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TRANSMITTAL LETTER TO THE UNITED STATES DESIGNATED/ELECTED OFFICE (DO/EO/US) CONCERNING A FILING UNDER 35 U.S.C. §371

Attorney's Docket Number	
HIRA.0236	
U.S. Application Number (if known)	**10/591947**

International Application Number	*International Filing Date*	*Priority Date Claimed*
PCT/JP2005/004720	**10 March 2005**	**12 March 2004 and 28 October 2004**

Title of Invention
MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. §371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. §371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. §371(f)). The submission must include items (5), (6), (9) and (21) indicated below.
4. ☒ The US has been elected (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. §371(c)(2))
   a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   b. ☒ has been communicated by the International Bureau.
   c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ A English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   a. ☒ is attached hereto
   b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☒ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. §371(c)(3))
   a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   b. ☐ have been communicated by the International Bureau.
   c. ☒ have not been made; however, the time limit for making such amendments has NOT expired.
   d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. §371(c)(3)).
9. ☒ An executed oath or declaration of the inventor(s) (35 U.S.C. 371(c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. §371(c)(5)).

Items 11 to 20 below concern other document(s) or information included:

11. ☒ An Information Disclosure Statement under 37 C.F.R. §§1.97 and 1.98.
12. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 C.F.R. §§3.28 and 3.31 is included.
13. ☒ A preliminary amendment.
14. ☐ An Application Data Sheet under 37 C.F.R. §1.76.
15. ☐ A substitute specification.
16. ☐ A power of attorney and/or address letter.
17. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C, 1.821-1.825
18. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
19. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
20. ☒ Other items or information: Request for Priority

This collection of information is required by 37 CFR 1.414 and 1.491-1.492. 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 1.11 and 1.14. This collection is estimated to take 15 minutes to complete, including gathering information, preparing, and submitting the completed 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: Mail Stop PCT, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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U.S. APPLICATION NO. (if known, see 37 CFR 1.5) 10/591947	INTERNATIONAL APPLICATION NO. PCT/JP2005/004720	ATTORNEY'S DOCKET NUMBER HIRA.0236	
		Applicant use	Office use only

21. ☐ The following fees are submitted:

☐ a) Basic national fee	$300.00	**$300.00**	
☐ b) Examination fee	$200.00	**$200.00**	
☐ c) Search fee	$400.00	**$400.00**	
TOTAL OF ABOVE CALCULATIONS =	$900.00	**$900.00**	

☐ Additional fee for specification and drawings filed in paper over 100 sheets (excluding sequence listing or computer program listing filed in an electronic medium). The fee is $250 for each additional 50 sheets of paper or fraction thereof

Total Sheets	Extra Sheets	Number of each additional 50 or fraction thereof (round up to a whole number)	RATE		
48 - 100=	/50 =	0	x $250.00	**$0.00**	

Surcharge of **$130.00** for furnishing the oath or declaration later than 30 months from the earliest claimed priority date (37 C.F.R. §1.492(e)).				**$0.00**	
CLAIMS	**NUMBER FILED**	**NUMBER EXTRA**	**RATE**		
Total Claims	39	19	x $50.00	**$950.00**	
Independent Claims	12	9	x $200.00	**$1,800.00**	
Multiple Dependant Claims (if applicable)			+ 360.00	**$0.00**	
			TOTAL OF ABOVE CALCULATIONS =	**$3,650.00**	
☐ Applicant claims small entity status. See 37 CFR 1.27. The fees indicated above are reduced by 1/2				**$0.00**	
			SUBTOTAL =	**$3,650.00**	
Processing fee of **$130.00** for furnishing the English translation later than 30 months from the earliest claimed priority date (37 C.F.R. §1.492(f)).				**$0.00**	
			TOTAL NATIONAL FEE =	**$3,650.00**	
Fee for recording the enclosed assignment (37 C.F.R. § 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 C.F.R. §§ 3.28, 3.31). **$40.00** per property				**$40.00**	
			TOTAL FEES ENCLOSED =	**$3,690.00**	
			Amount to be Refunded:		$
			Amount to be charged		$

a. ☒ A check in the amount of **$3,690.00** to cover the above fees is enclosed.

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Note: Where an appropriate time limit under 37 C.F.R. §1.495 has not been met, a petition to revive (37 C.F.R. §1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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Application for
UNITED STATES LETTERS PATENT

Of

SHINJI YUASA

FOR

MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

10/591947
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MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

BACKGROUND OF THE INVENTION

Field of the Invention

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.

Description of Related Art

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

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

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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.

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.

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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.

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

SUMMARY OF THE INVENTION

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.

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

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magnetoresistance for stable operation.

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

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.

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 first Fe(001) layer by electron beam evaporation under high vacuum, the tunnel barrier layer comprising a

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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.

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.

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 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

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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.

BRIEF DESCRIPTION OF THE DRAWINGS

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.

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.

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.

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

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

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

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).

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

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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.

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.

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

DESCRIPTION OF THE PREFERRED EMBODIMENTS

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.

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

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lattice defect.

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:

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

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:

$$\text{MR ratio} = (Rap - Rp)/Rp = 2P_1P_2/(1-P_1P_2), \text{ and}$$

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

where $\alpha = 1, 2$ (1)

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%.

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.

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 crystal (where the atoms are

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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] (Γ-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 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 Δ_1 band,

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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.

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 (2×10^{-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 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 1×10^{-8} Pa, and the O_2 partial pressure was 1×10^{-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).

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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.

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.

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

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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 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.

The aforementioned tunnel barrier height ϕ 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

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mV) is applied until non-linearity appears in the J-V characteristics, the height ϕ of the tunnel barrier and the effective thickness Δs of the tunnel barrier can be simultaneously determined by fitting the J-V characteristics using the Simmons' formula.

The effective thickness Δs 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 Δs of the tunnel barrier having been reduced from the actual MgO(001) layer thickness by the effect of the image potential produced at the interface between the MgO(001) layer and the alloy layer consisting mainly of Fe and Co.

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 ϕ 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:

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

where m is the mass of the free electron (9.11×10^{-31} kg), e is the elementary electric charge (1.60×10^{-19}C), and h is the Planck's constant (6.63×10^{-34} J·s). The effective thickness of the tunnel barrier Δs 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 ϕ of the tunnel barrier can be simply and yet accurately estimated.

Fig. 6 shows a typical magnetoresistance curve of the

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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) 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.

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.

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

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instead. Alternatively, a layer of Co or Ni with the thickness of one or several monoatomic layers may be inserted between the electrode layer and the MgO(001) layer.

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 ϕ 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.

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.

As described above, in accordance with the MTJ device technology of the present embodiment, an annealing process is carried out for crystallization after an amorphous MgO has been deposited by sputtering, thereby eliminating the need for large-sized equipment.

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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.

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.

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 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

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case where oxygen is introduced, the term refers to values on the order of 10^{-4} Pa.

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.

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What is claimed is:

1. A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier 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.

2. 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 on said tunnel barrier layer; and

a second ferromagnetic material layer comprising Fe(001) formed on a second side on said tunnel barrier layer, wherein

said MgO(001) layer is formed by a single-crystal MgO_x (001) layer or a poly-crystal MgO_x ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented.

3. A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

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a tunnel barrier layer comprising MgO(001);

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising a single-crystalline (001) layer or a poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said polycrystalline layer having the (001) crystal plane preferentially oriented therein;

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer and comprising a single-crystalline (001) layer or a poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said polycrystalline layer having the (001) crystal plane preferentially oriented therein, wherein

said tunnel barrier 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, wherein

the discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

4. A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer;

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline MgO (001) layer or

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

the discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

5. The magnetoresistive device according to claim 3 or 4, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

6. The magnetoresistive device according to claim 3 or 4, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

7. A memory device comprising:

a transistor; and

the magnetoresistive device according to any one of claims 1 to 6, wherein said magnetoresistive device is used as a load for said transistor.

8. A method of manufacturing a magnetoresistive device comprising:

preparing a substrate;

depositing a first single-crystalline (001) layer or a first poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said poly-crystalline layer having the (001) crystal plane preferentially oriented therein;

depositing a tunnel barrier layer on said first (001) layer of Fe or an Fe alloy of the BCC structure under high vacuum, said tunnel barrier layer comprising a

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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 single-crystalline (001) layer or a second poly-crystalline layer of Fe or an Fe alloy of the BCC structure on said tunnel barrier layer, said polycrystalline layer having the (001) crystal plane preferentially oriented therein.

9. A method of manufacturing a magnetoresistive 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 single-crystalline (001) layer or a first poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said polycrystalline layer having the (001) crystal plane preferentially oriented therein, and then carrying out an anneal process for crystallization;

a third step of depositing a tunnel barrier layer on said first (001) layer of Fe or an Fe alloy of the BCC structure under high vacuum, said 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 single-crystalline (001) layer or a second poly-crystalline layer of Fe or an Fe alloy of the BCC structure on said tunnel barrier layer, said poly-crystalline layer having the (001) crystal plane preferentially oriented therein.

10. The method of manufacturing the magnetoresistive device according to claim 8 or 9, further comprising the step of causing a seed layer to be grown between said first

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and said second steps, said 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.

11. The method of manufacturing the magnetoresistive device according to claim 8 or 9, wherein the step of forming said tunnel barrier layer comprising said single-crystalline MgO_x (001) or said polycrystalline MgO_x ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented further comprises the step of adjusting the value of x in MgO_x.

12. A method of manufacturing a magnetoresistive device comprising:

preparing a substrate;

depositing a first single-crystalline (001) layer or a first poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said poly-crystalline layer having the (001) crystal plane preferentially oriented therein;

forming an amorphous MgO layer on said first (001) layer of Fe or an Fe alloy of the BCC structure and then crystallizing said amorphous MgO layer by annealing so as to form a tunnel barrier layer comprising the single-crystalline MgO_x (001) or the poly-crystalline MgO_x ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented; and

forming a second single-crystalline (001) layer or a second poly-crystalline layer of Fe or an Fe alloy of the BCC structure on said tunnel barrier layer, said poly-crystalline layer having the (001) crystal plane preferentially oriented therein.

13. The method of manufacturing the magnetoresistive device according to claim 12,

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wherein said amorphous MgO layer is deposited by sputtering, using a target with the value of x in MgO_x adjusted.

14. The method of manufacturing the magnetoresistive device according to claim 12, wherein the step of forming said amorphous MgO comprises the step of adjusting the value of x in MgO_x.

15. A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising an amorphous magnetic alloy; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer and comprising an amorphous magnetic alloy, wherein

said tunnel barrier layer is formed by a single-crystalline MgO_x (001) or a poly-crystalline MgO_x ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented.

16. The magnetoresistive device according to claim 15, wherein the discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

17. A magnetoresistive device comprising a magnetic tunnel junction structure

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comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising an amorphous magnetic alloy; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer and comprising an amorphous magnetic alloy, wherein

said tunnel barrier layer is formed by a single-crystalline MgO_x (001) or a poly-crystalline MgO_x ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented, and wherein

the discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

18. The magnetoresistive device according to claim 16 or 17, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

19. The magnetoresistive device according to claim 16 or 17, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

20. A memory device comprising:

a transistor; and

the magnetoresistive device according to any one of claims 15 to 19, wherein said magnetoresistive device is used as a load for said transistor.

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21. A method of manufacturing a magnetoresistive device comprising:

preparing a substrate;

depositing a first ferromagnetic material layer comprising an amorphous magnetic alloy on said substrate;

forming an amorphous MgO layer on said first ferromagnetic material layer and then crystallizing said amorphous MgO layer by annealing so as to form a 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

depositing a second ferromagnetic material layer comprising an amorphous magnetic alloy on said tunnel barrier layer.

22. The method of manufacturing the magnetoresistive device according to claim 21, wherein the step of forming said tunnel barrier layer comprising said single-crystalline MgO_x (001) or said poly-crystalline MgO_x ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented involves deposition by sputtering using a target with the value of x in MgO_x adjusted.

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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 (2×10^{-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.

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FIG. 1 (A)

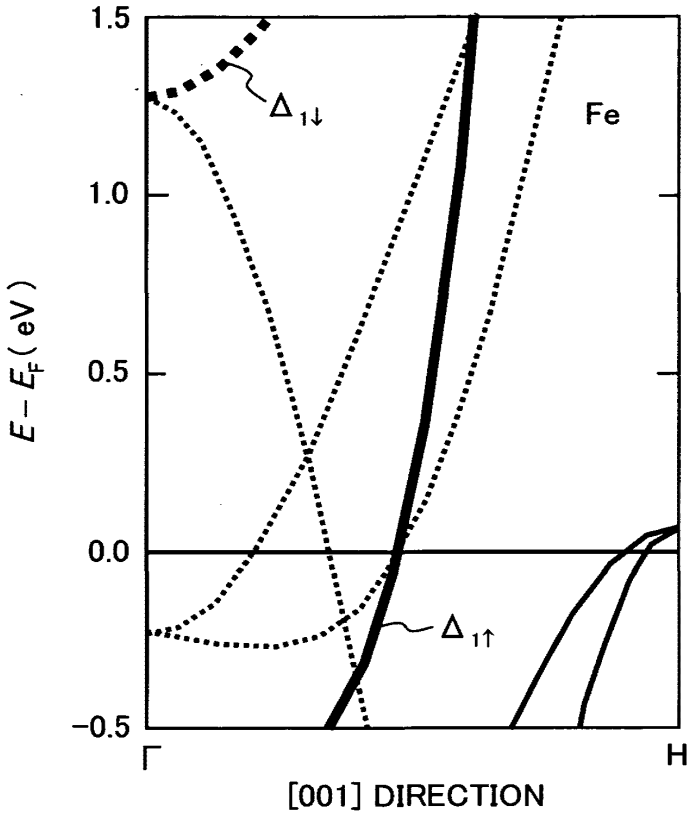
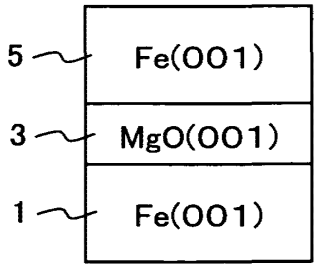


FIG. 1 (B)



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FIG. 2 (A)

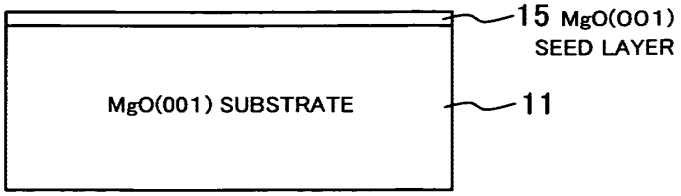


FIG. 2 (B)

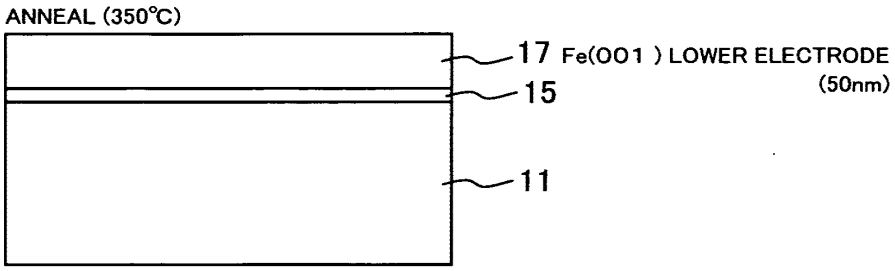


FIG. 2 (C)

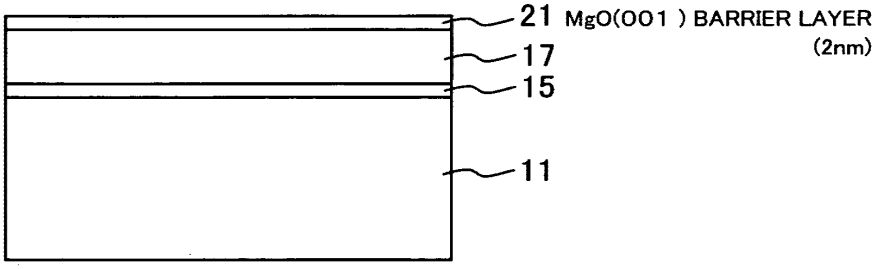
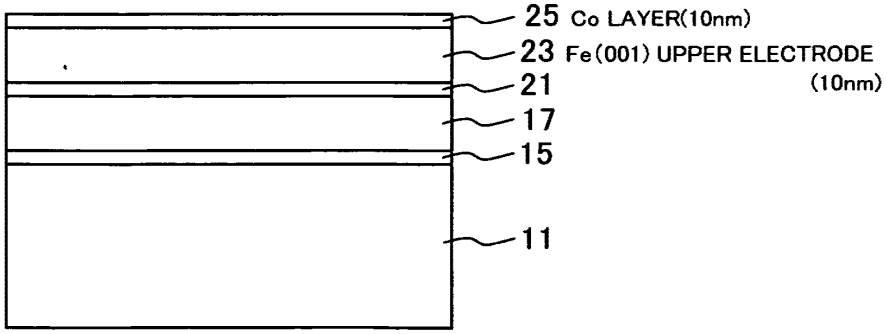


FIG. 2 (D)



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FIG. 3 (A)

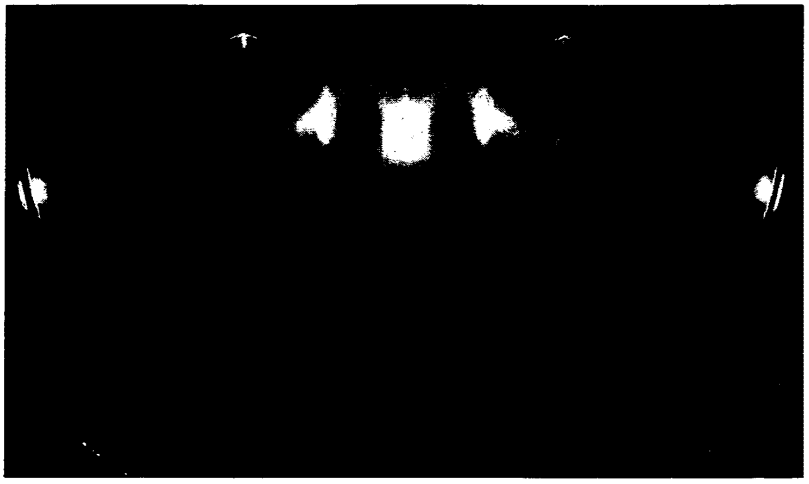
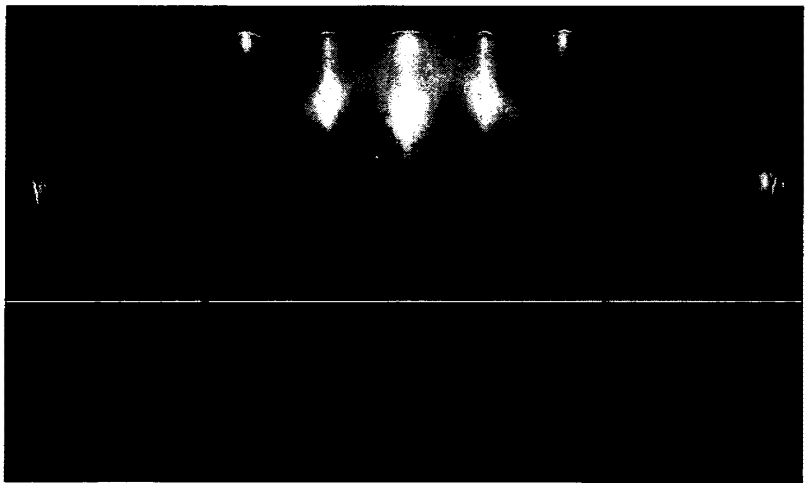
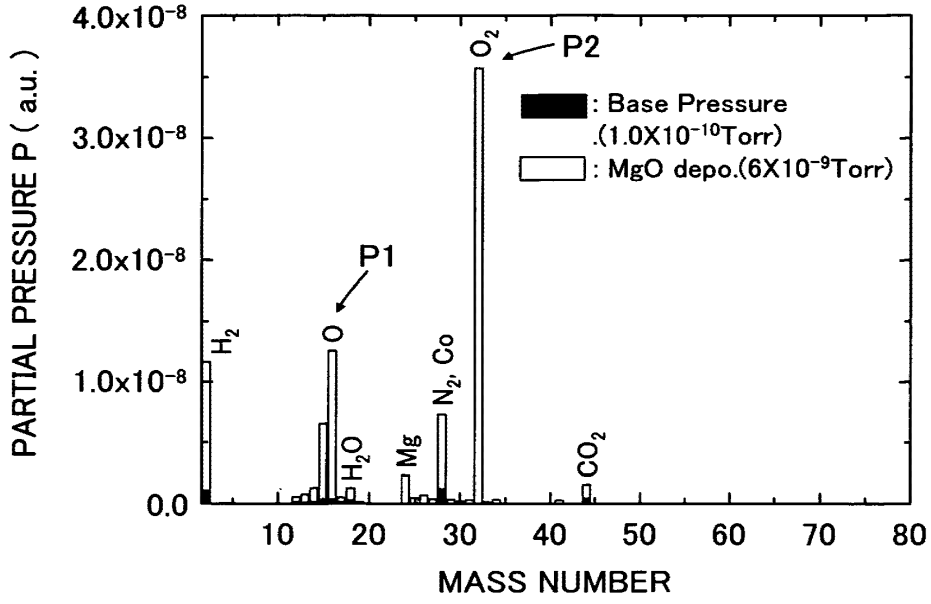


