowed.

6)☒ Claim(s) *16-19* is/are rejected.

7)☐ Claim(s) _____ is/are objected to.

8)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

9)☐ The specification is objected to by the Examiner.

10)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

11)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☒ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☐ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date _____.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

## DETAILED ACTION

1. The amendment filed on 4/28/11 has been fully considered and made of record in the instant application.

### *Response to Arguments*

2. Applicant's arguments with respect to claims 16-19 have been considered but are moot in view of the new ground(s) of rejection.

### *Claim Rejections - 35 USC § 103*

3. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

4. The factual inquiries set forth in *Graham* v. *John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

5. Claims 16-19 are rejected under 35 U.S.C. 103(a) as being unpatentable over Parkin et al. (US 7,726,384) in view of Parkin (2009/0324814) and Nashimoto et al. (US 5,759,265).

With respect to Claims 16-19, Parkin (384) discloses a first amorphous ferromagnetic material layer 334 (i.e. made of CoFeB alloy), a second amorphous ferromagnetic material layer 318 (i.e. made of CoFeB alloy), and a tunnel barrier layer 324 (i.e. made of $Al_2O_3$) located between the first and second amorphous ferromagnetic material layers 334, 318 (see cols. 3 lines 65-67, col. 4 lines 1-14, col. 12 lines 1-15, and col. 14 lines 20-35; Fig. 3). Parkin (384) fails to disclose the tunnel barrier layer made of a poly-crystalline magnesium oxide that includes magnesium oxide having oxygen vacancy defects. However, Parkin (814) discloses the tunnel barrier layer 124 (i.e. made of a poly-crystalline magnesium oxide) that includes magnesium oxide having some level of oxygen vacancy defects (see paragraph 11; Fig. 2A). Thus, Parkin (384) and Parkin (814) have substantially the same environment of a MTJ device with a tunnel barrier layer between 2 ferromagnetic materials. Therefore, one skilled in the art at the time of the invention would readily recognize substituting the poly-crystalline magnesium oxide for the $Al_2O_3$ tunnel barrier material of Parkin (384), since the poly-crystalline magnesium oxide is a known substitute for $Al_2O_3$ and improved the performance of the MTJ device as taught by Parkin (814). Parkin (384) and Parkin (814) fail to explicitly disclose a (001) crystal plane orientation. However, is it is well known in the semiconductor industry to have a (001) for a MgO layer as taught by Nashimoto (see col. 2 lines 40-55).

The prior art made of record and not relied upon is cited primarily to show the product of the instant invention.

***Conclusion***

6. Any inquiry concerning the communication or earlier communications from the examiner should be directed to Alonzo Chambliss whose telephone number is (571) 272-1927.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thao Le can be reached on (571) 272-1708. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system Status information for published applications may be obtained from either Private PMR or Public PMR. Status information for unpublished applications is available through Private PMR only. For more information about the PMR system see http://pair-dkect.uspto.gov. Should you have questions on access to the Private PMR system contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free) or EBC_Support@uspto.gov.

**AC**/July 18, 2011

/Alonzo Chambliss/
Primary Examiner, Art Unit 2892

| Notice of References Cited | Application/Control No. 12/923,643 | Applicant(s)/Patent Under Reexamination YUASA, SHINJI | |
|---|---|---|---|
| | Examiner ALONZO CHAMBLISS | Art Unit 2892 | Page 1 of 1 |

**U.S. PATENT DOCUMENTS**

| * | | Document Number Country Code-Number-Kind Code | Date MM-YYYY | Name | Classification |
|---|---|---|---|---|---|
| * | A | US-6,379,978 | 04-2002 | Goebel et al. | 438/3 |
| * | B | US-7,276,384 | 10-2007 | Parkin et al. | 438/3 |
| * | C | US-5,759,265 | 06-1998 | Nashimoto et al. | 117/105 |
| * | D | US-6,911,685 | 06-2005 | Anthony et al. | 257/295 |
| * | E | US-6,767,655 | 07-2004 | Hiramoto et al. | 428/811.2 |
| * | F | US-6,054,226 | 04-2000 | Takeda et al. | 428/682 |
| | G | US- | | | |
| | H | US- | | | |
| | I | US- | | | |
| | J | US- | | | |
| | K | US- | | | |
| | L | US- | | | |
| | M | US- | | | |

**FOREIGN PATENT DOCUMENTS**

| * | | Document Number Country Code-Number-Kind Code | Date MM-YYYY | Country | Name | Classification |
|---|---|---|---|---|---|---|
| | N | | | | | |
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**NON-PATENT DOCUMENTS**

| * | | Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages) |
|---|---|---|
| | U | |
| | V | |
| | W | |
| | X | |

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

| Index of Claims | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | **Examiner** | **Art Unit** |
| | Alonzo Chambliss | 2892 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ✓ | Rejected | - | Cancelled | N | Non-Elected | A | Appeal |
| = | Allowed | ÷ | Restricted | I | Interference | O | Objected |

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

| CLAIM | | DATE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Final | Original | 12/17/2010 | 07/18/2011 | | | | | | | |
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| | 4 | ✓ | | | | | | | | |
| | 5 | ✓ | | | | | | | | |
| | 6 | ✓ | | | | | | | | |
| | 7 | ✓ | | | | | | | | |
| | 8 | ✓ | | | | | | | | |
| | 9 | ✓ | | | | | | | | |
| | 10 | ✓ | | | | | | | | |
| | 11 | ✓ | | | | | | | | |
| | 12 | ✓ | | | | | | | | |
| | 13 | ✓ | | | | | | | | |
| | 14 | ✓ | | | | | | | | |
| | 15 | ✓ | | | | | | | | |
| | 16 | ✓ | ✓ | | | | | | | |
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| Search Notes | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | Examiner | Art Unit |
| | Alonzo Chambliss | 2892 |

| SEARCHED | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| | | | |

| SEARCH NOTES | | |
|---|---|---|
| Search Notes | Date | Examiner |
| East text search only - see attach printout | 12/16/10 | AC |
| Updated previous East text search only - see attached printout | 7/18/11 | AC |

| INTERFERENCE SEARCH | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| | | | |

## EAST Search History

### EAST Search History (Prior Art)

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 12 | "438"/$.ccls. and poly near5 (MgO magnesium) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2011/07/18 08:12 |
| L2 | 48 | "438"/$.ccls. and amorphous adj3 (ferromagnetic CoFe) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2011/07/18 08:12 |
| L3 | 74 | "438"/$.ccls. and amorphous near5 ferromagnetic | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2011/07/18 08:13 |

7/18/2011 8:13:32 AM

OPAP
OCT 06 2011
PATENT & TRADEMARK OFFICE

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | | |
|---|---|---|
| **In re U.S. Patent Application of** | ) | |
| | ) | |
| **YUASA** | ) | |
| | ) | **Art Unit 2892** |
| **Application Number: 12/923,643** | ) | |
| | ) | **Examiner:** |
| **Filed: September 30, 2010** | ) | **Alonzo Chambliss** |
| | ) | |
| **For: MAGNETIC MULTILAYER FILM (As Amended)** | ) | |
| | ) | |
| **Attorney Docket No. NAGI.0003** | ) | |

**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

**LETTER**

Sir:

The below-identified communications are submitted in the above-captioned application or proceeding:

(x) Information Disclosure Statement
with Form-1449 and references
( ) Check for $0.00

☒ The Commissioner is hereby authorized to charge payment of any fees associated with this communication, including fees under 37 C.F.R. § 1.16 and 1.17 or credit any overpayment to **Deposit Account Number 12-0555**.

Respectfully submitted,

Juan Carlos A. Marquez
Registration Number 34,072

**STITES & HARBISON PLLC**
1199 North Fairfax Street, Suite 900
Alexandria, Virginia 22314
(703) 739-4900
Customer No.: 38327
**October 6, 2011**

OPAP IAP8
OCT 06 2011
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | |
|---|---|
| In re U.S. Patent Application of | |
| YUASA | |
| | Art Unit 2892 |
| Application Number: 12/923,643 | |
| | Examiner: |
| Filed: September 30, 2010 | Alonzo Chambliss |
| For: MAGNETIC MULTILAYER FILM (As Amended) | |
| Attorney Docket No. NAGI-0003 | |

Commissioner of Patents
PO Box 1450
Alexandria, VA 22313-1450

## INFORMATION DISCLOSURE STATEMENT

Sir:

Pursuant to 37 C.F.R. §§ 1.56 and 1.97, this Information Disclosure Statement is being submitted in connection with the above-identified patent application. A listing of documents to be published on the face of any patent granted from this application is submitted herewith on the accompanying Form PTO-1449. Any other documents or information submitted for consideration by the Examiner are listed in this paper. A copy of each non-US or foreign patent or non-patent publication or any portion thereof listed or herein identified is submitted herewith.

### CERTIFICATION

1. This Information Disclosure Statement is being submitted:

[ ] **(a)** Concurrently with the [RCE] application or not more that three months from the filing date [of the RCE] of the above-identified U.S. patent application, whereby it is believed that no fee is due; OR

[ ] **(b)** Within three months of the filing date of the RCE in the above-identified U.S. patent application but before the mailing date of the first Office Action on the merits of the above-identified application, whereby it is believed that no fee is due; OR

[X] **(c)** After three months from the filing date of the above-identified U.S. patent application and after the mailing date of the first Office Action on the merits of the above-identified application, but prior to the issuance of any Final Action or Notice of Allowance sent in such application, whereby

Applicant(s) hereby submit the requisite certification hereinbelow, or authorization for the payment of the requisite fee is attached; OR

[ ] **(d)** After the issuance of a Final Action or Notice of Allowance, but before the payment of the Issue Fee, whereby Applicant(s) hereby submit the requisite certification hereinbelow, and the attached authorization for the payment of the requisite fee.

**2.** In accordance with the requirements of 37 C.F.R. §1.97, and Parts 1(c) or 1(d) above, Applicant(s) hereby certify that:

**[X]** Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; OR

[ ] No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Please charge any additional fees or credit any overpayments in connection with the submission of this Information Disclosure Statement to Deposit Account No 12-0555.

The Examiner is requested to acknowledge receipt and consideration of the information provided in this paper in accordance with prescribed procedures.

Respectfully submitted,

Juan Carlos A. Marquez
Registration Number 34,072

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Customer No. 38327
**October 6, 2011**



**WD EX1004**
**Western Digital v IP Bridge**
**Page 188**

OPA
OCT 06 2011
PATENT & TRADEMARK OFFICE

*Customized* PTO/SB/08a+b (07-09)

*Substitute for Form 1449/PTO*

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

| | |
|---|---|
| Application # | 12/923,643 |
| Confirmation # | 8219 |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2892 |
| Examiner | Chambliss, Alonzo |
| Sheet 1 of 1 | Docket # NAGI-0003 |

## U.S. PATENT DOCUMENTS

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
| | 2007-0195592 A1 | 08-23-2007 | Yuasa | |
| | | | | |
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## FOREIGN PATENT DOCUMENTS

| Exam. Initial* | Country-Number-Kind Code If known | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
|---|---|---|---|---|---|
| | JP 2008-004956 [1] | 01-10-2008 | Japan Science & Technology Agency;<br><br>National Institute of Advanced Industrial & Technology | | Abstract |
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## NON PATENT LITERATURE DOCUMENTS

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

| Examiner Signature | | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

1 Corresponds to U.S. Document No. 2007-0195592 A1 listed above.

# PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2008-004956
(43)Date of publication of application : 10.01.2008

(51)Int.Cl. *H01L 43/10 (2006. 01)*
*H01L 43/08 (2006. 01)*
*H01L 43/12 (2006. 01)*
*H01L 21/8246 (2006. 01)*
*H01L 27/105 (2006. 01)*

(21)Application number : 2007-210197
(22)Date of filing : 10.08.2007

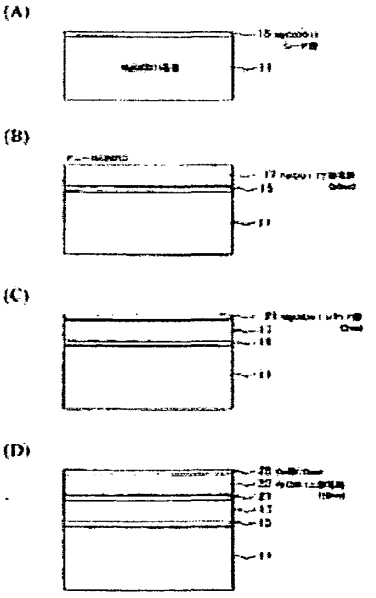
(71)Applicant : JAPAN SCIENCE & TECHNOLOGY AGENCY
NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL & TECHNOLOGY
(72)Inventor : YUASA SHINJI

(30)Priority

| Priority number | Priority date | Priority country |
|---|---|---|
| 2004071186 | 12.03.2004 | JP |
| 2004313350 | 28.10.2004 | JP |


## (54) MAGNETORESISTIVE ELEMENT, AND ITS MANUFACTURING METHOD

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a tunnel magnetoresistive element (TMR element) an output voltage of which can be increased and a resistance value of which is set to an optimum low value for MRAM, and to provide its manufacturing method.
SOLUTION: A single-crystalline MgO(001) substrate 11 is prepared. An epitaxial Fe(001) lower electrode (a first electrode) 17 with the thickness of 50 nm is grown on an MgO(001) seed layer 15 at room temperature, followed by annealing under ultrahigh vacuum (2 × 10−8 Pa) and at 350° C. An MgO(001) barrier layer 21 with the thickness of 2 nm is epitaxially formed on the Fe(001) lower electrode (the first electrode) 17 at room temperature, using MgO electron-beam evaporation. An Fe(001) upper electrode (a second electrode) 23 with the thickness of 10 nm is then formed on the MgO(001) barrier layer 21 at room temperature. This is successively followed by the deposition of a Co layer 21 with the thickness of 10 nm on the Fe(001) upper electrode (the second electrode) 23. After that, the sample prepared above is microfabricated into an Fe(001)/MgO(001)/Fe(001)TMR element.






WD EX1004
Western Digital v IP Bridge
Page 190

(19)日本国特許庁(JP)　(12)公開特許公報(A)　(11)特許出願公開番号
特開2008-4956
(P2008-4956A)
(43)公開日 平成20年1月10日(2008.1.10)

| (51) Int.Cl. | | F I | | | テーマコード（参考） |
|---|---|---|---|---|---|
| H01L 43/10 | (2006.01) | H01L | 43/10 | | 4M119 |
| H01L 43/08 | (2006.01) | H01L | 43/08 | Z | 5F092 |
| H01L 43/12 | (2006.01) | H01L | 43/12 | | |
| H01L 21/8246 | (2006.01) | H01L | 27/10 | 447 | |
| H01L 27/105 | (2006.01) | | | | |

審査請求 有　請求項の数 13　OL　（全 14 頁）

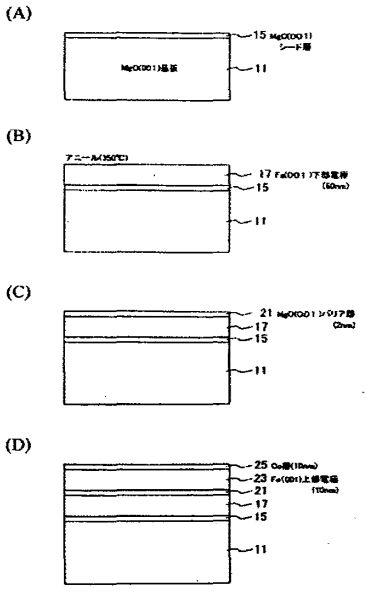
(21)出願番号　特願2007-210197 (P2007-210197)
(22)出願日　平成19年8月10日 (2007.8.10)
(62)分割の表示　特願2006-511062 (P2006-511062)の分割
原出願日　平成17年3月10日 (2005.3.10)
(31)優先権主張番号　特願2004-71186 (P2004-71186)
(32)優先日　平成16年3月12日 (2004.3.12)
(33)優先権主張国　日本国(JP)
(31)優先権主張番号　特願2004-313350 (P2004-313350)
(32)優先日　平成16年10月28日 (2004.10.28)
(33)優先権主張国　日本国(JP)

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(74)代理人　100105463
弁理士　関谷　三男
(74)代理人　100102576
弁理士　渡辺　敬章
(74)代理人　100108394
弁理士　今村　健一

最終頁に続く

(54)【発明の名称】磁気抵抗素子及びその製造方法

(57)【要約】　（修正有）
【課題】ＴＭＲ素子における出力電圧を大きくする。
【解決手段】単結晶ＭｇＯ（００１）基板１１を準備し、５０ｎｍ厚のエピタキシャルＦｅ（００１）下部電極（第１電極）１７をＭｇＯ（００１）シード層１５上に室温で成長し、次いで、超高真空（２×１０$^{-8}$Ｐａ）において、３５０℃でアニールを行う。２ｎｍ厚のＭｇＯ（００１）バリア層２１をＦｅ（００１）下部電極（第１電極）１７上に室温でエピタキシャル成長する。この際、ＭｇＯの電子ビーム蒸着を用いた。ＭｇＯ（００１）バリア層２１上に室温で、厚さ１０ｎｍのＦｅ（００１）上部電極（第２電極）２３を形成した。連続して、１０ｎｍ厚さのＣｏ層２１をＦｅ（００１）上部電極（第２電極）２３上に堆積した。次いで、上記の作成試料を微細加工してＦｅ（００１）／ＭｇＯ（００１）／Ｆｅ（００１）ＴＭＲ素子を形成する。これによりＭＲＡＭの出力電圧値を高めることができる。
【選択図】図２




WD EX1004
Western Digital v IP Bridge
Page 191

【特許請求の範囲】
【請求項１】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたＢＣＣ構造を有する第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有する第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項２】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたＦｅ（００１）からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅ（００１）からなる第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項３】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたＢＣＣ構造を有するＦｅ系合金の単結晶（００１）または（００１）結晶面が優先配向した多結晶からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有するＦｅ系合金の単結晶（００１）または（００１）結晶面が優先配向した多結晶からなる第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項４】
（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなることを特徴とする室温での出力電圧が２００ｍＶより高い磁気抵抗素子のトンネル障壁層。
【請求項５】
基板を準備する第１工程と、
前記基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積する第２工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（００１）層上に、トンネル障壁層を高真空下において堆積する第３工程と、
前記トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を形成する第４工程と、
を有する磁気抵抗素子の製造方法において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする方法。
【請求項６】
単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯからなる基板を準備する第１工程と、
前記基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積し、次いで、結晶化のためのアニー

WD EX1004
Western Digital v IP Bridge
Page 192

ルを行う第２工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（００１）層上にトンネル障壁層を高真空下において堆積する第３工程と、
前記トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を形成する第４工程と、
を有する磁気抵抗素子の製造方法において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする方法。

【請求項７】
前記第１工程と第２工程との間に、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯからなるシード層を成長させる工程を付加したことを特徴とする請求項５または６に記載の磁気抵抗素子の製造方法。

【請求項８】
基板を準備する工程と、
前記基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積する工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（００１）層上にアモルファスＭｇＯ層を形成し、アニールにより前記アモルファスＭｇＯ層を結晶化して単結晶ＭｇＯｘ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯｘ（０＜ｘ＜１）からなるトンネル障壁層を形成する工程と、
前記トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積する工程と、
を有すること特徴とする磁気抵抗素子の製造方法。

【請求項９】
前記アモルファスＭｇＯ層を形成するとき、スパッタリング法により、$MgO_x$のｘ値を調整済みのターゲットを用いて堆積、形成することを特徴とする請求項８に記載の磁気抵抗素子の製造方法。

【請求項１０】
前記アモルファスＭｇＯを形成する工程中に、$MgO_x$のｘ値を調整する工程を含むことを特徴とする請求項８に記載の磁気抵抗素子の製造方法。

【請求項１１】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたアモルファス磁性合金からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたアモルファス磁性合金からなる第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。

【請求項１２】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成された第１の強磁性体層と、前記トンネル障壁層の第２面側に形成された第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。

【請求項１３】
１つのトランジスタと、前記トランジスタの負荷として用いられる請求項１、２、３、１１または１２のいずれかに記載の磁気抵抗素子とを有する記憶素子。

WD EX1004
Western Digital v IP Bridge
Page 193

【発明の詳細な説明】
【技術分野】
【０００１】
本発明は、磁気抵抗素子及びその製造方法に関し、特に、高い磁気抵抗を有する磁気抵抗素子及びその製造方法に関する。
【背景技術】
【０００２】
MRAM (Magnetoresistive Random Access Memory) は、現在広く用いられている記憶素子であるＤＲＡＭに代わる大容量向け記憶素子であり、かつ、高速な不揮発性メモリとして広く研究開発が行われており、例えば、4MbitのMRAMがサンプル出荷されたという実績がある。
【０００３】
図８は、ＭＲＡＭの心臓部であるトンネル磁気抵抗素子（以下、「ＴＭＲ素子」と称する）の構造と、その動作原理を示す図である。図８（Ａ）に示すように、ＴＭＲ素子においては、酸化物からなるトンネル障壁（以下、「バリア層」とも称する）の両側を強磁性金属からなる第１及び第２の２つの電極により挟んだトンネル構造を有している。トンネル障壁層としては、アモルファスのＡｌ－Ｏ層が用いられている（非特許文献１参照）。図８（Ａ）に示すように、第１の強磁性電極と第２の強磁性電極との磁化の向きが平行な平行磁化の場合には、トンネル構造の界面における法線方向に関する素子の電気抵抗が小さくなる。一方、図８（Ｂ）に示すように、第１の強磁性電極と第２の強磁性電極との磁化の向きが平行な反平行磁化の場合には、トンネル構造の界面における法線方向に関する素子の電気抵抗が大きくなる。この抵抗値は、一般的な状態では変化せず、抵抗値が高いか低いかに基づいて情報“１”、“０”として記憶される。平行磁化と反平行磁化とは不揮発に記憶されるため、不揮発性メモリの基本素子として用いることができる。
【０００４】
図９は、ＭＲＡＭの基本構造例を示す図であり、図９（Ａ）はＭＲＡＭの斜視図であり、図９（Ｂ）は模式的な回路構成図であり、図９（Ｃ）は、構造例を示す断面図である。図９（Ａ）に示すように、ＭＲＡＭにおいてはワード線ＷＬとビット線ＢＬとが交差するように配置され、交差部にＭＲＡＭセルが配置されている。図９（Ｂ）に示すように、ワード線とビット線との交差部に配置されたＭＲＡＭセルは、ＴＭＲ素子と、このＴＭＲ素子と直列接続されたＭＯＳＦＥＴとを有しており、負荷抵抗として機能するＴＭＲ素子の抵抗値をＭＯＳＦＥＴにより読み取ることにより、記憶情報を読み出すことができる。尚、情報の書き換えは、例えば、ＴＭＲ素子への磁場の印加により行うことができる。図９（Ｃ）に示すように、ＭＲＡＭメモリセルは、ｐ型Ｓｉ基板１０１内に形成されたソース領域１０５とドレイン領域１０３と、その間に画定されるチャネル領域に対して形成されたゲート電極１１１とを有するＭＯＳＦＥＴ１００と、ＴＭＲ素子１１７とを有している。ソース領域１０５は接地（ＧＮＤ）され、ドレインは、ＴＭＲ素子を介してビット線ＢＬに接続されている。ワード線ＷＬはゲート電極１１１に対して図示しない領域において接続されている。
【０００５】
以上に説明したように、不揮発性メモリＭＲＡＭは、１つのＭＯＳＦＥＴ１００とＴＭＲ素子１１７とにより１つのメモリセルを形成することができるため、高集積化に適したメモリ素子ということができる。
【０００６】
【非特許文献１】D.Wang, et al.:Science 294 (2001) 1488.
【発明の開示】
【発明が解決しようとする課題】
【０００７】
現状の技術を用いることにより６４Ｍｂｉｔ程度のＭＲＡＭを実現する見通しは立っているが、それ以上の高集積化のためには、ＭＲＡＭの心臓部であるＴＭＲ素子の特性を向

WD EX1004
Western Digital v IP Bridge
Page 194

上させる必要がある。特に、ＴＭＲ素子の出力電圧を向上させるには、磁気抵抗の増大と電圧特性の改善の両方が必要である。図１０は、アモルファスＡｌ－Ｏをトンネル障壁とした従来型ＴＭＲ素子の磁気抵抗のバイアス電圧による変化を示す図である（Ｌ１）。図１０に示すように、従来型ＴＭＲ素子においては、磁気抵抗が小さく、特に電圧を印加することにより磁気抵抗が急激に小さくなる傾向がみられる。このような特性では、動作マージンを考慮した出力電圧が小さすぎるため、実際の記憶素子に用いるのが難しい。より具体的には、現状のＴＭＲ素子の磁気抵抗は約70%と低く、また出力電圧も200 ｍＶ以下と低いため、ＤＲＡＭの出力電圧に比べて実質的に半分であり、集積度を上げるに従い信号がノイズに埋もれて読み出せなくなってしまうという問題があった。