FIG. 3 (B)



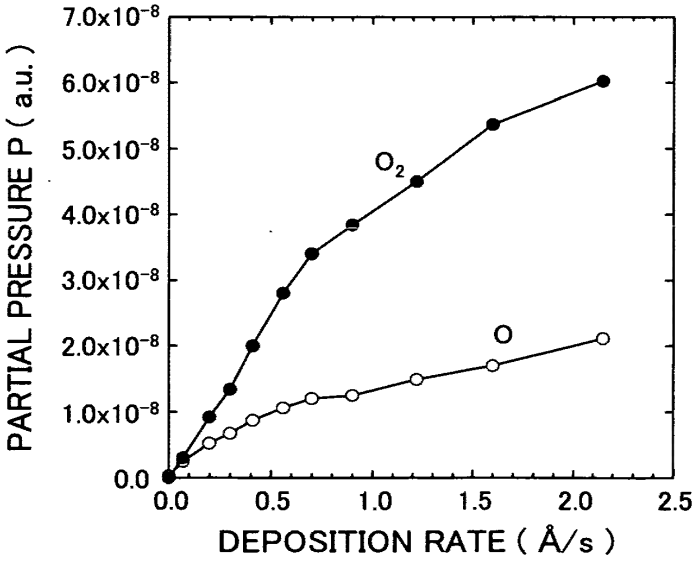
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FIG. 4



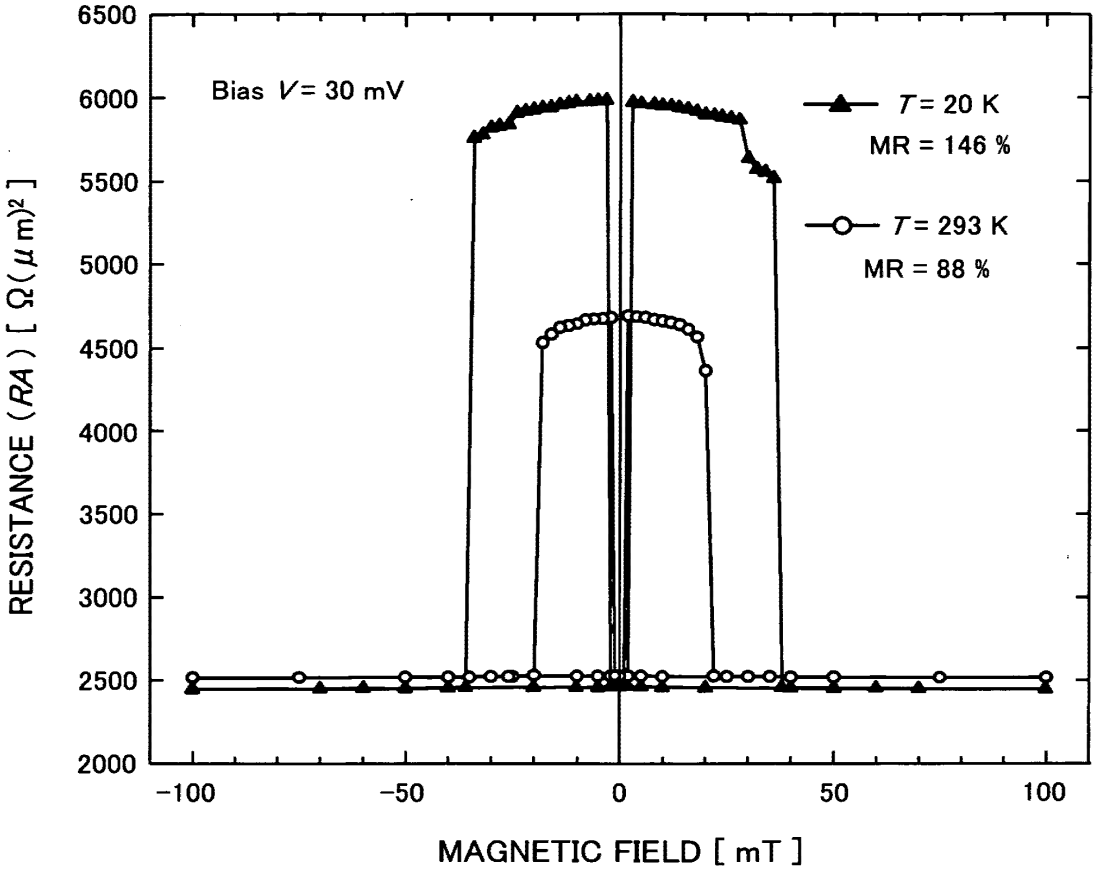
MASS SPECTRA

FIG. 5



OXYGEN PARTIAL PRESSURE DURING MgO EVAPORATION

FIG. 6



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FIG. 7 (A)

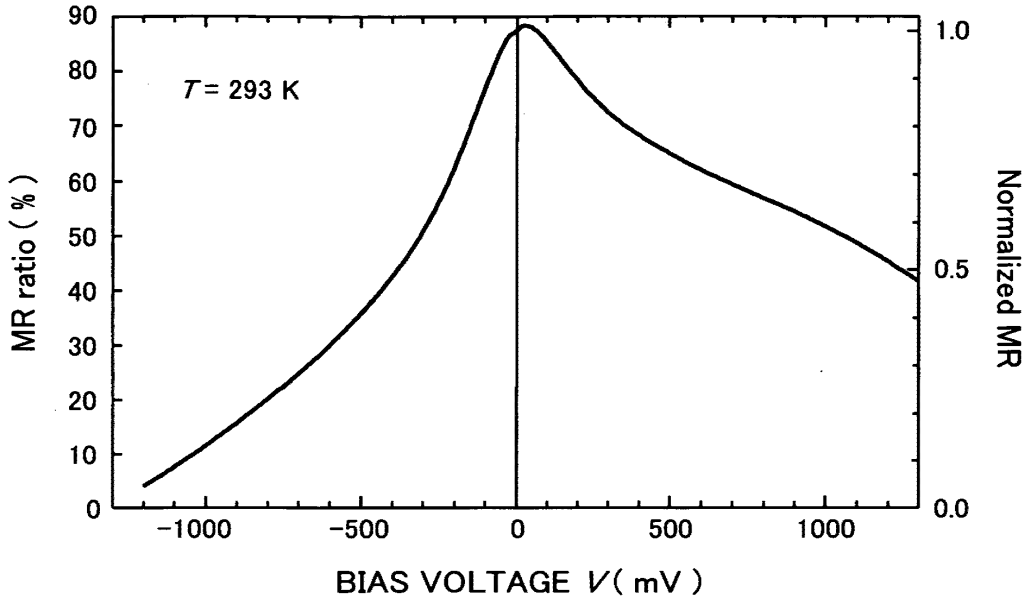
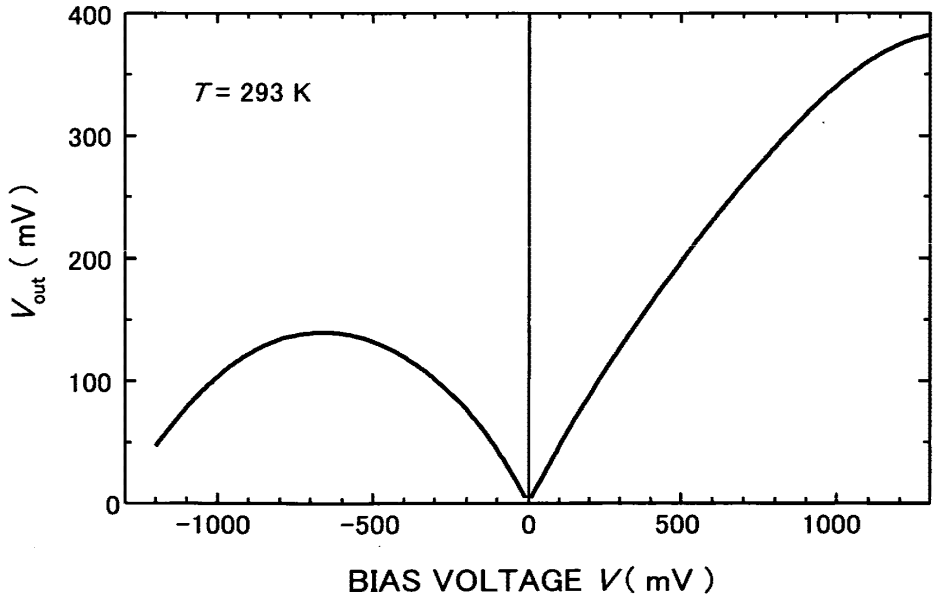


FIG. 7 (B)



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FIG. 8 (A)

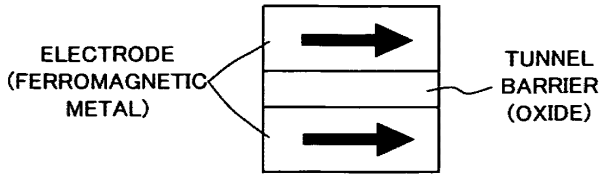
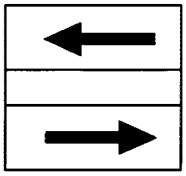


FIG. 8 (B)



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FIG. 9 (A)

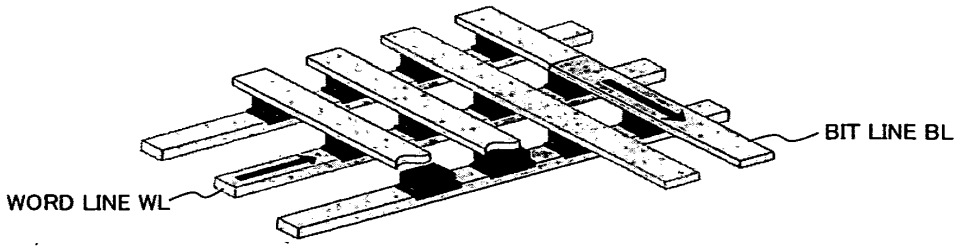


FIG. 9 (B)

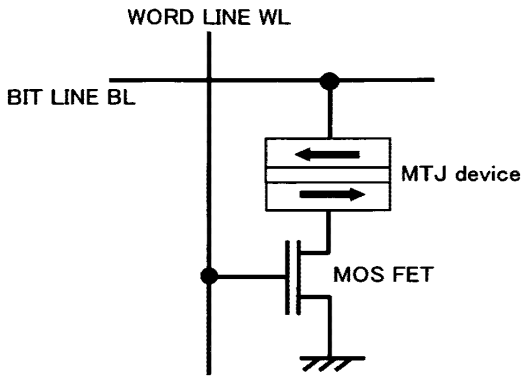
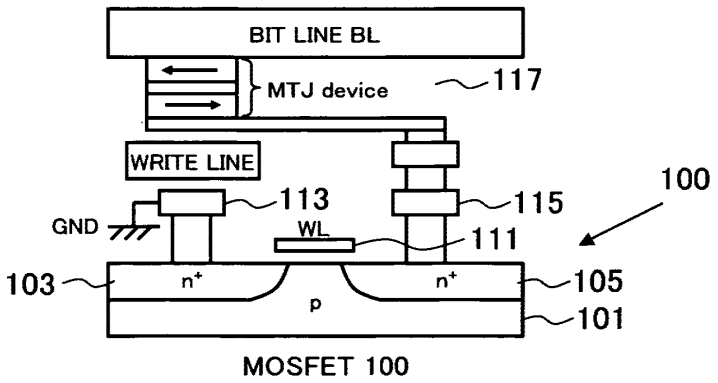


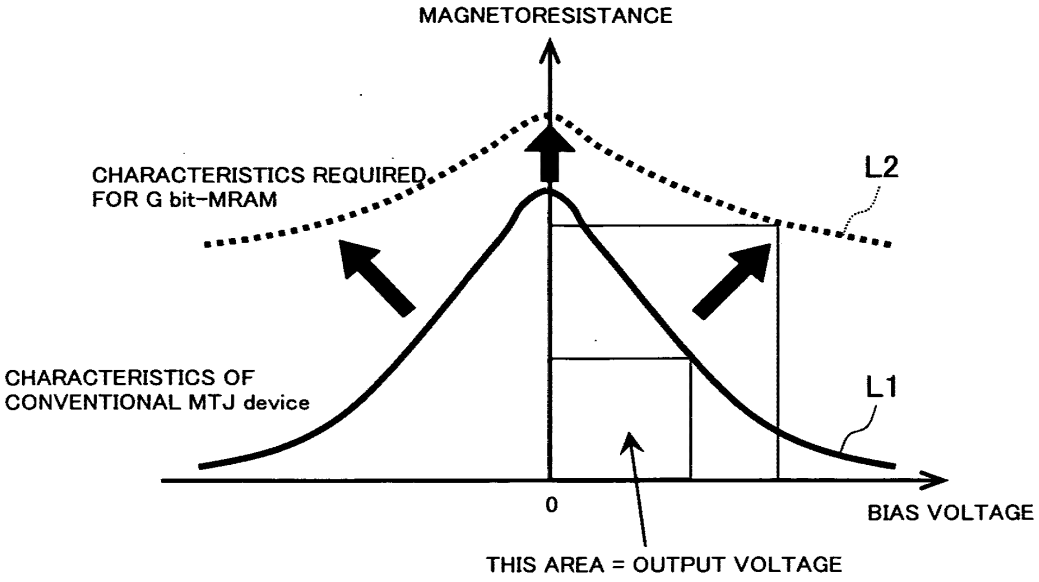
FIG. 9 (C)



MOSFET 100

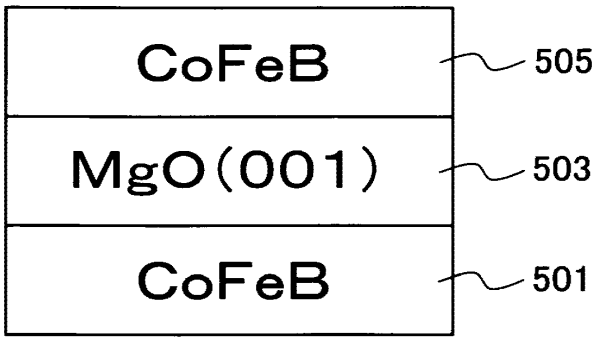
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FIG. 10



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FIG. 11



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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.

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NAME OF FIRST INVENTOR

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Signature of Inventor

August 21, 2006
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PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
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IAP9 Rec'd PCT/PTO 8 SEP 2006 10/591947

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. HIRA.0236)

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

PRELIMINARY AMENDMENT

Sir:

Applicants have amended the claims to eliminate the multiple dependencies and correct the claims in accordance with standard U.S. practice. Prior to an examination on the merits, please amend the above-identified application as follows:

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IN THE CLAIMS:

Please amend claims 3-7, 10-11 and 16-20, and add new claims 23-29 as follows:

1. (Original) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier 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.

2. (Original) 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 on said tunnel barrier layer; and

a second ferromagnetic material layer comprising Fe(001) formed on a second side on said tunnel barrier layer, wherein

said MgO(001) layer is formed by a single-crystal MgO_x (001) layer or a poly-crystal MgO_x ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented.

3. (Currently Amended) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer comprising MgO(001);

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising a single-crystalline (001) layer or a poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said polycrystalline layer having the (001) crystal plane preferentially oriented therein;

a second ferromagnetic material layer formed on a second side of said tunnel

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barrier layer and comprising a single-crystalline (001) layer or a poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said polycrystalline layer having the (001) crystal plane preferentially oriented therein, wherein

said tunnel barrier 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, wherein

[[the]] a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

4. (Currently Amended) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer;

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline MgO (001) layer or a poly-crystalline MgO layer in which the (001) crystal plane is preferentially oriented, wherein

[[the]] a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

5. (Currently Amended) The magnetoresistive device according to claim 3 [[or 4]], wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

6. (Currently Amended) The magnetoresistive device according to claim 3 [[or 4]], wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

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7. (Currently Amended) A memory device comprising:

a transistor; and

[[the]] a magnetoresistive device comprising a tunnel barrier layer; a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein said tunnel barrier 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 ~~according to any one of claims 1 to 6,~~ wherein said magnetoresistive device is used as a load for said transistor.

8. (Original) A method of manufacturing a magnetoresistive device comprising:

preparing a substrate;

depositing a first single-crystalline (001) layer or a first poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said poly-crystalline layer having the (001) crystal plane preferentially oriented therein;

depositing a tunnel barrier layer on said first (001) layer of Fe or an Fe alloy of the BCC structure under high vacuum, said 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 single-crystalline (001) layer or a second poly-crystalline layer of Fe or an Fe alloy of the BCC structure on said tunnel barrier layer, said polycrystalline layer having the (001) crystal plane preferentially oriented therein.

9. (Original) A method of manufacturing a magnetoresistive 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 a second step of depositing a first single-crystalline (001) layer or a first poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said polycrystalline layer having the (001) crystal plane preferentially oriented therein, and then carrying out an anneal process for crystallization;

a third step of depositing a tunnel barrier layer on said first (001) layer of Fe or an Fe alloy of the BCC structure under high vacuum, said tunnel barrier layer comprising a single-crystalline MgO_x (001) or a poly-crystalline MgO_x ($0 < x < 1$) in

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which the (001) crystal plane is preferentially oriented; and

a fourth step of forming a second single-crystalline (001) layer or a second poly-crystalline layer of Fe or an Fe alloy of the BCC structure on said tunnel barrier layer, said poly-crystalline layer having the (001) crystal plane preferentially oriented therein.

10. (Currently Amended) The method of manufacturing the magnetoresistive device according to claim 8 [[or 9]], further comprising the step of causing a seed layer to be grown between said first and said second steps, said 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.

11. (Currently Amended) The method of manufacturing the magnetoresistive device according to claim 8 [[or 9]], wherein the step of forming said tunnel barrier layer comprising said single-crystalline MgO_x (001) or said polycrystalline MgO_x ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented further comprises the step of adjusting the value of x in MgO_x.

12. (Original) A method of manufacturing a magnetoresistive device comprising:

preparing a substrate;

depositing a first single-crystalline (001) layer or a first poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said poly-crystalline layer having the (001) crystal plane preferentially oriented therein;

forming an amorphous MgO layer on said first (001) layer of Fe or an Fe alloy of the BCC structure and then crystallizing said amorphous MgO layer by annealing so as to form a tunnel barrier layer comprising the single-crystalline MgO_x (001) or the poly-crystalline MgO_x ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented; and

forming a second single-crystalline (001) layer or a second poly-crystalline layer of Fe or an Fe alloy of the BCC structure on said tunnel barrier layer, said poly-crystalline layer having the (001) crystal plane preferentially oriented therein.

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13. (Original) The method of manufacturing the magnetoresistive device according to claim 12, wherein said amorphous MgO layer is deposited by sputtering, using a target with the value of x in MgO_x adjusted.

14. (Original) The method of manufacturing the magnetoresistive device according to claim 12, wherein the step of forming said amorphous MgO comprises the step of adjusting the value of x in MgO_x.

15. (Original) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising an amorphous magnetic alloy; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer and comprising an amorphous magnetic alloy, wherein

said tunnel barrier layer is formed by a single-crystalline MgO_x (001) or a poly-crystalline MgO_x ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented.

16. (Currently Amended) The magnetoresistive device according to claim 15, wherein [[the]] a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

17. (Currently Amended) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising an amorphous magnetic alloy; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer and comprising an amorphous magnetic alloy, wherein

said tunnel barrier layer is formed by a single-crystalline MgO_x (001) or a

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poly-crystalline MgO_x ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented, and wherein

[[the]] a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

18. (Currently Amended) The magnetoresistive device according to claim 16 ~~or 17~~, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

19. (Currently Amended) The magnetoresistive device according to claim 16 ~~or 17~~, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

20. (Currently Amended) A memory device comprising:

a transistor; and

[[the]] a magnetoresistive device comprising a tunnel barrier layer; a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising an amorphous magnetic alloy; and a second ferromagnetic material layer formed on a second side of said tunnel barrier layer and comprising an amorphous magnetic alloy, wherein said tunnel barrier layer is formed by a single-crystalline MgO_x (001) or a poly-crystalline MgO_x ($0 < x < 1$) layer in which the (001) crystal plane is preferentially oriented ~~according to any one of claims 15 to 19~~, wherein said magnetoresistive device is used as a load for said transistor.

21. (Original) A method of manufacturing a magnetoresistive device comprising:

preparing a substrate;

depositing a first ferromagnetic material layer comprising an amorphous magnetic alloy on said substrate;

forming an amorphous MgO layer on said first ferromagnetic material layer and then crystallizing said amorphous MgO layer by annealing so as to form a 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

depositing a second ferromagnetic material layer comprising an amorphous

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magnetic alloy on said tunnel barrier layer.

22. (Original) The method of manufacturing the magnetoresistive device according to claim 21, wherein the step of forming said tunnel barrier layer comprising said single-crystalline MgO_x (001) or said poly-crystalline MgO_x ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented involves deposition by sputtering using a target with the value of x in MgO_x adjusted.

23. (New) The magnetoresistive device according to claim 4, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

24. (New) The magnetoresistive device according to claim 4, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

25. (New) The memory device according to claim 7, wherein

the first ferromagnetic material layer and the second ferromagnetic material layer are each a BCC structure.

26. (New) The memory device according to claim 7, wherein

the tunnel barrier layer comprises MgO(001), and

the first ferromagnetic material layer and the second ferromagnetic material layer each comprise Fe(001).

27. (New) The memory device according to claim 7, wherein

the tunnel barrier layer comprises MgO(001),

the first ferromagnetic material layer and the a second ferromagnetic material layer each comprises a single-crystalline (001) layer or a poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said polycrystalline layer having the (001) crystal plane preferentially oriented therein, and

a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

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28. (New) The memory device of claim 27, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

29. (New) The memory device of claim 27, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

30. (New) The memory device according to claim 7, wherein

the first ferromagnetic material layer and the second ferromagnetic material layer are each a BCC structure, and

a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

31. (New) The memory device of claim 30, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

32. (New) The memory device of claim 30, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

33. (New) The method of manufacturing the magnetoresistive device according to claim 9, further comprising the step of causing a seed layer to be grown between said first and said second steps, said 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.

34. (New) The method of manufacturing the magnetoresistive device according to claim 9, wherein the step of forming said tunnel barrier layer comprising said single-crystalline MgO_x (001) or said polycrystalline MgO_x ($0 < x < 1$) in which the (001) crystal plane is preferentially oriented further comprises the step of adjusting the value of x in MgO_x.

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35. (New) The magnetoresistive device according to claim 17, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

36. (New) The magnetoresistive device according to claim 17, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

37. (New) The memory device of claim 20, wherein the discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the MgO (001) layer is a perfect single-crystal.

38. (New) The memory device of claim 20, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

39. (New) The memory device of claim 20, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

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REMARKS

Applicants have amended 3-7, 10-11 and 16-20, and added new claims 23-39. As such, claims 1-39 stand for consideration in this application. No new matter has been added to the application as a result of these amendments.

In view of the above amendments and Applicants' comments stated herein, Applicants respectfully request an early and favorable action on the merits.

Respectfully submitted,

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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. HIRA.0236

Commissioner of Patents
P.O. Box 1450
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INFORMATION DISCLOSURE STATEMENT

Pursuant to 37 C.F.R. §§ 1.56 and 1.97, this Information Disclosure Statement is submitted in the above-identified National Stage U.S. 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 with the initial filing of the 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.

10/591947
IAP9 Rec'd PCT/PTO 08 SEP 2006

Please charge any additional fees or credit any overpayments in connection with this paper to Deposit Account No. 08-1480.

Respectfully submitted,

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September 8, 2006

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Form PTO 1449 U.S. Department of Commerce Patent and Trademark Office Information Disclosure Statement by Applicant	ATTY. DOCKET NUMBER HIRA.0236	SERIAL NUMBER To be Assigned
	APPLICANT YUASA	
	FILING DATE Concurrently Herewith	GROUP

U.S. Patent Documents

Examiner Initial		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB CLASS	FILING DATE

Foreign Patent Documents

Examiner Initial		DOCUMENT NUMBER	FILING DATE	COUNTRY	CLASS	SUB CLASS	TRANSLATION	
							YES	NO
		2003-318465	4/23/2002	Japan			Abstract	X
		2002-204004	12/28/2000	Japan			Abstract	X
		2002-289943	3/26/2001	Japan			Abstract	X
		2003-304010	4/9/2002	Japan			Abstract	X

Other Documents (Including Author, Title, Date Pertinent Pages, Etc.)

		International Search Report of PCT/JP2005/004720 mailed June 21, 2005

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation is considered, whether or not citation is in conformance with MPEP 609; draw a line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

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In re U.S. Patent Application of	)
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	)
ATTORNEY DOCKET NO. HIRA.0236	)

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REQUEST FOR PRIORITY
UNDER 35 U.S.C. § 119
AND THE INTERNATIONAL CONVENTION

Sir:

In the matter of the above-captioned application for a United States patent, notice is hereby given that the Applicant claims the priority date of the PCT application PCT/JP2005/004720, filed March 10, 2005, which claims the priority date of Japanese Patent Application Nos. 2004-071186 and 2004-313350 filed March 12, 2004 and October 28, 2004, respectively, all of which is incorporated by reference.

Respectfully submitted,

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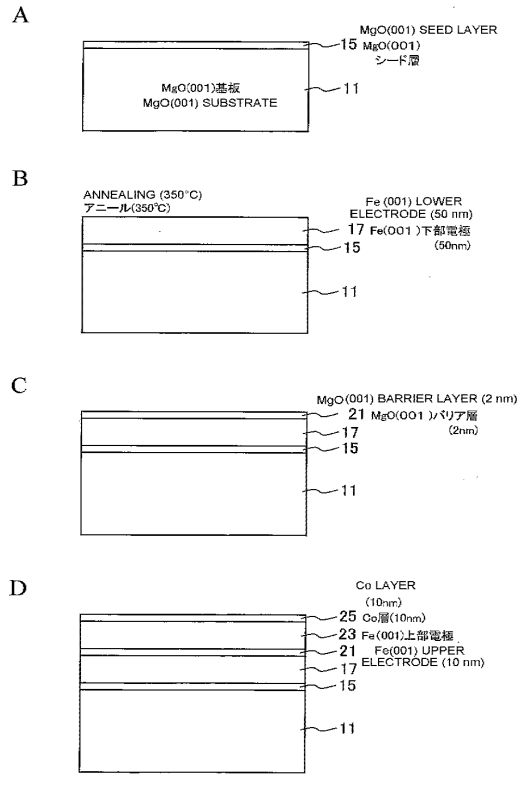
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[続葉有]

(54) Title: MAGNETORESISTIVE ELEMENT AND ITS MANUFACTURING METHOD

(54) 発明の名称: 磁気抵抗素子及びその製造方法



(57) Abstract: A single crystal MgO(001) substrate (11) is prepared. An epitaxial Fe(001) lower electrode (first electrode) (17) having a thickness of 50 nm is deposited on an MgO(001) seed layer (15) at room temperature. In an ultrahigh vacuum (2×10^{-8} Pa) state, annealing is preformed at 350°C. An MgO(001) barrier layer (21) having a thickness of 2 nm is epitaxially deposited on the Fe(001) lower electrode (first electrode) (17) at room temperature by MgO electron beam vacuum deposition. An Fe(001) upper electrode (second electrode) (23) having a thickness of 10 nm is deposited on the MgO(001) barrier layer (21) at room temperature. Consecutively, a Co layer (21) having a thickness of 10 nm is deposited on the Fe(001) upper electrode (second electrode) (23). The Co layer (21) enhances the holding capability of the upper electrode (23) to realize an antiparallel magnetization arrangement. By microfabrication the above produced sample, Fe(001)/MgO(001)/Fe(001) TMR element is fabricated. Thus, the output voltage value of an MRAM can be increased.

(57) 要約: 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。Ｃｏ層２１は、上部電極２３の上部電極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。これによりＭＲＡＭの出力電圧値を高めることができる。

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明細書

磁気抵抗素子及びその製造方法

技術分野

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

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。

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。

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

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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。

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。

非特許文献１：D. Wang, et al.:Science 294 (2001) 1488.

発明の開示

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

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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。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。

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。

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。

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。

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

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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。

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。

図面の簡単な説明

図１は、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（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（Ａ）は、Ｆｅ（００１）下部電極（第１電極）のＲＨＥＥＤイメージを

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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。

図４は、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６は、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（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は、ＴＭＲ素子の構造と、その動作原理を示す図である。

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。

図１１は、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。

発明を実施するための最良の形態

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$L2_1$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。

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,

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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。

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。

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

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、

$$P\alpha = (D\alpha\uparrow(E_F) - D\alpha\downarrow(E_F))/(D\alpha\uparrow(E_F) + D\alpha\downarrow(E_F)),\ \alpha = 1, 2 \quad (1)$$

と表される。

ここで、Ｐα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。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。

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

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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Δ_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ＦｅΔ_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。

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）

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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（２×１０$^{-8}$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（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１×１０$^{-8}$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。

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。

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。

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

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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。

尚、上記、トンネル障壁の高さφ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φ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。

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}）

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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。

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φ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。

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

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、$\Delta s \fallingdotseq t_{MgO}$－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φを簡便かつ正確に見積もることが出来る。

図６は、上記の方法により製造したＦｅ（００１）／ＭｇＯ（0･01）／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素子の抵抗ーエリア積（ＲＡ）は、数ｋΩμｍ^{2}であり、この値は、ＭＲＡＭに適した値である。

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

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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。

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。

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。

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。

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

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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。

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。

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。

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

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ＭＲ

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ＡＭ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。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。

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請求の範囲

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。

２．　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を備え、

前記ＭｇＯ（００１）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。

３．　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（００１）層または（００１）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を備え、該トンネル障壁層が、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磁気抵抗素子であって、

前記トンネル障壁層の伝導帯下端と、前記第１又は第２のうちの少なくとも一方の強磁性体層のフェルミ準位と、の間の不連続値（トンネル障壁の高さ）を、ＭｇＯ（００１）層が完全な単結晶である場合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。

４．　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

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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、該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層により形成されている磁気抵抗素子であって、

前記トンネル障壁層の伝導帯下端と、前記第１又は第２のうちの少なくともいずれか一方の強磁性体層のフェルミ準位と、の間の不連続値（トンネル障壁の高さ）を、ＭｇＯ（００１）層が完全な単結晶である場合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。

５．　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の範囲第３項又は第４項に記載の磁気抵抗素子。

６．　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の範囲第３項又は第４項に記載の磁気抵抗素子。

７．　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の範囲第１項から第６項までのいずれか１項に記載の磁気抵抗素子と

を有する記憶素子。

８．　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（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、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。

９．　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

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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

を有することを特徴とする磁気抵抗素子の製造方法。

１０．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することを特徴とする請求の範囲第８項又は第９項に記載の磁気抵抗素子の製造方法。

１１．前記単結晶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の範囲第８項又は第９項に記載の磁気抵抗素子の製造方法。

１２．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（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、アニールにより該アモルファスＭｇＯ層を結晶化して単結晶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（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。

１３．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の範囲第１２項に

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記載の磁気抵抗素子の製造方法。

１４．　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の範囲第１２項に記載の磁気抵抗素子の製造方法。

１５．　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。

１６．　前記トンネル障壁層の伝導帯下端と、前記第１又は第２のうちの少なくとも一方の強磁性体層のフェルミ準位と、の間の不連続値（トンネル障壁の高さ）を、ＭｇＯ（００１）層が完全な単結晶である場合における理想的な値よりも低くしたことを特徴とする請求の範囲第１５項に記載の磁気抵抗素子。

１７．　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層により形成されている磁気抵抗素子であって、

前記トンネル障壁層の伝導帯下端と、前記第１又は第２のうちの少なくともいずれか一方の強磁性体層のフェルミ準位と、の間の不連続値（トンネル障壁の高さ）を、ＭｇＯ（００１）層が完全な単結晶である場合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。

１８．　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の範囲第１６項又は第１７項に記載の磁気抵抗素子。

１９．　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の範囲第１６項又は第１７項に記載の磁気抵抗素子。

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２０．　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の範囲第１５項から第１９項までのいずれか１項に記載の磁気抵抗素子と
を有する記憶素子。

２１．　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（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。

２２．　前記単結晶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請求の範囲第２１項に記載の磁気抵抗素子の製造方法。

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図1 (A)

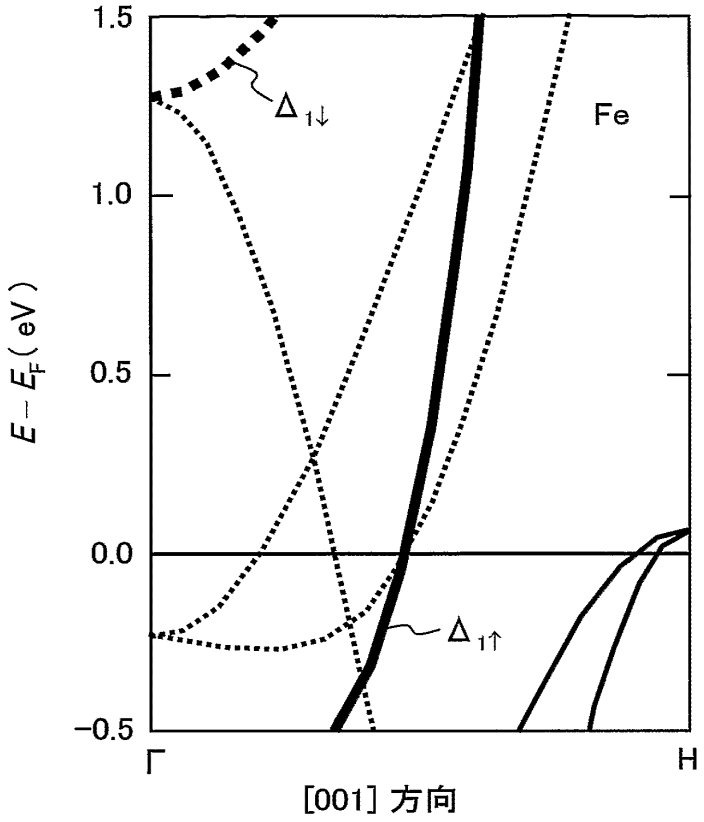
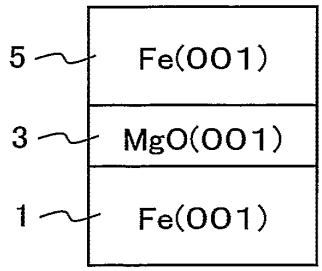


図1 (B)



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図2 (A)

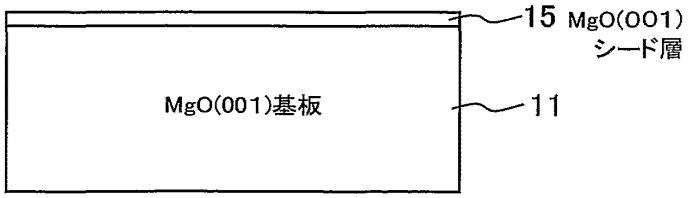


図2 (B)

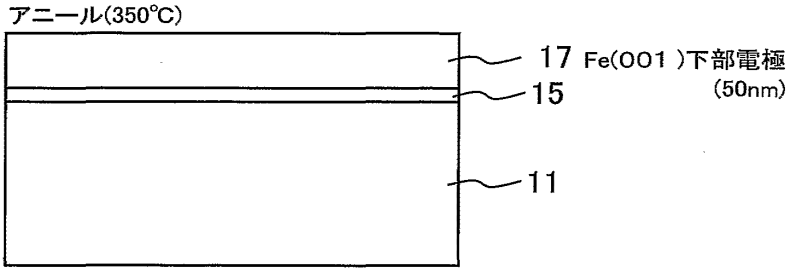


図2 (C)

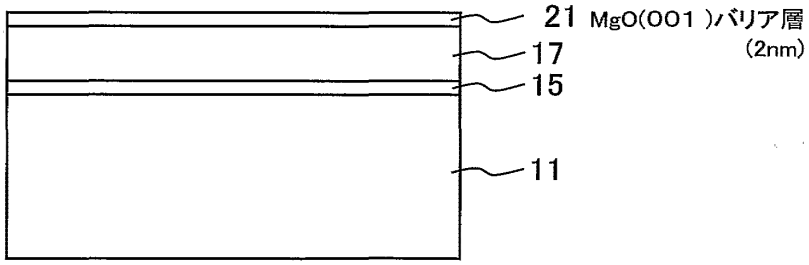
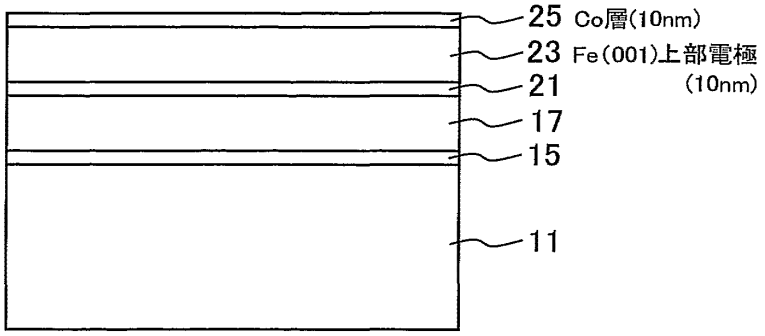


図2 (D)



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図3 (A)

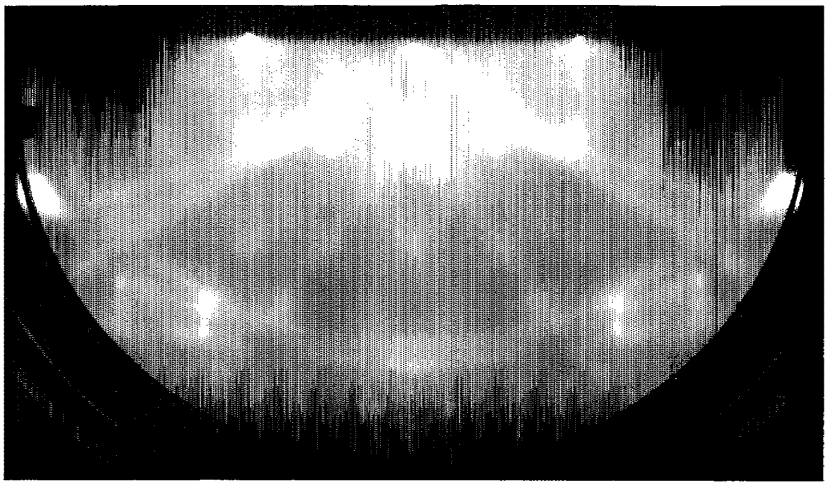
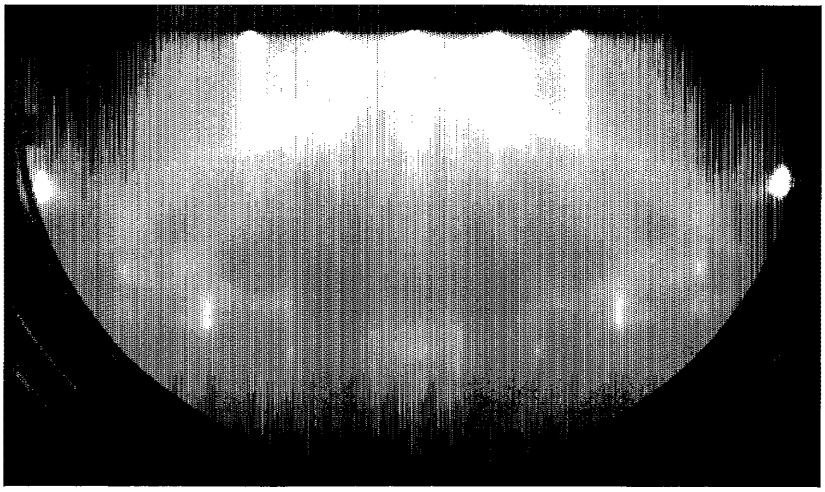
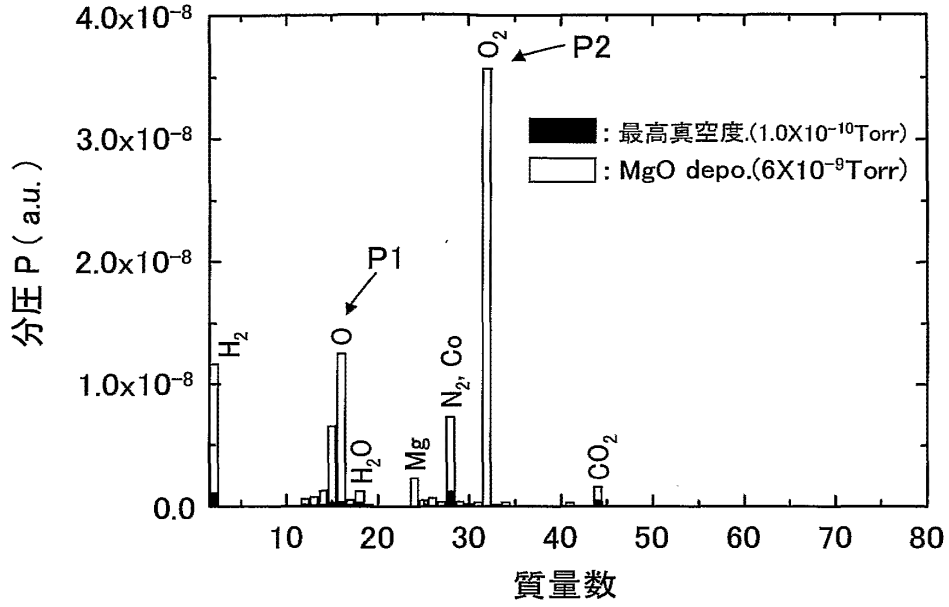


図3 (B)



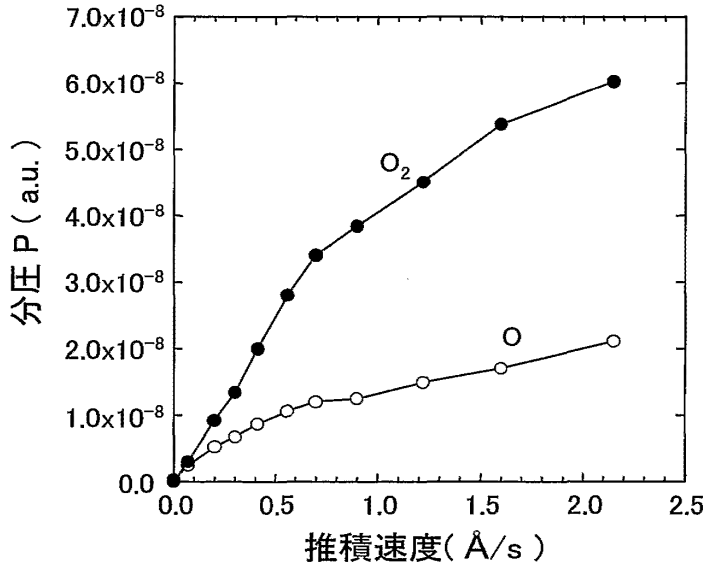
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図4