【０００８】

本発明は、ＴＭＲ素子における出力電圧を大きくすることを目的とする。さらに、大きな磁気抵抗により、安定に動作する記憶装置を提供することを目的とする。

【課題を解決するための手段】

【０００９】

本発明の一観点によれば、トンネル障壁層と、該トンネル障壁層の第１面側に形成されたＢＣＣ構造を有する第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有する第２の強磁性体層と、を有する磁気トンネル接合構造を備え、前記トンネル障壁層が、単結晶$MgO_x$（００１）あるいは（００１）結晶面が優先配向した多結晶$MgO_x$（$0<x<1$）層により形成されていることを特徴とする磁気抵抗素子が提供される。

【００１０】

また、ＭｇＯ（００１）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたＦｅ（００１）からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅ（００１）からなる第２の強磁性体層と、を有する磁気トンネル接合構造であって、前記ＭｇＯ層が、単結晶$MgO_x$（００１）あるいは（００１）結晶面が優先配向した多結晶$MgO_x$（$0<x<1$）層により形成されていることを特徴とする磁気抵抗素子が提供される。前記ＭｇＯ（００１）層の伝導帯下端と前記Ｆｅ（００１）層のフェルミエネルギーの間の不連続値（トンネル障壁高さ）を、欠陥のない完全な単結晶における理想的な値よりも低くしたことを特徴とする。上記構成を用いると、磁気抵抗が増大しＴＭＲ素子の出力電圧を大きくすることができた。１つのトランジスタの負荷として上記磁気抵抗素子を用いると、不揮発性の記憶素子を形成することができた。

【００１１】

本発明の他の観点によれば、基板を準備する工程と、該基板上に第１のＦｅ（００１）層を堆積する工程と、前記第１のＦｅ（００１）層上に電子ビーム蒸着法により単結晶$MgO_x$（００１）あるいは（００１）結晶面が優先配向した多結晶$MgO_x$（$0<x<1$）からなるトンネル障壁層を高真空下において堆積する工程と、該トンネル障壁層上に第２のＦｅ（００１）層を形成する工程とを有することを特徴とする磁気抵抗素子の製造方法が提供される。

【００１２】

また、単結晶$MgO_x$（００１）あるいは（００１）結晶面が優先配向した多結晶$MgO_x$（$0<x<1$）からなる基板を準備する第１工程と、該基板上に第１のＦｅ（００１）層を堆積し、次いで、表面を平坦にするためのアニールを行う第２工程と、前記第１のＦｅ（００１）層上に電子ビーム蒸着法により単結晶$MgO_x$（００１）あるいは（００１）結晶面が優先配向した多結晶$MgO_x$（$0<x<1$）からなるトンネル障壁層を高真空下において堆積する第３工程と、該トンネル障壁層上に第２のＦｅ（００１）層を形成する第４工程とを有することを特徴とする磁気抵抗素子の製造方法が提供される。尚、前記第１工程と第２工程との間に、単結晶$MgO_x$（００１）あるいは（００１）結晶面が優先配向した多結晶$MgO_x$（$0<x<1$）からなるシード層を成長する工程を有していても良い。また、前記ＭｇＯ層を、$MgO_x$のｘ値を調整済みのターゲットを用いて堆積しても良い。この際、前記ＭｇＯを形成する工程中に、$MgO_x$のｘ値を調整しても良い

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【００１３】

本発明のさらに別の観点によれば、ＭｇＯ（００１）からなるトンネル障壁層と、該トンネル障壁層の第１面側に形成されたアモルファス磁性合金からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたアモルファス磁性合金からなる第２の強磁性体層と、を有する磁気トンネル接合構造を備え、前記ＭｇＯ（００１）層の伝導帯下端と前記アモルファス磁性合金からなる第１又は第２の強磁性体層とのフェルミ準位の間の不連続値（トンネル障壁の高さ）を、欠陥のない完全な単結晶における理想的な値よりも低くしたことを特徴とする磁気抵抗素子が提供される。

【発明の効果】

【００１４】

本発明によれば、従来のＴＭＲ素子に比べて大きな磁気抵抗を得ることができ、ＴＭＲ素子の出力電圧を大きくすることができ、かつＴＭＲ素子の抵抗値をＭＲＡＭに最適な低抵抗にすることができる。従って、ＴＭＲ素子を用いたＭＲＡＭの高集積化が容易になるという利点がある。

【発明を実施するための最良の形態】

【００１５】

本明細書において、ＭｇＯは立方晶（ＮａＣｌ型構造）であるため、（００１）面、（１００）面、（０１０）面は全て等価である。ここでは、膜面に垂直な方向をｚ軸とすることにより、膜面を（００１）と統一的に記述している。また、本明細書において、電極層の結晶構造であるＢＣＣ構造とは体心立方晶のことである。より具体的には、化学的秩序のないＢＣＣ構造、いわゆるＡ２型構造、および化学的秩序のあるＢＣＣ構造、例えばＢ２型構造やＬ$2_1$構造、などのことを意味し、これらのＢＣＣ構造の結晶格子が僅かに歪んだものも含まれる。

【００１６】

本明細書において用いた欠陥のない完全な単結晶における「理想的な値」との用語は、紫外線光電子分光の実験から推測した値である（参考文献：W. Wulfhekel, et al.: Appl. Phys. Lett. 78 (2001) 509.）。このような状態では、酸素欠損や格子欠陥がほとんど無い理想的な単結晶ＭｇＯのトンネル障壁の高さの上限値と言うことができるため、理想的な値という用語を用いた。

【００１７】

発明の実施の形態について説明する前に、発明者の行った考察について説明を行う。ＴＭＲ素子の磁気抵抗（ＭＲ）比は、以下の式で表される。

【００１８】

$\Delta R/Rp = (Rap - Rp)/Rp$

ここで、Ｒｐ及びＲａｐは、２つの電極の磁化が平行と反平行の場合のトンネル接合抵抗である。Ｊｕｌｌｉｒｅの公式によれば、低バイアス電圧におけるＭＲ比は、以下のように表される。

ＭＲ比＝$(Rap - Rp)/Rp = 2P_1P_2/(1 - P_1P_2)$であり、

$P_\alpha = (D_\alpha\uparrow(E_F) - D_\alpha\downarrow(E_F))/(D_\alpha\uparrow(E_F) + D_\alpha\downarrow(E_F))$、$\alpha = 1, 2$　　(1)

と表される。

【００１９】

ここで、$P_\alpha$は、電極のスピン分極率であり、$D_\alpha\uparrow(E_F)$と$D_\alpha\downarrow(E_F)$とは、それぞれ、多数スピンバンドと少数スピンバンドのフェルミエネルギー（$E_F$）における状態密度（Ｄｅｎｓｉｔｙ　ｏｆ　ｓｔａｔｅ：ＤＯＳ）である。強磁性遷移金属及び合金のスピンの偏極はおおよそ０．５以下であるため、Ｊｕｌｌｉｒｅの公式によれば、最も高い推定ＭＲ比として約７０％が予測される。

【００２０】

ＴＭＲ素子をアモルファスのＡｌ－Ｏのトンネル障壁と多結晶電極とを用いて作製する

と、室温でのＭＲ比として約７０％という値が得られているが、ＤＲＡＭ並の出力電圧である２００ｍＶを得るのは難しく、上述のようにＭＲＡＭ実現の対する問題点となっている。

【００２１】

発明者は、酸化マグネシウム（ＭｇＯ）の単結晶（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯをトンネル障壁として用いたＴＭＲ素子を成長するアプローチを試みている。従来のアモルファスのＡｌ－Ｏ障壁とは異なり、酸化マグネシウムは結晶（原子が規則正しく配列した物質）であるため、電子が散乱されず、電子のコヒーレント状態がトンネル過程において保存されることが予測される。図１は、本実施の形態によるＴＭＲ素子構造（図１（Ｂ））と、強磁性体金属であるＦｅ（００１）のエネルギーバンド構造を示す図であり、波数空間の［００１］方向に対するＥ－$E_F$の関係を示す図（図１（Ａ））である。図１（Ｂ）に示すように、本実施の形態によるＴＭＲ素子構造は、第１のＦｅ（００１）層１と、第２のＦｅ（００１）層５と、これらの間に挟まれた単結晶$MgO_x$（００１）層あるいは（００１）結晶面が優先配向した多結晶$MgO_x$（０＜ｘ＜１）層３と、を有して構成されている。上記Ｊｕｌｌｉｒｅのモデルによれば、伝導電子の運動量がトンネル過程において保存されるとすると、ＭｇＯを透過するトンネル電流はトンネル障壁に垂直な方向（接合界面に対する法線方向）の波数ベクトル$k_z$を有する電子が支配的になる。図１（Ａ）に示す［００１］（Γ－Ｈ）方向におけるＦｅのエネルギーバンド図によれば、フェルミ準位$E_F$における状態密度（ＤＯＳ）は、多数スピンと少数スピンのサブバンドがフェルミ準位$E_F$において状態を有しているため、それほど高い偏極率を示さない。しかしながら、電子のコヒーレント状態がトンネル過程において保存される場合には、障壁に垂直な軸に関して完全に対称な波動関数を有する伝導電子のみが障壁領域における状態と接続し、有限のトンネル確率を持つことになる。Ｆｅ（００１）電極の$\Delta_1$バンドが前記のような完全に対称な波動関数を有する。図１（Ａ）に示すように、多数スピンΔ１バンド（実線）がフェルミ準位$E_F$に状態を有するが、少数スピンΔ１バンド（破線）はフェルミ準位$E_F$に状態を有しない。このようなＦｅ$\Delta_1$バンドのハーフメタル的な特徴により、非常に高いＭＲ比がコヒーレントなスピン偏極トンネルにおいて得られる可能性がある。エピタキシャル（単結晶あるいは（００１）配向多結晶）のＴＭＲ素子は、トンネル過程中における電子の散乱が抑制されるため、上記のようなコヒーレントなトンネルを実現するためには理想的であると考えられる。

【００２２】

以下、本発明の第１の実施の形態による磁気抵抗素子及びその製造方法について図面を参照しつつ説明を行う。図２（Ａ）から図２（Ｄ）までは、本発明の実施の形態によるＦｅ（００１）／ＭｇＯ（００１）／Ｆｅ（００１）構造を有する磁気抵抗素子（以下、「Ｆｅ（００１）／ＭｇＯ（００１）／Ｆｅ（００１）ＴＭＲ素子」と称する。）の製造工程を模式的に示す図である。Ｆｅ（００１）は、ＢＣＣ構造を有する強磁性体である。まず、単結晶ＭｇＯ（００１）基板１１を準備し、ＭＢＥ法（分子線エピタキシー法）により、単結晶ＭｇＯ（００１）基板１１の表面のモフォロジーを改善するため、ＭｇＯ（００１）シード層１５を成長する。連続して、図１（Ｂ）に示すように、５０ｎｍ厚のエピタキシャルＦｅ（００１）下部電極（第１電極）１７をＭｇＯ（００１）シード層１５上に室温で成長し、次いで、超高真空下（$2\times10^{-8}$ Ｐａ）において、３５０℃でアニールを行う。尚、電子線蒸着における条件は、加速電圧が８ｋＶであり、成長速度が０．０２ｎｍ／秒、成長温度が室温（約２９３Ｋ）、電子線蒸着のソース材料としては化学量論的組成のＭｇＯ（ＭｇとＯとの比が１：１）を用い、ソースと基板との距離を４０ｃｍとし、最高到達真空度が$1\times10^{-8}$ Ｐａ、$O_2$分圧が$1\times10^{-6}$ Ｐａである。尚、化学量論的組成のＭｇＯ（ＭｇとＯとの比が１：１）の代わりに、Ｏ欠損を有するソースを使用することも可能である。

【００２３】

図３（Ａ）は、この際のＦｅ（００１）下部電極（第１電極）１７のＲＨＥＥＤイメージを示す図である。図３（Ａ）に示すように、Ｆｅ（００１）下部電極（第１電極）１７

WD EX1004
Western Digital v IP Bridge
Page 197

は良好な結晶性と平坦性を有していることを示している。次いで、図２（Ｃ）に示すように、２ｎｍ厚のＭｇＯ（００１）バリア層２１をＦｅ（００１）下部電極（第１電極）１７上に室温でエピタキシャル成長する。この際も、ＭｇＯの電子ビーム蒸着法を用いた。図３（Ｂ）は、この際のＭｇＯ（００１）バリア層２１のＲＨＥＥＤイメージを示す図である。図３（Ｂ）に示すように、ＭｇＯ（００１）バリア層２１も良好な結晶性と平坦性を有していることを示している。

【００２４】

図２（Ｄ）に示すように、ＭｇＯ（００１）バリア層２１上に、室温で厚さ１０ｎｍのＦｅ（００１）上部電極（第２電極）２３を形成した。連続して、１０ｎｍ厚さのＣｏ層２５をＦｅ（００１）上部電極（第２電極）２３上に堆積した。Ｃｏ層２５は、上部電極２３の保持力を高めることによって反平行磁化配置を実現するためのものである。次いで、上記の作成試料を微細加工してＦｅ（００１）／ＭｇＯ（００１）／Ｆｅ（００１）ＴＭＲ素子を形成する。

【００２５】

上記電子ビームによるＭｇＯ蒸着は、$10^{-9}$ Ｔｏｒｒの超高真空状態で成膜を行った。この方法では、例えばガラス基板上に３００ｎｍの成膜を行った場合でも、無色透明であり、良好な結晶膜が形成されていることがわかる。図４は、ＭｇＯ成長時における成膜チャンバ内の四重極Ｍａｓｓスペクトルの観測結果を示す図である。図４に示すように、ＯのスペクトルＰ１と$O_2$のスペクトルＰ２とに関する分圧が高いことがわかる。図５は、ＭｇＯ蒸着中の酸素分圧の膜堆積速度依存を示す図である。図５に示すように、酸素分圧自体がかなり高いこと、堆積速度とともに酸素分圧も高くなること、などは、ＭｇＯの堆積時におけるＭｇＯからの酸素の離脱を示唆するものであり、離脱した酸素は真空ポンプによって成膜装置の外に排気されることから、$MgO_x$（０．９＜ｘ＜１）のように酸素欠損が生じている可能性がある。酸素欠損が生じるとＭｇＯトンネル障壁の高さが低くなると考えられ（例えば、0.10～0.85ｅＶ、より詳細には0.2～0.5ｅＶの範囲内）、これにより、トンネル電流が増加するものと考えられる。尚、一般的なＡｌ－Ｏトンネル障壁の場合、Ｆｅ（００１）との間のトンネル障壁の高さは、０．７～２．５ｅＶと考えられる。これに対して、ＭｇＯ結晶は理想的なトンネル障壁の高さは３．６ｅＶであり、実験値としては０．９～３．７ｅＶの値が得られている。本実施の形態による方法を用いると、０．３ｅＶ程度のトンネル障壁の高さが推定され、トンネル障壁の低抵抗化が可能であることがわかる。但し、その他の要因、例えば前述のコヒーレントなトンネルの影響も関連している可能性がある。尚、酸素欠損に基づく$MgO_x$のｘの値としては、０．９８＜ｘ＜１、より好ましくは０．９９＜ｘ＜１程度であり、Ｍｇ単体のようなものは含まれず、ＭｇＯの特性が基本的には維持される範囲である。

【００２６】

尚、上記、トンネル障壁の高さ$\phi$は、ＴＭＲ素子の電気伝導特性（トンネル電流密度Ｊとバイアス電圧Ｖの関係）を、ＷＫＢ近似に基づいたＳｉｍｍｏｎｓの公式（非特許文献Ｊ．Ｇ．Simmons: J. Appl. Phys. 34, pp.1793–1803 (1963).の（２０）式）に当てはまるように最小自乗法でフィッティングすることによって求めた。この際、電子の有効質量として、自由電子の質量（ｍ＝９．１１×$10^{-31}$ ｋｇ）を用いてフィッティングを行った。Ｊ－Ｖ特性に非線形性が現れる程度のバイアス電圧Ｖ（通常５００ｍＶ～１０００ｍＶ程度）まで印加すれば、Ｓｉｍｍｏｎｓの式を用いてＪ－Ｖ特性をフィッティングすることにより、トンネル障壁の高さ$\phi$とトンネル障壁の有効厚さΔｓを同時に決定することが出来る。

【００２７】

ここで、トンネル障壁の有効厚さΔｓは、ＴＭＲ素子の断面透過電子顕微鏡（ＴＥＭ）写真から求めた実際のＭｇＯ（００１）トンネル障壁層の厚さ（$t_{MgO}$）よりも、約０．５ｎｍほど薄い値となった。これは、ＭｇＯ（００１）層とＦｅやＣｏを主成分とする合金層の界面に生じる鏡像ポテンシャルの効果によって、トンネル障壁の有効厚さΔｓが実際のＭｇＯ（００１）層の厚さよりも薄くなった結果である。

WD EX1004
Western Digital v IP Bridge
Page 198

【００２８】
尚、断面ＴＥＭ写真を用いて$t_{MgO}$を正確に求めることができる場合は、以下に述べるような手法で、より簡便にトンネル障壁の高さ$\phi$を見積もることが出来る。すなわち、ＴＭＲ素子に印加するバイアス電圧Ｖが低い（通常、１００ｍＶ以下）場合、トンネル電流密度Ｊはバイアス電圧Ｖに比例し、Ｊ－Ｖ特性は線形関係となる。このような低バイアス電圧の領域では、Ｓｉｍｍｏｎｓの式は、式（２）のように記述できる。
【００２９】
$$J=[(2m\phi)^{1/2}/\Delta s](e/h)^2\times\exp[-(4\pi\Delta s/h)\times(2m\phi)^{1/2}]\times V \quad (2)$$
ここで、ｍは自由電子の質量（９．１１×１０$^{-31}$ｋｇ）、ｅは素電荷（１．６０×１０$^{-19}$Ｃ）、ｈはプランク定数（６．６３×１０$^{-34}$Ｊ・ｓ）である。また、トンネル障壁の有効厚さΔｓは、Δｓ≒$t_{MgO}$－０．５ｎｍである。ＴＭＲ素子の低バイアス電圧領域のＪ－Ｖ特性を（２）式にフィッティングすれば、トンネル障壁の高さ$\phi$を簡便かつ正確に見積もることが出来る。
【００３０】
図６は、上記の方法により製造したＦｅ（００１）／ＭｇＯ（００１）／Ｆｅ（００１）ＴＭＲ素子の典型的な磁気抵抗曲線を示す図である。測定温度２０ＫにおいてＭＲ比１４６％であり、測定温度２９３ＫにおいてＭＲ比は８８％であった。この値は、現在までに室温において得られた最も高いＭＲ比である。このような高いＭＲ比は、Ｆｅ（００１）電極のスピン分極率によって説明することはできず、むしろ、コヒーレントなスピン偏極トンネリングに関連すると考えられる。１６０個のＴＭＲ素子を試作した結果、ＭＲ比とトンネル抵抗値とに関するばらつきは、２０％以内であった。ＴＭＲ素子の歩留まりも実験室段階で９０％以上であった。このような高い値は、本アプローチの有効性を示唆している。ＴＭＲ素子の抵抗－エリア積（ＲＡ）は、数ｋΩ$\mu m^2$であり、この値は、ＭＲＡＭに適した値である。
【００３１】
図７（ａ）は、室温におけるＭＲ比のバイアス電圧依存性を示す図である。図７（ａ）に示すように、ＭＲ比のバイアス電圧依存性はかなり低いことがわかる。非対称な特性を示すが、ＭＲ比が半減する電圧$V_{half}$は１２５０ｍＶという非常に高い値が得られている。尚、従来のＡｌ－Ｏ系におけるＭＲ比の半減する電圧$V_{half}$は３００～６００ｍＶである。図７（ｂ）に、ＴＭＲ素子の出力電圧$V_{out}$は（＝バイアス電圧×（Ｒａｐ－Ｒｐ）／Ｒａｐ）を示す。出力電圧$V_{out}$の最大値は順バイアスにおいて３８０ｍＶの値が得られている。この値は、Ａｌ－Ｏバリアの場合の値（２００ｍＶ弱）の約２倍の値である。このように、ＭＲ比と出力電圧との両方で高い値が得られたことは、本実施の形態による技術の有効性を示している。
【００３２】
尚、上記実施の形態においては、ＢＣＣのＦｅ（００１）を用いたが、代わりにＢＣＣのＦｅ系合金、例えば、Ｆｅ－Ｃｏ合金、Ｆｅ－Ｎｉ合金、Ｆｅ－Ｐｔ合金を用いることもできる。或いは電極層とＭｇＯ（００１）層との間に、１原子層又は数原子層程度の厚さのＣｏ、Ｎｉなどを挿入しても良い。
【００３３】
次に、本発明の第２の実施の形態による磁気抵抗素子及びその製造方法について説明を行う。本実施の形態によるＦｅ（００１）／ＭｇＯ（００１）／Ｆｅ（００１）ＴＭＲ素子の製造方法では、まずスパッタリング法などによりＭｇＯ（００１）を多結晶またはアモルファス状態で堆積し、その後にアニール処理を行うことにより（００１）結晶面が配向した多結晶または単結晶化する点を特徴とする。スパッタリング条件は、例えば。温度が室温（２９３Ｋ）であり、ターゲットとしては２インチ$\phi$のＭｇＯを用い、Ａｒ雰囲気中でスパッタリングを行った。加速電力は２００Ｗであり、成長速度は０．００８ｎｍ／ｓである。この条件で堆積したＭｇＯはアモルファス状態であるため、室温から３００℃まで温度を上昇させ、３００℃において一定時間保持をすることにより、結晶化されたＭ

WD EX1004
Western Digital v IP Bridge
Page 199

ｇＯを得ることが出来る。

【００３４】

尚、Ｏ欠損の導入方法としては、成長時にＯ欠損が生じる条件で成長を行う方法、Ｏ欠損を後から導入する方法、Ｏ欠損のある状態から例えば酸素プラズマ処理又は自然酸化などにより酸化を行ってある程度のＯ欠陥まで調整する方法のいずれを用いても良い。

【００３５】

以上、本実施の形態による磁気抵抗素子技術によれば、スパッタリング法を用いてアモルファスＭｇＯを堆積した後にアニール処理により結晶化するため、それほど大がかりな装置が必要ないという利点がある。

【００３６】

次に、本発明の実施の形態の変形例による磁気抵抗素子について図面を参照しつつ説明を行う。図１１は、本発明の実施の形態の変形例によるＴＭＲ素子の構造を示す図であり、図１（Ｂ）に対応する図である。図１１に示すように、本実施の形態による磁気抵抗素子は、上記実施の形態による磁気抵抗素子と同様に、単結晶$MgO_x$（００１）あるいは（００１）結晶面が優先配向した酸素欠損多結晶$MgO_x$（$0<x<1$）層５０３の両側に設けられる電極として、アモルファス強磁性合金、例えばＣｏＦｅＢ層５０１、５０５を用いた点に特徴がある。アモルファス強磁性合金は、例えば蒸着法或いはスパッタリング法を用いて形成可能である。得られた特性等は第１の実施の形態の場合とほぼ同様である。

【００３７】

尚、アモルファス磁性合金については、例えば、FeCoB、FeCoBSi、FeCoBP、FeZr、CoZrなどを用いることもできる。また、素子を作製した後にアニール処理を施すと電極層のアモルファス磁性合金が部分的あるいは全体的に結晶化する場合があるが、これによってＭＲ比が大きく劣化することはない。したがって、このように結晶化したアモルファス磁性合金を電極層に用いても構わない。

【００３８】

以上、本実施の形態による磁気抵抗素子について説明したが、本発明はこれらに制限されるものではない。その他、種々の変更、改良、組み合わせが可能なことは当業者に自明であろう。例えば、ＭｇＯ層に酸素欠陥を導入する代わりに、例えばＣａやＳｒをドーピングすることでトンネル障壁の高さを調整する方法を用いても良い。また、ＭｇＯ層の堆積方法として、電子ビーム蒸着法又はスパッタリング法を例にして説明したが、その他の堆積法も適用可能であることは言うまでもない。また、高真空との用語は、例えば酸素を導入しない場合において、概ね$10^{-6}$Ｐａ以下の値を指し、一方、酸素を積極的に導入する場合でも、$10^{-4}$Ｐａ程度の値を指す。

【産業上の利用可能性】

【００３９】

ＭＲＡＭの出力電圧値が従来の約２倍に向上し、ギガビット級の超高集積ＭＲＡＭに適する。

【図面の簡単な説明】

【００４０】

【図１】本発明の第１の実施の形態によるＴＭＲ素子の構造（図１（Ｂ））と、強磁性体金属であるＦｅ（００１）のエネルギーバンド構造を示す図であり、波数空間の［００１］方向に対する$E-E_F$の関係を示す図（図１（Ａ））である。

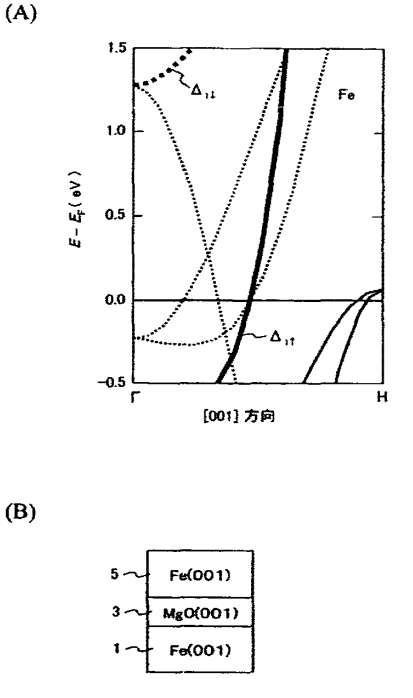
【図２】図２（Ａ）から図２（Ｄ）までは、本発明の実施の形態によるＦｅ（００１）／ＭｇＯ（００１）／Ｆｅ（００１）構造を有する磁気抵抗素子（以下、「Ｆｅ（００１）／ＭｇＯ（００１）／Ｆｅ（００１）ＴＭＲ素子」と称する。）の製造工程を模式的に示す図である。

【図３】図３（Ａ）は、Ｆｅ（００１）下部電極（第１電極）のＲＨＥＥＤイメージを示す図であり、図３（Ｂ）は、この際のＭｇＯ（００１）バリア層のＲＨＥＥＤイメージを示す図である。

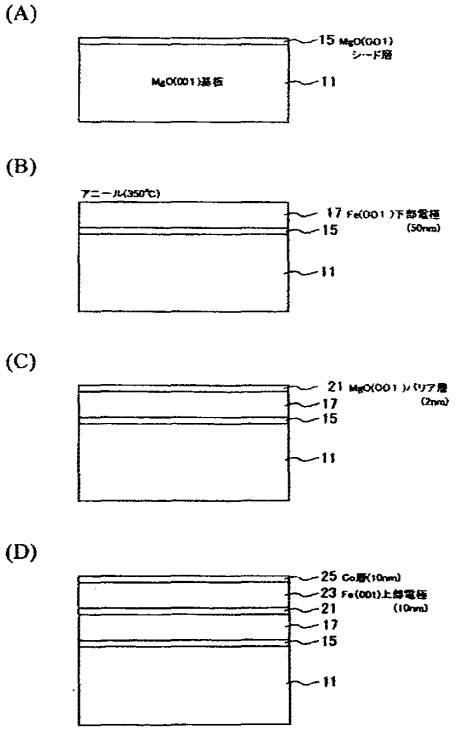
WD EX1004
Western Digital v IP Bridge
Page 200

【図４】ＭｇＯ蒸着時における成膜チャンバ中の四重極Ｍａｓｓスペクトルの観測結果を示す図である。
【図５】ＭｇＯ蒸着中の酸素分圧の膜堆積速度依存を示す図である。
【図６】Ｆｅ（００１）／ＭｇＯ（００１）／Ｆｅ（００１）ＴＭＲ素子の典型的な磁気抵抗曲線を示す図である。
【図７】図７（Ａ）は、室温におけるＭＲ比のバイアス電圧依存性を示す図である。図７（Ｂ）は、ＴＭＲ素子の出力電圧Ｖ$_{out}$は（＝バイアス電圧×（Ｒａｐ－Ｒｐ）／Ｒａｐ）を示す図である。
【図８】ＴＭＲ素子の構造と、その動作原理を示す図である。
【図９】ＭＲＡＭの基本構造例を示す図であり、図９（Ａ）はＭＲＡＭの斜視図であり、図９（Ｂ）は模式的な回路構成図であり、図９（Ｃ）は、構造例を示す断面図である。
【図１０】アモルファスＡｌ－Ｏをトンネル障壁とした従来型ＴＭＲ素子の磁気抵抗のバイアス電圧による変化を示す図である。
【図１１】本発明の実施の形態の変形例によるＴＭＲ素子の素子構造を示す図であり、図１（Ｂ）に対応する図である。
【符号の説明】
【００４１】
１…第１のＦｅ（００１）層、５…第２のＦｅ（００１）層、３…単結晶$MgO_x$（００１）層あるいは（００１）結晶面が優先配向した多結晶$MgO_x$（$0<x<1$）層。

【図１】




【図２】

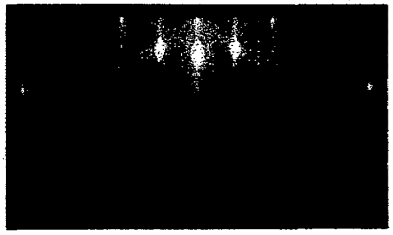


【図３】

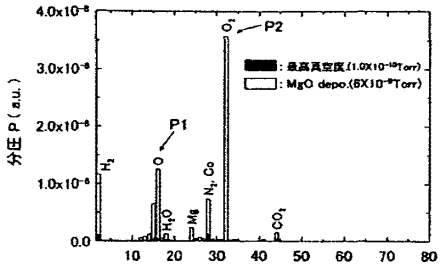
(A)



(B)

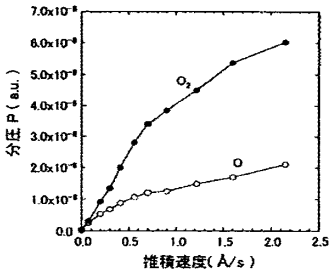


【図４】



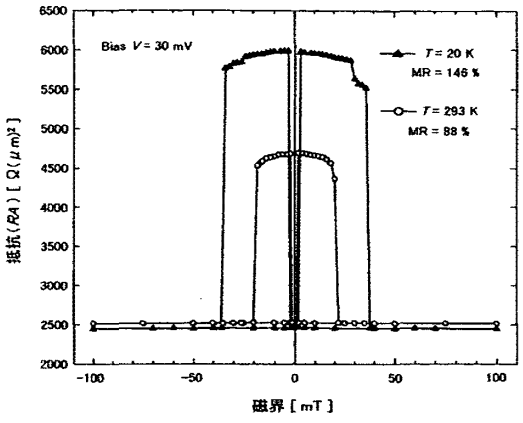

Massスペクトル

【図５】



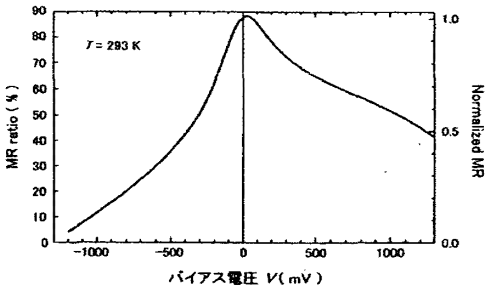

MgO蒸着中の酸素分圧

【図６】

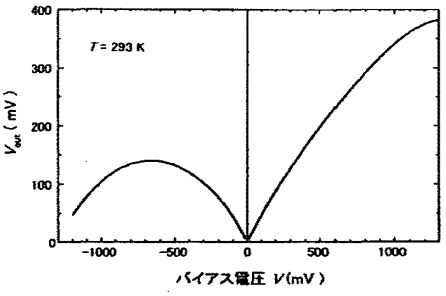



【図７】

(A)

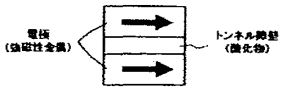



(B)



【図８】

(A)

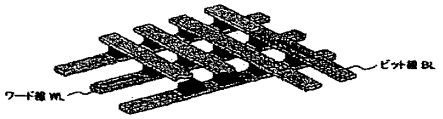



(B)

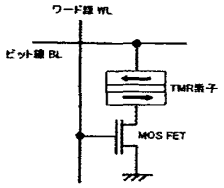


【図９】

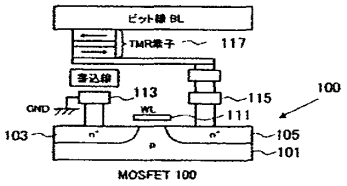
(A)



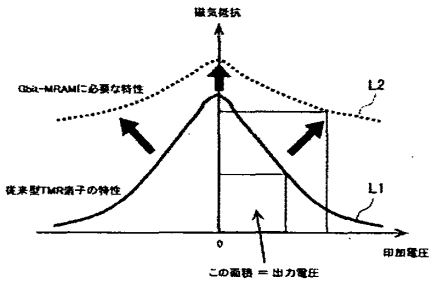

(B)



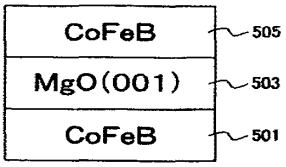

(C)




【図１０】




【図１１】



フロントページの続き

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Ｈ０１Ｌ　43/12
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【手続補正１】
【補正対象書類名】特許請求の範囲
【補正対象項目名】全文
【補正方法】変更
【補正の内容】
【特許請求の範囲】
【請求項１】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたＢＣＣ構造を有する第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有する第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項２】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたＦｅ（００１）からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅ（００１）からなる第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項３】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたＢＣＣ構造を有するＦｅ系合金の単結晶（００１）または（００１）結晶面が優先配向した多結晶からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有するＦｅ系合金の単結晶（００１）または（００１）結晶面が優先配向した多結晶からなる第２の強

磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項４】
（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなることを特徴とする室温での出力電圧が２００ｍＶより高い磁気抵抗素子のトンネル障壁層。
【請求項５】
基板を準備する第１工程と、
前記基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積する第２工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（００１）層上に、トンネル障壁層を高真空下において堆積する第３工程と、
前記トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を形成する第４工程と、
を有する磁気抵抗素子の製造方法において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする方法。
【請求項６】
単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯからなる基板を準備する第１工程と、
前記基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積し、次いで、結晶化のためのアニールを行う第２工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（００１）層上にトンネル障壁層を高真空下において堆積する第３工程と、
前記トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を形成する第４工程と、
を有する磁気抵抗素子の製造方法において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする方法。
【請求項７】
前記第１工程と第２工程との間に、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯからなるシード層を成長させる工程を付加したことを特徴とする請求項５または６に記載の磁気抵抗素子の製造方法。
【請求項８】
基板を準備する工程と、
前記基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積する工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（００１）層上にアモルファスＭｇＯ層を形成し、アニールにより前記アモルファスＭｇＯ層を結晶化して単結晶ＭｇＯｘ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯｘ（０＜ｘ＜１）からなるトンネル障壁層を形成する工程と、
前記トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（０

０１）層または（００１）結晶面が優先配向した多結晶層を堆積する工程と、
を有すること特徴とする磁気抵抗素子の製造方法。
【請求項９】
前記アモルファスＭｇＯ層を形成するとき、スパッタリング法により、ＭｇＯｘのｘ値を調整済みのターゲットを用いて堆積、形成することを特徴とする請求項８に記載の磁気抵抗素子の製造方法。
【請求項１０】
前記アモルファスＭｇＯを形成する工程中に、ＭｇＯｘのｘ値を調整する工程を含むことを特徴とする請求項８に記載の磁気抵抗素子の製造方法。
【請求項１１】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたアモルファス磁性合金からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたアモルファス磁性合金からなる第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項１２】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成された第１の強磁性体層と、前記トンネル障壁層の第２面側に形成された第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項１３】
１つのトランジスタと、前記トランジスタの負荷として用いられる請求項１、２、３、１１または１２のいずれかに記載の磁気抵抗素子とを有する記憶素子。
【請求項１４】
多結晶酸化マグネシウムを有するトンネル障壁層、該トンネル障壁層の第１面側に位置する第１強磁性体層及び該トンネル障壁層の第２面側に位置する第２強磁性体層を有する、ことを特徴とする磁気抵抗素子。
【請求項１５】
多結晶酸化マグネシウムを有するトンネル障壁層、該トンネル障壁層の第１面側に位置するＢＣＣ構造の第１強磁性体層及び該トンネル障壁層の第２面側に位置するＢＣＣ構造の第２強磁性体層を有する、ことを特徴とする磁気抵抗素子。
【請求項１６】
多結晶酸化マグネシウムを有するトンネル障壁層、該トンネル障壁層の第１面側に位置し、ＢＣＣ構造のＦｅ又はＦｅ系合金からなる第１強磁性体層及び該トンネル障壁層の第２面側に位置し、ＢＣＣ構造のＦｅ又はＦｅ系合金からなる第２強磁性体層を有する、ことを特徴とする磁気抵抗素子。
【請求項１７】
アモルファスＣｏＦｅＢ磁性合金からなる第１の強磁性体層、多結晶ＭｇＯｘ（０＜ｘ＜１）からなるトンネル障壁層及びアモルファスＣｏＦｅＢ磁性合金からなる第２の強磁性体層を有する、ことを特徴とする多層膜構造体。

WD EX1004
Western Digital v IP Bridge
Page 207

【公報種別】特許法第１７条の２の規定による補正の掲載
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Ｈ０１Ｌ　43/10　(2006.01)
Ｈ０１Ｌ　43/08　(2006.01)
Ｈ０１Ｌ　43/12　(2006.01)
Ｈ０１Ｌ　21/8246　(2006.01)
Ｈ０１Ｌ　27/105　(2006.01)
【ＦＩ】
Ｈ０１Ｌ　43/10
Ｈ０１Ｌ　43/08　Ｚ
Ｈ０１Ｌ　43/12
Ｈ０１Ｌ　27/10　４４７

【手続補正書】
【提出日】平成20年9月2日(2008.9.2)
【手続補正１】
【補正対象書類名】特許請求の範囲
【補正対象項目名】全文
【補正方法】変更
【補正の内容】
【特許請求の範囲】
【請求項１】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたＢＣＣ構造を有する第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有する第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項２】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたＦｅ（００１）からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＦｅ（００１）からなる第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項３】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたＢＣＣ構造を有するＦｅ系合金の単結晶（００１）または（００１）結晶面が優先配向した多結晶からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有するＦｅ系合金の単結晶（００１）または（００１）結晶面が優先配向した多結晶からなる第２の強

磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項４】
（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなることを特徴とする室温での出力電圧が２００ｍＶより高い磁気抵抗素子のトンネル障壁層。
【請求項５】
基板を準備する第１工程と、
前記基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積する第２工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（００１）層上に、トンネル障壁層を高真空下において堆積する第３工程と、
前記トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を形成する第４工程と、
を有する磁気抵抗素子の製造方法において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする方法。
【請求項６】
単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯからなる基板を準備する第１工程と、
前記基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積し、次いで、結晶化のためのアニールを行う第２工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（００１）層上にトンネル障壁層を高真空下において堆積する第３工程と、
前記トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を形成する第４工程と、
を有する磁気抵抗素子の製造方法において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする方法。
【請求項７】
前記第１工程と第２工程との間に、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯからなるシード層を成長させる工程を付加したことを特徴とする請求項５または６に記載の磁気抵抗素子の製造方法。
【請求項８】
基板を準備する工程と、
前記基板上に第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（００１）層または（００１）結晶面が優先配向した多結晶層を堆積する工程と、
前記第１のＦｅまたはＢＣＣ構造を有するＦｅ系合金の（００１）層上にアモルファスＭｇＯ層を形成し、アニールにより前記アモルファスＭｇＯ層を結晶化して単結晶ＭｇＯｘ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯｘ（０＜ｘ＜１）からなるトンネル障壁層を形成する工程と、
前記トンネル障壁層上に第２のＦｅまたはＢＣＣ構造を有するＦｅ系合金の単結晶（０

０１）層または（００１）結晶面が優先配向した多結晶層を堆積する工程と、
を有すること特徴とする磁気抵抗素子の製造方法。
【請求項９】
前記アモルファスＭｇＯ層を形成するとき、スパッタリング法により、ＭｇＯｘのｘ値を調整済みのターゲットを用いて堆積、形成することを特徴とする請求項８に記載の磁気抵抗素子の製造方法。
【請求項１０】
前記アモルファスＭｇＯを形成する工程中に、ＭｇＯｘのｘ値を調整する工程を含むことを特徴とする請求項８に記載の磁気抵抗素子の製造方法。
【請求項１１】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成されたアモルファス磁性合金からなる第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたアモルファス磁性合金からなる第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項１２】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成された第１の強磁性体層と、前記トンネル障壁層の第２面側に形成された第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項１３】
ＢＣＣ構造を有する第１の強磁性体層、ＢＣＣ構造を有する第２の強磁性体層及び該第１の強磁性体層と該第２の強磁性体層との間に位置する酸素欠損の酸化マグネシウム結晶層を有することを特徴とする磁気抵抗素子。
【請求項１４】
１つのトランジスタと、前記トランジスタの負荷として用いられる請求項１、２、３、１１、１２または１３のいずれかに記載の磁気抵抗素子とを有する記憶素子。

【公報種別】特許法第１７条の２の規定による補正の掲載
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【年通号数】公開・登録公報2008-001
【出願番号】特願2007-210197(P2007-210197)
【国際特許分類】
Ｈ０１Ｌ　43/10　(2006.01)
Ｈ０１Ｌ　43/08　(2006.01)
Ｈ０１Ｌ　43/12　(2006.01)
Ｈ０１Ｌ　21/8246　(2006.01)
Ｈ０１Ｌ　27/105　(2006.01)
【ＦＩ】
Ｈ０１Ｌ　43/10
Ｈ０１Ｌ　43/08　Ｚ
Ｈ０１Ｌ　43/12
Ｈ０１Ｌ　27/10　４４７

【手続補正書】
【提出日】平成22年4月13日(2010.4.13)
【手続補正１】
【補正対象書類名】特許請求の範囲
【補正対象項目名】全文
【補正方法】変更
【補正の内容】
【特許請求の範囲】
【請求項１】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成された第１の強磁性体層と、前記トンネル障壁層の第２面側に形成された第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなり、
素子の室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項２】
前記第１の強磁性体層と前記第２の強磁性体層が、ともにＢＣＣ構造を有することを特徴とする請求項１記載の磁気抵抗素子。
【請求項３】
前記第１の強磁性体層と前記第２の強磁性体層が、ともにＢＣＣ構造を有するＦｅ系合金の単結晶（００１）または（００１）結晶面が優先配向した多結晶からなることを特徴とする請求項１記載の磁気抵抗素子。
【請求項４】
前記Ｆｅ系合金がＣｏＦｅＢ合金であることを特徴とする請求項３記載の磁気抵抗素子。
【請求項５】
（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなることを特徴とする室温での出力電圧が２００ｍＶより高い磁気抵抗素子のトンネル障壁層。

【請求項６】
ＢＣＣ構造を有する第１の強磁性体層、ＢＣＣ構造を有する第２の強磁性体層及び前記第１の強磁性体層と前記第２の強磁性体層との間に位置する酸素欠損の酸化マグネシウム結晶層を有し、室温での出力電圧が２００ｍＶより高いことを特徴とする磁気抵抗素子。
【請求項７】
トンネル障壁層と、前記トンネル障壁層の第１面側に形成された第１の強磁性体層と、前記トンネル障壁層の第２面側に形成された第２の強磁性体層と、を有する磁気トンネル接合構造を備えた磁気抵抗素子において、
前記トンネル障壁層が、単結晶ＭｇＯ（００１）あるいは（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなることを特徴とする磁気抵抗素子。
【請求項８】
前記第１の強磁性体層と、前記第２の強磁性体層が、ともにＢＣＣ構造を有することを特徴とする請求項７記載の磁気抵抗素子。
【請求項９】
前記第１の強磁性体層と、前記第２の強磁性体層が、ともにＢＣＣ構造を有するＦｅ系合金の単結晶（００１）または（００１）結晶面が優先配向した多結晶からなることを特徴とする請求項７記載の磁気抵抗素子。
【請求項１０】
前記Ｆｅ系合金がＣｏＦｅＢ合金であることを特徴とする請求項９記載の磁気抵抗素子。
【請求項１１】
（００１）結晶面が優先配向した多結晶ＭｇＯであって、酸素欠損を有し、かつ、トンネル障壁の高さが０．２～０．５ｅＶのものからなることを特徴とするトンネル障壁層。
【請求項１２】
室温でのＭＲ比が７０％を超える請求項１、２，３，４、６，７，８，９または１０のいずれかに記載の磁気抵抗素子。
【請求項１３】
１つのトランジスタと、前記トランジスタの負荷として用いられる請求項１、２、３、４、６、７、８、９、１０または１２のいずれかに記載の磁気抵抗素子とを有する記憶素子。
【請求項１４】
ＣｏおよびＦｅを含む磁性合金からなる強磁性体層の上に形成された（００１）結晶面が優先配向した酸素欠損を有する多結晶ＭｇＯからなる磁気抵抗素子のトンネル障壁層。
【請求項１５】
ＣｏおよびＦｅを含むアモルファス磁性合金からなる強磁性体層の上に形成された（００１）結晶面が優先配向した酸素欠損を有する多結晶ＭｇＯからなる磁気抵抗素子のトンネル障壁層。

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | |
|---|---|
| In re U.S. Patent Application of | |
| YUASA | |
| | Art Unit 2892 |
| Application Number: 12/923,643 | |
| | Examiner: |
| Filed: September 30, 2010 | Alonzo Chambliss |
| For: MAGNETIC TUNNEL JUNCTION DEVICE (AS AMENDED) | |
| Attorney Docket No. NAGI-0003 | |

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

## RESPONSE AND AMENDMENT UNDER 37 C.F.R. § 1.111

Sir:

This is in response to the Office Action mailed on July 22, 2011, the period of response to which is set to expire on October 22, 2011. Please amend the above-referenced application as follows:

IN THE SPECIFICATION

Please amend/replace the Title of the Invention for the instant application as follows:

MAGNETIC TUNNEL JUNCTION DEVICE~~MULTILAYER FILM~~



WD EX1004
Western Digital v IP Bridge
Page 214

IN THE CLAIMS

Claims 20-22 are pending in this application, wherein claims 16-19 are being canceled without prejudice or disclaimer, and wherein claims 20-22 are being newly added, as follows:

1-19. (Canceled).

20. (New) A magnetoresistive device having a tunnel barrier junction structure, the magnetoresistive device comprising:

a first ferromagnetic material layer having a BCC structure;

a second ferromagnetic material layer having a BCC structure; and

a magnesium oxide layer located between the first and second ferromagnetic material layers, and

wherein the magnesium oxide layer is a single-crystalline in which (001) crystal plane is preferentially oriented or a poly-crystalline in which (001) crystal plane is preferentially oriented, and

wherein the magnesium oxide layer has a tunnel barrier height in a range of 0.2 to 0.5 eV.

21. (New) The magnetoresistive device according to claim 20, wherein at least one of the first and second ferromagnetic material layers comprises CoFeB alloy.

22. (New) A magnetoresistive device having a tunnel barrier junction structure, the magnetoresistive device comprising:

a first ferromagnetic material layer having a BCC structure;

a second ferromagnetic material layer having a BCC structure; and

a magnesium oxide layer located between the first and second ferromagnetic material layers, and

wherein the magnesium oxide layer is a single-crystalline in which (001) crystal plane is preferentially oriented or a poly-crystalline in which (001) crystal plane is preferentially oriented, and

wherein at least one of the first and second ferromagnetic material layers comprises CoFeB alloy.



WD EX1004
Western Digital v IP Bridge
Page 215

## REMARKS

The above amendments to the above-captioned application along with the following remarks are being submitted as a full and complete response to the Office Action dated July 22, 2011 (U.S. Patent Office Paper No. 20110717). In view of the above amendments and the following remarks, the Examiner is respectfully requested to give due reconsideration to this application, to indicate the allowability of the claims, and to pass this case to issue.

Status of the Claims

As outlined above, claims 20-22 stand for consideration in this application, wherein claims 16-19 are being canceled without prejudice or disclaimer, and wherein claims 20-22 are being newly added.

All amendments to the application are fully supported therein. For example, the amendments to the claims are supported by paragraphs [0012] and [0050-51] of the present application as originally filed. Applicants hereby submit that no new matter is being introduced into the application through the submission of this response.

Prior Art Rejections

The Examiner rejected claims 16-19 under 35 U.S.C. §103(a) as being unpatentable over Parkin I (U.S. Patent No. 7,276,384) in view of Parkin II (U.S. Patent Application Publication No. 2009/0324814), and in further view of Nashimoto (U.S. Patent No. 5,759,265). Applicants have reviewed the above-noted rejections, and hereby respectfully traverse.

A proper obviousness rejection that relies on a combination of prior art elements requires establishing that the prior art references, when combined, teach or suggest all of the claim limitations. MPEP §2143. Furthermore, "[a]ll words in a claim must be considered in judging the patentability of that claim against the prior art." *In re Wilson*, 424 F.2d 1382, 1385 (C.C.P.A. 1970). That is, to render a claim obvious under 35 U.S.C. §103, a determination must be made that the claimed invention "as a whole" would have been obvious to a person of ordinary skill in the art when the invention was unknown and just before it was made. MPEP §2142.