Massスペクトル

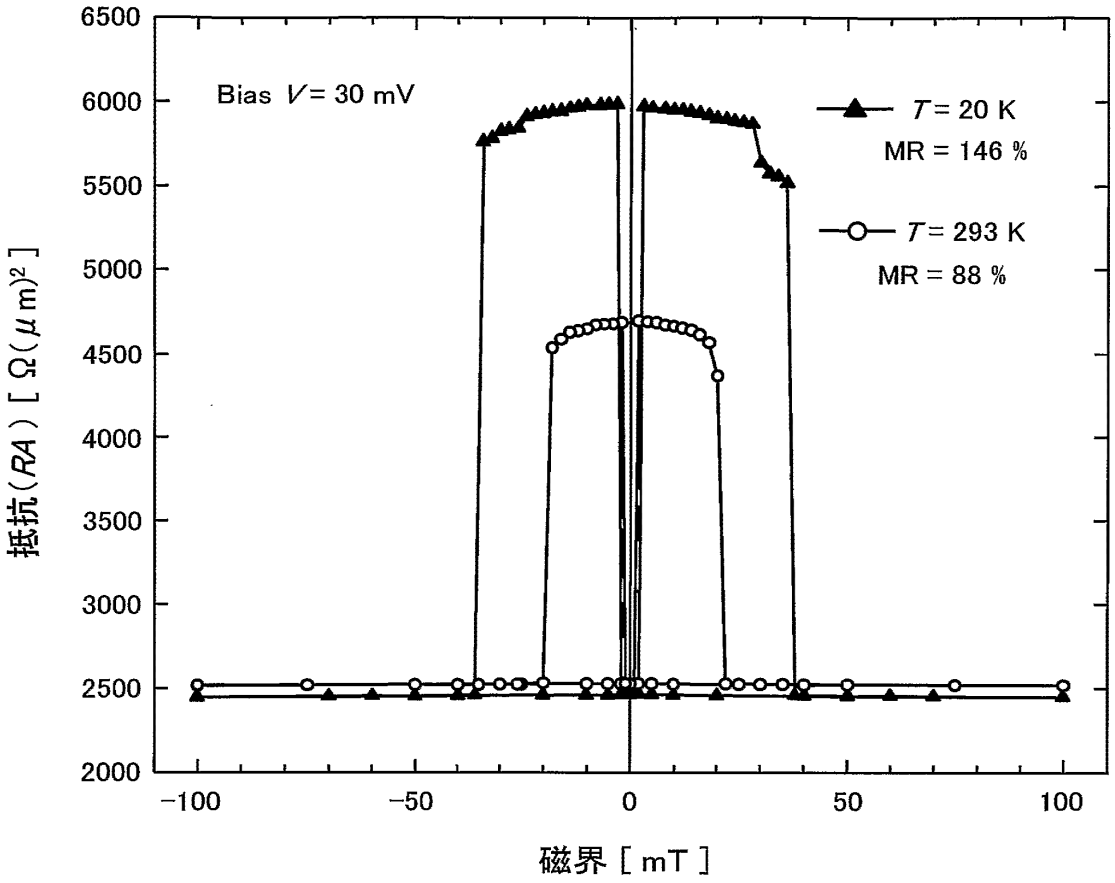
図5



MgO蒸着中の酸素分圧

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図6



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図7 (A)

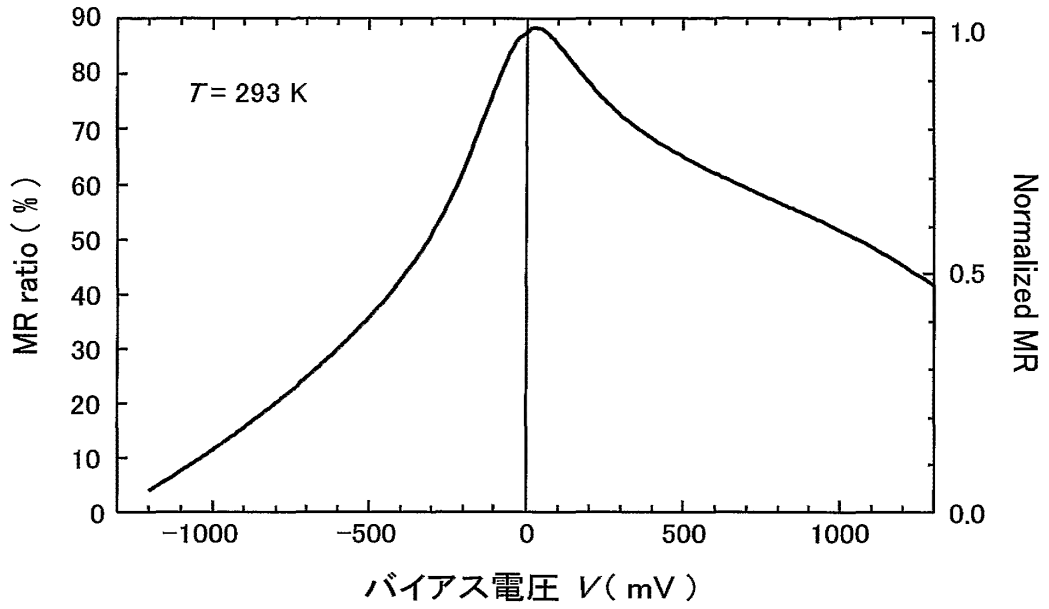
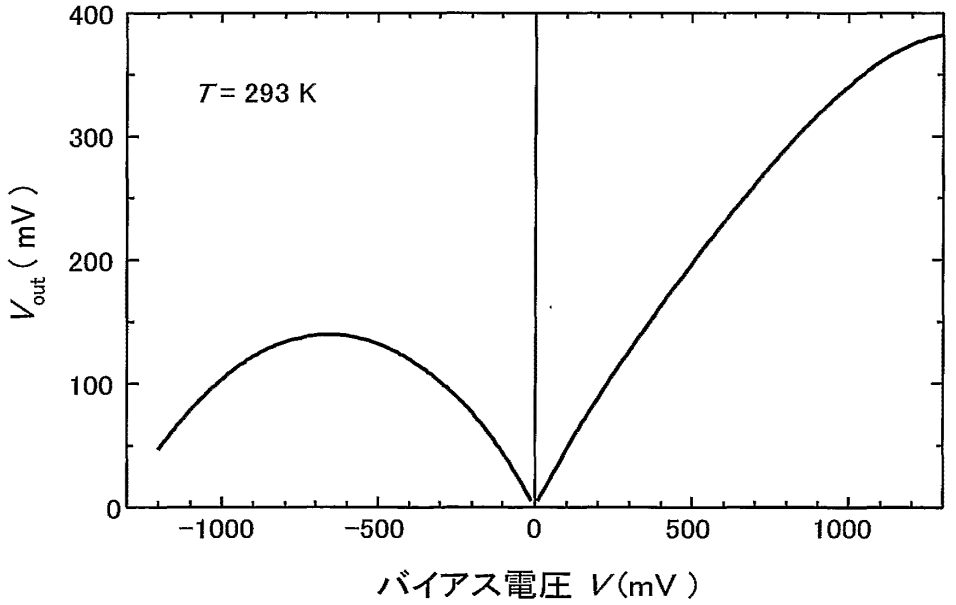


図7 (B)



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図8 (A)

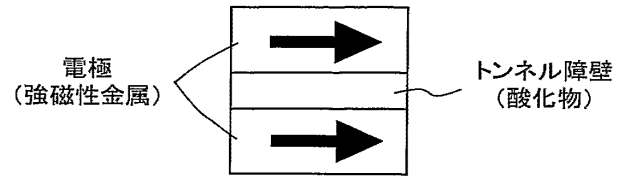
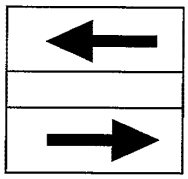


図8 (B)



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図9 (A)

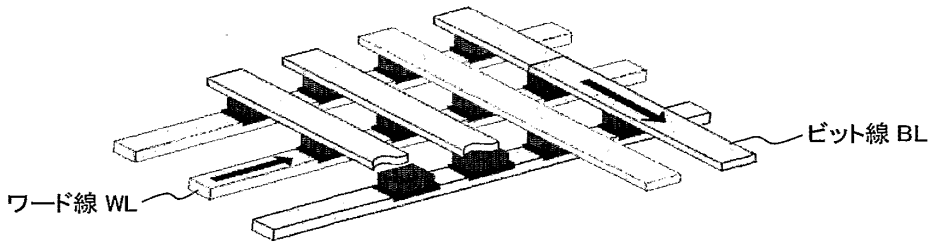


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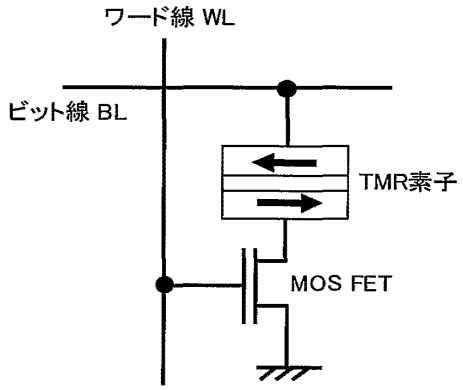
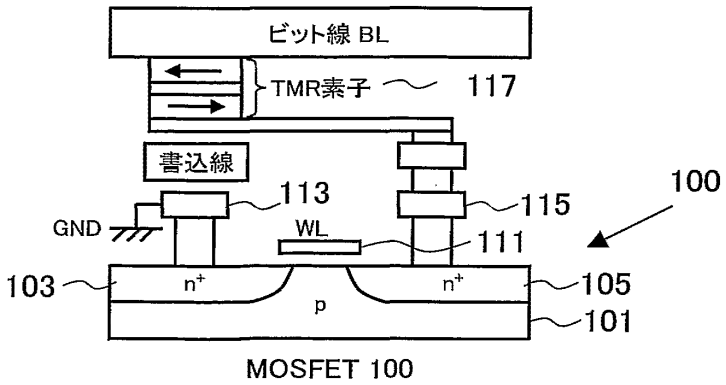


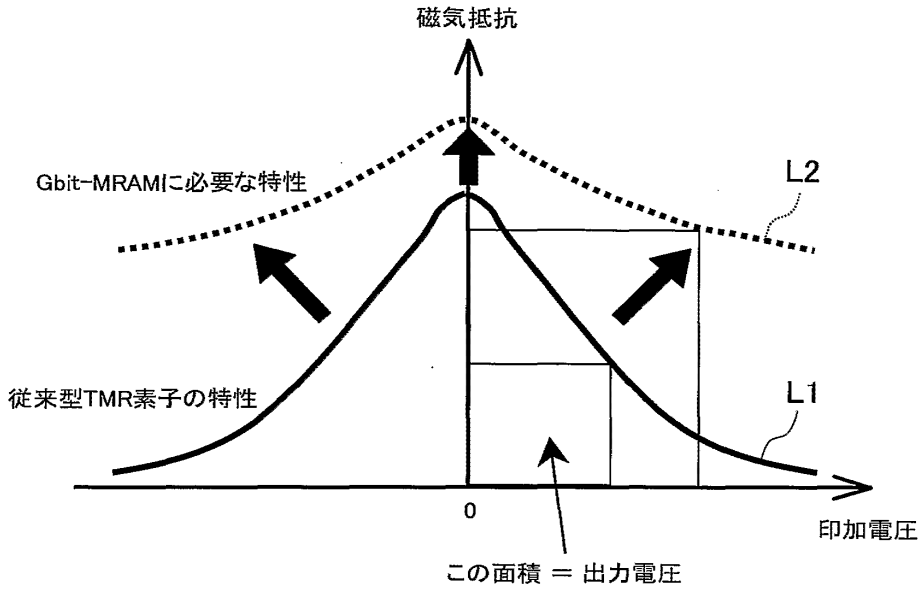
図9 (C)



MOSFET 100

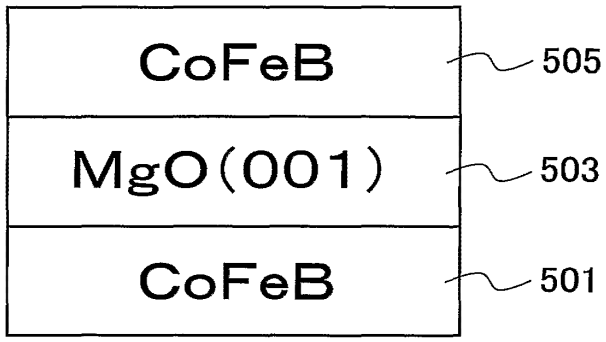
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図10



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図11



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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/004720

A. CLASSIFICATION OF SUBJECT MATTER
Int.Cl[7] H01L43/08, H01F10/32, H01L27/105, 43/10, 43/12

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
Int.Cl[7] H01L43/08, H01F10/32, H01L27/105, 43/10, 43/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2005
Kokai Jitsuyo Shinan Koho 1971-2005 Toroku Jitsuyo Shinan Koho 1994-2005

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Science Citation Index Expanded(Web of Science)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y A	JP 2003-318465 A (National Institute of Advanced Industrial Science and Technology), 07 November, 2003 (07.11.03), Full text & WO 2002/099905 A1 & US 2004/318465 A1 & EP 1391942 A1	1,2,8-10 3-7,11,15-20 12-14,21,22
Y A	JP 2002-204004 A (Toshiba Corp.), 19 July, 2002 (19.07.02), Par. No. [0035] (Family: none)	3-7,11,15-20 12-14,21,22
Y A	JP 2002-289943 A (Toshiba Corp.), 04 October, 2002 (04.10.02), Par. No. [0059] (Family: none)	3-7,11,15-20 12-14,21,22

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
08 June, 2005 (08.06.05)	21 June, 2005 (21.06.05)
Name and mailing address of the ISA/ Japanese Patent Office Facsimile No.	Authorized officer Telephone No.

Form PCT/ISA/210 (second sheet) (January 2004)

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2005/004720

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y A	JP 2003-204010 A (Sony Corp.), 24 October, 2003 (24.10.03), Par. Nos. [0029] to [0031] & WO 2003/085750 A1	15-20 21,22

Form PCT/ISA/210 (continuation of second sheet) (January 2004)

国際調査報告

国際出願番号 PCT／JP2005／004720

A. 発明の属する分野の分類（国際特許分類（IPC））

Int.Cl.[7] H01L43/08, H01F10/32, H01L27/105, 43/10, 43/12

B. 調査を行った分野

調査を行った最小限資料（国際特許分類（IPC））

Int.Cl.[7] H01L43/08, H01F10/32, H01L27/105, 43/10, 43/12

最小限資料以外の資料で調査を行った分野に含まれるもの

日本国実用新案公報	1922－1996年
日本国公開実用新案公報	1971－2005年
日本国実用新案登録公報	1996－2005年
日本国登録実用新案公報	1994－2005年

国際調査で使用した電子データベース（データベースの名称、調査に使用した用語）

Science Citation Index Expanded (Web of Science)

C. 関連すると認められる文献

引用文献のカテゴリー＊	引用文献名 及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求の範囲の番号
X Y A	JP 2003-318465 A (独立行政法人産業技術総合研究所) 2003.11.07, 全文 & WO 2002/099905 A1 & US 2004/318465 A1 & EP 1391942 A1	1, 2, 8-10, 3-7, 11, 15-20 12-14, 21, 22
Y A	JP 2002-204004 A (株式会社東芝) 2002.07.19, 段落【0035】 (ファミリーなし)	3-7, 11, 15-20 12-14, 21, 22
Y A	JP 2002-289943 A (株式会社東芝) 2002.10.04, 段落【0059】 (ファミリーなし)	3-7, 11, 15-20 12-14, 21, 22

☑ C欄の続きにも文献が列挙されている。

☐ パテントファミリーに関する別紙を参照。

＊ 引用文献のカテゴリー

「A」特に関連のある文献ではなく、一般的技術水準を示すもの

「E」国際出願日前の出願または特許であるが、国際出願日以後に公表されたもの

「L」優先権主張に疑義を提起する文献又は他の文献の発行日若しくは他の特別な理由を確立するために引用する文献（理由を付す）

「O」口頭による開示、使用、展示等に言及する文献

「P」国際出願日前で、かつ優先権の主張の基礎となる出願の日の後に公表された文献

「T」国際出願日又は優先日後に公表された文献であって出願と矛盾するものではなく、発明の原理又は理論の理解のために引用するもの

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「Y」特に関連のある文献であって、当該文献と他の1以上の文献との、当業者にとって自明である組合せによって進歩性がないと考えられるもの

「&」同一パテントファミリー文献

国際調査を完了した日 08.06.2005	国際調査報告の発送日 21.6.2005
国際調査機関の名称及びあて先 日本国特許庁（ISA／JP） 郵便番号100－8915 東京都千代田区霞が関三丁目4番3号	特許庁審査官（権限のある職員） 井原 純 電話番号 03－3581－1101 内線 3462
	4M 3349

様式PCT／ISA／210（第2ページ）（2004年1月）

Ｃ（続き）．　関連すると認められる文献

引用文献のカテゴリー＊	引用文献名　及び一部の箇所が関連するときは、その関連する箇所の表示	関連する請求の範囲の番号
Y	JP 2003-204010 A（ソニー株式会社）2003.10.24，段落【００２９】	15-20
A	－【００３１】	21,22
	& WO 2003/085750 A1	

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10. 3. 2005

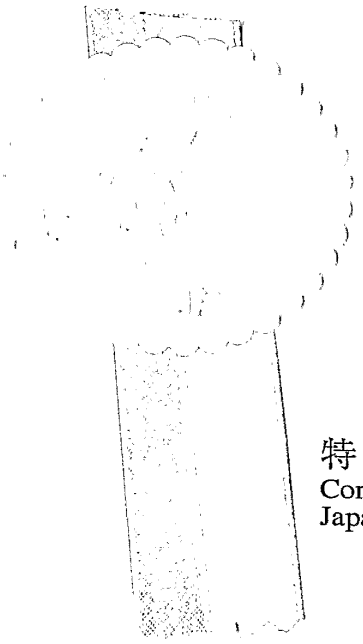
日 本 国 特 許 庁
JAPAN PATENT OFFICE

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
Date of Application: ２００４年１０月２８日

出 願 番 号
Application Number: 特願２００４－３１３３５０
[ST. 10/C]: ［ＪＰ２００４－３１３３５０］

出 願 人
Applicant(s): 独立行政法人科学技術振興機構
独立行政法人産業技術総合研究所



２００５年 ２月２１日

特許庁長官
Commissioner,
Japan Patent Office

小 川 洋

出証番号 出証特２００５－３０１２９４５

【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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【特許出願人】
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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

出証特２００５－３０１２９４５

【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

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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ＭｇＯx（１００）あるいは（１００）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ＭｇＯx（１００）あるいは（１００）結晶面が優先配向した多結晶ＭｇＯx（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ＭｇＯx（１００）あるいは（１００）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ＭｇＯx（１００）あるいは（１００）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、
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、ＭｇＯx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、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ＭｇＯx（１００）あるいは（１００）結晶面が優先配向した多結晶ＭｇＯx（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

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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。

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【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

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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。

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【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。
$$\Delta R/Rp=(Rap-Rp)/Rp$$
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。
【００１６】
ここで、P_α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

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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ｋｚ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ＦｅΔ_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。

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【００２１】
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。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

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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。

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【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】

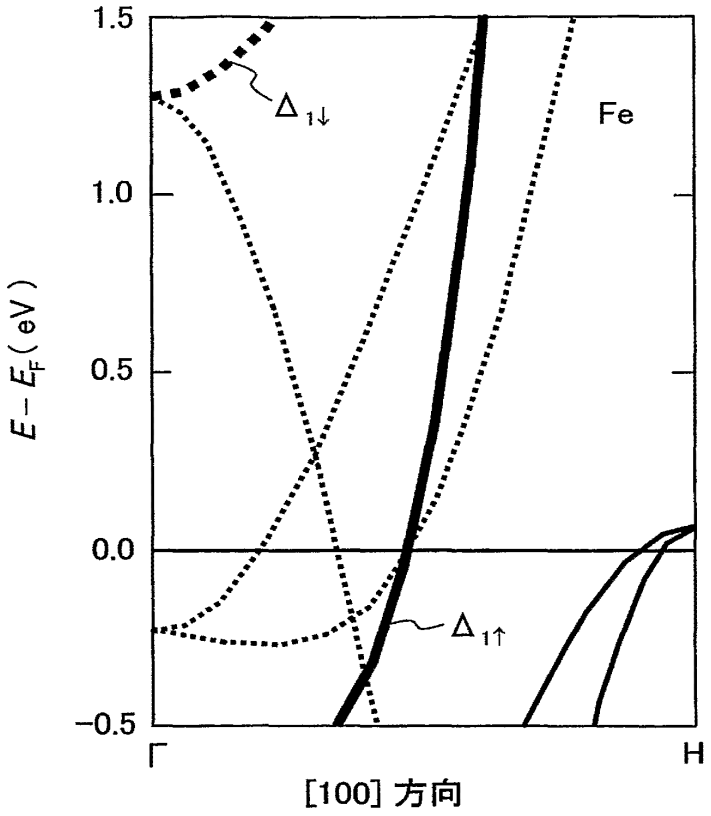
【００３３】

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）。

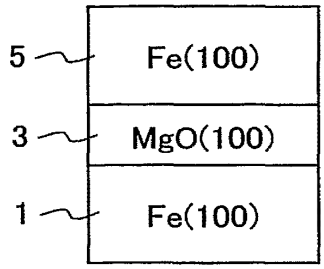
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【書類名】図面
【図１】

(A)

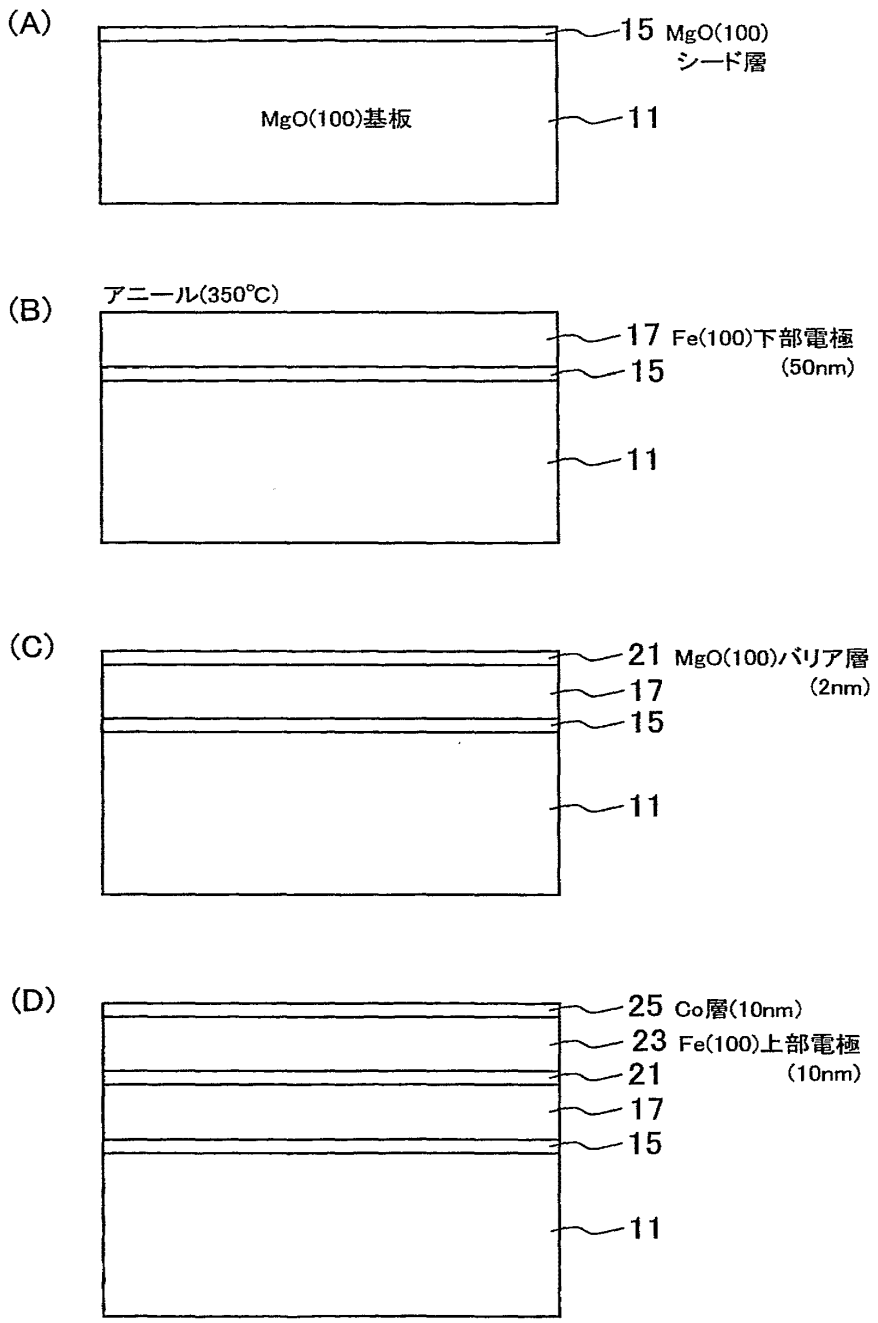


(B)



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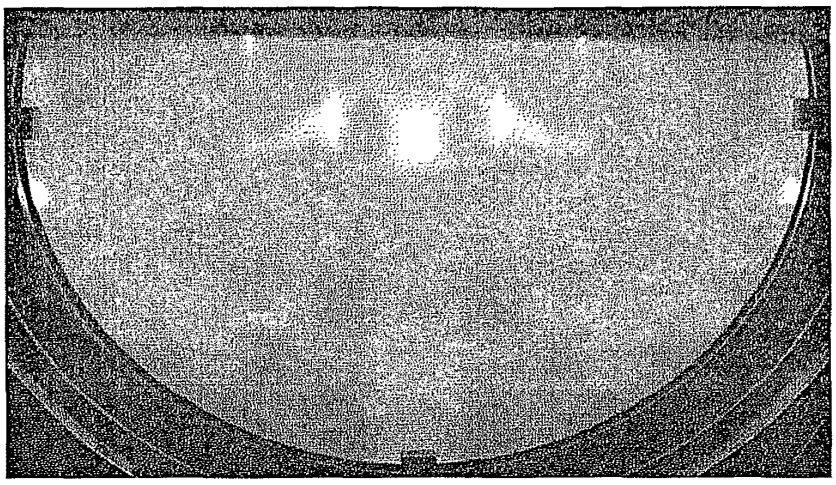
【図２】



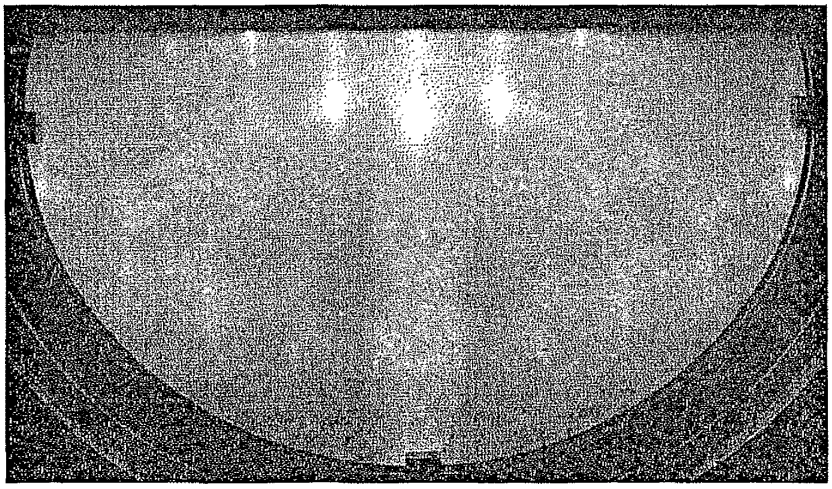
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【図３】

(a)

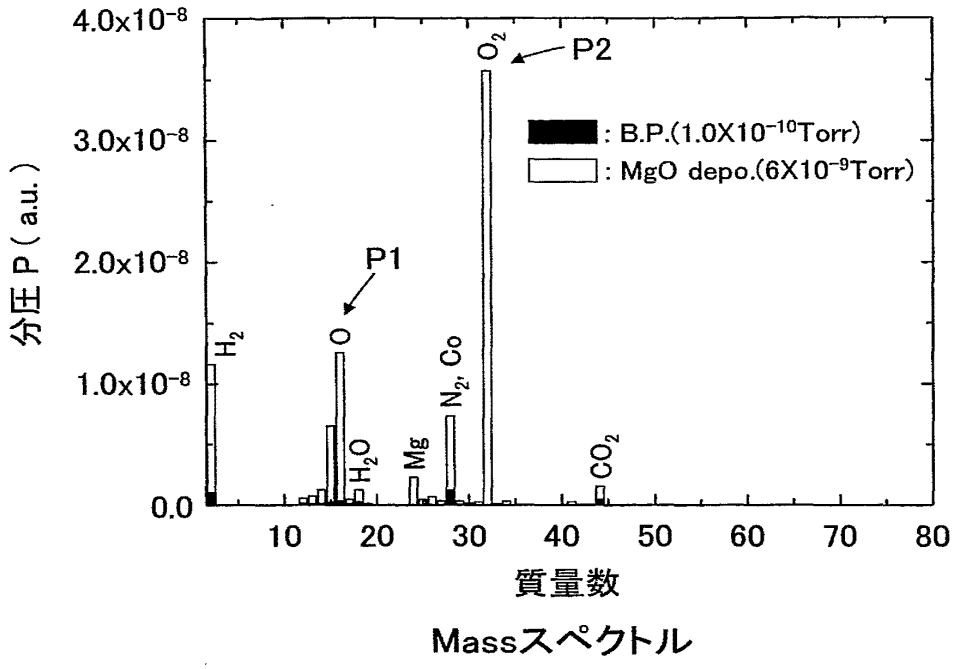


(b)



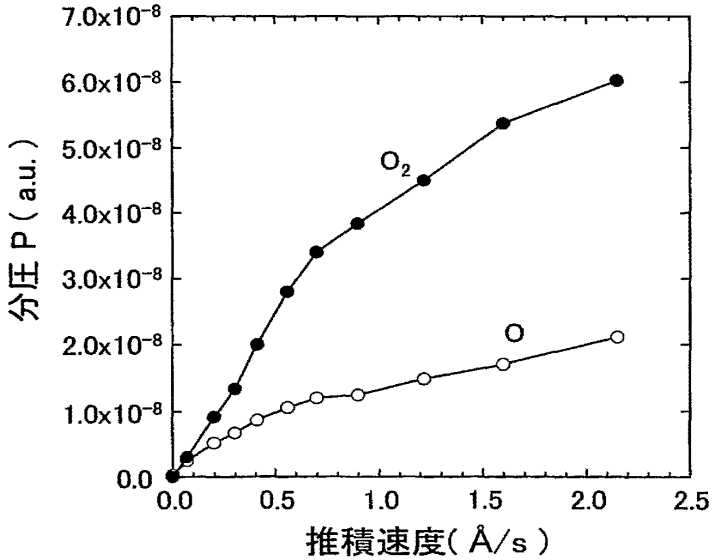
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【図４】



Massスペクトル

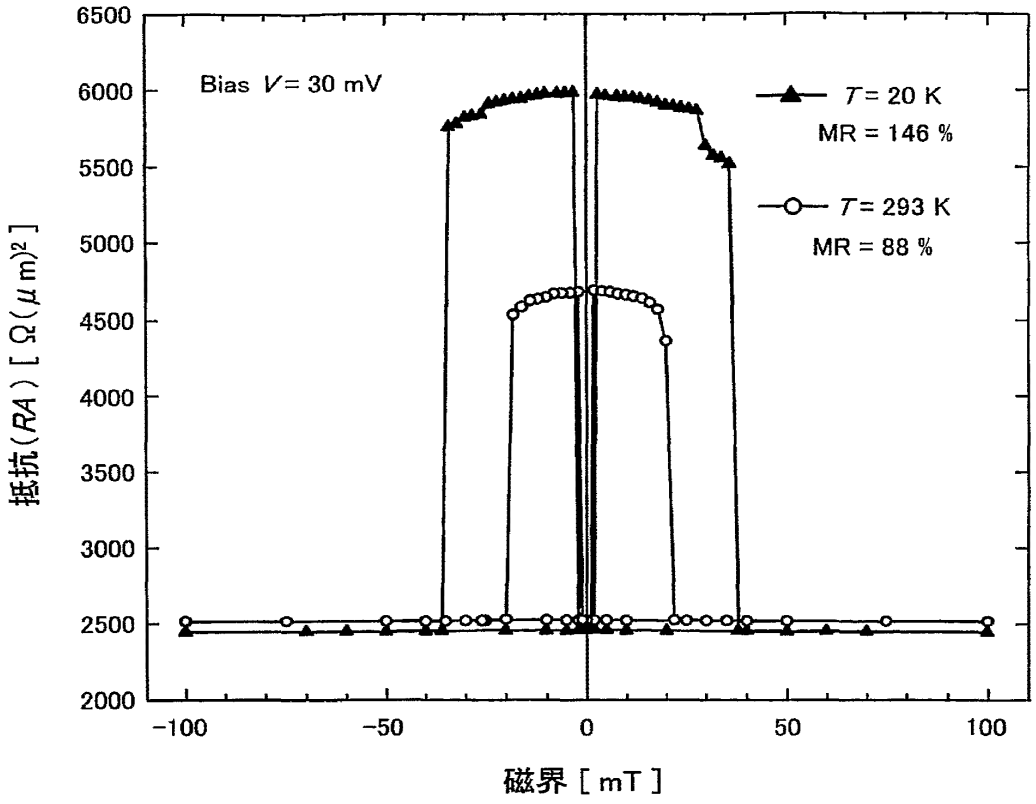
【図５】



MgO蒸着中の酸素分圧

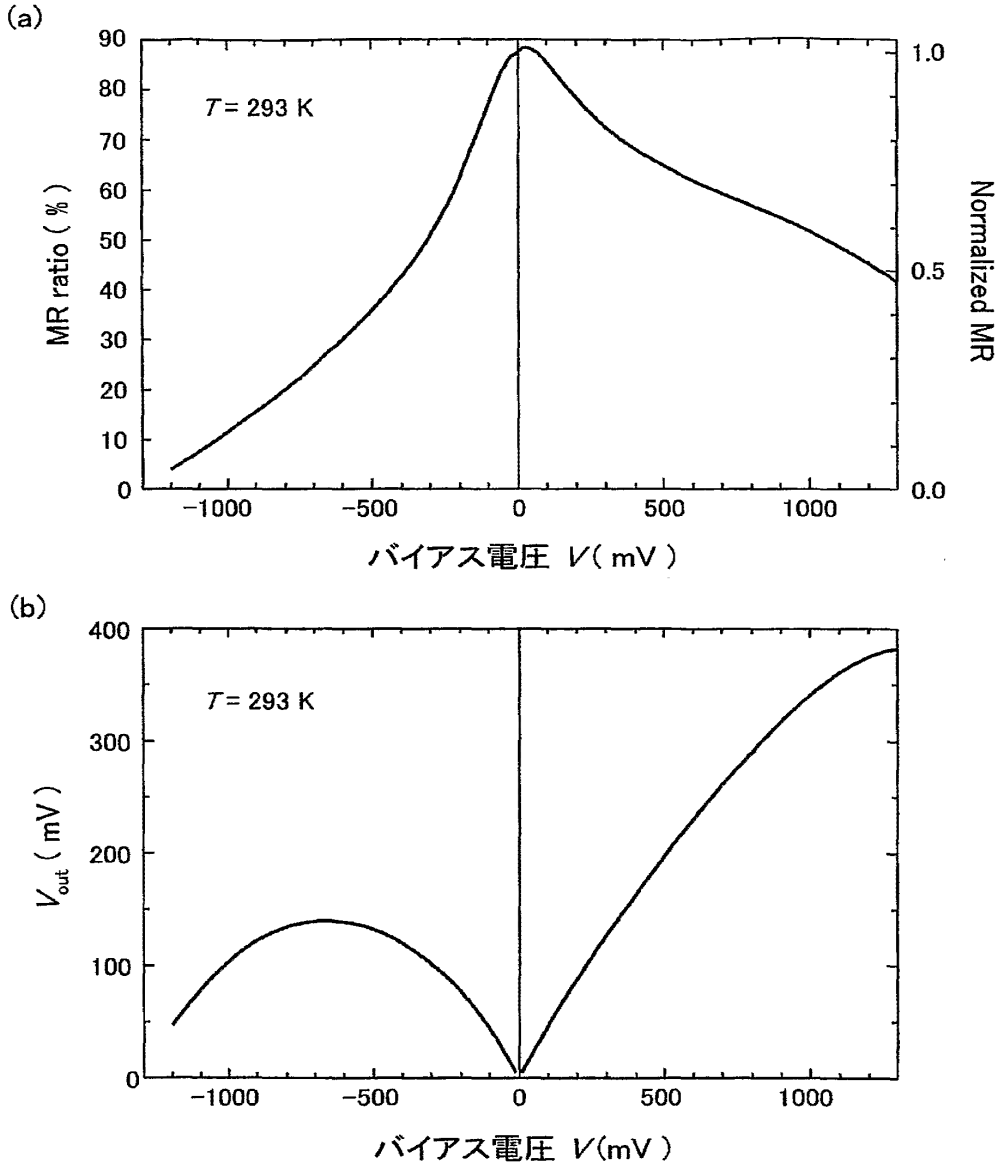
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【図６】



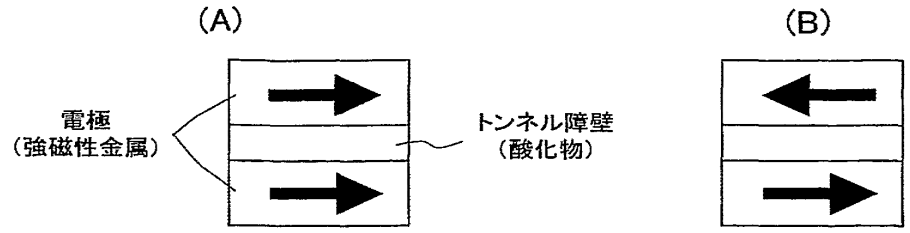
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【図７】



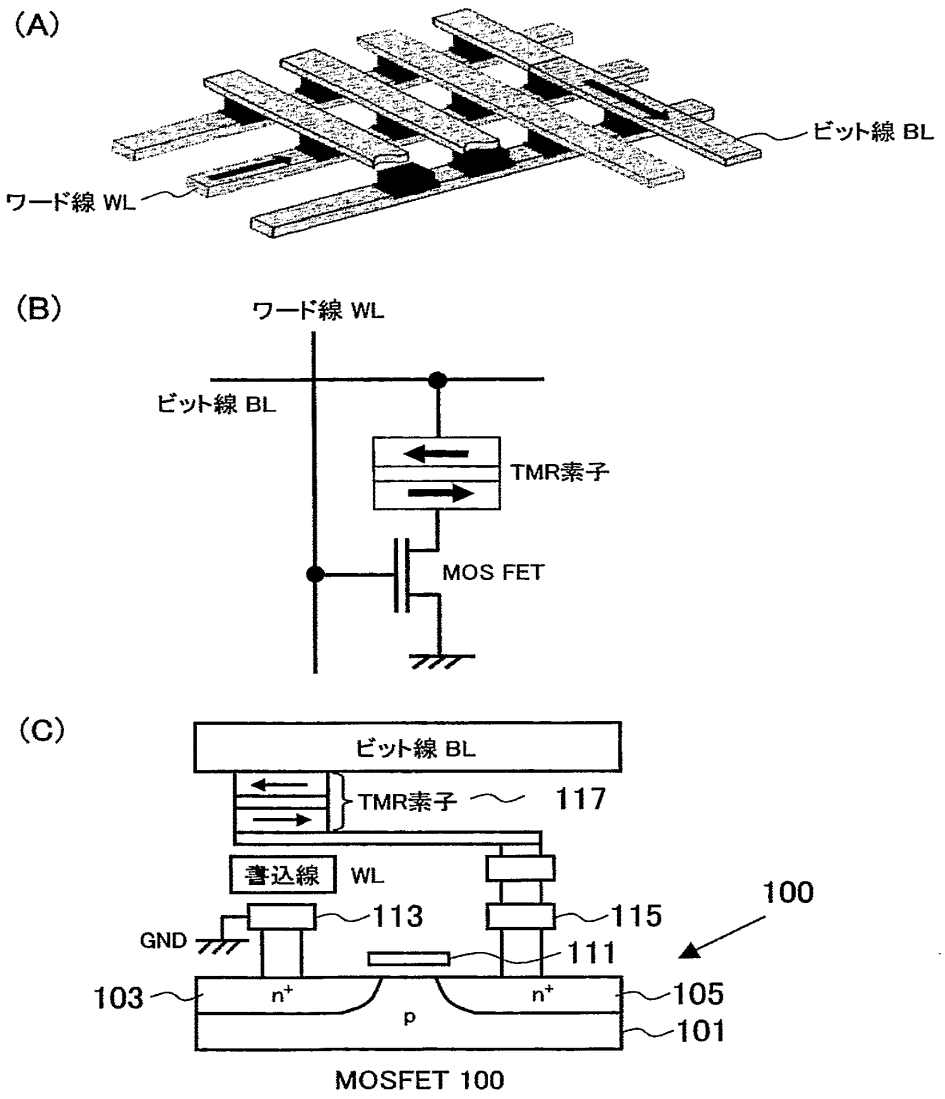
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【図８】