As outlined above, claims 20-22 remain of record. Accordingly, Applicants respectfully submit that Parkin I, either alone or in combination Parkin II and/or Nashimoto, fails to teach, suggest, or disclose each and every limitation of claims 20-22. For example,



WD EX1004
Western Digital v IP Bridge
Page 216

none of the cited references teach or suggest "a first ferromagnetic material layer **having a BCC structure** [and] a second ferromagnetic material layer **having a BCC structure**" as required by independent claim 20. Rather, Parkin I contrastingly describes "[a] magnetic tunnel element that...includes **a first layer formed from an amorphous material, an amorphous tunnel barrier layer**, and an interface layer between the first layer and the tunnel barrier layer....The first layer is formed from at least one material selected from the group consisting of **amorphous ferromagnetic material, amorphous ferromagnetic materials, and amorphous non-magnetic materials**." (Abstract) (emphasis added).

More particularly, Parkin I describes that "[t]he first layer is preferably formed from at least one material selected from the group consisting of an amorphous ferromagnetic material and an amorphous ferrimagnetic material. For example, the first layer can be a CoFeB alloy of the form $(Co_{70}Fe_{30})_{100-x}B_x$ in which x is between about 15 and 20. Alternatively, the first layer is an alloy of the form CoFeX or CoFeXY, in which X and Y are chosen from the group consisting of B, Hf, Zr, C, Be, Si, Ge, P and Al, so that at least one of X and Y of the alloy causes the alloy to be amorphous." (Cols. 3-4, ll. 64-6). Parkin I further describes that "[a]lthough the preferred embodiment of the current invention has been described with regard to a tunnel barrier layer 324 formed from an amorphous layer of $Al_2O_3$, the tunnel barrier can also be formed from other amorphous materials." (Col. 13, ll. 32-36).

Amorphous materials or layers, as described in Parkin I, clearly do not have a crystal structure such as a BCC structure. Thus, a first amorphous ferromagnetic material layer and an amorphous tunnel barrier layer, as described in Parkin I, are clearly not "a first ferromagnetic material layer having a BCC structure [and] a second ferromagnetic material layer having a BCC structure" as required by claim 20. Likewise, Parkin II merely describes a magnetic tunnel junction device that includes "a fixed ferromagnetic layer 118 [and] a 'free' ferromagnetic layer 134." (Para. [0052]). Parkin II fails to include any mention or suggestion of "a first ferromagnetic material layer having a BCC structure [and] a second ferromagnetic material layer having a BCC structure" as required by claim 20. Furthermore, Nashimoto also fails to include any mention or suggestion of "a first ferromagnetic material layer having a BCC structure [and] a second ferromagnetic material layer having a BCC structure" as required by claim 20. For this reason alone, claim 20 is patentable over the cited references.

For at least these reasons, Applicants respectfully submit that Parkin I, either alone or in combination Parkin II and/or Nashimoto, fails to teach, disclose, or suggest each and every



**WD EX1004**
**Western Digital v IP Bridge**
**Page 217**

limitation of claim 20 and, therefore, that claim 20 is now in condition for allowance. For at least similar reasons to those discussed above with reference to claim 20, Applicants respectfully submit that Parkin I, either alone or in combination Parkin II and/or Nashimoto, also fails to teach, disclose, or suggest the similar limitation required by independent claim 22 of "a first ferromagnetic material layer having a BCC structure [and] a second ferromagnetic material layer having a BCC structure" and, therefore, that claim 22 is also now in condition for allowance.

Where an independent claim is nonobvious under 35 U.S.C. §103, then any claim depending therefrom is nonobvious. *In re Fine*, 5 U.P.S.Q.2d 1596, 1598 (Fed. Cir. 1988). Because claim 21 depends directly from claim 20, Applicants respectfully submit that Parkin I, either alone or in combination Parkin II and/or Nashimoto, does not render obvious claim 21 for at least the reasons set forth above that it does not render obvious claim 20 and, therefore, that claim 21 is also now in condition for allowance.

Therefore, Applicants respectfully submit that the present invention as claimed is distinguishable and thereby allowable over the prior art of record.

Conclusion

In view of all the above, Applicants respectfully submit that certain clear and distinct differences as discussed exist between the present invention as now claimed and the prior art references upon which the rejections in the Office Action rely. These differences are more than sufficient to establish that the present invention as now claimed would not have been anticipated nor rendered obvious given the prior art. Rather, the present invention as a whole is distinguishable, and thereby allowable over the prior art.



**WD EX1004**
**Western Digital v IP Bridge**
**Page 218**

Favorable reconsideration of this application as amended is respectfully solicited. Should there be any outstanding issues requiring discussion that would further the prosecution and allowance of the above-captioned application, the Examiner is invited to contact the Applicants' undersigned representative at the address and phone number indicated below.

Respectfully submitted,

Nicholas B. Trenkle
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Juan Carlos A. Marquez
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Customer No. 38327
**October 24, 2011**

222705:1:ALEXANDRIA



**WD EX1004**
**Western Digital v IP Bridge**
**Page 219**

OCT 24 2011
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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | | |
|---|---|---|
| **In re U.S. Patent Application of** | ) | |
| | ) | |
| **YUASA** | ) | |
| | ) | **Art Unit 2892** |
| **Application Number: 12/923,643** | ) | |
| | ) | **Examiner:** |
| **Filed: September 30, 2010** | ) | **Alonzo Chambliss** |
| | ) | |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE (AS AMENDED)** | ) | |
| | ) | |
| | ) | |
| **Attorney Docket No. NAGI-0003** | ) | |

**Mail Stop Amendment**
**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## COVER LETTER

Sir:

[x ] The fee for submission of claims is calculated as shown below:

| FOR | TOTAL WITH NEW CLAIMS ADDED | TOTAL CURRENTLY ON FILE | CLAIMS ALREADY PAID | RATE | CALCULATION |
|---|---|---|---|---|---|
| Total Claims | 3 | 4 | (Over 20) | x $60 | 0 |
| Independent Claims | 2 | 2 | (Over 3) | x $250 | 0 |
| MULTIPLE DEPENDENT CLAIM(S) | | | | + $450 | 0 |
| REDUCTION FOR FILING BY SMALL ENTITY (note 37 C.F.R. §§ 1.9, 1.27, 1.28). | | | | x ½ | |
| | | | TOTAL | | $0 |

In addition, the below-identified communications are submitted in the above-captioned application or proceeding:

[ x ] Response and Amendment to Office Action (with claim amendments)
[ ] Substitute Abstract
[ ] Preliminary Amendment
[ x ] Information Disclosure Statement
[ ] ___ sheet of replacement drawings
[ ] RCE
[ ] Other: _____

[ ] Applicant(s) hereby request and petition that the time for taking action in this case be extended pursuant to 37 C.F.R. § 1.136(a) for:
[ ] **one (1) month** [ ] **two (2) months** [ ] **three (3) months**

The fee set in 37 C.F.R. § 1.17 for the extension of time is **$**_____ for a large/small entity.

[ x ] Credit card information for **$180.00** to cover the IDS fee associated with this filing is enclosed.

[ ] Please charge my **Deposit Account Number** _____ in the amount of _____ to cover the fees for _____.

[ x ] The Commissioner is hereby authorized to charge any additional fees associated with this communication, including fees under 37 C.F.R. § 1.16 and 1.17, or credit any overpayment to **Deposit Account Number 12-0555.**

Respectfully submitted,

Douglas E. Jackson FOR #28,518

Juan Carlos A. Marquez
Registration No. 34,072

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**October 24, 2011**

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|---|---|
| **In re U.S. Patent Application of** | |
| **YUASA** | **Art Unit 2892** |
| **Application Number: 12/923,643** | **Examiner: Alonzo Chambliss** |
| **Filed: September 30, 2010** | |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE (AS AMENDED)** | |
| **Attorney Docket No. NAGI-0003** | |

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**Commissioner of Patents**
**PO Box 1450**
**Alexandria, VA 22313-1450**

## INFORMATION DISCLOSURE STATEMENT

Sir:

Pursuant to 37 C.F.R. §§ 1.56 and 1.97, this Information Disclosure Statement is being submitted in connection with the above-identified patent application. A listing of documents to be published on the face of any patent granted from this application is submitted herewith on the accompanying Form PTO-1449. Any other documents or information submitted for consideration by the Examiner are listed in this paper. A copy of each non-US or foreign patent or non-patent publication or any portion thereof listed or herein identified is submitted herewith.

### CERTIFICATION

**1.** This Information Disclosure Statement is being submitted:

[ ] **(a)** Concurrently with the [RCE] application or not more that three months from the filing date [of the RCE] of the above-identified U.S. patent application, whereby it is believed that no fee is due; OR

[ ] **(b)** After three months from the filing date of the above-identified U.S. patent application but before the mailing date of the first Office Action on the merits of the above-identified application, whereby it is believed that no fee is due; OR

[X] **(c)** After three months from the filing date of the above-identified U.S. patent application and after the mailing date of the first Office Action on the merits of the above-identified application, but prior to the issuance of any Final Action or Notice of Allowance sent in such application, whereby Applicant(s) hereby submit the requisite certification hereinbelow, or authorization for the payment of the requisite fee is attached; OR

[ ] **(d)** After the issuance of a Final Action or Notice of Allowance, but before the payment of the Issue Fee, whereby Applicant(s) hereby submit the requisite certification hereinbelow, and the attached authorization for the payment of the requisite fee.

**2.** In accordance with the requirements of 37 C.F.R. §1.97, and Parts 1(c) or 1(d) above, Applicant(s) hereby certify that:

[ ] Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement, whereby it is believed that no fee is due or payable at this time; OR

[ ] No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Please charge any additional fees or credit any overpayments in connection with the submission of this Information Disclosure Statement to Deposit Account No 12-0555.



**WD EX1004**
**Western Digital v IP Bridge**
**Page 223**

The Examiner is requested to acknowledge receipt and consideration of the information provided in this paper in accordance with prescribed procedures.

Respectfully submitted,

Douglas E Jackson FOR #28,518

Juan Carlos A. Marquez
Registration Number 34,072

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**October 24, 2011**



**WD EX1004**
**Western Digital v IP Bridge**
**Page 224**

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*Customized* PTO/SB/08a+b (07-09)

*Substitute for Form 1449/PTO*

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Sheet 1 of 1

| | |
|---|---|
| Application # | 12/923,643 |
| Confirmation # | 8219 |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2892 |
| Examiner | Alonzo Chambliss |
| Docket # | NAGI-0003 |

## *U.S. PATENT DOCUMENTS*

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
| | 2008/0062581 A1 | 03-13-2008 | Parkin | |
| | 2007/0258170 A1 | 11-08-2007 | Yuasa | |
| | 7,884,403 B2 | 02-08-2011 | Yuasa | |
| | 6,544,801 B1 | 04-08-2003 | Slaughter et al. | |
| | 5,514,484 | 05-07-1996 | Nishimoto | |
| | | | | |
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## *FOREIGN PATENT DOCUMENTS*

| Exam. Initial* | Country-Number-Kind Code If known | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
|---|---|---|---|---|---|
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## *NON PATENT LITERATURE DOCUMENTS*

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
|---|---|---|
| | | |
| | | |
| | | |
| | | |

| Examiner Signature | | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

| **PATENT APPLICATION FEE DETERMINATION RECORD**<br>Substitute for Form PTO-875 | Application or Docket Number<br>12/923,643 | Filing Date<br>09/30/2010 | ☐ To be Mailed |
|---|---|---|---|

## APPLICATION AS FILED – PART I

| | (Column 1) | (Column 2) | SMALL ENTITY ☐ | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|
| FOR | NUMBER FILED | NUMBER EXTRA | RATE ($) | FEE ($) | | RATE ($) | FEE ($) |
| ☐ BASIC FEE (37 CFR 1.16(a), (b), or (c)) | N/A | N/A | N/A | | | N/A | |
| ☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | N/A | N/A | | | N/A | |
| ☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | N/A | N/A | | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | minus 20 = | * | X $ = | | OR | X $ = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | minus 3 = | * | X $ = | | | X $ = | |
| ☐ APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | | | |
| ☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j)) | | | | | | | |
| * If the difference in column 1 is less than zero, enter "0" in column 2. | | | TOTAL | | | TOTAL | |

## APPLICATION AS AMENDED – PART II

| | | (Column 1) | | (Column 2) | (Column 3) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **10/24/2011** | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * 3 | Minus | ** 20 | = 0 | X $ = | | OR | X $60= | 0 |
| | Independent (37 CFR 1.16(h)) | * 2 | Minus | ***3 | = 0 | X $ = | | OR | X $250= | 0 |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | **0** |

| | | (Column 1) | | (Column 2) | (Column 3) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X $ = | | OR | X $ = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X $ = | | OR | X $ = | |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | |

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/ROSS W. BROWN/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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| **PATENT APPLICATION FEE DETERMINATION RECORD**<br>Substitute for Form PTO-875 | Application or Docket Number<br>12/923,643 | Filing Date<br>09/30/2010 | ☐ To be Mailed |
|---|---|---|---|

## APPLICATION AS FILED – PART I

| | (Column 1) | (Column 2) | SMALL ENTITY ☐ | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|
| FOR | NUMBER FILED | NUMBER EXTRA | RATE ($) | FEE ($) | | RATE ($) | FEE ($) |
| ☐ BASIC FEE (37 CFR 1.16(a), (b), or (c)) | N/A | N/A | N/A | | | N/A | |
| ☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | N/A | N/A | | | N/A | |
| ☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | N/A | N/A | | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | minus 20 = | * | X $ = | | OR | X $ = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | minus 3 = | * | X $ = | | | X $ = | |
| ☐ APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | | | |
| ☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j)) | | | | | | | |
| * If the difference in column 1 is less than zero, enter "0" in column 2. | | | TOTAL | | | TOTAL | |

## APPLICATION AS AMENDED – PART II

| | | (Column 1) | | (Column 2) | (Column 3) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **10/24/2011** | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * 3 | Minus | ** 20 | = 0 | X $ = | | OR | X $60= | 0 |
| | Independent (37 CFR 1.16(h)) | * 2 | Minus | ***6 | = 0 | X $ = | | OR | X $250= | 0 |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | **0** |

| | | (Column 1) | | (Column 2) | (Column 3) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X $ = | | OR | X $ = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X $ = | | OR | X $ = | |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | |

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/CHRISTINE MOLLISH/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

UNITED STATES PATENT AND TRADEMARK OFFICE

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www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

38327 7590 11/14/2011

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER | |
|---|---|
| CHAMBLISS, ALONZO | |
| ART UNIT | PAPER NUMBER |
| 2892 | |

| NOTIFICATION DATE | DELIVERY MODE |
|---|---|
| 11/14/2011 | ELECTRONIC |

**Please find below and/or attached an Office communication concerning this application or proceeding.**

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

iplaw@stites.com

| Office Action Summary | Application No. | Applicant(s) | |
|---|---|---|---|
| | 12/923,643 | YUASA, SHINJI | |
| | Examiner | Art Unit | |
| | ALONZO CHAMBLISS | 2892 | |

*-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --*

**Period for Reply**

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE 3 MONTH(S) OR THIRTY (30) DAYS, WHICHEVER IS LONGER, FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

**Status**

1)☒ Responsive to communication(s) filed on *24 October 2011*.

2a)☒ This action is **FINAL**. 2b)☐ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

**Disposition of Claims**

5)☒ Claim(s) *20-22* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *20-22* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

**Application Papers**

10)☐ The specification is objected to by the Examiner.

11)☐ The drawing(s) filed on _____ is/are: a)☐ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

12)☐ The oath or declaration is objected to by the Examiner. Note the attached Office Action or form PTO-152.

**Priority under 35 U.S.C. § 119**

13)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

a)☐ All b)☐ Some * c)☐ None of:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

* See the attached detailed Office action for a list of the certified copies not received.

**Attachment(s)**

1) ☐ Notice of References Cited (PTO-892)
2) ☐ Notice of Draftsperson's Patent Drawing Review (PTO-948)
3) ☒ Information Disclosure Statement(s) (PTO/SB/08) Paper No(s)/Mail Date *10/6/11,10/24/11*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☒ Other: *see detailed action*.

## DETAILED ACTION

1. The amendment filed on 10/24/11 has been fully considered and made of record in the instant application.

### *Response to Arguments*

2. Applicant's arguments with respect to claims 20-22 have been considered but are moot in view of the new ground(s) of rejection.

### *Claim Rejections - 35 USC § 103*

3. The following is a quotation of 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

4. The factual inquiries set forth in *Graham* v. *John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.
2. Ascertaining the differences between the prior art and the claims at issue.
3. Resolving the level of ordinary skill in the pertinent art.
4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

5. Claim 22 is rejected under 35 U.S.C. 103(a) as being unpatentable over Parkin (US 2008/0062581) in view Nashimoto (US 5,514,484)

With respect to Claim 22, Parkin discloses a substrate 111 and a first amorphous ferromagnetic material layer 115 made of CoFeB alloy of a BCC structure on a substrate 111. An amorphous second ferromagnetic material layer 175 comprising a CoFeB alloy. A tunnel barrier layer 120' made of MgO located between the first and second ferromagnetic material layers 115,175, wherein the tunnel barrier layer comprising a poly-crystalline MgO layer in which (100) crystal plane is substantially oriented. Parkin discloses less oxygen between the tunnel barrier layer and the upper ferromagnetic layer (see abstract, paragraphs 41, 42, 45, and 71; Figs. 3 and 11). Parkin fails to explicitly recite a barrier layer which is a (001) crystal plane oriented. However, Nashimoto discloses that it is well known in the semiconductor industry that a MgO barrier layer can have a (100) or (001) crystal plane as evident by Nashimoto see col. 6 lines 25-40 and col. 8 lines 1-15). Thus, Parkin and Nashimoto have substantially the same environment of a MgO layer formed on a substrate. Therefore, one skilled in the art at the time of invention would readily recognize the MgO barrier layer of Parkin can have a (001) structure, since the (001) structure is well known in the semiconductor industry to substitute a (001) structure for a (100) structure in the MgO layer as evident by Nashimoto.

***Double Patenting***

6. The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent

and to prevent possible harassment by multiple assignees. A nonstatutory obviousness-type double patenting rejection is appropriate where the conflicting claims are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the conflicting application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement.

Effective January 1, 1994, a registered attorney or agent of record may sign a terminal disclaimer. A terminal disclaimer signed by the assignee must fully comply with 37 CFR 3.73(b).

7. Claims 20 and 21 are rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claim 1 of U.S. Patent No. 7,884,403. Although the conflicting claims are not identical, they are not patentably distinct from each other because both the instant application and the patent recites a first and

second ferromagnetic layers having a BCC structure and a magnesium oxide layer located between the first and second ferromagnetic material layers.

8. Claim 22 is rejected on the ground of nonstatutory obviousness-type double patenting as being unpatentable over claim 4 of U.S. Patent No. 7,884,403. Although the conflicting claims are not identical, they are not patentably distinct from each other because both the instant application and the patent recites a first and second ferromagnetic layers having a BCC structure and a magnesium oxide layer located between the first and second ferromagnetic material layers. At least one of the ferromagnetic material layers comprises CoFeB.

The prior art made of record and not relied upon is cited primarily to show the product of the instant invention.

## *Conclusion*

9. Applicant's amendment necessitated the new ground(s) of rejection presented in this Office action. Accordingly, **THIS ACTION IS MADE FINAL**. See MPEP § 706.07(a). Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of

the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the date of this final action.

Any inquiry concerning the communication or earlier communications from the examiner should be directed to Alonzo Chambliss whose telephone number is (571) 272-1927.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Thao Le can be reached on (571) 272-1708. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system Status information for published applications may be obtained from either Private PMR or Public PMR. Status information for unpublished applications is available through Private PMR only. For more information about the PMR system see http://pair-dkect.uspto.gov. Should you have questions on access to the Private PMR system contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free) or EBC_Support@uspto.gov.

**AC**/November 6, 2011

/Alonzo Chambliss/
Primary Examiner, Art Unit 2892

**EAST Search History**

**EAST Search History (Prior Art)**

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 2054 | (MgO magnesium adj3 oxide poly adj2 crystalline) and CoFe | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2011/11/06 22:14 |
| L2 | 1048 | (MgO magnesium adj3 oxide poly adj2 crystalline) and CoFeB | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2011/11/06 22:14 |
| L3 | 960 | (MgO magnesium adj3 oxide poly adj2 crystalline) and CoFeB and ferromagnetic | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2011/11/06 22:16 |
| L4 | 530 | (MgO magnesium adj3 oxide poly adj2 crystalline) same CoFeB and ferromagnetic | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2011/11/06 22:16 |

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WD EX1004
Western Digital v IP Bridge
Page 235

| Search Notes | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | Examiner | Art Unit |
| | Alonzo Chambliss | 2892 |

| SEARCHED | | | |
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| Class | Subclass | Date | Examiner |
| | | | |

| SEARCH NOTES | | |
|---|---|---|
| Search Notes | Date | Examiner |
| East text search only - see attach printout | 12/16/10 | AC |
| Updated previous East text search only - see attached printout | 7/18/11 | AC |
| Updated previous East text serach only - see attached printout | 11/6/11 | AC |

| INTERFERENCE SEARCH | | | |
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| Class | Subclass | Date | Examiner |
| | | | |

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*Customized* PTO/SB/08a+b (07-09)

*Substitute for Form 1449/PTO*

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

| | |
|---|---|
| Application # | 12/923,643 |
| Confirmation # | 8219 |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2892 |
| Examiner | Chambliss, Alonzo |
| Sheet 1 of 1 | Docket # NAGI-0003 |

## U.S. PATENT DOCUMENTS

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
| | 2007-0195592 A1 | 08-23-2007 | Yuasa | |

## FOREIGN PATENT DOCUMENTS

| Exam. Initial* | Country-Number-Kind Code If known | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
|---|---|---|---|---|---|
| | JP 2008-004956 [1] | 01-10-2008 | Japan Science & Technology Agency;<br><br>National Institute of Advanced Industrial & Technology | | Abstract |

## NON PATENT LITERATURE DOCUMENTS

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
|---|---|---|
| | | |

| Examiner Signature | /Alonzo Chambliss/ (11/06/2011) | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

1 Corresponds to U.S. Document No. 2007-0195592 A1 listed above.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

Receipt date: 10/24/2011




12923643 - GAU: 2892

*Customized* PTO/SB/08a+b (07-09)

*Substitute for Form 1449/PTO*

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Sheet 1 of 1

| | |
|---|---|
| Application # | 12/923,643 |
| Confirmation # | 8219 |
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| Art Unit | 2892 |
| Examiner | Alonzo Chambliss |
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| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
| | 2008/0062581 A1 | 03-13-2008 | Parkin | |
| | 2007/0258170 A1 | 11-08-2007 | Yuasa | |
| | 7,884,403 B2 | 02-08-2011 | Yuasa | |
| | 6,544,801 B1 | 04-08-2003 | Slaughter et al. | |
| | 5,514,484 | 05-07-1996 | Nishimoto | |
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## FOREIGN PATENT DOCUMENTS

| Exam. Initial* | Country-Number-Kind Code If known | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
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## NON PATENT LITERATURE DOCUMENTS

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
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| Examiner Signature | /Alonzo Chambliss/ (11/06/2011) | Date Considered | |
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* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

**EAST Search History**

**EAST Search History (Prior Art)**

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WD EX1004
Western Digital v IP Bridge
Page 239

| Index of Claims | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | Examiner | Art Unit |
| | Alonzo Chambliss | 2892 |

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☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

| CLAIM | | DATE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Final | Original | 12/17/2010 | 07/18/2011 | 11/06/2011 | | | | | | |
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| Index of Claims | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | **Examiner** | **Art Unit** |
| | Alonzo Chambliss | 2892 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ✓ | Rejected | - | Cancelled | N | Non-Elected | A | Appeal |
| = | Allowed | ÷ | Restricted | I | Interference | O | Objected |

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

| CLAIM | | DATE | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Final | Original | 12/17/2010 | 07/18/2011 | 11/06/2011 | | | | | | |
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WD EX1004
Western Digital v IP Bridge
Page 241

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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | | |
|---|---|---|
| **In re U.S. Patent Application of** | ) | |
| | ) | |
| **YUASA** | ) | |
| | ) | **Art Unit 2892** |
| **Application Number: 12/923,643** | ) | |
| | ) | **Examiner:** |
| **Filed: September 30, 2010** | ) | **Alonzo Chambliss** |
| | ) | |
| **For: MAGNETIC MULTILAYER FILM (As Amended)** | ) | |
| | ) | |
| **Attorney Docket No. NAGI.0003** | ) | |

**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

**LETTER**

Sir:

The below-identified communications are submitted in the above-captioned application or proceeding:

(x) Information Disclosure Statement with Form-1449 and reference
(x) Check for $180.00

☒ The Commissioner is hereby authorized to charge payment of any fees associated with this communication, including fees under 37 C.F.R. § 1.16 and 1.17 or credit any overpayment to **Deposit Account Number 12-0555**.