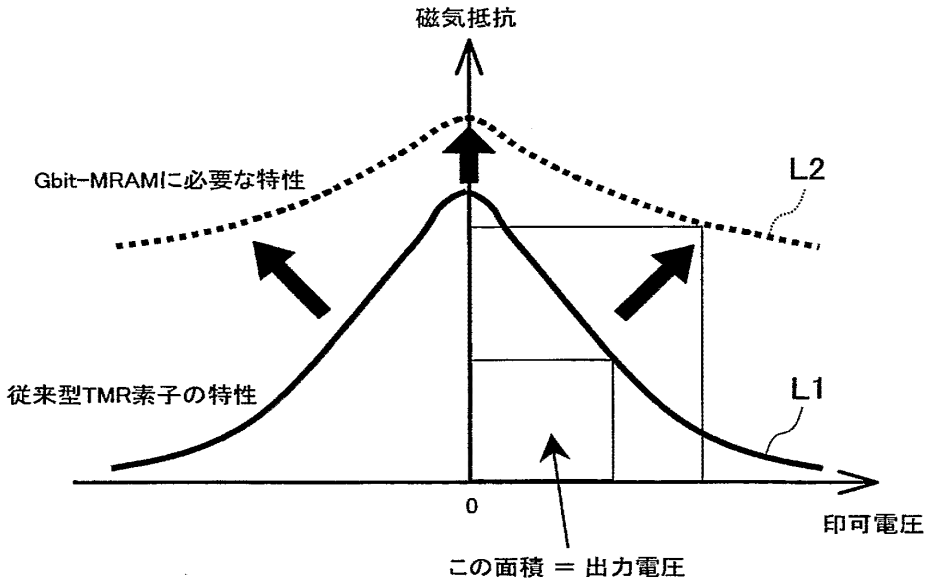
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【図９】

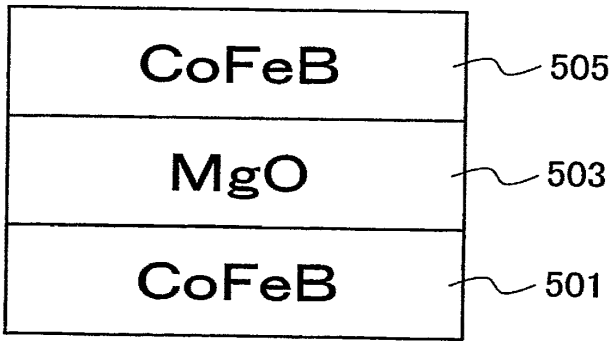


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【図１０】



【図１１】



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【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

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特願２００４－３１３３５０

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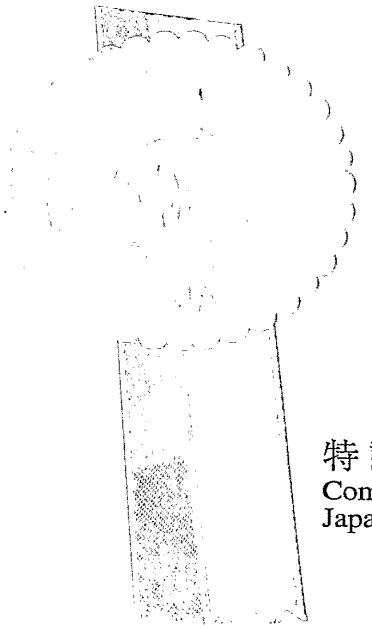
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【書類名】特許請求の範囲
【請求項１】
トンネル障壁層と、該トンネル障壁層の第１面側に形成されたＢＣＣ構造を有する第１の強磁性体層と、前記トンネル障壁層の第２面側に形成されたＢＣＣ構造を有する第２の強磁性体層と、を有する磁気トンネル接合構造であって、
前記トンネル障壁層が、単結晶MgO_x（１００）あるいは（１００）結晶面が優先配向した多結晶MgO_x（$x<1$）層により形成されていることを特徴とする磁気抵抗素子。
【請求項２】
ＭｇＯ（１００）からなるトンネル障壁層と、該トンネル障壁層の第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

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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ＭｇＯx（１００）あるいは（１００）結晶面が優先配向した多結晶ＭｇＯx（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ＭｇＯx（１００）あるいは（１００）結晶面が優先配向した多結晶ＭｇＯx（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ＭｇＯx（１００）あるいは（１００）結晶面が優先配向した多結晶ＭｇＯx（ｘ＜１）からなるトンネル障壁層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ＭｇＯx（１００）あるいは（１００）結晶面が優先配向した多結晶ＭｇＯx（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、ＭｇＯx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、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１１に記載の磁気抵抗素子の製造方法。

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【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

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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

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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。
$$\Delta R/Rp=(Rap-Rp)/Rp$$
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
$$ここで、P_\alpha=(D_\alpha\uparrow(E_F)-D_\alpha\downarrow(E_F))/(D_\alpha\uparrow(E_F)+D_\alpha\downarrow(E_F))、\alpha=1,2 \quad (1)$$ と表される。
【００１６】
ここで、P_α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。
【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

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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（2×10^{-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。

【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

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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

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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^{-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】

【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（

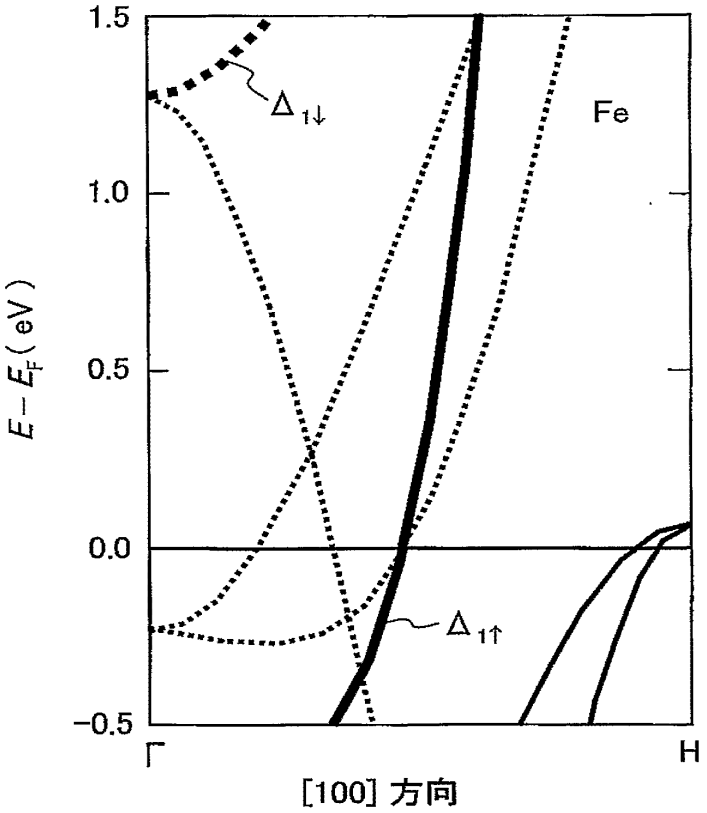
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ｘ＜１）、１５…ＭｇＯ（１００）シード層、１７…エピタキシャルＦｅ（１００）下部電極（第１電極）、２１…ＭｇＯ（１００）バリア層、２３…エピタキシャルＦｅ（１００）上部電極（第２電極）。

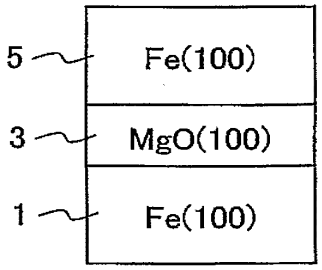
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【書類名】図面
【図１】

(A)

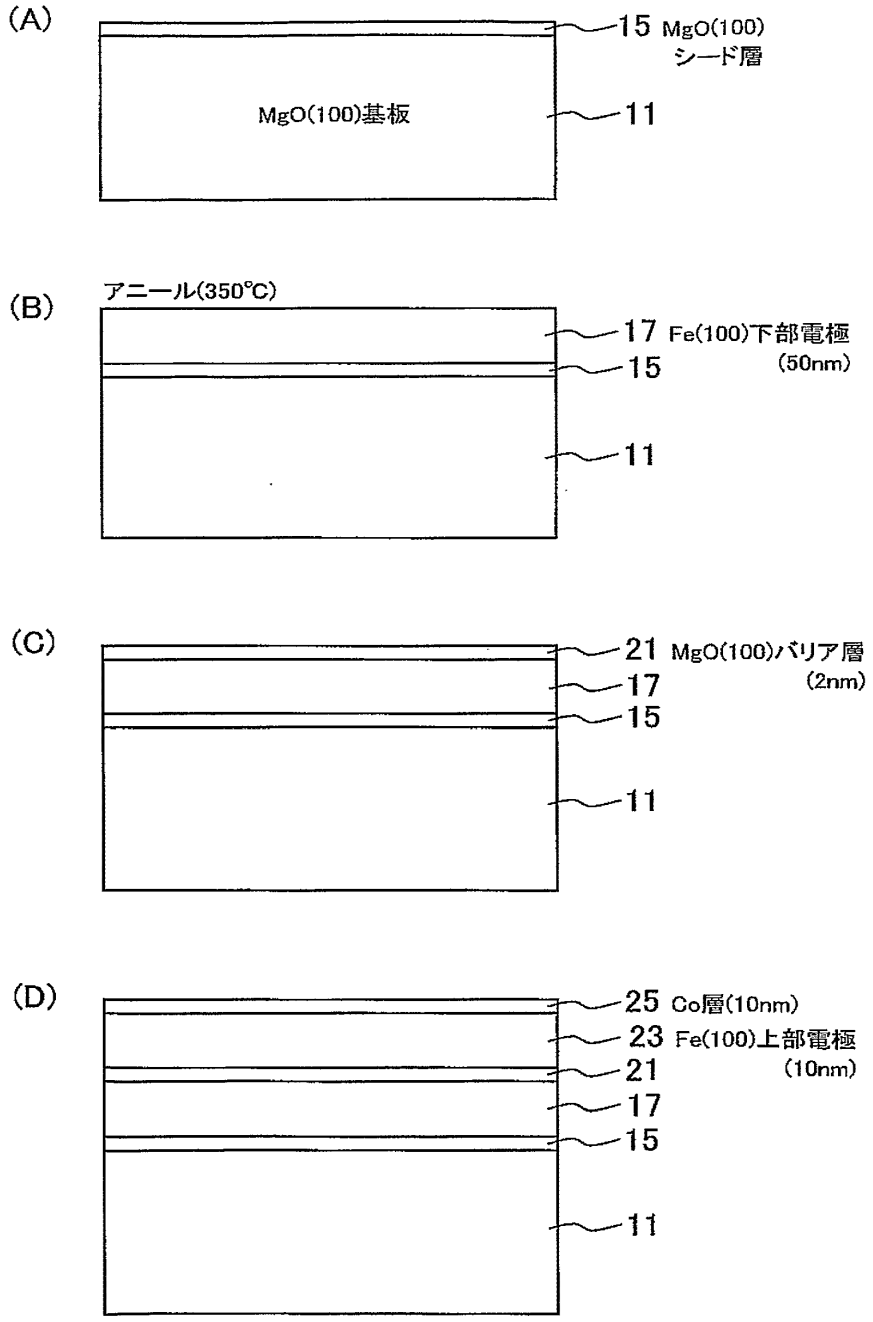


(B)



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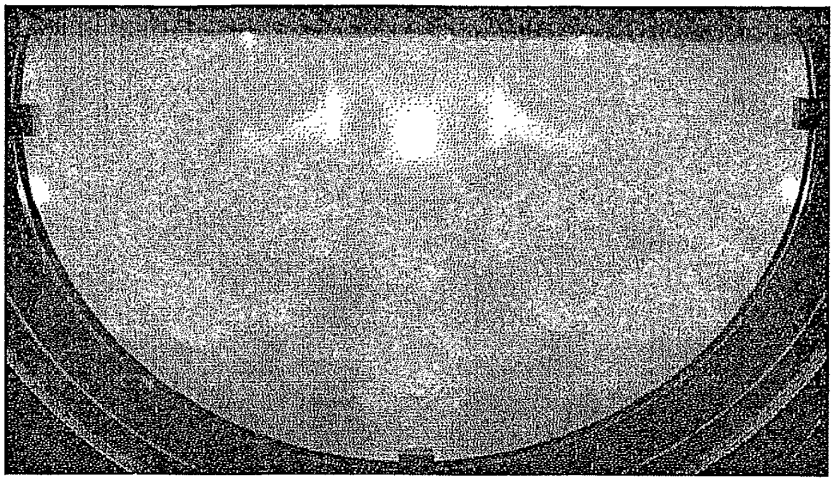
【図２】



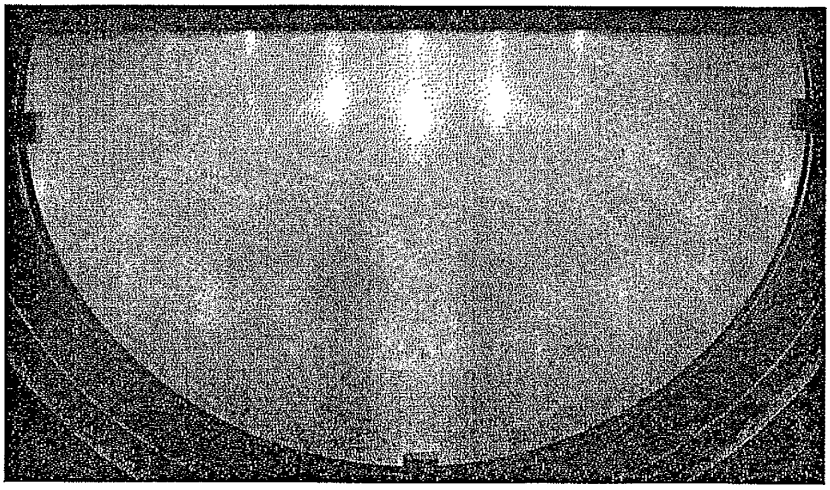
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【図３】

(a)

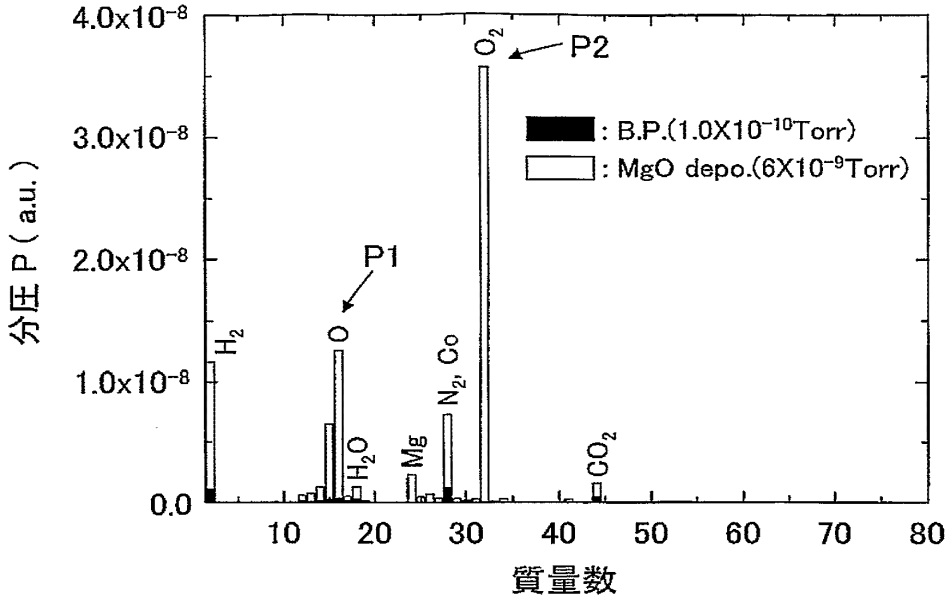


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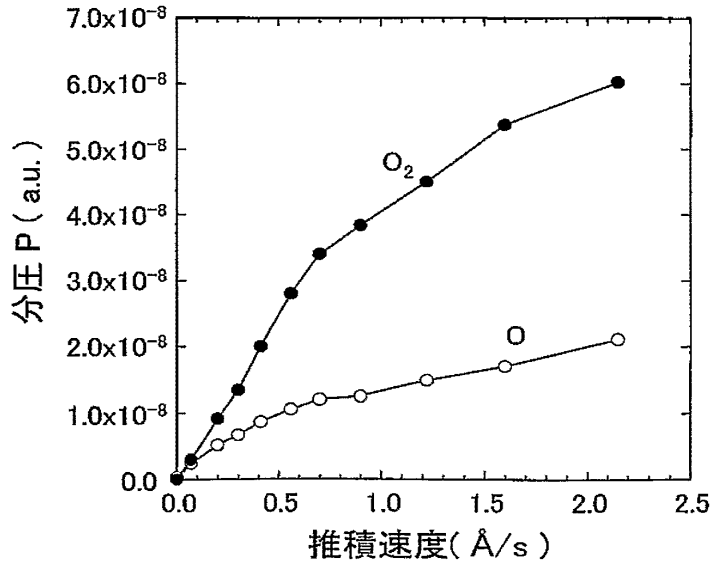
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【図４】



Massスペクトル

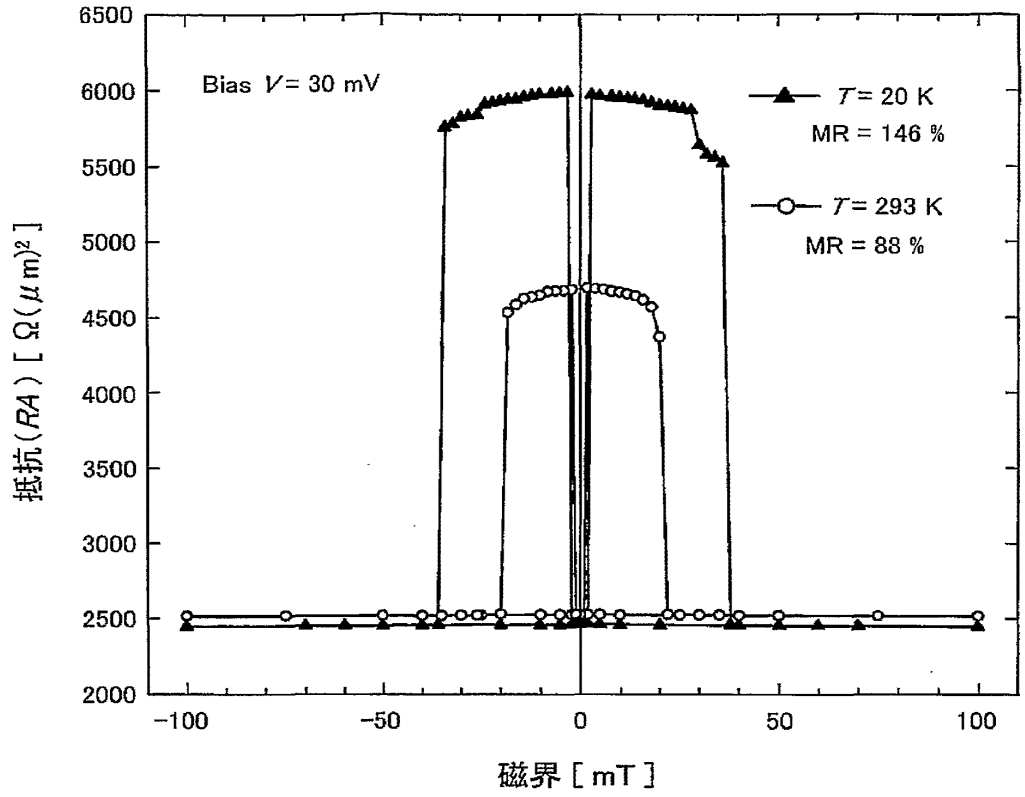
【図５】



MgO蒸着中の酸素分圧

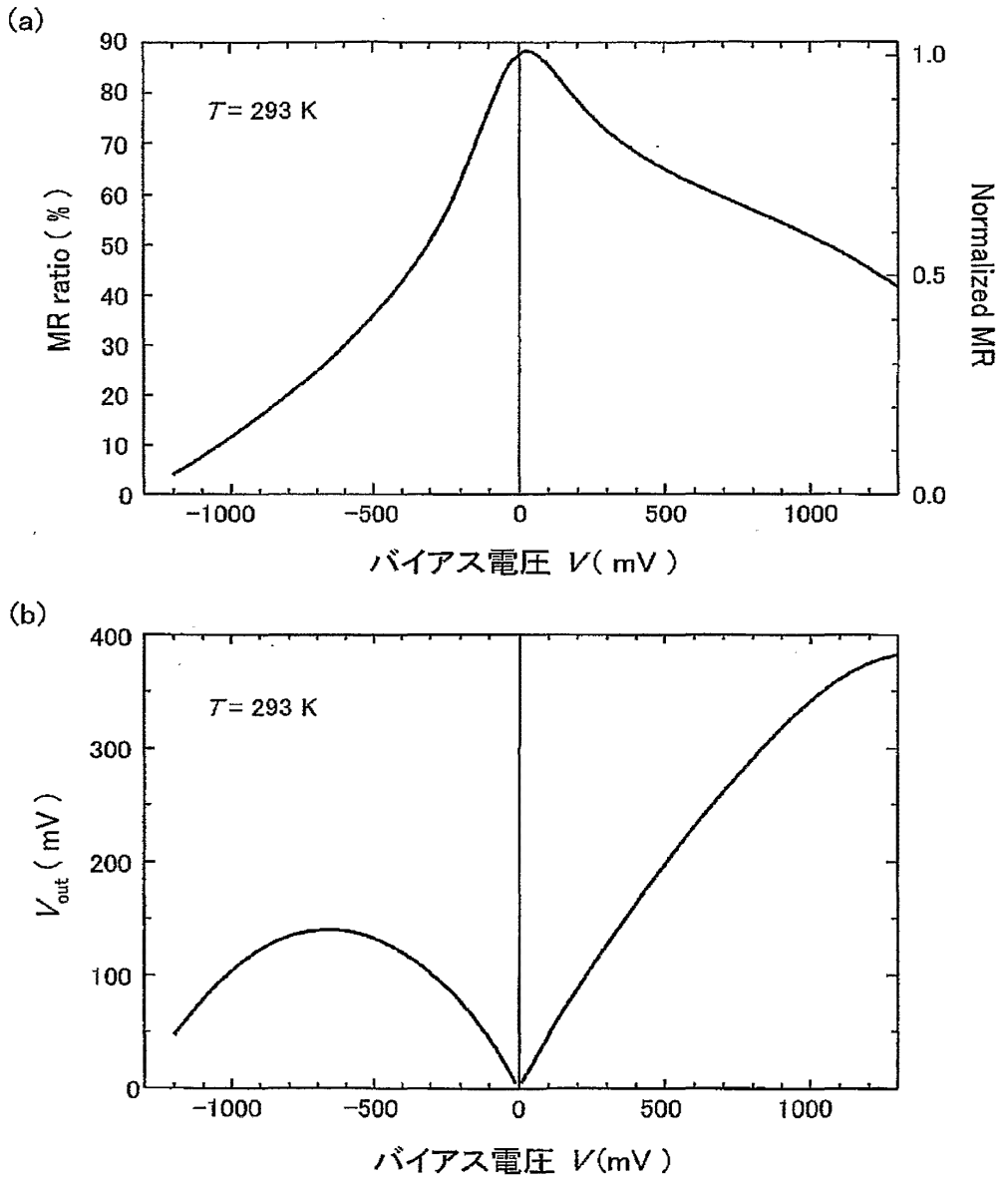
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【図６】

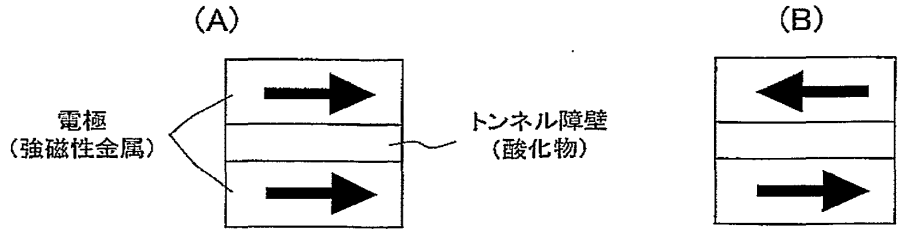


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【図７】



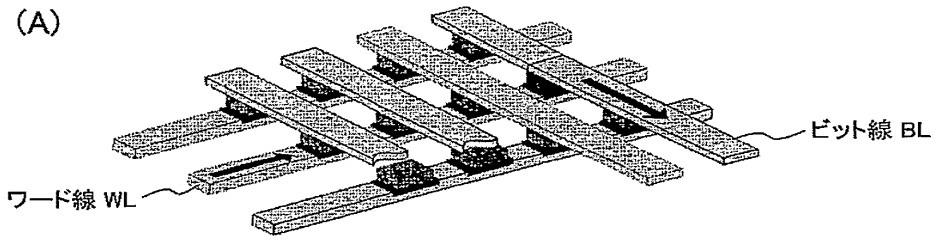
【図８】



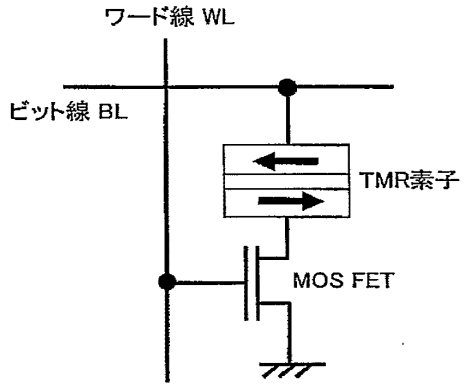
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【図９】

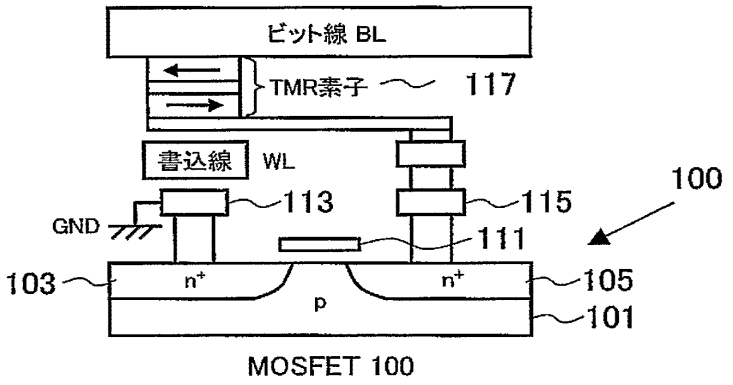
(A)



(B)



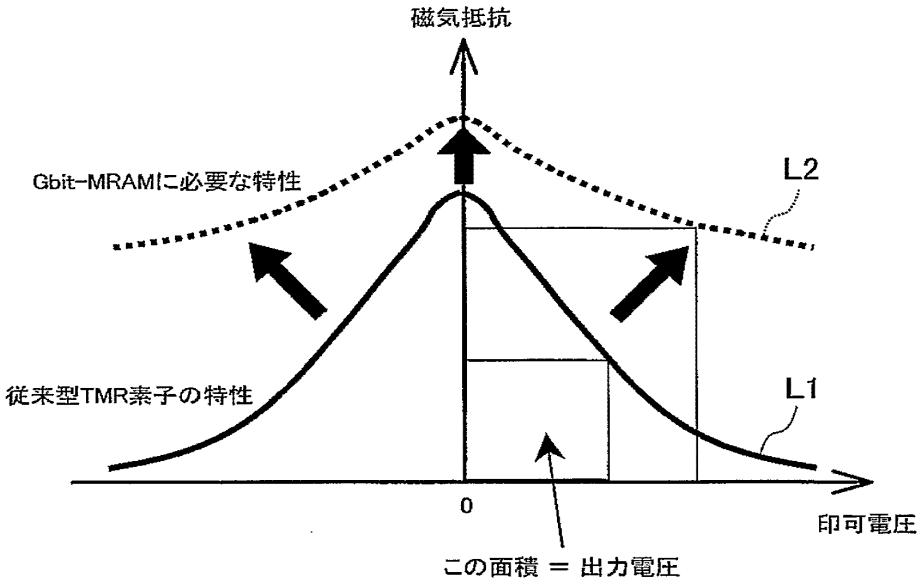
(C)



MOSFET 100

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【図１０】



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【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

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特願２００４－０７１１８６

出　願　人　履　歴　情　報

識別番号　　［５０３３６０１１５］

１．変更年月日　　２００３年１０月　１日
［変更理由］　新規登録
住　所　　埼玉県川口市本町４丁目１番８号
氏　名　　独立行政法人　科学技術振興機構

２．変更年月日　　２００４年　４月　１日
［変更理由］　名称変更
住　所　　埼玉県川口市本町４丁目１番８号
氏　名　　独立行政法人科学技術振興機構

出証番号　出証特２００５－３０１２９３９

特願２００４－０７１１８６

出　願　人　履　歴　情　報

識別番号　［３０１０２１５３３］

１．変更年月日　２００１年　４月　２日
［変更理由］　新規登録
住　所　東京都千代田区霞が関１－３－１
氏　名　独立行政法人産業技術総合研究所

出証番号　出証特２００５－３０１２９３９

10/591947

PATENT APPLICATION FEE DETERMINATION RECORD
Effective December 8, 2004

Application or Docket Number: 38327

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)	SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
			RATE	FEE		RATE	FEE
U.S. NATIONAL STAGE FEES							
BASIC FEE	SMALL ENT. = $ 150	LARGE ENT. = $ 300	BASIC FEE		OR	BASIC FEE	300
EXAMINATION FEE	Satisfies PCT Article 33(1)-(4) = $ 50 / $ 100	All other situations = $ 100 / $ 200	EXAM. FEE			EXAM. FEE	200
SEARCH FEE	U.S. is ISA = $ 50 / $ 100 ALL other countries = $ 200 / $ 400	ALL other situations = $ 250 / $ 500	SEARCH FEE			SEARCH FEE	400
FEE FOR EXTRA SPEC. PGS.	39 minus 100 =	/ 50 =	X $ 125 =			X $ 250 =	
TOTAL CHARGEABLE CLAIMS	39 minus 20 =	* 19	X $ 25 =		OR	X $ 50 =	950
INDEPENDENT CLAIMS	12 minus 3 =	*	X $ 100 =		OR	X $ 200 =	1800
MULTIPLE DEPENDENT CLAIM PRESENT ☐			+ $ 180 =		OR	+ $ 360 =	
* If the difference in column 1 is less than zero, enter "0" in column 2			TOTAL		OR	TOTAL	3650

CLAIMS 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	*	Minus	**	=	X $ 25 =		OR	X $ 50 =	
	Independent	*	Minus	***	=	X $ 100 =		OR	X $ 200 =	
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM ☐					+ $ 180 =		OR	+ $ 360 =	
						TOTAL ADDIT. FEE		OR	TOTAL ADDIT. 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	*	Minus	**	=	X $ 25 =		OR	X $ 50 =	
	Independent	*	Minus	***	=	X $ 100 =		OR	X $ 200 =	
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM ☐					+ $ 180 =		OR	+ $ 360 =	
						TOTAL ADDIT. FEE		OR	TOTAL ADDIT. 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.

Barbara Campbell, PCT National Stage Division

FORM PTO-875 (Rev. 02/2005) — Patent and Trademark Office - U.S. DEPARTMENT OF COMMERCE

MULTIPLE DEPENDENT CLAIM FEE CALCULATION SHEET

(FOR USE WITH FORM PTO-875)

SERIAL NO.	FILING DATE
10/591,947	
APPLICANT(S)	

CLAIMS

	AS FILED		AFTER 1st AMENDMENT		AFTER 2nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
TOTAL IND.			12			
TOTAL DEP.			27			
TOTAL CLAIMS			39			

	AS FILED		AFTER 1st AMENDMENT		AFTER 2nd AMENDMENT	
	IND.	DEP.	IND.	DEP.	IND.	DEP.
TOTAL IND.						
TOTAL DEP.						
TOTAL CLAIMS						

U.S. DEPARTMENT of COMMERCE

DO/ EO WORKSHEET

P. Kidwell Patent Application Specialist/ National Stage Division

U.S. Appl. No. 10/ 521947 International Appl. No. PCT/ JP05/04720

Application filed by : ☐ 20 months ☑ 30 months

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Publication Date : 22 Sep 2005 Not Published : ☐ U.S. only designated ☐ EP request Published : ☐ EP request

INTERNATIONAL APPLICATION PAPERS IN THE APPLICATION FILE :

☑ International Application *(RECORD COPY)*

☐ Article 19 Amendments

☐ PCT/IPEA/409 IPER : ☐ EP ☐ JP ☐ SE ☐ AU ☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ ___

☐ Annexes to 409

☐ PCT/ISA/237 : ☐ EP ☐ JP ☐ SE ☐ AU ☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ ___

☐ PCT/IPEA/409 or PCT/ISA/237 was NOT AVAILABLE at the time of paralegal review

☐ PCT/IB/306

☐ Request form PCT/RO/101

☑ PCT/ISA/210 - Search Report : ☐ EP ☑ JP ☐ SE ☐ AU ☐ US ☐ FR ☐ CN ☐ ES ☐ RU ☐ AT ☐ KR ☐ ___ ☐ NONE

☐ Search Report References

☑ Priority Document (s) No. 2

☐ N/A

☐ Priority Document was NOT AVAILABLE at the time of paralegal review

☐ Other : _____

RECEIPTS FROM THE APPLICANT *(other than checked above) :*

☑ Basic National Fee *(or authorization to charge)*

☑ Description ☑ Claims ☑ Abstract

☑ Drawing Figure(s) - (# of drwgs. 10)

☐ Translation of Article 19 Amendments ☐ entered ☐ not entered :
☐ not a page for page substitution
☐ replaced by Article 34 Amendment

☐ Annexes to 409 ☐ entered ☐ not entered :
☐ not a page for page substitution
☐ no translation ☐ other : _____

☑ Application Data Sheet

☑ Power of Attorney

☐ Change of Address

☑ Preliminary Amendment(s) Filed on : 1. ☐ same as 371 request date 2. 9/08/06 3. _____

☑ Information Disclosure Statement(s) Filed on : 1. ☐ same as 371 request date 2. 9/08/04 3. _____

☐ Assignment Document (forwarded to Assignment Branch)

☐ Assignee Statement Under 37 CFR 3.73(b)

☐ Assignee PG Publication Notice

☐ Substitute Specification Filed on : 1. ☐ same as 371 request date 2. _____ 3. _____

☐ Verified Small Status Statement

☑ Oath/ Declaration (executed)

☐ Oath/ Declaration ☐ unsigned ☐ no citizenship ☐ other

☐ DNA Diskette ☐ Sequence Listing

☐ Other : _____

NOTES : ☐ I.A. used as Specification ☐ Other :

5 U.S.C. 371 - Receipt of Request (PTO-1390)	
ate Acceptable Oath/ Declaration Received	9/08/04
ate of Completion of requirements under 35 U.S.C. 371	
ate of Completion of DO/ EO 903 - Notification of Acceptance	5/11/07
ate of Completion of DO/ EO 905 - Notification of Missing Requirements	
ate of Completion of DO/ EO 909 - Notification of Abandonment	
ate of Completion of DO/ EO 916 - Notification of Defective Response	
ate of Completion of DO/ EO 922 - Notification to Comply w/ Requirements for Patent pplications Containing Nucleotide and/or Amino Acid Sequence Disclosures	
ate of Completion of DO/ EO 923	

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD
Substitute for Form PTO-875

Application or Docket Number	Filing Date	☐ To be Mailed
10591947		

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))	N/A	N/A	N/A			N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (l), 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

A. PE

AMENDMENT	(Column 1)		(Column 2)	(Column 3)	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
9.8.06	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA					
Total (37 CFR 1.16(i))	* 39	Minus	20	= 19	X $25 =		OR	X $50=	950
Independent (37 CFR 1.16(h))	* 12	Minus	3	= 9	X $100 =		OR	X $200=	1800
☐ 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	2750

AMENDMENT	(Column 1)		(Column 2)	(Column 3)	RATE ($)	ADDITIONAL FEE ($)	OR	RATE ($)	ADDITIONAL FEE ($)
	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA					
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:

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.

CLAIMS ONLY

Application Number: 10591947

Filing Date:

Applicant(s):

* May be used for additional claims or amendments

CLAIMS	AS FILED		AFTER FIRST AMENDMENT		AFTER SECOND AMENDMENT		*		*		*	
	Indep	Depend	Indep	Depend	Indep	Depend	Indep	Depend	Indep	Depend	Indep	Depend
1	/						51					
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49							99					
50							100					
Total Indep	12						Total Indep					
Total Depend	27						Total Depend					
Total Claims	39						Total Claims					

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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
10/591,947	09/08/2006	2827	3650	HIRA.0236	39	12

CONFIRMATION NO. 8009

38327
REED SMITH LLP
3110 FAIRVIEW PARK DRIVE, SUITE 1400
FALLS CHURCH, VA22042

FILING RECEIPT

Date Mailed: 05/14/2007

Receipt is acknowledged of this regular Patent Application. It will be considered in its order and you will be notified as to the results of the examination. Be sure to provide the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION when inquiring about this application. 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 mail to the Commissioner for Patents P.O. Box 1450 Alexandria Va 22313-1450. 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 (if appropriate).**

Applicant(s)

Shinji Yuasa, Ibaraki, JAPAN;

Power of Attorney: The patent practitioners associated with Customer Number 38327

Domestic Priority data as claimed by applicant

This application is a 371 of PCT/JP05/04720 03/10/2005

Foreign Applications

JAPAN 2004-071186 03/12/2004
JAPAN 2004-313350 10/28/2004

If Required, Foreign Filing License Granted: 05/12/2007

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US10/591,947**

Projected Publication Date: 08/23/2007

Non-Publication Request: No

Early Publication Request: No

Title

Magnetic tunnel junction device and method of manufacturing the same

Preliminary Class

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

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U.S. APPLICATION NUMBER NO.	FIRST NAMED APPLICANT	ATTY. DOCKET NO.
10/591,947	Shinji Yuasa	HIRA.0236

INTERNATIONAL APPLICATION NO.	
PCT/JP05/04720	
I.A. FILING DATE	PRIORITY DATE
03/10/2005	03/12/2004

38327
REED SMITH LLP
3110 FAIRVIEW PARK DRIVE, SUITE 1400
FALLS CHURCH, VA 22042

CONFIRMATION NO. 8009

371 ACCEPTANCE LETTER

OC000000023852047

Date Mailed: 05/14/2007

NOTICE OF ACCEPTANCE OF APPLICATION UNDER 35 U.S.C 371 AND 37 CFR 1.495

The applicant is hereby advised that the United States Patent and Trademark Office in its capacity as a Designated / Elected Office (37 CFR 1.495), has determined that the above identified international application has met the requirements of 35 U.S.C. 371, and is ACCEPTED for national patentability examination in the United States Patent and Trademark Office.

The United States Application Number assigned to the application is shown above and the relevant dates are:

09/08/2006	09/08/2006
DATE OF RECEIPT OF 35 U.S.C. 371(c)(1), (c)(2) and (c)(4) REQUIREMENTS	DATE OF COMPLETION OF ALL 35 U.S.C. 371 REQUIREMENTS

A Filing Receipt (PTO-103X) will be issued for the present application in due course. **THE DATE APPEARING ON THE FILING RECEIPT AS THE " FILING DATE" IS THE DATE ON WHICH THE LAST OF THE 35 U.S.C. 371 (c)(1), (c)(2) and (c)(4) REQUIREMENTS HAS BEEN RECEIVED IN THE OFFICE. THIS DATE IS SHOWN ABOVE.** *The filing date of the above identified application is the international filing date of the international application (Article 11(3) and 35 U.S.C. 363).* Once the Filing Receipt has been received, send all correspondence to the Group Art Unit designated thereon.

The following items have been received:

- Copy of the International Application filed on 09/08/2006
- Copy of the International Search Report filed on 09/08/2006
- Preliminary Amendments filed on 09/08/2006
- Information Disclosure Statements filed on 09/08/2006
- Oath or Declaration filed on 09/08/2006
- Request for Immediate Examination filed on 09/08/2006
- U.S. Basic National Fees filed on 09/08/2006
- Priority Documents filed on 09/08/2006
- Power of Attorney filed on 09/08/2006
- Non-English Language Application filed on 09/08/2006
- Specification filed on 09/08/2006

- Claims filed on 09/08/2006
- Abstracts filed on 09/08/2006
- Drawings filed on 09/08/2006

Applicant is reminded that any communications to the United States Patent and Trademark Office must be mailed to the address given in the heading and include the U.S. application no. shown above (37 CFR 1.5)

PAULETTE R KIDWELL
Telephone: (703) 308-9140 EXT 216

PART 3 - OFFICE COPY

FORM PCT/DO/EO/903 (371 Acceptance Notice)

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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APPLICATION NUMBER	FILING OR 371(c) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236

CONFIRMATION NO. 8009

38327
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3110 FAIRVIEW PARK DRIVE, SUITE 1400
FALLS CHURCH, VA22042

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

Publication No. US-2007-0195592-A1
Publication Date: 08/23/2007

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.

Pre-Grant Publication Division, 703-605-4283

IAP12 Rec'd PCT/PTO 10 JAN 2008

OIPE IAP87 JAN 10 2008 PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of)
)
YUASA) **Unit 2827**
)
Application Number: 10/591,947)
)
Filed: September 8, 2006)
)
For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME)
)
ATTORNEY DOCKET NO. HIRA.0236)

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	55	39	19 (Over 20)	x $50	800.00
Independent Claims	21	12	9 (Over 3)	x $210	1,890.00
MULTIPLE DEPENDENT CLAIM(S)				+ $370	0
REDUCTION FOR FILING BY SMALL ENTITY (note 37 C.F.R. §§ 1.9, 1.27, 1.28).				x ½	
			TOTAL		2,690.00

01/11/2008 GFREY1 00000055 10591947
01 FC:1614 1890.00 OP
02 FC:1615 800.00 OP

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

[ ] Response to Office Action (w/claim amendments)
[ ] Substitute Specification
[x] Preliminary Amendment
[ ] Information Disclosure Statement w/PTO Form 1449 & refs.
[ ] Petition for Extension of Time
[ ] Terminal Disclaimer
[ ] Letter to Draftsperson w/__ sheets of replacement drawings
[ ] Other _____

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[ ] Please charge my **Deposit Account Number** _____ in the amount of _____ to cover the fees for _____. A duplicate copy of this paper is enclosed.

[x] A check in the amount of **$2,690.00** to cover the Excess Claims fee is enclosed.

[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 08-1480**.

Respectfully submitted,

_____

Stanley P. Fisher
Registration Number 24,344

_____

Juan Carlos A. Marquez
Registration No. 34,072

REED SMITH LLP
3110 Fairview Park Drive
Suite 1400
Falls Church, Virginia 22042
(703) 641-4200
January 10, 2008

::ODMA\PCDOCS\FRXLIB\515383\1

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JAN 10 2008
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	)	
	)	
YUASA	)	**Unit 2827**
	)	
Application Number: 10/591,947	)	
	)	
Filed: September 8, 2006	)	
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME	)	
	)	
	)	
ATTORNEY DOCKET NO. HIRA.0236	)	

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

PRELIMINARY AMENDMENT

Sir:

This is supplemental to the Preliminary Amendment filed on September 8, 2006 concurrently with the application. Prior to an examination on the merits, please amend the above-identified application as follows:

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Western Digital v IP Bridge
Page 155

IN THE CLAIMS:

Please cancel claims 8-14, 17, 26, 33-34 without prejudice or disclaimer, amend claims 1-4, 7, 15-16, 20-22, 26-27, 30, 35-37, and add new claims 40-65 as follows:

1. (Currently Amended) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline (001) MgO_x ($0 < x \leq 1$) ~~(001) layer~~ or a poly-crystalline MgO_x ($0 < x < 1$) [[layer]] in which [[the]] (001) crystal plane is preferentially oriented.