Respectfully submitted,

Juan Carlos A. Marquez
Registration Number 34,072

**STITES & HARBISON PLLC**
1199 North Fairfax Street, Suite 900
Alexandria, Virginia 22314
(703) 739-4900
Customer No.: 38327
**December 29, 2011**

230701:1:ALEXANDRIA

OPAP IAP3 DEC 29 2011 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | | |
|---|---|---|
| **In re U.S. Patent Application of** | ) | |
| | ) | |
| **YUASA** | ) | |
| | ) | **Art Unit 2892** |
| **Application Number: 12/923,643** | ) | |
| | ) | **Examiner:** |
| **Filed: September 30, 2010** | ) | **Alonzo Chambliss** |
| | ) | |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE (AS AMENDED)** | ) | |
| | ) | |
| **Attorney Docket No. NAGI-0003** | ) | |

**Commissioner of Patents**
**PO Box 1450**
**Alexandria, VA 22313-1450**

## INFORMATION DISCLOSURE STATEMENT

Sir:

Pursuant to 37 C.F.R. §§ 1.56 and 1.97, this Information Disclosure Statement is being submitted in connection with the above-identified patent application. A listing of documents to be published on the face of any patent granted from this application is submitted herewith on the accompanying Form PTO-1449. Any other documents or information submitted for consideration by the Examiner are listed in this paper. A copy of each non-US or foreign patent or non-patent publication or any portion thereof listed or herein identified is submitted herewith.

### CERTIFICATION

1. This Information Disclosure Statement is being submitted:

[ ] (a) Concurrently with the [RCE] application or not more that three months from the filing date [of the RCE] of the above-identified U.S. patent application, whereby it is believed that no fee is due; OR

[ ] (b) Within three months of the filing date of the RCE in the above-identified U.S. patent application but before the mailing date of the first Office Action on the merits of the above-identified application, whereby it is believed that no fee is due; OR

[x] (c) After three months from the filing date of the above-identified U.S. patent application and after the mailing date of the first Office Action on the merits of the above-identified application, but prior to the issuance of any Final Action or Notice of Allowance sent in such application, whereby

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Applicant(s) hereby submit the requisite certification hereinbelow, or authorization for the payment of the requisite fee is attached; OR

[ ] **(d)** After the issuance of a Final Action or Notice of Allowance, but before the payment of the Issue Fee, whereby Applicant(s) hereby submit the requisite certification hereinbelow, and the attached authorization for the payment of the requisite fee.

**2.** In accordance with the requirements of 37 C.F.R. §1.97, and Parts 1(c) or 1(d) above, Applicant(s) hereby certify that:

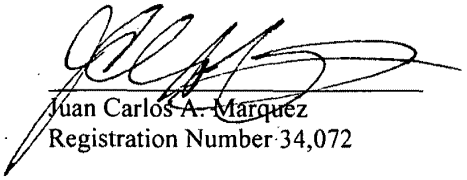
[ ] Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; OR

[ ] No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Please charge any additional fees or credit any overpayments in connection with the submission of this Information Disclosure Statement to Deposit Account No 12-0555.

The Examiner is requested to acknowledge receipt and consideration of the information provided in this paper in accordance with prescribed procedures.

Respectfully submitted,



Juan Carlos A. Marquez
Registration Number 34,072

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**December 29, 2011**

230690:1:ALEXANDRIA



**WD EX1004**
**Western Digital v IP Bridge**
**Page 244**

OPAP IAP3 DEC 29 2011 PATENT & TRADEMARK OFFICE

*Customized* PTO/SB/08a+b (07-09)

*Substitute for Form 1449/PTO*

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Sheet 1 of 1

| | |
|---|---|
| Application # | 12/923,643 |
| Confirmation # | 8219 |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2892 |
| Examiner | Chambliss, Alonzo |
| Docket # | NAGI-0003 |

## *U.S. PATENT DOCUMENTS*

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
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## *FOREIGN PATENT DOCUMENTS*

| Exam. Initial* | Country-Number-Kind Code [If known] | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
|---|---|---|---|---|---|
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## *NON PATENT LITERATURE DOCUMENTS*

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
|---|---|---|
| | "Giant tunnel magnetoresistance in magnetic tunnel junctions with a crystalline $M_gO(001)$ barrier," S. Yuasa and D.D. Djayaprawira, Journal of Applied Physics D: Applied Physics, 1 Phys, D: Appl. Phys. 40 (2007) R337-R354 | Yes |
| | | |
| | | |
| | | |

| Examiner Signature | | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

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PATENT & TRADEMARK OFFICE

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | |
|---|---|
| **In re U.S. Patent Application of** | |
| **YUASA** | **Art Unit 2892** |
| **Application Number: 12/923,643** | **Examiner** |
| **Filed: September 30, 2010** | **Alonzo Chambliss** |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE (AS AMENDED)** | |
| **Attorney Docket No. NAGI-0003** | |

**Mail Stop AF**
**Commissioner for Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## RESPONSE AND AMENDMENT UNDER 37 C.F.R. § 1.116

Sir:

This is in response to the Final Office Action mailed on November 14, 2011, the period of response to which is set to expire on February 14, 2012. Please amend the above-referenced application as follows:

**IN THE CLAIMS**

Claims 20 and 21 are pending in this application, wherein claim 22 is being canceled without prejudice or disclaimer, as follows:

1-19. (Canceled).

20. (Previously Presented) A magnetoresistive device having a tunnel barrier junction structure, the magnetoresistive device comprising:

a first ferromagnetic material layer having a BCC structure;

a second ferromagnetic material layer having a BCC structure; and

a magnesium oxide layer located between the first and second ferromagnetic material layers, and

wherein the magnesium oxide layer is a single-crystalline in which (001) crystal plane is preferentially oriented or a poly-crystalline in which (001) crystal plane is preferentially oriented, and

wherein the magnesium oxide layer has a tunnel barrier height in a range of 0.2 to 0.5 eV.

21. (Previously Presented) The magnetoresistive device according to claim 20, wherein at least one of the first and second ferromagnetic material layers comprises CoFeB alloy.

22. (Canceled).



WD EX1004
Western Digital v IP Bridge
Page 247

## REMARKS

The above amendments to the above-captioned application along with the following remarks are being submitted as a full and complete response to the Final Office Action dated November 14, 2011 (U.S. Patent Office Paper No. 2011106). In view of the above amendments and the following remarks, the Examiner is respectfully requested to give due reconsideration to this application, to indicate the allowability of the claims, and to pass this case to issue.

Status of the Claims

As outlined above, claims 20 and 21 stand for consideration in this application, wherein claim 22 is being canceled without prejudice or disclaimer. Applicants hereby submit that no new matter is being introduced into the application through the submission of this response.

Prior Art Rejections

The Examiner rejected claim 22 under 35 U.S.C. §103(a) as being unpatentable over Parkin (U.S. Patent Application Publication No. 2008/0062581) in view of Nashimoto (U.S. Patent No. 5,514,484). As set forth above, claim 22 is being canceled without prejudice or disclaimer, thereby rendering moot and/or obviating the rejection thereof under 35 U.S.C. §103(a).

The Examiner also rejected claims 20-22 as being unpatentable over claims 1 and 4 of U.S. Patent No. 7,884,403 ("the '403 application") on grounds of nonstatutory obviousness-type double patenting. In response, Applicants respectfully submit that the present application and the '403 application were commonly owned pursuant to 35 U.S.C. §103(c)(1) at the time the claimed invention of the present application was made. Accordingly, Applicants are submitting a terminal disclaimer in compliance with 37 C.F.R. 1.321 herewith, thereby rendering moot and/or obviating the non-statutory obviousness-type double patenting rejection.

Therefore, Applicants respectfully submit that the present invention as claimed is distinguishable and thereby allowable over the prior art of record.



WD EX1004
Western Digital v IP Bridge
Page 248

Conclusion

In view of all the above, Applicants respectfully submit that, the present invention as a whole is allowable over the prior art. Favorable reconsideration of this application is respectfully solicited. Should there be any outstanding issues requiring discussion that would further the prosecution and allowance of the above-captioned application, the Examiner is invited to contact the Applicants' undersigned representative at the address and phone number indicated below..

Respectfully submitted,

Nicholas B. Trenkle
Registration Number 54,500

Douglas E. Jackson FOR #28,578

Juan Carlos A. Marquez
Registration Number 34,072

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(703) 739-9577 Fax
Customer No. 38327
**February 14, 2012**

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**WD EX1004**
**Western Digital v IP Bridge**
**Page 249**

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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**In re U.S. Patent Application of**

**YUASA**

**Application Number: 12/923,643**

**Filed: September 30, 2010**

**For: MAGNETIC TUNNEL JUNCTION DEVICE (AS AMENDED)**

**Attorney Docket No. NAGI-0003**

**Art Unit 2892**

**Examiner**
**Alonzo Chambliss**

**Mail Stop Amendment**
**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## COVER LETTER

Sir:

[x ] The fee for submission of claims is calculated as shown below:

| FOR | TOTAL WITH NEW CLAIMS ADDED | TOTAL CURRENTLY ON FILE | CLAIMS ALREADY PAID | RATE | CALCULATION |
|---|---|---|---|---|---|
| Total Claims | 2 | 3 | (Over 20) | x $60 | 0 |
| Independent Claims | 1 | 2 | (Over 3) | x $250 | 0 |
| MULTIPLE DEPENDENT CLAIM(S) | | | | + $450 | 0 |
| REDUCTION FOR FILING BY SMALL ENTITY (note 37 C.F.R. §§ 1.9, 1.27, 1.28). | | | | x ½ | |
| | | | TOTAL | | $0 |

In addition, the below-identified communications are submitted in the above-captioned application or proceeding:

[x ] Response and Amendment to Office Action (with claim amendments)
[ ] Substitute Abstract
[x ] Terminal Disclaimer
[ ] Information Disclosure Statement
[ ] __ sheets of replacement drawings
[ ] RCE
[ ] Other:

[ ] Applicant(s) hereby request and petition that the time for taking action in this case be extended pursuant to 37 C.F.R. § 1.136(a) for:
[ ] **one (1) month** [ ] **two (2) months** [ ] **three (3) months**

The fee set in 37 C.F.R. § 1.17 for the extension of time is $_____ for a large/small entity.

[ x ] Credit card information for **$160.00** to cover the Terminal Disclaimer fee associated with this filing is enclosed.

[ ] Please charge my **Deposit Account Number** _____ in the amount of _____ to cover the fees for _____.

[ x ] The Commissioner is hereby authorized to charge any additional fees associated with this communication, including fees under 37 C.F.R. § 1.16 and 1.17, or credit any overpayment to **Deposit Account Number 12-0555.**

Respectfully submitted,

Douglas E Jackson FOR #28,578

Juan Carlos A. Marquez
Registration No. 34,072

**STITES & HARBISON PLLC**
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Customer No. 38327

**February 14, 2012**

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**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | |
|---|---|
| **In re U.S. Patent Application of** | |
| **YUASA** | **Art Unit 2892** |
| **Application Number: 12/923,643** | **Examiner** |
| **Filed: September 30, 2010** | **Alonzo Chambliss** |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE (AS AMENDED)** | |
| **Attorney Docket No. NAGI-0003** | |

**Mail Stop Amendment**
**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## TERMINAL DISCLAIMER

Sir:

I, Juan Carlos A. Marquez, represent that I am the attorney of record for the above-identified application.

The invention has been assigned to Japan Science and Technology Agency and National Institute of Advanced Industrial Science and Technology, who are the owners by assignment of 100 percent of the right, title and interest in the above-captioned patent application.

Japan Science and Technology Agency and National Institute of Advanced Industrial Science and Technology are also the owners of 100 percent of the right, title and interest to U.S. Patent No. 7,884,403 by assignment and hereby disclaims, except as otherwise provided hereinbelow, the terminal part of any patent granted on the above-captioned patent application, which would extend beyond the expiration date of the full statutory term of the **prior applications** U.S. Patent No. 7,884,403, the term of said **prior applications** is defined in 35 U.S.C. §§154 and 173, and as the term of said **prior applications** is presently shortened by any terminal disclaimer. Japan Science and Technology Agency and National Institute of Advanced Industrial Science and Technology hereby agree that any patent so granted on the instant application shall be enforceable only for and during such period that it and the **prior**

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**applications** are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, Japan Science and Technology Agency and National Institute of Advanced Industrial Science and Technology do not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term as defined in 35 U.S.C. §§154 and 173 of the **prior applications**, "as the term of said **prior applications** is presently shortened by any terminal disclaimer," in the event that said **prior applications** later: (a) expires for failure to pay a maintenance fee; (b) is held unenforceable; (c) is found invalid by a court of competent jurisdiction; (d) is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321; (e) has all claims canceled by a reexamination certificate; (f) is reissued; or (g) is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

Respectfully submitted,

Douglas E. Jackson FOR #28,518

Juan Carlos A. Marquez
Registration Number 34,072

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Telephone: 703-739-4900
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Customer No. 38327

**February 14, 2012**

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PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

| **PATENT APPLICATION FEE DETERMINATION RECORD**<br>Substitute for Form PTO-875 | Application or Docket Number<br>12/923,643 | Filing Date<br>09/30/2010 | ☐ To be Mailed |
|---|---|---|---|

## APPLICATION AS FILED – PART I

| | (Column 1) | (Column 2) | SMALL ENTITY ☐ | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|
| FOR | NUMBER FILED | NUMBER EXTRA | RATE ($) | FEE ($) | | RATE ($) | FEE ($) |
| ☐ BASIC FEE (37 CFR 1.16(a), (b), or (c)) | N/A | N/A | N/A | | | N/A | |
| ☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | N/A | N/A | | | N/A | |
| ☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | N/A | N/A | | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | minus 20 = | * | X $ = | | OR | X $ = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | minus 3 = | * | X $ = | | | X $ = | |
| ☐ APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | | | |
| ☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j)) | | | | | | | |
| * If the difference in column 1 is less than zero, enter "0" in column 2. | | | TOTAL | | | TOTAL | |

## APPLICATION AS AMENDED – PART II

| | | (Column 1) | | (Column 2) | (Column 3) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| AMENDMENT | 02/14/2012 | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| | Total (37 CFR 1.16(i)) | * 2 | Minus | ** 20 | = 0 | X $ = | | OR | X $60= | 0 |
| | Independent (37 CFR 1.16(h)) | * 1 | Minus | ***3 | = 0 | X $ = | | OR | X $250= | 0 |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | 0 |

| | | (Column 1) | | (Column 2) | (Column 3) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| AMENDMENT | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X $ = | | OR | X $ = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X $ = | | OR | X $ = | |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | |

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/ANNETTE SMITH/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

| **PATENT APPLICATION FEE DETERMINATION RECORD**<br>Substitute for Form PTO-875 | Application or Docket Number<br>12/923,643 | Filing Date<br>09/30/2010 | ☐ To be Mailed |
|---|---|---|---|

## APPLICATION AS FILED – PART I

| | (Column 1) | (Column 2) | SMALL ENTITY ☐ | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|
| FOR | NUMBER FILED | NUMBER EXTRA | RATE ($) | FEE ($) | | RATE ($) | FEE ($) |
| ☐ BASIC FEE (37 CFR 1.16(a), (b), or (c)) | N/A | N/A | N/A | | | N/A | |
| ☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | N/A | N/A | | | N/A | |
| ☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | N/A | N/A | | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | minus 20 = | * | X $ = | | OR | X $ = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | minus 3 = | * | X $ = | | | X $ = | |
| ☐ APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | | | |
| ☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j)) | | | | | | | |
| * If the difference in column 1 is less than zero, enter "0" in column 2. | | | TOTAL | | | TOTAL | |

## APPLICATION AS AMENDED – PART II

| | | (Column 1) | | (Column 2) | (Column 3) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 02/14/2012 | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * 2 | Minus | ** 20 | = 0 | X $ = | | OR | X $60= | 0 |
| | Independent (37 CFR 1.16(h)) | * 1 | Minus | ***6 | = 0 | X $ = | | OR | X $250= | 0 |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | 0 |

| | | (Column 1) | | (Column 2) | (Column 3) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X $ = | | OR | X $ = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X $ = | | OR | X $ = | |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | |

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/CHRISTINE MOLLISH/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

| Application Number | Application/Control No. | Applicant(s)/Patent under Reexamination | |
|---|---|---|---|
| | 12/923,643 | YUASA, SHINJI | |
| | | | |

| Document Code - DISQ | Internal Document – DO NOT MAIL |
|---|---|

| TERMINAL DISCLAIMER | ☒ APPROVED | ☐ DISAPPROVED |
|---|---|---|
| Date Filed : 02/14/12 | This patent is subject to a Terminal Disclaimer | |

| Approved/Disapproved by: |
|---|
| Lawana Hixon |

U.S. Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

# NOTICE OF ALLOWANCE AND FEE(S) DUE

38327 7590 03/07/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER |
|---|
| CHAMBLISS, ALONZO |

| ART UNIT | PAPER NUMBER |
|---|---|
| 2892 | |

DATE MAILED: 03/07/2012

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | NO | $1740 | $300 | $0 | $2040 | 06/07/2012 |

**THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.**

**THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.**

**HOW TO REPLY TO THIS NOTICE:**

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

**IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.**



PTOL-85 (Rev. 02/11)

**WD EX1004**
**Western Digital v IP Bridge**
**Page 257**

## PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail** **Mail Stop ISSUE FEE**
**Commissioner for Patents**
**P.O. Box 1450**
**Alexandria, Virginia 22313-1450**
**or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

38327 7590 03/07/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

**Certificate of Mailing or Transmission**

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | NO | $1740 | $300 | $0 | $2040 | 06/07/2012 |

| EXAMINER | ART UNIT | CLASS-SUBCLASS |
|---|---|---|
| CHAMBLISS, ALONZO | 2892 | 257-295000 |

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.



**WD EX1004**
**Western Digital v IP Bridge**
**Page 258**

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

38327 7590 03/07/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER | |
|---|---|
| CHAMBLISS, ALONZO | |
| ART UNIT | PAPER NUMBER |
| 2892 | |

DATE MAILED: 03/07/2012

**Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)**
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.



PTOL-85 (Rev. 02/11)

## Privacy Act Statement

**The Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

| Notice of Allowability | Application No. | Applicant(s) | |
|---|---|---|---|
| | 12/923,643 | YUASA, SHINJI | |
| | Examiner | Art Unit | |
| | ALONZO CHAMBLISS | 2892 | |

***-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--***

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *the terminal disclaimer filed on 2/14/12*.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *20 and 21*.
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
**THIS THREE-MONTH PERIOD IS NOT EXTENDABLE**.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
6. ☐ CORRECTED DRAWINGS ( as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review ( PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   **Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).**
7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

**Attachment(s)**

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 12/29/11
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☒ Other *See Detailed Action*.



**WD EX1004**
**Western Digital v IP Bridge**

## DETAILED ACTION

### *Information Disclosure Statement*

1. The information disclosure statement (IDS) submitted on 12/29/11 was filed before the mailing date of the notice of allowance on 3/1/12. The submission is in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner.

### *Terminal Disclaimer*

2. The terminal disclaimer filed on 2/14/12 disclaiming the terminal portion of any patent granted on this application which would extend beyond the expiration date of U.S. Patent No. 7,884,403 has been reviewed and is accepted. The terminal disclaimer has been recorded.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Any inquiry concerning the communication or earlier communications from the examiner should be directed to Alonzo Chambliss whose telephone number is (571) 272-1927.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the group receptionist whose telephone number is (703) 308-7956.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system Status information for

published applications may be obtained from either Private PMR or Public PMR. Status information for unpublished applications is available through Private PMR only. For more information about the PMR system see http://pair-kect.uspto.gov. Should you have questions on access to the Private PMR system contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free) or EBC_Support@uspto.gov.

AC/March 1, 2012 /Alonzo Chambliss/

Primary Examiner, Art Unit 2892

| Search Notes | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | Examiner | Art Unit |
| | Alonzo Chambliss | 2892 |

| SEARCHED | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| | | | |

| SEARCH NOTES | | |
|---|---|---|
| Search Notes | Date | Examiner |
| East text search only - see attach printout | 12/16/10 | AC |
| Updated previous East text search only - see attached printout | 7/18/11 | AC |
| Updated previous East text serach only - see attached printout | 11/6/11 | AC |
| Updated previous East text search only - see attached printout | 3/1/12 | AC |

| INTERFERENCE SEARCH | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| 257 | 4,295,421,427 | 3/1/12 | AC |
| 365 | 171 | 3/1/12 | |

**EAST Search History**

**EAST Search History (Prior Art)**

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 522 | "257"/$.ccls. and (Fe ferromagnetice) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:35 |
| L2 | 350 | "365"/$.ccls. and (Fe ferromagnetice) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:36 |
| L3 | 619 | 257/E29.323 | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:36 |
| L4 | 124 | 257/E29.323 and (Fe ferromagnetice) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:37 |
| L5 | 8 | 257/E27.104 and (Fe ferromagnetice) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:37 |
| L6 | 11 | 257/E29.164 and (Fe ferromagnetice) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:38 |
| L7 | 7 | 257/E21.208 and (Fe ferromagnetice) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:38 |
| L8 | 58 | yuasa.in. and (Fe ferromagnetice) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:40 |
| L9 | 14 | japan adj3 science.as. and (Fe ferromagnetice) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:40 |
| L10 | 15 | national adj3 institute adj3 advanced adj3 industrial.as. and (Fe ferromagnetice) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/03/01 21:41 |

**3/1/2012 9:41:41 PM**
**C:\Users\achambliss\Documents\EAST\Workspaces\12652379.wsp**

FEB 1 4 2012
IAP13
PATENT & TRADEMARK OFFICE

OK TO ENTER: /AC/ (03/01/2012)

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | |
|---|---|
| **In re U.S. Patent Application of** | |
| **YUASA** | **Art Unit 2892** |
| **Application Number: 12/923,643** | **Examiner** |
| **Filed: September 30, 2010** | **Alonzo Chambliss** |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE (AS AMENDED)** | |
| **Attorney Docket No. NAGI-0003** | |

**Mail Stop AF**
**Commissioner for Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## RESPONSE AND AMENDMENT UNDER 37 C.F.R. § 1.116

Sir:

This is in response to the Final Office Action mailed on November 14, 2011, the period of response to which is set to expire on February 14, 2012. Please amend the above-referenced application as follows:

Receipt date: 12/29/2011




12923643 - GAU: 2892

*Customized* PTO/SB/08a+b (07-09)

*Substitute for Form 1449/PTO*

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Sheet 1 of 1

| | |
|---|---|
| Application # | 12/923,643 |
| Confirmation # | 8219 |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2892 |
| Examiner | Chambliss, Alonzo |
| Docket # | NAGI-0003 |

## U.S. PATENT DOCUMENTS

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
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## FOREIGN PATENT DOCUMENTS

| Exam. Initial* | Country-Number-Kind Code If known | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
|---|---|---|---|---|---|
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## NON PATENT LITERATURE DOCUMENTS

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
|---|---|---|
| | "Giant tunnel magnetoresistance in magnetic tunnel junctions with a crystalline $M_gO(001)$ barrier," S. Yuasa and D.D. Djayaprawira, Journal of Applied Physics D: Applied Physics, 1 Phys, D: Appl. Phys. 40 (2007) R337-R354 | Yes |
| | | |
| | | |
| | | |

| Examiner Signature | /Alonzo Chambliss/ (03/01/2012) | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

1

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

| Issue Classification | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | **Examiner** | **Art Unit** |
| | ALONZO CHAMBLISS | 2892 |

| ORIGINAL | | INTERNATIONAL CLASSIFICATION | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLASS | SUBCLASS | CLAIMED | | | | | | | | | NON-CLAIMED | | | | | |
| 257 | 295 | H | 0 | 1 | L | 27 / 108 (2006.0) | | | | | | | | | | |
| CROSS REFERENCE(S) | | G | 1 | 1 | C | 11 / 14 (2006.0) | | | | | | | | | | |
| CLASS | SUBCLASS (ONE SUBCLASS PER BLOCK) | | | | | | | | | | | | | | | |
| 257 | 427 | E29.323 | E27.104 | E29.164 | E21.208 | | | | | | | | | | | |
| 365 | 171 | | | | | | | | | | | | | | | |

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

| Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original |
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|---|---|---|---|
| NONE | | **Total Claims Allowed:** | |
| (Assistant Examiner) | (Date) | 2 | |
| /ALONZO CHAMBLISS/<br>Primary Examiner.Art Unit 2892 | 3/1/12 | O.G. Print Claim(s) | O.G. Print Figure |
| (Primary Examiner) | (Date) | 1 | 1B |



**WD EX1004**
**Western Digital v IP Bridge**
**Page 269**

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| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

7590 04/19/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER | |
|---|---|
| CHAMBLISS, ALONZO | |
| ART UNIT | PAPER NUMBER |
| 2897 | |

DATE MAILED: 04/19/2012

# PRIORITY ACKNOWLEDGMENT

☑ 1. Receipt is acknowledged of priority papers submitted under 35 U.S.C. 119. The papers have been placed of record in the file.

☐ 2. Applicant's claim for priority, based on papers filed in parent Application Number _____ submitted under 35 U.S.C. 119, is acknowledged.

☐ 3. The priority papers, submitted _____, after payment of the issue fee are

- ☐ acknowledged
  While the priority claim or certified copy filed will be placed in the file record, neither will be reviewed and the patent when published will not include the priority claim.
  See 37 CFR 1.55(a)(2).
- ☐ not acknowledged since the processing fee in 37 CFR 1.17(i) has not been received.

☐ 4. For utility and plant applications filed on or after November 29, 2000, the priority claim is not entered because the claim was not presented within the time limit required by 37 CFR 1.55(a)(1). A petition to accept a delayed claim for priority under 35 U.S.C. 119(a) - (d) or (f), or 365(a) may be filed. See 37 CFR 1.55(c) and MPEP 201.14(a).

571-272-4200 or 1-888-786-0101
Application Assistance Unit
Office of Data Management



PTOL-147 (Rev. 03/08)

OPAP WP3 JUN 07 2012 PATENT & TRADEMARK OFFICE

OFW/RCE

Customized PTO/SB/30 (04-09)

# REQUEST FOR CONTINUED EXAMINATION (RCE) Transmittal

Mail Stop RCE

| | |
|---|---|
| Application # | 12/923,643 |
| | |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2892 |
| Examiner | Alonzo Chambliss |
| Docket # | NAGI-0003 |

**This is a Request for Continued Examination under 37 CFR § 1.114 of the above-noted application.**

*RCE practice does not apply to any utility application filed prior to June 8, 1995, or to any design application. Prosecution must be closed.*

Submission **required** under 37 CFR § 1.114

*Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise (with a separate request for non-entry).*

☐ **Previously submitted**. *If a final Office action is outstanding, any amendments filed after the final Office action may be considered by the PTO as a submission even if the box for the following line is not checked.*

☐ Consider the arguments in the Response/Amendment previously filed on _____.

☐ Other:

☒ **Enclosed**

☒ Preliminary Amendment

☐ Affidavit(s)/Declaration

☐ Information Disclosure Citation

☐ Other:

Miscellaneous

☐ Applicant(s) hereby request and petition that the time for taking action in this case be extended pursuant to 37 C.F.R. § 1.136(a) for __-month.

☐ **Other:**

**FEES** calculated below (after reduction for an amendment if noted above).

| | *NOW* | *Basic/Previous Number* | *Present Extra* | *Rate* | $ |
|---|---|---|---|---|---|
| ☐ TOTAL CLAIMS | 4 | 2 | 0 | X $ 60 = | 0 |
| ☐ INDEPENDENT CLAIMS | 1 | 1 | 0 | X $ 250 = | |
| ☒ RCE fee required under 37 CFR 1.17(e) | | | | $ 930 = | 930 |
| | | | | **TOTAL OF ABOVE CALCULATIONS** = | 930 |
| ☐ Reduction by ½ for small entity status of applicant | | | | – | |
| | | | | **SUBTOTAL** = | |
| ☐ Extension of time fee for __-month | | | | = | |
| ☐ Other fee for | | | | = | |
| | | | | **TOTAL OF ALL FEES** = | **930** |

☒ Payment of **$930** is made by:

☒ **CREDIT CARD** (Form PTO-2038 is enclosed).

☐ **ELECTRONIC FUNDS TRANSFER** submitted herewith.

☒ The Director is authorized to charge any fee, additional fee or extension fee due in connection herewith to Deposit Account No. 12-0555:

(1) **if** no payment or an insufficient payment is enclosed and a fee is due in connection herewith; or

(2) **if** no petition for extension of time is enclosed but an EOT is required - and in this event, applicant hereby petitions under 37 CFR 1.136(a) for an extension of time of as many months as are required to render this submission timely.

Date: June 7, 2012

Douglas E Jacobson FR #28,518

Signed By Name: Juan Carlos A. Marquez.

Attorney of Record Registration No.: 34,072

**STITES & HARBISON PLLC** • 1199 North Fairfax St. • Suite 900 • Alexandria, VA 22314

TEL: 703-739-4900 • FAX: 703-739-9577 • CUSTOMER NO. 38327

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OPAP WP3
JUN 07 2012
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | |
|---|---|
| **In re U.S. Patent Application of** | |
| **YUASA** | **Art Unit 2892** |
| **Application Number: 12/923,643** | **Examiner** |
| **Filed: September 30, 2010** | **Alonzo Chambliss** |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE (AS AMENDED)** | |
| **Attorney Docket No. NAGI-0003** | |

**Mail Stop RCE**
**Commissioner for Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## PRELIMINARY AMENDMENT

Sir:

This is in response to the Notice of Allowance mailed on April 7, 2012. The period during which the issue fee and the publication fee can be paid is set to expire on June 7, 2012. A Request for Continued Examination (RCE) is being submitted concurrently herewith. Please amend the above-referenced application as follows:

**IN THE CLAIMS**

Claims 20 and 21 have been allowed in this application, wherein claim 20 is being amended to improve form, and wherein claims 23 and 24 are being newly added, as follows:

1-19. (Canceled).

20. (Currently Amended) A magnetoresistive device having a tunnel barrier junction structure, the magnetoresistive device comprising:

a first ferromagnetic material layer ~~having a~~of BCC structure;

a second ferromagnetic material layer ~~having a~~of a BCC structure; and

a ~~magnesium oxide~~tunnel barrier layer located between the first and second ferromagnetic material layers, and

wherein the ~~magnesium oxide~~tunnel barrier layer [[is]]comprises:

a single-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented or a poly- crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented, and

wherein the ~~magnesium oxide~~tunnel barrier layer has a tunnel barrier height $\varphi$ in a range of 0.2 to 0.5 eV.

21. (Previously Presented) The magnetoresistive device according to claim 20, wherein at least one of the first and second ferromagnetic material layers comprises CoFeB alloy.

22. (Canceled).

23. (New) The magnetoresistive device according to claim 20, wherein said tunnel barrier height $\varphi$ is obtained by fitting J-V characteristics of the tunnel barrier junction structure to an equation (1)

$$J= [(2m\varphi)^{1/2}/ \Delta s] (e/h)^2 \times \exp [-(4\pi\Delta s/h) \times (2m\varphi)^{1/2}] \times V \quad (1)$$

where J is a tunnel current density flowing through the tunnel barrier layer, V is an applied bias voltage that is 100 mV or smaller, m is a mass of the free electron, e is the elementary electric charge, h is the Planck's constant, $\Delta s$ is an effective thickness of the tunnel barrier layer that is approximately equivalent to ($T_{MgO}$ - 0.5 nm), and $t_{MgO}$ is an actual thickness of the tunnel barrier layer determined using a cross-sectional transmission electron microscope image.



WD EX1004
Western Digital v IP Bridge
Page 273

24. (New) The magnetoresistive device according to claim 20, wherein at least one of the first and second ferromagnetic material layers comprises CoFeB alloy.



WD EX1004
Western Digital v IP Bridge
Page 274

## REMARKS

The above amendments to the above-captioned application along with the following remarks are being submitted after the Notice of Allowance dated April 7, 2012, as a Preliminary Amendment under 37 C.F.R. § 1.114. A Request for Continued Examination (RCE) is being submitted concurrently herewith. In view of the above amendments and the following remarks, the Examiner is respectfully requested to give due reconsideration to this application, to confirm the allowability of the claims, and to pass this case to issue.

Status of the Claims

As outlined above, clams 20 and 21 have been allowed in this application, wherein claim 20 is being amended to improve form, and wherein claims 23 and 24 are being newly added. All amendments to the application are fully supported therein. For example, the amendments to the claims are supported by paragraphs [0050] and [0052] of the present application as originally filed. Applicants hereby submit that no new matter is being introduced into the application through the submission of this amendment.

The amendments to the claims being submitted herein merely embody corrections that have now been recognized as needed to properly describe and clarify the subject matter of claim 20 as provided in the Response submitted on February 14, 2012. These corrections are needed for proper protection of the invention as claimed. As the amendments to the claims merely correct the claims to more accurately correspond with the subject matter described in the specification, Applicants respectfully submit that the amendments will require no substantial amount of additional work on the part of the Office. In particular, the amendments will require neither an additional search nor more than a cursory review of the record.

Furthermore, Applicants respectfully submit that claim 20 as amended remains allowable over the prior art of record. Moreover, because claims 21, 23, and 24 depend either directly or indirectly from claim 20, Applicants respectfully submit that claims 21, 23, and 24 are allowable for at least the same reasons as claim 20.



WD EX1004
Western Digital v IP Bridge
Page 275

Conclusion

Favorable reconsideration of this application as amended is respectfully solicited. Should there be any outstanding issues requiring discussion that would further the prosecution and allowance of the above-captioned application, the Examiner is invited to contact the Applicants' undersigned representative at the address and telephone number indicated below.

Respectfully submitted,

Nicholas B. Trenkle
Registration Number 54,500

Douglas E. Jacobson FOR #28,518

Juan Carlos A. Marquez
Registration Number 34,072

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**June 7, 2012**

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**WD EX1004**
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**Page 276**

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# NOTICE OF ALLOWANCE AND FEE(S) DUE

38327 7590 06/29/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER |
|---|
| CHAMBLISS, ALONZO |

| ART UNIT | PAPER NUMBER |
|---|---|
| 2897 | |

DATE MAILED: 06/29/2012

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | NO | $1740 | $300 | $0 | $2040 | 10/01/2012 |

**THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.**

**THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.**

**HOW TO REPLY TO THIS NOTICE:**

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

**IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.**



PTOL-85 (Rev. 02/11)

**WD EX1004**
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**Page 277**

## PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail** **Mail Stop ISSUE FEE**
**Commissioner for Patents**
**P.O. Box 1450**
**Alexandria, Virginia 22313-1450**
**or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

38327 7590 06/29/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

**Certificate of Mailing or Transmission**

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | NO | $1740 | $300 | $0 | $2040 | 10/01/2012 |

| EXAMINER | ART UNIT | CLASS-SUBCLASS |
|---|---|---|
| CHAMBLISS, ALONZO | 2897 | 257-295000 |

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

38327 7590 06/29/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER | |
|---|---|
| CHAMBLISS, ALONZO | |
| ART UNIT | PAPER NUMBER |
| 2897 | |

DATE MAILED: 06/29/2012

**Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)**
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.



PTOL-85 (Rev. 02/11)

## Privacy Act Statement

**The Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

| Notice of Allowability | Application No. | Applicant(s) | |
|---|---|---|---|
| | 12/923,643 | YUASA, SHINJI | |
| | Examiner | Art Unit | |
| | ALONZO CHAMBLISS | 2897 | |

***-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--***

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *the RCE filed on 6/7/12*.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *20,21,23 and 24*.
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☐ All b) ☐ Some* c) ☐ None of the:
      1. ☐ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
**THIS THREE-MONTH PERIOD IS NOT EXTENDABLE**.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.
6. ☐ CORRECTED DRAWINGS ( as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review ( PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   **Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).**
7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

**Attachment(s)**

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☒ Other *see Detailed Action*.

## DETAILED ACTION

### *Continued Examination Under 37 CFR 1.114*

1. A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after allowance or after an Office action under *Ex Parte Quayle*, 25 USPQ 74, 453 O.G. 213 (Comm'r Pat. 1935). Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, prosecution in this application has been reopened pursuant to 37 CFR 1.114. Applicant's submission filed on 6/7/12 has been entered.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Any inquiry concerning the communication or earlier communications from the examiner should be directed to Alonzo Chambliss whose telephone number is (571) 272-1927.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Fernando L. Toledo can be reached on (571) 272-1867. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system Status information for

published applications may be obtained from either Private PMR or Public PMR. Status information for unpublished applications is available through Private PMR only. For more information about the PMR system see http://pair-kect.uspto.gov. Should you have questions on access to the Private PMR system contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free) or EBC_Support@uspto.gov.

AC/June 21, 2012 /Alonzo Chambliss/

Primary Examiner, Art Unit 2897

| Search Notes | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | Examiner | Art Unit |
| | Alonzo Chambliss | 2892 |

| SEARCHED | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| | | | |

| SEARCH NOTES | | |
|---|---|---|
| Search Notes | Date | Examiner |
| East text search only - see attach printout | 12/16/10 | AC |
| Updated previous East text search only - see attached printout | 7/18/11 | AC |
| Updated previous East text serach only - see attached printout | 11/6/11 | AC |
| Updated previous East text search only - see attached printout | 3/1/12 | AC |
| Updated previous East text search only - see attached printout | 6/21/12 | AC |

| INTERFERENCE SEARCH | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| 257 | 4,295,421,427 | 3/1/12 | AC |
| 365 | 171 | 3/1/12 | AC |
| 257 | 4,295,421,427 | 6/21/12 | AC |
| 365 | 171 | 6/21/12 | AC |
| 438 | 3 | 6/21/12 | AC |

**EAST Search History**

**EAST Search History (Prior Art)**

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 704 | "257"/$.ccls. and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:53 |
| L2 | 337 | "257"/$.ccls. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:54 |
| L3 | 529 | "365"/$.ccls. and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:55 |
| L4 | 233 | "365"/$.ccls. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:55 |
| L5 | 226 | "438"/$.ccls. and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:55 |
| L6 | 175 | 257/E29.323 and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:55 |
| L7 | 9 | 257/E27.104 and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:56 |
| L8 | 12 | 257/E29.164 and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:56 |
| L9 | 8 | 257/E21.208 and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:56 |
| L10 | 65 | yuasa.in. and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:56 |

| | | | | | | |
|---|---|---|---|---|---|---|
| L11 | 17 | japan adj2 science.as. and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:56 |
| L12 | 15 | national adj3 institute adj3 advanced adj2 industrial.as. and (Fe ferromagnetic) and (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/06/21 18:57 |

**EAST Search History (Interference)**

< This search history is empty>

**6/ 21/ 2012 6:59:36 PM**
**C:\ Users\ achambliss\ Documents\ EAST\ Workspaces\ 12652379.wsp**



WD EX1004
Western Digital v IP Bridge
Page 286

| Issue Classification | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | **Examiner** | **Art Unit** |
| | ALONZO CHAMBLISS | 2892 |

| ORIGINAL | | INTERNATIONAL CLASSIFICATION | |
|---|---|---|---|
| CLASS | SUBCLASS | CLAIMED | NON-CLAIMED |
| 257 | 295 | H 0 1 L 27 / 108 (2006.0) | |
| CROSS REFERENCE(S) | | G 1 1 C 11 / 14 (2006.0) | |
| | | H 0 1 L 21 / 00 (2006.01.01) | |

| CLASS | SUBCLASS (ONE SUBCLASS PER BLOCK) | | | | |
|---|---|---|---|---|---|
| 257 | 427 | E29.323 | E27.104 | E29.164 | E21.208 |
| 365 | 171 | | | | |
| 438 | 3 | | | | |

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

| Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 17 | | 33 | | | | | | | | | | |
| | 2 | | 18 | | 34 | | | | | | | | | | |
| | 3 | | 19 | | 35 | | | | | | | | | | |
| | 4 | 1 | 20 | | 36 | | | | | | | | | | |
| | 5 | 2 | 21 | | 37 | | | | | | | | | | |
| | 6 | | 22 | | 38 | | | | | | | | | | |
| | 7 | 3 | 23 | | 39 | | | | | | | | | | |
| | 8 | 4 | 24 | | 40 | | | | | | | | | | |
| | 9 | | 25 | | 41 | | | | | | | | | | |
| | 10 | | 26 | | 42 | | | | | | | | | | |
| | 11 | | 27 | | 43 | | | | | | | | | | |
| | 12 | | 28 | | 44 | | | | | | | | | | |
| | 13 | | 29 | | 45 | | | | | | | | | | |
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| | 15 | | 31 | | | | | | | | | | | | |
| | 16 | | 32 | | | | | | | | | | | | |

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|---|---|---|---|
| NONE | | **Total Claims Allowed:** | |
| (Assistant Examiner) | (Date) | 4 | |
| /ALONZO CHAMBLISS/<br>Primary Examiner.Art Unit 2892 | 6/21/12 | O.G. Print Claim(s) | O.G. Print Figure |
| (Primary Examiner) | (Date) | 1 | 1B |



WD EX1004
Western Digital v IP Bridge
Page 287

OPAP IAP3 JUL 16 2012 PATENT & TRADEMARK OFFICE

RCE/RCE

Customized PTO/SB/30 (04-09)

# REQUEST FOR CONTINUED EXAMINATION (RCE) Transmittal

Mail Stop RCE

| | |
|---|---|
| Application # | 12/923,643 |
| | |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2892 |
| Examiner | Alonzo Chambliss |
| Docket # | NAGI-0003 |

**This is a Request for Continued Examination under 37 CFR § 1.114 of the above-noted application.**

*RCE practice does not apply to any utility application filed prior to June 8, 1995, or to any design application. Prosecution must be closed.*

Submission **required** under 37 CFR § 1.114

*Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise (with a separate request for non-entry).*

☐ **Previously submitted**. *If a final Office action is outstanding, any amendments filed after the final Office action may be considered by the PTO as a submission even if the box for the following line is not checked.*

☐ Consider the arguments in the Response/Amendment previously filed on _____.

☐ Other:

☒ **Enclosed**

☐ Preliminary Amendment

☐ Affidavit(s)/Declaration

☒ Information Disclosure Citation

☐ Other:

**Miscellaneous**

☐ Applicant(s) hereby request and petition that the time for taking action in this case be extended pursuant to 37 C.F.R. § 1.136(a) for __-month.

☐ **Other:**

**FEES** calculated below (after reduction for an amendment if noted above).

| | *NOW* | *Basic/Previous Number* | *Present Extra* | *Rate* | $ |
|---|---|---|---|---|---|
| ☐ TOTAL CLAIMS | 4 | 2 | 0 | X $ 60 = | |
| ☐ INDEPENDENT CLAIMS | 1 | 1 | 0 | X $ 250 = | |
| ☒ RCE fee required under 37 CFR 1.17(e) | | | | $ 930 = | 930 |
| | | | | TOTAL OF ABOVE CALCULATIONS = | 930 |
| ☐ Reduction by ½ for small entity status of applicant | | | | – | |
| | | | | SUBTOTAL = | |
| ☐ Extension of time fee for __-month | | | | = | |
| ☐ Other fee for | | | | = | |
| | | | | **TOTAL OF ALL FEES =** | **930** |

☒ Payment of **$930** is made by:

☒ CREDIT CARD (Form PTO-2038 is enclosed).

☐ ELECTRONIC FUNDS TRANSFER submitted herewith.

☒ The Director is authorized to charge any fee, additional fee or extension fee due in connection herewith to Deposit Account No. 12-0555:

(1) if no payment or an insufficient payment is enclosed and a fee is due in connection herewith; or

(2) if no petition for extension of time is enclosed but an EOT is required - and in this event, applicant hereby petitions under 37 CFR 1.136(a) for an extension of time of as many months as are required to render this submission timely.

Date: July 16, 2012

Douglas E. Jacobson for #28,518

Signed By Name: Juan Carlos A. Marquez.
Attorney of Record Registration No.: 34,072

**STITES & HARBISON PLLC** • 1199 North Fairfax St. • Suite 900 • Alexandria, VA 22314
TEL: 703-739-4900 • FAX: 703-739-9577 • CUSTOMER NO. 38327

07/17/2012 LNGUYEN1 00000041 12923643
01 FC:1801 930.00 OP

254161:1:ALEXANDRIA

OPAP IAP3
JUL 16 2012
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

| | |
|---|---|
| **In re U.S. Patent Application of** | **Confirmation No. 8219** |
| **YUASA** | **Group Art Unit 2897** |
| **Application Number: 12/923,643** | **Examiner:** |
| **Filed: September 30, 2010** | **Alonzo Chambliss** |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE** | |
| **Attorney Docket No. NAGI-0003** | |

**Commissioner of Patents**
**PO Box 1450**
**Alexandria, VA 22313-1450**

## INFORMATION DISCLOSURE STATEMENT

Sir:

Pursuant to 37 C.F.R. §§ 1.56 and 1.97, this Information Disclosure Statement is being submitted in connection with the above-identified patent application. A listing of documents to be published on the face of any patent granted from this application is submitted herewith on the accompanying Form PTO-1449. Any other documents or information submitted for consideration by the Examiner are listed in this paper. A copy of each non-US or foreign patent or non-patent publication or any portion thereof listed or herein identified is submitted herewith.

### CERTIFICATION

1. This Information Disclosure Statement is being submitted:

[x ] **(a)** Concurrently with the RCE application or not more that three months from the filing date [of the RCE of the above-identified U.S. patent application, whereby it is believed that no fee is due; OR

[ ] **(b)** Within three months of the filing date of the RCE in the above-identified U.S. patent application but before the mailing date of the first Office Action on the merits of the above-identified application, whereby it is believed that no fee is due; OR

[ ] **(c)** After three months from the filing date of the above-identified U.S. patent application and after the mailing date of the first Office Action on the merits of the above-identified application, but prior to the issuance of any Final Action or Notice of Allowance sent in

such application, whereby Applicant(s) hereby submit the requisite certification hereinbelow, or authorization for the payment of the requisite fee is attached; OR

[ ] **(d)** After the issuance of a Final Action or Notice of Allowance, but before the payment of the Issue Fee, whereby Applicant(s) hereby submit the requisite certification hereinbelow, and the attached authorization for the payment of the requisite fee.

**2.** In accordance with the requirements of 37 C.F.R. §1.97, and Parts 1(c) or 1(d) above, Applicant(s) hereby certify that:

[ ] Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; OR

[ ] No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Please charge any additional fees or credit any overpayments in connection with the submission of this Information Disclosure Statement to Deposit Account No 12-0555.

The Examiner is requested to acknowledge receipt and consideration of the information provided in this paper in accordance with prescribed procedures.

Respectfully submitted,

Douglas E Jackson FOR #28,518

Juan Carlos A. Marquez
Registration Number 34,072

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**July 16, 2012**

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**WD EX1004**
**Western Digital v IP Bridge**
**Page 290**

OPAP IAP3 JUL 16 2012 PATENT & TRADEMARK OFFICE

*Customized* PTO/SB/08a+b (07-09)

| *Substitute for Form 1449/PTO* | | |
|---|---|---|
| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** | Application # | 12/923,643 |
| | Confirmation # | 8219 |
| | Filing Date | June 29, 2012 |
| | First Inventor | YUASA |
| | Art Unit | 2897 |
| | Examiner | Alonzo Chambliss |
| Sheet 1 of 5 | Docket # | NAGI-0003 |

| ***U.S. PATENT DOCUMENTS*** | | | | |
|---|---|---|---|---|
| **Exam. Initial*** | **Document No. Number – Kind Code** | **Publ. Date MM-DD-YYYY** | **Name Patentee or Applicant** | **Relevance Passages/Figs.** |
| | 2008/0055793 [8] | 03-06-2008 | Djayaprawira et al. | |
| | 2006/0056115 [10] | 03-16-2006 | Djayaprawira et al. | |
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| U.S. PATENT DOCUMENTS | | | | |
|---|---|---|---|---|
| **Exam. Initial*** | **Document No.** Number – Kind Code | **Publ. Date** MM-DD-YYYY | **Name** Patentee or Applicant | **Relevance** Passages/Figs. |
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| FOREIGN PATENT DOCUMENTS | | | | | |
|---|---|---|---|---|---|
| **Exam. Initial*** | **Country-Number-Kind Code** [if known] | **Publ. Date** MM-DD-YYYY | **Name** Patentee or Applicant | **Relevance** Passages/ Figs. | **Trans-lation** |
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| | | | | | |

## NON PATENT LITERATURE DOCUMENTS

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
|---|---|---|
| | Office Action issued from Japanese Patent Office, in corresponding Japanese Patent Application No. 2011-226907, dated January 31, 2012, pp. 1-3. | Yes |
| | ARAKI et al., "Fabrication and Electric Properties of Lapped Type of TMR Heads for ~50 Gb/In$^2$ and Beyond," IEEE Transactions on Magnetics, Vol. 38, No. 1, pp. 72-77, January 2002 | Yes |
| | David D. DJAYAPRAWIRA et al., "230% Room-Temperature Magnetoresistance in CoFeB/MgO/CoFeB Magnetic Tunnel Junctions," Applied Physics Letters, Vol. 86, 092501-092502-3, February 23, 2005. | Yes |
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| | David D. DJAYAPRAWIRA et al., "Novel Sputtering Technology of Magnetic Tunnel Junctions for MRAM Application," Papers 01 the 66$^{th}$ Symposium on Semiconductors and Integrated Circuits Technology, Vol. 66, pp. 58-61, 2004 | Yes |
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| | H. DOMON et al. "Reduction of Magnetic Interaction in CoB/Pd Multilayer Perpendicular Media Using a Phase-Separated Pd-SiO Underlayer," Journal of Applied Physics, Vol. 93, No. 10, pp. 8164-8166, May 15, 2003. | Yes |
| | Extended European Search Report, issued from European Patent Office, of European Application No. 08159511.8, dated June 5, 2009. | Yes |
| | T. KAKUTA et al., " Novel PVD Tool for Magnetoresistive Random Access Memory (MRAM) Mass Production," Anelva Technical Report, Vol. 10, pp, 27-33, January 25, 2004. | Abstract |
| | A. KOBAYASHI et al., "TMR Devices Fabricated with RIE Etching Using Co+ $NH_3$," Journal of the Magnetics Society of Japan, Vol. 28, No. 2, February 1, 2004. | Abstract |
| | J.S. MOODERA et al., "Large Magnetoresistance at Room Temperature in Ferromagnetic Thin Film Tunnel Junctions," Physical Review Letters, Vol. 74, No. 16, pp. 3273-3276, April 17, 1995. | Yes |
| | J.S. MOODERA, "Interface Magnetism and Spin Wave Scattering in Ferromagnet-Insulator-Ferromagnet Tunnel Junctions," Physical Review Letters, Vol. 80, No. 13, pp. 2941-2944, March 30, 1998. | Yes |
| | J. MURAI et al., "Direct Observation of Magnon Excitation in a Ferromagnetic Tunnel Junction Using Inelastic-Electron-Tunneling Spectroscopy," Japanese Journal of Applied Physics, Vol. 38, pp. L1106-L1108, October 1, 1999. | Yes |
| | K. NAGASAKA et al., "CPP Operational Mode of GMR Head," Fujitsu Sci. Tech. J., Vol. 37, No. 2, pp. 192-200, December 2001. | Yes |
| | T. OSADA et al., "Dry Etching of Magnetic Thin Film Stacks Using CO/$NH_3$ and $CH_3OH$ Gases for Tunneling Magneto-Resistance Devices," 2004 Dry Process International Symposium, Vol. 4, pp. 127-131, 2004. | Yes |

| ***NON PATENT LITERATURE DOCUMENTS*** | | |
|---|---|---|
| **Exam. Initial*** | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | **Translation** |
| | Stuart S.P. PARKIN et al." Giant Tunnelling Magnetoresistance At Room Temperature with MgO (100) Tunnel Barriers," Nature Materials, Vol, 3, pp. 862-867, December 2004. | Yes |
| | M. TAKAGISHI et al., "The Applicability of CPP-GMR Heads for Magnetic Recording," IEEE Transactions on Magnetics, Vol. 38, No. 5, pp. 2277-2282, September 2002. | Yes |
| | A. TANAKA et al., "Spin-Valve Heads in the Current-Perpendicular-to-Plane Mode for Ultrahigh-Density Recording," IEEE Transactions on Magnetics, Vol. 38, No. 1, January 2002. | Yes |
| | K. TSUNEKAWA et al., "Surface Treatment Techniques in Fabrication of GMR and TMR Films, "Journal of the Magnetics Society of Japan, Vol. 28, No. 11, pp. 1074-1080, November 1, 2004. | Yes |
| | D. WANG et al., "70% TMR at Room Temperature for SDT Sandwich Junctions With CoFeB as Free and Reference Layers," IEEE Transactions on Magnetics, Vol. 40, No. 4, pp. 2270-2271, July 2004. | Yes |
| | S. YOSHIMURA et al., " Magnetic Grain Size Reduction by Using Oxygen Exposure Process Onto Very Thin Islandlike WCr Seedlayer in Longitudinal Recording Media," Journal of Applied Physics, Vol. 91, No. 10, pp. 8629-8631, May 15, 2002. | Yes |
| | S. YOSHIMURA et al. "Grain Size Reduction by Utilizing A Very Thin, High-Melting-Point WCr Seedlayer in Longitudinal Media: Media Noise Reduction in High $H_k^{grain}$ Media, Vol. 25, No. 4-2, pp. 627-630 (2001). | Abstract |
| | YU et al., "Electron Transport Properties in Magnetic Tunnel Junctions with Epitaxial NiFe (111) Ferromagnetic Bottom Electrodes," Applied Physics Letters, Vol. 82, No. 26, pp. 4735-4737, June 30, 2003. | Yes |
| | S. YUASA et al. "Magnetic Tunnel Junctions With Single-Crystal Electrodes: A Crystal Anisotropy of Tunnel Magneto-Resistance," Europhysics Letters, Vol. 52, No. 3, pp. 344-350 November 1, 2000. | Yes |
| | S. YUASA et al., " High Tunnel Magnetoresistance at Room Temperature in Fully Epitaxial Fe/MgO/Fe Tunnel Junctions due to Coherent Spin-Polarized Tunneling," Japanese Journal of Applied Physics Vol. 43, No. 4B, 2004, pp. L588-L590. | Yes |
| | S. YUASA et al., "Giant Room-Temperature Magnetoresistance in Single-Crystal Fe/MgO/Fe Magnetic Tunnel Junctions," Nature Materials Vol. 3, pp. 868-871, October 31, 2004 | Yes |
| | S. YUASA et al., "Spin-Polarized Resonant Tunneling In Magnetic Tunnel Junctions," Science, Vol. 297, pp. 234-237, July 12, 2002. | Yes |

| Sheet 5 of 5 | US Patent Application No. 12/923,643 | Docket No.: NAGI-0003 |
|---|---|---|
| | | |
| | S. Zhang et al. "Quenching of Magnetoresistance by Hot Electrons in Magnetic Tunnel Junctions," Physical Review Letters, Vol. 79, No. 19, pp. 3744-3747, November 10, 1997. | Yes |
| | | |
| | | |

| Examiner Signature | | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

[3] Corresponds to JP 2002-359413, JP 2003-086863 and KR 2003-0097904
[4] Corresponds to JP 2004-12805 listed above
[5] Corresponds to JP 2004-153258 listed above
[6] Corresponds to KR 2002-0042448 listed above
[7] Corresponds to US 2006-0003185 listed above
[8] Corresponds to JP 2006-080116 and US 2006-0056115 listed above
[9] Corresponds to JP 2002-270790 listed above
[10] Corresponds to EP 1633007 and Extended Search Report of EP Application No. 08 159 511.8
[11] Corresponds to US 2008-0062581

254002:1:ALEXANDRIA

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

# NOTICE OF ALLOWANCE AND FEE(S) DUE

38327 7590 08/07/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER |
|---|
| CHAMBLISS, ALONZO |

| ART UNIT | PAPER NUMBER |
|---|---|
| 2897 | |

DATE MAILED: 08/07/2012

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | NO | $1740 | $300 | $0 | $2040 | 11/07/2012 |

**THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.**

**THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.**

**HOW TO REPLY TO THIS NOTICE:**

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

**IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.**



PTOL-85 (Rev. 02/11)

**WD EX1004**
**Western Digital v IP Bridge**
**Page 296**

## PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail** **Mail Stop ISSUE FEE**
**Commissioner for Patents**
**P.O. Box 1450**
**Alexandria, Virginia 22313-1450**
**or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

38327 7590 08/07/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

**Certificate of Mailing or Transmission**

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | NO | $1740 | $300 | $0 | $2040 | 11/07/2012 |

| EXAMINER | ART UNIT | CLASS-SUBCLASS |
|---|---|---|
| CHAMBLISS, ALONZO | 2897 | 257-295000 |

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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**Page 297**

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| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

38327 7590 08/07/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER | |
|---|---|
| CHAMBLISS, ALONZO | |
| ART UNIT | PAPER NUMBER |
| 2897 | |

DATE MAILED: 08/07/2012

**Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)**
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.



PTOL-85 (Rev. 02/11)

## Privacy Act Statement

**The Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

| Notice of Allowability | Application No. | Applicant(s) | |
|---|---|---|---|
| | 12/923,643 | YUASA, SHINJI | |
| | Examiner | Art Unit | |
| | ALONZO CHAMBLISS | 2897 | |

***-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--***

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *the RCE filed on 7/16/12*.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are *20,21,23 and 24*.

4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☒ All b) ☐ Some* c) ☐ None of the:
      1. ☒ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
**THIS THREE-MONTH PERIOD IS NOT EXTENDABLE**.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

6. ☐ CORRECTED DRAWINGS ( as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review ( PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   **Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).**

7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

**Attachment(s)**

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 7/16/12
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☒ Other *See Detailed Action*.

## DETAILED ACTION

### *Continued Examination Under 37 CFR 1.114*

1. A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after allowance or after an Office action under *Ex Parte Quayle*, 25 USPQ 74, 453 O.G. 213 (Comm'r Pat. 1935). Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, prosecution in this application has been reopened pursuant to 37 CFR 1.114. Applicant's submission filed on 7/16/12 has been entered.

### *Information Disclosure Statement*

2. The information disclosure statement (IDS) submitted on 7/16/12 was filed before the mailing date of the notice of allowance on 7/27/12. The submission is in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Any inquiry concerning the communication or earlier communications from the examiner should be directed to Alonzo Chambliss whose telephone number is (571) 272-1927.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Fernando L. Toledo can be reached on (571) 272-1867. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system Status information for published applications may be obtained from either Private PMR or Public PMR. Status information for unpublished applications is available through Private PMR only. For more information about the PMR system see http://pair-kect.uspto.gov. Should you have questions on access to the Private PMR system contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free) or EBC_Support@uspto.gov.

**AC**/July 27, 2012 /Alonzo Chambliss/

Primary Examiner, Art Unit 2897

| Search Notes | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | Examiner | Art Unit |
| | Alonzo Chambliss | 2892 |

| SEARCHED | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| | | | |

| SEARCH NOTES | | |
|---|---|---|
| Search Notes | Date | Examiner |
| East text search only - see attach printout | 12/16/10 | AC |
| Updated previous East text search only - see attached printout | 7/18/11 | AC |
| Updated previous East text serach only - see attached printout | 11/6/11 | AC |
| Updated previous East text search only - see attached printout | 3/1/12 | AC |
| Updated previous East text search only - see attached printout | 6/21/12 | AC |
| Updated previous East text search only - see attached printout | 7/27/12 | AC |

| INTERFERENCE SEARCH | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| 257 | 4,295,421,427 | 3/1/12 | AC |
| 365 | 171 | 3/1/12 | AC |
| 257 | 4,295,421,427 | 6/21/12 | AC |
| 365 | 171 | 6/21/12 | AC |
| 438 | 3 | 6/21/12 | AC |
| 257 | 4,295,421,427 | 7/27/12 | AC |
| 365 | 171 | 7/27/12 | AC |
| 438 | 3 | 7/27/12 | AC |

*Customized* PTO/SB/08a+b (07-09)

*Substitute for Form 1449/PTO*

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

| | |
|---|---|
| Application # | 12/923,643 |
| Confirmation # | 8219 |
| Filing Date | June 29, 2012 |
| First Inventor | YUASA |
| Art Unit | 2897 |
| Examiner | Alonzo Chambliss |
| Docket # | NAGI-0003 |

Sheet 1 of 5

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| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
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*Customized* PTO/SB/08a+b (07-09)

| Sheet 2 of 5 | US Patent Application No. 12/293,643 | Docket No.: NAGI-0003 |
|---|---|---|

| U.S. PATENT DOCUMENTS | | | | |
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| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
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| | | | | | |

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| Sheet 3 of 5 | US Patent Application No. 12/293,643 | Docket No. NAGI-0003 |
|---|---|---|

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| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
|---|---|---|
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| | | | |
| Examiner Signature | /Alonzo Chambliss/ (07/27/2012) | Date Considered | |

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

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[4] Corresponds to JP 2004-12805 listed above
[5] Corresponds to JP 2004-153258 listed above
[6] Corresponds to KR 2002-0042448 listed above
[7] Corresponds to US 2006-0003185 listed above
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[11] Corresponds to US 2008-0062581

254002:1:ALEXANDRIA

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

**EAST Search History**

**EAST Search History (Prior Art)**

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 345 | "257"/$.ccls. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/07/27 13:05 |
| L2 | 240 | "365"/$.ccls. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/07/27 13:06 |
| L3 | 122 | "438"/$.ccls. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/07/27 13:07 |
| L4 | 114 | 257/E29.323 and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/07/27 13:07 |
| L5 | 5 | 257/E27.104 and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/07/27 13:07 |
| L6 | 6 | 257/E29.164 and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/07/27 13:07 |
| L7 | 25 | yuasa.in. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/07/27 13:07 |
| L8 | 13 | japan adj2 science.as. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/07/27 13:08 |
| L11 | 11 | national adj2 institute adj2 advanced adj2 industrial.as. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide) and magnetic adj3 device | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/07/27 13:09 |

**EAST Search History (Interference)**

<This search history is empty>

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**C:\ Users\ achambliss\ Documents\ EAST\ Workspaces\ 12652379.wsp**



**WD EX1004**
**Western Digital v IP Bridge**
**Page 310**

| Issue Classification | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | **Examiner** | **Art Unit** |
| | ALONZO CHAMBLISS | 2892 |

| ORIGINAL | | INTERNATIONAL CLASSIFICATION | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLASS | SUBCLASS | CLAIMED | | | | | | | | | | NON-CLAIMED | | | | |
| 257 | 295 | H | 0 | 1 | L | 27 / 108 (2006.0) | | | | | | | | | | |
| CROSS REFERENCE(S) | | G | 1 | 1 | C | 11 / 14 (2006.0) | | | | | | | | | | |
| | | H | 0 | 1 | L | 21 / 00 (2006.0) | | | | | | | | | | |

| CLASS | SUBCLASS (ONE SUBCLASS PER BLOCK) | | | | |
|---|---|---|---|---|---|
| 257 | 427 | E29.323 | E27.104 | E29.164 | E21.208 |
| 365 | 171 | | | | |
| 438 | 3 | | | | |

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

| Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 17 | | 33 | | | | | | | | | | |
| | 2 | | 18 | | 34 | | | | | | | | | | |
| | 3 | | 19 | | 35 | | | | | | | | | | |
| | 4 | 1 | 20 | | 36 | | | | | | | | | | |
| | 5 | 2 | 21 | | 37 | | | | | | | | | | |
| | 6 | | 22 | | 38 | | | | | | | | | | |
| | 7 | 3 | 23 | | 39 | | | | | | | | | | |
| | 8 | 4 | 24 | | 40 | | | | | | | | | | |
| | 9 | | 25 | | 41 | | | | | | | | | | |
| | 10 | | 26 | | 42 | | | | | | | | | | |
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| | 16 | | 32 | | | | | | | | | | | | |

| NONE<br><br>(Assistant Examiner) (Date) | **Total Claims Allowed:**<br>4 | |
|---|---|---|
| /ALONZO CHAMBLISS/<br>Primary Examiner.Art Unit 2892 7/27/12<br><br>(Primary Examiner) (Date) | O.G. Print Claim(s)<br>1 | O.G. Print Figure<br>1B |



**WD EX1004**
**Western Digital v IP Bridge**
**Page 311**

OPAP
AUG 21 2012
PATENT AND TRADEMARK OFFICE
WP3

DFW/RCE

Customized PTO/SB/30 (04-09)

# REQUEST FOR CONTINUED EXAMINATION (RCE) Transmittal

Mail Stop RCE

| | |
|---|---|
| Application # | 12/923,643 |
| | |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2892 |
| Examiner | Alonzo Chambliss |
| Docket # | NAGI-0003 |

**This is a Request for Continued Examination under 37 CFR § 1.114 of the above-noted application.**

*RCE practice does not apply to any utility application filed prior to June 8, 1995, or to any design application. Prosecution must be closed.*

Submission **required** under 37 CFR § 1.114

*Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise (with a separate request for non-entry).*

☐ **Previously submitted.** *If a final Office action is outstanding, any amendments filed after the final Office action may be considered by the PTO as a submission even if the box for the following line is not checked.*

☐ Consider the arguments in the Response/Amendment previously filed on _____.

☐ Other:

☒ **Enclosed**

☐ Preliminary Amendment

☐ Affidavit(s)/Declaration

☒ Information Disclosure Citation

☐ Other:

Miscellaneous

☐ Applicant(s) hereby request and petition that the time for taking action in this case be extended pursuant to 37 C.F.R. § 1.136(a) for __-month.

☐ **Other:**

**FEES** calculated below (after reduction for an amendment if noted above).

| | *NOW* | *Basic/Previous Number* | *Present Extra* | *Rate* | $ |
|---|---|---|---|---|---|
| ☐ TOTAL CLAIMS | 4 | 2 | 0 | X $ 60 = | |
| ☐ INDEPENDENT CLAIMS | 1 | 1 | 0 | X $ 250 = | |
| ☒ RCE fee required under 37 CFR 1.17(e) | | | | $ 930 = | 930 |
| | | | | **TOTAL OF ABOVE CALCULATIONS** = | 930 |
| ☐ Reduction by ½ for small entity status of applicant | | | | – | |
| | | | | **SUBTOTAL** = | |
| ☐ Extension of time fee for __-month | | | | = | |
| ☐ Other fee for | | | | = | |
| | | | | **TOTAL OF ALL FEES =** | **930** |

☒ Payment of **$930** is made by: ☒ **CREDIT CARD** (Form PTO-2038 is enclosed).

☐ **ELECTRONIC FUNDS TRANSFER** submitted herewith.

☒ The Director is authorized to charge any fee, additional fee or extension fee due in connection herewith to Deposit Account No. 12-0555:

(1) **if** no payment or an insufficient payment is enclosed and a fee is due in connection herewith; or

(2) **if** no petition for extension of time is enclosed but an EOT is required - and in this event, applicant hereby petitions under 37 CFR 1.136(a) for an extension of time of as many months as are required to render this submission timely.

Date: August 21, 2012

Signed By / Name: Juan Carlos A. Marquez.

Attorney of Record Registration No.: 34,072

**STITES & HARBISON PLLC** • 1199 North Fairfax St. • Suite 900 • Alexandria, VA 22314

TEL: 703-739-4900 • FAX: 703-739-9577 • CUSTOMER NO. 38327

258403:1:ALEXANDRIA

08/22/2012 HVUONG1 00000005 12923643

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OPAP IAP3
AUG 21 2012
PATENT & TRADEMARK OFFICE

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

| | | |
|---|---|---|
| **In re U.S. Patent Application of** | ) | **Confirmation No. 8219** |
| | ) | |
| **YUASA** | ) | |
| | ) | **Art Unit 2897** |
| **U.S. Patent Application No.: 12/923,643** | ) | |
| | ) | **Examiner:** |
| **Filed: September 30, 2010** | ) | **Alonzo Chambliss** |
| | ) | |
| **For: MAGNETIC TUNNEL JUNCTION DEVICE** | ) | |
| | ) | |
| **Attorney Docket No. NAGI-0003** | ) | |

**Commissioner of Patents**
**PO Box 1450**
**Alexandria, VA 22313-1450**

## INFORMATION DISCLOSURE STATEMENT

Sir:

Pursuant to 37 C.F.R. §§ 1.56 and 1.97, this Information Disclosure Statement is being submitted in connection with the above-identified patent application. A listing of documents to be published on the face of any patent granted from this application is submitted herewith on the accompanying Form PTO-1449. Any other documents or information submitted for consideration by the Examiner are listed in this paper. A copy of each non-US or foreign patent or non-patent publication or any portion thereof listed or herein identified is submitted herewith.

### CERTIFICATION

**1.** This Information Disclosure Statement is being submitted:

[x ] **(a)** Concurrently with the RCE application or not more that three months from the filing date of the RCE of the above-identified U.S. patent application, whereby it is believed that no fee is due; OR

[ ] **(b)** Within three months of the filing date of the RCE in the above-identified U.S. patent application but before the mailing date of the first Office Action on the merits of the above-identified application, whereby it is believed that no fee is due; OR

[ ] **(c)** After three months from the filing date of the above-identified U.S. patent application and after the mailing date of the first Office Action on the merits of the above-identified application, but prior to the issuance of any Final Action or Notice of Allowance sent in

such application, whereby Applicant(s) hereby submit the requisite certification hereinbelow, or authorization for the payment of the requisite fee is attached; OR

[ ] **(d)** After the issuance of a Final Action or Notice of Allowance, but before the payment of the Issue Fee, whereby Applicant(s) hereby submit the requisite certification hereinbelow, and the attached authorization for the payment of the requisite fee.

2. In accordance with the requirements of 37 C.F.R. §1.97, and Parts 1(c) or 1(d) above, Applicant(s) hereby certify that:

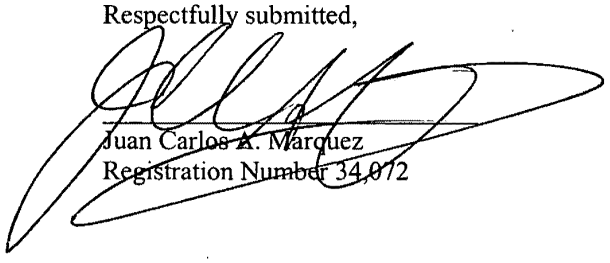
[ ] Each item of information contained in this Information Disclosure Statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this Information Disclosure Statement; OR

[ ] No item of information contained in this Information Disclosure Statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of this Information Disclosure Statement.

Please charge any additional fees or credit any overpayments in connection with the submission of this Information Disclosure Statement to Deposit Account No 12-0555.

The Examiner is requested to acknowledge receipt and consideration of the information provided in this paper in accordance with prescribed procedures.

Respectfully submitted,



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Registration Number 34,072

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**August 21, 2012**

#258413-v1-IDS.doc



**WD EX1004**
**Western Digital v IP Bridge**
**Page 314**

OPAP WP3
AUG 21 2012
PATENT & TRADEMARK OFFICE

*Customized* PTO/SB/08a+b (07-09)

*Substitute for Form 1449/PTO*

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Sheet 1 of 1

| | |
|---|---|
| Application # | 12/923,643 |
| Confirmation # | 8219 |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2897 |
| Examiner | Alonzo Chambliss |
| Docket # | NAGI-0003 |

## *U.S. PATENT DOCUMENTS*

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
| | | | | |
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## *FOREIGN PATENT DOCUMENTS*

| Exam. Initial* | Country-Number-Kind Code [if known] | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
|---|---|---|---|---|---|
| | EP 0 145 403 A2 | 06-19-1985 | Energy Conversion Devices, Inc. | | Yes |
| | EP 1 061 592 A2 | 12-20-2000 | Matsushita Electric Industrial Co., Ltd. | | Yes |
| | | | | | |
| | | | | | |

## *NON PATENT LITERATURE DOCUMENTS*

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
|---|---|---|
| | N. INABA et al., "Magnetic and Crystallographic Properties of Co-Cr-Pt Longitudinal Media Prepared on MgO Seedlayers Deposited by ECR Sputtering," IEEE Transactions on Magnetics,vol. 36, No. 5, September 2000, pp. 2372-2374. | Yes |
| | R.T. BREWER et al., "Reflection High-Energy Electron Diffraction Experimental Analysis of Polycrystalline MgO Films With Grain Size and Orientation Distributions," Journal of Applied Physics, vol. 93, No. 1, January 1, 2003, pp. 205-210. | Yes |
| | R.T. BREWER et al., "Rapid Biaxial Texture Development During Nucleation of MgO Thin Films During Ion Beam-Assisted Deposition," Applied Physics Letters, vol. 80, No. 18, May 6, 2002, pp. 3388-3390. | Yes |
| | | |
| | | |

| Examiner Signature | | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

258410:1:ALEXANDRIA

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

| **PATENT APPLICATION FEE DETERMINATION RECORD**<br>Substitute for Form PTO-875 | Application or Docket Number<br>12/923,643 | Filing Date<br>09/30/2010 | ☐ To be Mailed |
|---|---|---|---|

## APPLICATION AS FILED – PART I

| | (Column 1) | (Column 2) | SMALL ENTITY ☐ | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|
| FOR | NUMBER FILED | NUMBER EXTRA | RATE ($) | FEE ($) | | RATE ($) | FEE ($) |
| ☐ BASIC FEE (37 CFR 1.16(a), (b), or (c)) | N/A | N/A | N/A | | | N/A | |
| ☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m)) | N/A | N/A | N/A | | | N/A | |
| ☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q)) | N/A | N/A | N/A | | | N/A | |
| TOTAL CLAIMS (37 CFR 1.16(i)) | minus 20 = | * | X $ = | | OR | X $ = | |
| INDEPENDENT CLAIMS (37 CFR 1.16(h)) | minus 3 = | * | X $ = | | | X $ = | |
| ☐ APPLICATION SIZE FEE (37 CFR 1.16(s)) | If the specification and drawings exceed 100 sheets of paper, the application size fee due is $250 ($125 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s). | | | | | | |
| ☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j)) | | | | | | | |
| * If the difference in column 1 is less than zero, enter "0" in column 2. | | | TOTAL | | | TOTAL | |

## APPLICATION AS AMENDED – PART II

| | | (Column 1) | | (Column 2) | (Column 3) | SMALL ENTITY | | OR | OTHER THAN SMALL ENTITY | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **08/21/2012** | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * 20 | Minus | ** 20 | = 0 | X $ = | | OR | X $60= | 0 |
| | Independent (37 CFR 1.16(h)) | * 3 | Minus | ***3 | = 0 | X $ = | | OR | X $250= | 0 |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | **0** |

| | | (Column 1) | | (Column 2) | (Column 3) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | CLAIMS REMAINING AFTER AMENDMENT | | HIGHEST NUMBER PREVIOUSLY PAID FOR | PRESENT EXTRA | RATE ($) | ADDITIONAL FEE ($) | | RATE ($) | ADDITIONAL FEE ($) |
| AMENDMENT | Total (37 CFR 1.16(i)) | * | Minus | ** | = | X $ = | | OR | X $ = | |
| | Independent (37 CFR 1.16(h)) | * | Minus | *** | = | X $ = | | OR | X $ = | |
| | ☐ Application Size Fee (37 CFR 1.16(s)) | | | | | | | | | |
| | ☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j)) | | | | | | | OR | | |
| | | | | | | TOTAL ADD'L FEE | | OR | TOTAL ADD'L FEE | |

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

Legal Instrument Examiner:
/LINDA 18 WISE/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

*If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.*

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

# NOTICE OF ALLOWANCE AND FEE(S) DUE

38327 7590 09/10/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER |
|---|
| CHAMBLISS, ALONZO |

| ART UNIT | PAPER NUMBER |
|---|---|
| 2897 | |

DATE MAILED: 09/10/2012

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | NO | $1740 | $300 | $0 | $2040 | 12/10/2012 |

**THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.**

**THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.**

**HOW TO REPLY TO THIS NOTICE:**

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:

A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status above is to be removed, check box 5b on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check box 5a on Part B - Fee(s) Transmittal and pay the PUBLICATION FEE (if required) and 1/2 the ISSUE FEE shown above.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

**IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.**



PTOL-85 (Rev. 02/11)

**WD EX1004**
**Western Digital v IP Bridge**
**Page 317**

## PART B - FEE(S) TRANSMITTAL

**Complete and send this form, together with applicable fee(s), to: Mail** **Mail Stop ISSUE FEE**
**Commissioner for Patents**
**P.O. Box 1450**
**Alexandria, Virginia 22313-1450**
**or Fax (571)-273-2885**

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

38327 7590 09/10/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

**Certificate of Mailing or Transmission**

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE DUE | PUBLICATION FEE DUE | PREV. PAID ISSUE FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|---|
| nonprovisional | NO | $1740 | $300 | $0 | $2040 | 12/10/2012 |

| EXAMINER | ART UNIT | CLASS-SUBCLASS |
|---|---|---|
| CHAMBLISS, ALONZO | 2897 | 257-295000 |

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list

(1) the names of up to 3 registered patent attorneys or agents OR, alternatively,

(2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:

❑ Issue Fee

❑ Publication Fee (No small entity discount permitted)

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**

❑ A check is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)

❑ a. Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

❑ b. Applicant is no longer claiming SMALL ENTITY status. See 37 CFR 1.27(g)(2).

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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**WD EX1004**
**Western Digital v IP Bridge**
**Page 318**

UNITED STATES PATENT AND TRADEMARK OFFICE

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| APPLICATION NO. | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

38327 7590 09/10/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

| EXAMINER | |
|---|---|
| CHAMBLISS, ALONZO | |
| ART UNIT | PAPER NUMBER |
| 2897 | |

DATE MAILED: 09/10/2012

**Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)**
(application filed on or after May 29, 2000)

The Patent Term Adjustment to date is 0 day(s). If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the Patent Term Adjustment will be 0 day(s).

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.



PTOL-85 (Rev. 02/11)

## Privacy Act Statement

**The Privacy Act of 1974 (P.L. 93-579)** requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

| Notice of Allowability | Application No. | Applicant(s) | |
|---|---|---|---|
| | 12/923,643 | YUASA, SHINJI | |
| | Examiner | Art Unit | |
| | ALONZO CHAMBLISS | 2897 | |

***-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--***

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *the RCE filed on 8/21/12* .

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are *20,21,23 and 24*.

4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☒ All b) ☐ Some* c) ☐ None of the:
      1. ☒ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
**THIS THREE-MONTH PERIOD IS NOT EXTENDABLE**.

5. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

6. ☐ CORRECTED DRAWINGS ( as "replacement sheets") must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review ( PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No./Mail Date _____.
   (b) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   **Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).**

7. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

**Attachment(s)**

1. ☐ Notice of References Cited (PTO-892)
2. ☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
3. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 8/21/12
4. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
5. ☐ Notice of Informal Patent Application
6. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
7. ☐ Examiner's Amendment/Comment
8. ☐ Examiner's Statement of Reasons for Allowance
9. ☒ Other *See Detailed Action*.



**WD EX1004**
**Western Digital v IP Bridge**

***Continued Examination Under 37 CFR 1.114***

1. A request for continued examination under 37 CFR 1.114, including the fee set forth in 37 CFR 1.17(e), was filed in this application after allowance or after an Office action under *Ex Parte Quayle*, 25 USPQ 74, 453 O.G. 213 (Comm'r Pat. 1935). Since this application is eligible for continued examination under 37 CFR 1.114, and the fee set forth in 37 CFR 1.17(e) has been timely paid, prosecution in this application has been reopened pursuant to 37 CFR 1.114. Applicant's submission filed on 8/21/12 has been entered.

***Information Disclosure Statement***

2. The information disclosure statement (IDS) submitted on 8/21/12 was filed after the mailing date of the notice of allowance on 8/7/12. The submission is in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner.

**EXAMINER'S AMENDMENT**

3. An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

Authorization for this examiner's amendment was given in a telephone interview with Nicholas B. Trenkle on September 5, 2012.

CLAIMS:

In claim 24, line 1 delete " 20 " insert -- 23 --.

Any comments considered necessary by applicant must be submitted no later than the payment of the issue fee and, to avoid processing delays, should preferably accompany the issue fee. Such submissions should be clearly labeled "Comments on Statement of Reasons for Allowance."

Any inquiry concerning the communication or earlier communications from the examiner should be directed to Alonzo Chambliss whose telephone number is (571) 272-1927.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Fernando L. Toledo can be reached on (571) 272-1867. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system Status information for published applications may be obtained from either Private PMR or Public PMR. Status information for unpublished applications is available through Private PMR only. For more information about the PMR system see http://pair-kect.uspto.gov. Should you have questions on access to the Private PMR system contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free) or EBC_Support@uspto.gov.

**AC**/September 5, 2012 /Alonzo Chambliss/

Primary Examiner, Art Unit 2897

| Search Notes | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | Examiner | Art Unit |
| | Alonzo Chambliss | 2892 |

| SEARCHED | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| | | | |

| SEARCH NOTES | | |
|---|---|---|
| Search Notes | Date | Examiner |
| East text search only - see attach printout | 12/16/10 | AC |
| Updated previous East text search only - see attached printout | 7/18/11 | AC |
| Updated previous East text serach only - see attached printout | 11/6/11 | AC |
| Updated previous East text search only - see attached printout | 3/1/12 | AC |
| Updated previous East text search only - see attached printout | 6/21/12 | AC |
| Updated previous East text search only - see attached printout | 7/27/12 | AC |
| Updated previous East text search only - see attached printout | 9/5/12 | AC |

| INTERFERENCE SEARCH | | | |
|---|---|---|---|
| Class | Subclass | Date | Examiner |
| 257 | 4,295,421,427 | 3/1/12 | AC |
| 365 | 171 | 3/1/12 | AC |
| 257 | 4,295,421,427 | 6/21/12 | AC |
| 365 | 171 | 6/21/12 | AC |
| 438 | 3 | 6/21/12 | AC |
| 257 | 4,295,421,427 | 7/27/12 | AC |
| 365 | 171 | 7/27/12 | AC |
| 438 | 3 | 7/27/12 | AC |
| 257 | 4,295,421,427 | 9/5/12 | AC |
| 365 | 171 | 9/5/12 | AC |
| 438 | 3 | 9/5/12 | AC |

OPAP WP3 AUG 21 2012 PATENT & TRADEMARK OFFICE



*Customized* PTO/SB/08a+b (07-09)

*Substitute for Form 1449/PTO*

# INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Sheet 1 of 1

| | |
|---|---|
| Application # | 12/923,643 |
| Confirmation # | 8219 |
| Filing Date | September 30, 2010 |
| First Inventor | YUASA |
| Art Unit | 2897 |
| Examiner | Alonzo Chambliss |
| Docket # | NAGI-0003 |

## U.S. PATENT DOCUMENTS

| Exam. Initial* | Document No. Number – Kind Code | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. |
|---|---|---|---|---|
| | | | | |
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## FOREIGN PATENT DOCUMENTS

| Exam. Initial* | Country-Number-Kind Code [if known] | Publ. Date MM-DD-YYYY | Name Patentee or Applicant | Relevance Passages/Figs. | Trans-lation |
|---|---|---|---|---|---|
| | EP 0 145 403 A2 | 06-19-1985 | Energy Conversion Devices, Inc. | | Yes |
| | EP 1 061 592 A2 | 12-20-2000 | Matsushita Electric Industrial Co., Ltd. | | Yes |
| | | | | | |
| | | | | | |

## NON PATENT LITERATURE DOCUMENTS

| Exam. Initial* | Include NAME of the author (in CAPS), Title of Article/Item, Date, Page(s), Volume-Issue No., Publisher, City and/or Country where published | Translation |
|---|---|---|
| | N. INABA et al., "Magnetic and Crystallographic Properties of Co-Cr-Pt Longitudinal Media Prepared on MgO Seedlayers Deposited by ECR Sputtering," IEEE Transactions on Magnetics,vol. 36, No. 5, September 2000, pp. 2372-2374. | Yes |
| | R.T. BREWER et al., "Reflection High-Energy Electron Diffraction Experimental Analysis of Polycrystalline MgO Films With Grain Size and Orientation Distributions," Journal of Applied Physics, vol. 93, No. 1, January 1, 2003, pp. 205-210. | Yes |
| | R.T. BREWER et al., "Rapid Biaxial Texture Development During Nucleation of MgO Thin Films During Ion Beam-Assisted Deposition," Applied Physics Letters, vol. 80, No. 18, May 6, 2002, pp. 3388-3390. | Yes |
| | | |
| | | |

| Examiner Signature | /Alonzo Chambliss/ (09/04/2012) | Date Considered | |
|---|---|---|---|

* *Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP §609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to the applicant.*

258410:1:ALEXANDRIA

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

**EAST Search History**

**EAST Search History (Prior Art)**

| Ref # | Hits | Search Query | DBs | Default Operator | Plurals | Time Stamp |
|---|---|---|---|---|---|---|
| L1 | 969 | "257"/$.ccls. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:53 |
| L2 | 124 | "257"/$.ccls. and (second top upper) near5 (Fe ferromagnetic) adj3 (layer film) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:53 |
| L3 | 203 | "257"/$.ccls. and (second top upper) near5 (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:54 |
| L4 | 70 | "438"/$.ccls. and (second top upper) near5 (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:54 |
| L5 | 330 | "438"/$.ccls. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:55 |
| L6 | 641 | "365"/$.ccls. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:55 |
| L7 | 174 | "365"/$.ccls. and (second top upper) near5 (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:55 |
| L8 | 269 | 257/E29.323 and (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:55 |
| L9 | 17 | 257/E27.104 and (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:56 |
| L10 | 46 | yuasa.in. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:56 |

| | | | | | | |
|---|---|---|---|---|---|---|
| L11 | 38 | japan adj2 science.as. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 18:58 |
| L15 | 27 | national adj2 institute adj2 advanced adj2 industrial.as. and (Fe ferromagnetic) same (MgO magnesium adj3 oxide and magnetic adj3 (device structure)) | US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB | OR | ON | 2012/09/05 19:02 |

**EAST Search History (Interference)**

< This search history is empty>

**9/5/2012 7:03:10 PM**
**C:\Users\achambliss\Documents\EAST\Workspaces\12652379.wsp**

| Issue Classification | Application/Control No. | Applicant(s)/Patent Under Reexamination |
|---|---|---|
| | 12923643 | YUASA, SHINJI |
| | **Examiner** | **Art Unit** |
| | ALONZO CHAMBLISS | 2892 |

| ORIGINAL | | INTERNATIONAL CLASSIFICATION | |
|---|---|---|---|
| CLASS | SUBCLASS | CLAIMED | NON-CLAIMED |
| 257 | 295 | H 0 1 L 27 / 108 (2006.0) | |
| CROSS REFERENCE(S) | | G 1 1 C 11 / 14 (2006.0) | |
| | | H 0 1 L 21 / 00 (2006.0) | |

| CLASS | SUBCLASS (ONE SUBCLASS PER BLOCK) | | | | |
|---|---|---|---|---|---|
| 257 | 427 | E29.323 | E27.104 | E29.164 | E21.208 |
| 365 | 171 | | | | |
| 438 | 3 | | | | |

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

| Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original | Final | Original |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | | 17 | | 33 | | | | | | | | | | |
| | 2 | | 18 | | 34 | | | | | | | | | | |
| | 3 | | 19 | | 35 | | | | | | | | | | |
| | 4 | 1 | 20 | | 36 | | | | | | | | | | |
| | 5 | 2 | 21 | | 37 | | | | | | | | | | |
| | 6 | | 22 | | 38 | | | | | | | | | | |
| | 7 | 3 | 23 | | 39 | | | | | | | | | | |
| | 8 | 4 | 24 | | 40 | | | | | | | | | | |
| | 9 | | 25 | | 41 | | | | | | | | | | |
| | 10 | | 26 | | 42 | | | | | | | | | | |
| | 11 | | 27 | | 43 | | | | | | | | | | |
| | 12 | | 28 | | 44 | | | | | | | | | | |
| | 13 | | 29 | | 45 | | | | | | | | | | |
| | 14 | | 30 | | | | | | | | | | | | |
| | 15 | | 31 | | | | | | | | | | | | |
| | 16 | | 32 | | | | | | | | | | | | |

| | | | |
|---|---|---|---|
| NONE | | **Total Claims Allowed:** | |
| (Assistant Examiner) | (Date) | 4 | |
| /ALONZO CHAMBLISS/<br>Primary Examiner.Art Unit 2892 | 9/5/12 | O.G. Print Claim(s) | O.G. Print Figure |
| (Primary Examiner) | (Date) | 1 | 1B |



**WD EX1004**
**Western Digital v IP Bridge**
**Page 329**

## PART B - ISSUE FEE (S) TRANSMITTAL

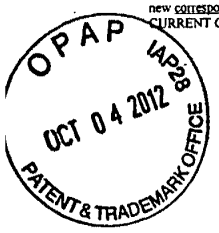
**Complete and mail this form, together with applicable fees, to:**

**Box ISSUE FEE**
**Assistant Commissioner for Patents**
**Washington, D.C. 20231**

MAILING INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate FEE ADDRESS for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

STITES & HARBISON, PLLC
SUITE 900
1199 N. FAIRFAX STREET
ALEXANDRIA, VA 22314




Note: The certificate of mailing below can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate

**Certificate of Mailing**

I hereby certify that this Issue Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelop addressed to the Box Issue Fee address on the date indicated below..

(Depositor's name)
(Signature)
(Date)

| APPLICATION NO | FILING DATE | FIRST NAMED INVENTOR | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 09/30/2010 | Shinji Yuasa | NAGI-0003 | 8219 |

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE

| APPLN. TYPE | SMALL ENTITY | ISSUE FEE | PUBLICATION FEE | TOTAL FEE(S) DUE | DATE DUE |
|---|---|---|---|---|---|
| nonprovisional | NO | $1740 | $300 | $2040 | 12/10/2012 |

| EXAMINER | ART UNIT | CLASS – SUBCLASS |
|---|---|---|
| CHAMBLISS, Alonzo | 2897 | 257-295000 |

1. Change of correspondence address or indication of "Fee Address" (37 CFR §1.363). Use of PTO form(s) and Customer Number are recommended, but not required.

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47) attached.

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (have as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed

1. Stites & Harbison, PLLC
2. Juan Carlos A. Marquez, Esq

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

| (A) NAME OF ASSIGNEE | (B) RESIDENCE: (CITY and STATE OR COUNTRY) |
|---|---|
| **Japan Science and Technology Agency** | **Saitama, Japan** |
| **National Institute of Advanced Industrial Science and Technology** | **Tokyo, Japan** |

Please check the appropriate assignee category indicated below (will not be printed on the patent) ☐ individual ☒ Corporation or private group entity ☐ government

4a. The following fees are enclosed:

☒ Issue fee

☒ Publication Fee

☐ Advance Order - # of Copies:

4b. Payment of Fee(s):

☒ Payment by credit card. Form PTO-2038 is attached.

☒ The Commissioner is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number 12-0555.

The COMMISSIONER OF PATENTS AND TRADEMARKS is requested to apply the Issue Fee and Publication Fee (if any) to the application identified above.

(Authorized Signature) (Date) October 4, 2012

Juan C.A. Marquez Reg. No. 34,072

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered patent attorney or agent; or the assignee or other party in interest as shown by the records of the Patent and Trademark Office

Burden Hour Statement: This form is estimated to take 0.2 hours to complete. Time will vary depending on the needs of the individual case. Any comments on the amount of time required to complete this form should be sent to the Chief Information Officer, United States Patent and Trademark Office, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND FEES AND THIS FORM TO: Box Issue Fee, Assistant Commissioner for Patents, Washington, D.C. 20231

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number

TRANSMIT THIS FORM WITH FEE(S)



PTOL-85 (Rev.07-01) Approved for use through 01/31/2004. OMB 0651-0033

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

10/05/2012 HVUONG2 00000060 12923643

01 FC:1501 1740.00 OP
02 FC:1504 300.00 OP

263487:1:ALEXANDRIA

US_ACTIVE-100195432.1 10/4/12 1:28 PM

OPAP IAP3 JUL 16 2012 PATENT & TRADEMARK OFFICE



*Customized* PTO/SB/08a+b (07-09)

| *Substitute for Form 1449/PTO* | | |
|---|---|---|
| **INFORMATION DISCLOSURE STATEMENT BY APPLICANT** | Application # | 12/923,643 |
| | Confirmation # | 8219 |
| | Filing Date | June 29, 2012 |
| | First Inventor | YUASA |
| | Art Unit | 2897 |
| | Examiner | Alonzo Chambliss |
| Sheet 1 of 5 | Docket # | NAGI-0003 |

| ***U.S. PATENT DOCUMENTS*** | | | | |
|---|---|---|---|---|
| **Exam. Initial*** | **Document No. Number – Kind Code** | **Publ. Date MM-DD-YYYY** | **Name Patentee or Applicant** | **Relevance Passages/Figs.** |
| | 2008/0055793 [8] | 03-06-2008 | Djayaprawira et al. | |
| | 2006/0056115 [10] | 03-16-2006 | Djayaprawira et al. | |
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| Change(s) applied to document. /T.W./ 10/31/2012 | 2006/0012926 A1 | 01-19-2006 | Parkin | |
| | 2006/0125034 A1 | 06-15-2006 | Ohba et al. | |
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| | 5,945,694 A | 08-31-1999 | Reyes et al. | |
| | 6,181,537 B1 | 01-30-2001 | Gill | |
| | 6,201,672 B1 | 03-13-2001 | Pinarbasi | |
| | 6,252,750 B1 | 06-26-2001 | Gill | |
| | 6,275,362 B1 | 08-14-2001 | Pinarbasi | |
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| | 7,149,105 B2 | 12-12-2006 | Brown | |
| | 7,220,498 B2 | 05-22-2007 | Nagahama et al. | |

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

| APPLICATION NO. | ISSUE DATE | PATENT NO. | ATTORNEY DOCKET NO. | CONFIRMATION NO. |
|---|---|---|---|---|
| 12/923,643 | 11/27/2012 | 8319263 | NAGI-0003 | 8219 |

38327 7590 11/07/2012

Juan Carlos A. Marquez
c/o Stites & Harbison PLLC
1199 North Fairfax Street
Suite 900
Alexandria, VA 22314-1437

# ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

**Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)**
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 0 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Shinji Yuasa, Ibaraki, JAPAN;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

OPAP IAP28 FEB 14 2013 PATENT & TRADEMARK OFFICE

CofC

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**In re U.S. Patent Application of**

**YUASA**

**Application Number: 12/923,643**
**Patent No. 8,319,263**

**Filed: September 30, 2010**
**Issued: November 27, 2012**

**For: MAGNETIC TUNNEL JUNCTION DEVICE**

**Attorney Docket No. NAGI-0003**

Certificate
FEB 22 2013
of Correction

**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

## REQUEST FOR CERTIFICATE OF CORRECTION

Sir:

The Commissioner is hereby respectfully requested to approve and issue a Certificate of Correction in accordance with the attached Certificate of Correction in order to amend claims 1 and 3 to correct minor errors.

Attached is a copy of the Request for a Certificate of Correction setting forth the requested change, along with a credit card form 2038 in the amount of $100.00

The Commissioner is hereby respectfully requested to grant a Certificate of Correction in accordance with the attached Certificate of Correction.

02/20/2013 SDIRETA2 00000001 8319263 100.00 OP
01 FC:1811

The Commissioner is also hereby authorized to charge payment of any fees associated with this communication, including fees under 37 C.F.R. § 1.16 and 1.17 or credit any overpayment to **Deposit Account Number 12-0555**.

Respectfully submitted,

**STITES & HARBISON, PLLC**
1199 N. Fairfax Street, Suite 900
Alexandria, Virginia 22314
(703) 739-4900
Customer No.: 38327
**February 14, 2013**

Juan Carlos A. Marquez
Registration Number 34,072

OPAP IAP28 FEB 14 2013 PATENT & TRADEMARK OFFICE

**IN THE UNITED STATES PATENT AND TRADEMARK OFFICE**

**In re U.S. Patent Application of**

**YUASA**

**Application Number: 12/923,643**
**Patent No. 8,319,263**

**Filed: September 30, 2010**
**Issued: November 27, 2012**

**For: MAGNETIC TUNNEL JUNCTION DEVICE**

**Attorney Docket No. NAGI-0003**

**Commissioner of Patents**
**P.O. Box 1450**
**Alexandria, VA 22313-1450**

**LETTER**

Sir:

The below-identified communications are submitted in the above-captioned application or proceeding:

(x) Request for Certificate of Correction
(x) Certificate of Correction (Form PTO-1050)
(x) Credit Card Form-2038 for $100.00

(x) The Commissioner is hereby authorized to charge payment of any fees associated with this communication, including fees under 37 C.F.R. § 1.16 and 1.17 or credit any overpayment to **Deposit Account Number 12-0555.**

Respectfully submitted,

Juan Carlos A. Marquez
Registration Number 34,072

**STITES & HARBISON, PLLC**
1199 N. Fairfax Street, Suite 900
Alexandria, Virginia 22314
(703) 739-4900
Customer No.: 38327
**February 14, 2013**

PTO/SB/44 (04-04)
Approved for use through 04/30/2007. OMB 0651-0033
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.
(Also Form PTO-1050)

**UNITED STATES PATENT AND TRADEMARK OFFICE**
CERTIFICATE OF CORRECTION

PATENT NO. : 8,319,263 B2

DATED : November 27, 2012

INVENTOR(S) : YUASA

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Please amend the claims as follows:

Claim 1, column 10, lines 11 and 12,

please delete --wherein the tunnel barrier layer has a tunnel barrier height $\omega$ in a range of 0.2 to 0.5 eV.—

and please add "wherein the tunnel barrier layer has a tunnel barrier height $\Phi$ in a range of 0.2 to 0.5 eV."

Claim 3 column 10, line 20,

please delete

$$--J= [(2m\Psi)^{1/2}/ \Delta s] (e/h)^2 \times \exp [-(4\pi\Delta s/h) \times (2m\Psi)^{1/2}] \times V \quad (1)--$$

and please add

$$"J= [(2m\Phi)^{1/2}/ \Delta s] (e/h)^2 \times \exp [-(4\pi\Delta s/h) \times (2m\Phi)^{1/2}] \times V \quad (1)"$$

MAILING ADDRESS OF SENDER:
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PATENT NO. **8,319,263 B2**

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UNITED STATES PATENT AND TRADEMARK OFFICE

# CERTIFICATE OF CORRECTION



PATENT NO. : 8,319,263 B2
APPLICATION NO. : 12/923643
DATED : November 27, 2012
INVENTOR(S) : Yuasa

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Claim 1, column 10, lines 11 and 12,

please delete "wherein the tunnel barrier layer has a tunnel barrier height ω in a range of 0.2 to 0.5 eV."

and please add "wherein the tunnel barrier layer has a tunnel barrier height Φ in a range of 0.2 to 0.5 eV."

Claim 3, column 10, line 20,

please delete

"$J= [(2m\Psi)^{1/2}/ \Delta s] (e/h)^2 \times \exp [-(4\pi\Delta s/h) \times (2m\Psi)^{1/2}] \times V$ (1)"

and please add

"$J= [(2m\Phi)^{1/2}/ \Delta s] (e/h)^2 \times \exp [-(4\pi\Delta s/h) \times (2m\Phi)^{1/2}] \times V$ (1)"

Signed and Sealed this
Second Day of April, 2013

Teresa Stanek Rea
*Acting Director of the United States Patent and Trademark Office*