2. (Currently Amended) 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 on said tunnel barrier layer; and

a second ferromagnetic material layer comprising Fe(001) formed on a second side on said tunnel barrier layer, wherein

said ~~MgO(001)~~ tunnel barrier layer is formed by a single-crystal (001) MgO_x ($0 < x < 1$) ~~(001) layer~~ or a poly-crystal MgO_x ($0 < x < 1$) [[layer]] in which [[the]] (001) crystal plane is preferentially oriented.

3. (Currently Amended) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer ~~comprising MgO(001)~~;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising a single-crystalline (001) layer or a poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said polycrystalline layer having [[the]] (001) crystal plane preferentially oriented therein;

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Western Digital v IP Bridge
Page 156

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer and comprising a single-crystalline (001) layer or a poly-crystalline layer of Fe or an Fe alloy of the BCC structure, said polycrystalline layer having the (001) crystal plane preferentially oriented therein, wherein

said tunnel barrier layer is formed by a single-crystalline (001) MgO_x ($0 < x < 1$) ~~(001) layer~~ or a poly-crystalline MgO_x ($0 < x < 1$) [[layer]] in which [[the]] (001) crystal plane is preferentially oriented, wherein

a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the ~~MgO (001)~~ tunnel barrier layer is formed by a perfect single-crystal MgO.

4. (Currently Amended) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer;

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline (001) MgO_x ($0 < x < 1$) ~~(001) layer~~ or a poly-crystalline MgO [[layer]] in which [[the]] (001) crystal plane is preferentially oriented, wherein

a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the ~~MgO (001)~~ tunnel barrier layer is formed by a perfect single-crystal MgO.

5. (Previously Presented) The magnetoresistive device according to claim 3, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

6. (Previously Presented) The magnetoresistive device according to claim 3, wherein

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said discontinuous value is in the range of 0.10 to 0.85 eV.

7. (Currently Amended) A memory device comprising:

a transistor; and

a magnetoresistive device comprising a tunnel barrier layer; a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein said tunnel barrier layer is formed by a single-crystalline (001) MgO_x ($0 < x < 1$) ~~(001) layer~~ or a poly-crystalline MgO_x ($0 < x < 1$) [[layer]] in which [[the]] (001) crystal plane is preferentially oriented, wherein said magnetoresistive device is used as a load for said transistor.

8-14. (Cancelled)

15. (Currently Amended) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising an amorphous magnetic alloy; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer and comprising an amorphous magnetic alloy, wherein

said tunnel barrier layer is formed by ~~a single crystalline MgO_x (001) or~~ a poly-crystalline MgO_x ($0 < x < 1$) [[layer]] in which [[the]] (001) crystal plane is preferentially oriented.

16. (Currently Amended) The magnetoresistive device according to claim 15, wherein a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the ~~MgO (001)~~ tunnel barrier layer is formed by a perfect single-crystal MgO.

17. (Cancelled).

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Western Digital v IP Bridge
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18. (Previously Presented) The magnetoresistive device according to claim 16, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

19. (Previously Presented) The magnetoresistive device according to claim 16, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

20. (Currently Amended) A memory device comprising:

a transistor; and

a magnetoresistive device comprising a tunnel barrier layer; a first ferromagnetic material layer formed on a first side of said tunnel barrier layer and comprising an amorphous magnetic alloy; and a second ferromagnetic material layer formed on a second side of said tunnel barrier layer and comprising an amorphous magnetic alloy, wherein said tunnel barrier layer is formed by ~~a single crystalline MgO_x (001) or~~ a poly-crystalline MgO_x ($0 < x < 1$) [[layer]] in which [[the]] (001) crystal plane is preferentially oriented, wherein said magnetoresistive device is used as a load for said transistor.

21. (Currently Amended) A method of manufacturing a magnetoresistive device comprising:

preparing a substrate;

depositing a first ferromagnetic material layer comprising an amorphous magnetic alloy on said substrate;

forming an amorphous MgO layer on said first ferromagnetic material layer and then crystallizing said amorphous MgO layer by annealing so as to form a tunnel barrier layer comprising ~~a single crystalline MgO_x (001) or~~ a poly-crystalline MgO_x ($0 < x < 1$) in which [[the]] a (001) crystal plane is preferentially oriented; and

depositing a second ferromagnetic material layer comprising an amorphous magnetic alloy on said tunnel barrier layer.

22. (Currently Amended) The method of manufacturing the magnetoresistive device according to claim 21, wherein the step of forming said tunnel barrier layer comprising ~~said single crystalline MgO_x (001) or~~ said poly-crystalline MgO_x ($0 < x <$

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1) in which [[the]] (001) crystal plane is preferentially oriented involves deposition by sputtering using a target with the value of x in MgO_x adjusted.

23. (Previously Presented) The magnetoresistive device according to claim 4, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

24. (Previously Presented) The magnetoresistive device according to claim 4, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

25. (Previously Presented) The memory device according to claim 7, wherein

the first ferromagnetic material layer and the second ferromagnetic material layer are each a BCC structure.

26. (Currently Amended) The memory device according to claim 7, wherein

~~the tunnel barrier layer comprises MgO(001), and~~

the first ferromagnetic material layer and the second ferromagnetic material layer each comprise Fe(001).

27. (Currently Amended) The memory device according to claim 7, wherein

~~the tunnel barrier layer comprises MgO(001),~~

the first ferromagnetic material layer and the a second ferromagnetic material layer each comprises a single-crystalline (001) [[layer]]or a poly-crystalline [[layer]] of Fe or an Fe alloy of the BCC structure, said polycrystalline [[layer]] having [[the]] (001) crystal plane preferentially oriented therein, and

a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the ~~MgO (001)~~ tunnel barrier layer is formed by a perfect single-crystal MgO.

28. (Previously Presented) The memory device of claim 27, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

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29. (Previously Presented) The memory device of claim 27, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

30. (Currently Amended) The memory device according to claim 7, wherein

the first ferromagnetic material layer and the second ferromagnetic material layer are each a BCC structure, and

a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the ~~MgO (001)~~ tunnel barrier layer is formed by a perfect single-crystal MgO.

31. (Previously Presented) The memory device of claim 30, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

32. (Previously Presented) The memory device of claim 30, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

33-34. (Cancelled).

35. (Currently Amended) The magnetoresistive device according to claim [[17]]16, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

36. (Currently Amended) The magnetoresistive device according to claim [[17]]16, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

37. (Currently Amended) The memory device of claim 20, wherein the discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is smaller than an ideal value in the case where the ~~MgO (001)~~ tunnel barrier layer is formed by a perfect single-crystal MgO.

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38. (Previously Presented) The memory device of claim 20, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

39. (Previously Presented) The memory device of claim 20, wherein said discontinuous value is in the range of 0.10 to 0.85 eV.

40. (New) A method of manufacturing a magnetoresistive device comprising;

preparing a substrate;

depositing a first ferromagnetic material layer comprising an amorphous magnetic alloy on said substrate;

forming an amorphous MgO layer on said first ferromagnetic material layer and then crystallizing said amorphous MgO layer by annealing so as to form a tunnel barrier layer comprising a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented; and

depositing a second ferromagnetic material layer comprising an amorphous magnetic alloy on said tunnel barrier layer; and

annealing so as to crystallize said amorphous magnetic alloy.

41. (New) A method of manufacturing a magnetoresistive device of claim 40, wherein said ferromagnetic material is CoFeB alloy.

42. (New) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier,

wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, and

a discontinuous value (the potential barrier height of the tunnel barrier) between the bottom of the conduction band of said tunnel barrier layer and the Fermi

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energy of at least one of said first and said second ferromagnetic layers is in the range of 0.10 to 0.85 eV.

43. (New) A magnetoresistive device of claim 42, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

44. (New) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier,

wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, and

a magnetoresistance ratio of said device is more than 70 %.

45. (New) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier,

wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented,

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

a discontinuous value (the potential barrier height of the tunnel barrier), between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers, is in the range of 0.10 to 0.85 eV.

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46. (New) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer, and

a second ferromagnetic material layer formed on a second side of said tunnel barrier,

wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented,

a magnetoresistance ratio of said device is more than 70%,

a discontinuous value (the potential barrier height of the tunnel barrier), between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers, is in the range of 0,10 to 0.85 eV, and

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

47. (New) A magnetoresistive device of claim 45, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

48. (New) A magnetoresistive device comprising a magnetic tunnel junction structure comprising;

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier,

wherein

said tunnel barrier layer is formed by a polycrystalline MgO_x ($0 < x -< 1$) in which (001) crystal plane is preferentially oriented, and

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

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49. (New) A tunnel barrier layer on a ferromagnetic material layer, wherein said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, and a discontinuous value (the potential barrier height of the tunnel barrier) is in the range of 0.10 to 0.85 eV.

50. (New) A tunnel barrier layer of claim 49, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

51. (New) A tunnel barrier layer

comprising a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, and

having a discontinuous value (the potential barrier height of the tunnel barrier) is in the range of 0.10 to 0.85 eV.

52. (New) A tunnel barrier layer of claim 49, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

53. (New) A tunnel barrier layer used for a magnetoresistive device having an output voltage of more than 200 mV, wherein said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

54. (New) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier,

wherein

said first or second ferromagnetic material layer comprising an amorphous ferromagnetic alloy, and

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

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55. (New) A magnetoresistive device of claim 54, wherein said ferromagnetic alloy is CoFeB alloy.

56. (New) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier,

wherein

said first or second ferromagnetic material layer comprising an amorphous ferromagnetic alloy,

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, and

a discontinuous value (the potential barrier height of the tunnel barrier), between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers, is in the range of 0.10 to 0.85 eV.

57. (New) A magnetoresistive device of claim 56, wherein said discontinuous value is in die range of 0.2 to 0.5 eV.

58. (New) A magnetoresistive device of claim 56, wherein said ferromagnetic alloy is CoFeB alloy.

59. (New) A magnetoresistive device comprising a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer, and

a second ferromagnetic material layer formed on a second side of said tunnel

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barrier,

wherein

said first or second ferromagnetic material layer comprising an amorphous ferromagnetic alloy,

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented,

a discontinuous value (the potential barrier height of the tunnel barrier), between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers, is in the range of 0.2 to 0.5 eV, and

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

60. (New) A tunnel barrier layer on ferromagnetic material layer, wherein said ferromagnetic material layer comprising an amorphous ferromagnetic alloy,

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

61. (New) A tunnel barrier layer of claim 60, wherein said ferromagnetic alloy is CoFeB alloy.

62. (New) A tunnel barrier layer of claim 60, wherein said tunnel barrier layer has a discontinuous value (the potential barrier height of the tunnel barrier) of 0.2 to 0.5 eV.

63. (New) A magnetoresistive device of claim 46, wherein said discontinuous value is in the range of 0.2 to 0.5 eV.

64. (New) A magnetoresistive device of claim 57, wherein said ferromagnetic alloy is CoFeB alloy.

65. (New) A tunnel barrier layer of claim 61, wherein said tunnel barrier layer has a discontinuous value (the potential barrier height of the tunnel barrier) of 0.2 to 0.5 eV.

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REMARKS

In view of the above amendments and Applicants' comments stated herein, Applicants respectfully request an early and favorable action on the merits.

Claims 1-7, 15-16, 18-25, 27-32, 35-65 are under consideration in this application. Claims 8-14, 17, 26, 33-34 are being cancelled without prejudice or disclaimer. Claims 1-4, 7, 15-16, 20-22, 26-27, 30, 35-37 are being amended, as set forth above and in the attached marked-up presentation of the claim amendments, in order to more particularly define and distinctly claim Applicants' invention. New claims 40-65 are being added. All the new claims are supported by the specification. Applicants hereby submit that no new matter is being introduced into the application through the submission of this Supplemental Preliminary Amendment.

Present Invention

The magnetoresistive device (i.e., a magnetic tunnel junction device ("MTJ device") of the present invention is provided with the following three characteristics:

(1) A tunnel barrier layer comprises MgO_x.

(2) Said MgO_x is a single-crystalline (001) MgO_x ($0 < x < 1$) or a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

(3) x is $0<x<1$. (Namely, if this is represented as "MgO crystals," the crystals have oxygen vacancy defects.)

The MTJ device of the present invention delivers the following performance:

(i) A larger MR ratio (i.e., TMR ratio) at room temperature, i.e., exceeding 70% at room temperature);

(ii) A lower discontinuous value*, i.e., 0.1 to 0.85 eV, in particular, 0.2 to 0.5 eV (*A discontinuous value, between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers, is smaller than an ideal discontinuous value (in the case where said tunnel barrier layer is formed by a perfect single-crystal MgO). The discontinuous value hereinafter is cited as the height ϕ of the tunnel barrier).

(iii) A higher output voltage, i.e., more than 200 mV at room temperature.

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Favorable consideration 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,

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January 10, 2008

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Approved for use through 1/31/2007. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 10/591,947	Filing Date 09/08/2006	☐ 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	
	01/10/2008	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	* 55	Minus	** 39	= 16	X $ =		OR	X $50=	800
	Independent (37 CFR 1.16(h))	* 21	Minus	***12	= 9	X $ =		OR	X $210=	1890
	☐ 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	**2690**

		(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:
/TAMMY ACREE/

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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OIPE IAP97 JAN 22 2008 PATENT & TRADEMARK OFFICE

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	)	
	)	
YUASA	)	**Unit 2827**
	)	
Application Number: 10/591,947	)	
	)	
Filed: September 8, 2006	)	
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME	)	
	)	
ATTORNEY DOCKET NO. HIRA.0236	)	

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:

( ) Priority Document
( ) Request for Priority
( ) Response to Notice of Non-Compliant Amendment
(X) Information Disclosure Statement w/1449 and references
( ) Petition under 37 C.F.R. 1.47(a)
( ) Check

☒ 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 08-1480**. A duplicate copy of this sheet is attached.

Respectfully submitted,

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January 22, 2008



IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	)	
	)	
YUASA	)	**Unit 2827**
	)	
Application Number: 10/591,947	)	
	)	
Filed: September 8, 2006	)	
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME	)	
	)	
ATTORNEY DOCKET NO. HIRA.0236	)	

Commissioner of Patents
P.O. Box 1450
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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 after three months of the filing date but prior to the mailing date of the first Office Action of the above-captioned U.S. patent application. Accordingly, no fee is due or payable at this time.



It is also hereby certified that each item of information contained in this statement was cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this statement.

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. 08-1480.

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Form PTO 1449	ATTY. DOCKET NUMBER	SERIAL NUMBER
U.S. Department of Commerce Patent and Trademark Office	HIRA.0236	10/591,947
	APPLICANT YUASA	
Information Disclosure Statement by Applicant	FILING DATE September 8, 2006	GROUP 2827

U.S. Patent Documents

Examiner Initial		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB CLASS	FILING DATE
		2007/0128470	6/7/2007	Nagahama et al.			2/12/2007
		2004/0144995	7/29/2004	Nagahama et al.			5/24/2002
		2004/0245553	12/9/2004	Hosomi et al.			4/8/2003
		2006/0056115	3/16/2006	Djayaprawira et al.			9/7/2005

Foreign Patent Documents

Examiner Initial		DOCUMENT NUMBER	FILING DATE	COUNTRY	CLASS	SUB-CLASS	TRANSLATION	
							YES	NO
		2003-318465*	4/23/2002	Japan			Abstract	
		WO 2002/099905	5/24/2002	PCT			Abstract	
		EP 1 391 942	5/24/2002	EP			X	
		2002-204004	12/28/2000	Japan			Abstract	X
		2002-289943	3/26/2001	Japan			Abstract	X
		2003-304010**	4/9/2002	Japan			Abstract	
		WO 2003/085750	4/8/2003	PCT			Abstract	
		EP 1 494 295	4/8/2003	EP			X	
		2006-080116***	9/7/2004	Japan			Abstract	

* 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.

Other Documents (Including Author, Title, Date Pertinent Pages, Etc.)

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EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation is considered, whether or not citation is in conformance with MPEP 609; draw a line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

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Form PTO 1449 U.S. Department of Commerce Patent and Trademark Office Information Disclosure Statement by Applicant	ATTY. DOCKET NUMBER HIRA.0236	SERIAL NUMBER 10/591,947
	APPLICANT YUASA	
	FILING DATE September 8, 2006	GROUP 2892

U.S. Patent Documents

Examiner Initial		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB CLASS	FILING DATE

Foreign Patent Documents

Examiner Initial		DOCUMENT NUMBER	FILING DATE	COUNTRY	CLASS	SUB CLASS	TRANSLATION	
							YES	NO
		EP 1 633 007 A2	09/05/2005	Europe			X	
		EP 1 633 007 A3	09/05/2005	Europe			X	

Other Documents (Including Author, Title, Date Pertinent Pages, Etc.)

		Mitani, S., *et al.*, "Fe/MgO/FeCo (100) Epitaxial Magnetic Tunnel Junctions Prepared by Using *in situ* Plasma Oxidation", Journal of Applied Physics, Vol. 93, No. 10, Parts 2 and 3, May 15, 2003, pp. 8041-8043.
		Popova, E., *et al.*, "Epitaxial MgO Layer for Low-Resistance and Coupling-Free Magnetic Tunnel Junctions", Applied Physics Letters, Vol. 81, No. 6, August 5, 2002, pp.1035-1037.
		Boubeta, C. Martinez, et al., "Magnetic Coupling in Epitaxial TM/MgO/Fe(001) (TM=FeCo, Fe/Co, Fe) Macroscopic and MicroscopicTrilayers", Journal of Applied Physics, Vo. 94, No. 6, September 15, 2003, pp. 4006-4012.
		Supplementary European Search Report from European Patent Office for Application No. 05720955.3 2222, Patent No. 1737055, PCT/JP2005004720 dated July 2, 2008.

EXAMINER	DATE CONSIDERED

EXAMINER: Initial if citation is considered, whether or not citation is in conformance with MPEP 609; draw a line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	
YUASA	
Application Number: 10/591,947	**Group Art Unit: 2892**
Filed: September 8, 2006	**Examiner: Alonzo Chambliss**
For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME	
ATTORNEY DOCKET NO.: HIRA.0236	

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:

( ) Priority Document
( ) Notice of Priority
( ) Response to Missing Parts with executed declaration
(x) Information Disclosure Statement with Form-1449 and references
( ) Notice of Related Applications
( ) 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 08-1480**. A duplicate copy of this sheet is attached.

Respectfully submitted,

Stanley P. Fisher
Registration Number 24,344

Juan Carlos A. Marquez
Registration Number 34,072

REED SMITH LLP
3110 Fairview Park Drive
Suite 1400
Falls Church, Virginia 22042
August 7, 2008

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AUG 07 2008
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	)	
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YUASA	)	
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Application Number: 10/591,947	)	**Group Art Unit: 2892**
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Filed: September 8, 2006	)	**Examiner: Alonzo Chambliss**
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	)	
ATTORNEY DOCKET NO.: HIRA.0236	)	

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 after three months of the filing date but prior to the mailing date of the first Office Action of the above-captioned U.S. patent application. Accordingly, no fee is due or payable at this time.

It is also hereby certified that each item of information contained in this statement was cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of this statement.

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. 08-1480.

Respectfully submitted,

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

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In re U.S. Patent Application of

YUASA

Application Number: 10/591,947

Filed: September 8, 2006

For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

Attorney Docket No. HIRA.0236

Art Unit 2827

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	54	55	35 (Over 20)	x $52	0
Independent Claims	26	21	18 (Over 3)	x $220	1,100.00
MULTIPLE DEPENDENT CLAIM(S)				+ $390	0
REDUCTION FOR FILING BY SMALL ENTITY (note 37 C.F.R. §§ 1.9, 1.27, 1.28). IF APPLICABLE, VERIFIED STATEMENT MUST BE ATTACHED				x ½	
			TOTAL		1,100.00

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

- [x] Supplemental Preliminary Amendment (with Claim Amendments)
- [ ] Substitute Specification
- [ ] Assignment
- [ ] Letter to Draftsperson
- [ ] Terminal Disclaimer
- [ ] Substitute Specification (clean and marked-up version)
- [ ] Statements & Pre-exam search report with References
- [ ] Information Disclosure Statement with references

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[ ] Please charge my **Deposit Account Number** _____ in the amount of _____ to cover the fees for _____. A duplicate copy of this paper is enclosed.

[x] A check in the amount of **$1,100.00** to cover the fee is enclosed.

[x] The Commissioner is hereby authorized to charge any additional fees associated with this communication, or credit any overpayment to **Deposit Account Number 08-1480**.

Respectfully submitted,

_____

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November 7, 2008

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of

YUASA

Application Number: 10/591,947

Filed: September 8, 2006

For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

Attorney Docket No. HIRA.0236



Art Unit 2827

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
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- [ ] Statements & Pre-exam search report with References
- [ ] Information Disclosure Statement with references

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[x] A check in the amount of **$1,100.00** to cover the fee is enclosed.

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Respectfully submitted,

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In re U.S. Patent Application of	)	
	)	
YUASA	)	**Art Unit 2827**
	)	
Application Number: 10/591,947	)	
	)	**Examiner**
Filed: September 8, 2006	)	**Alonzo CHAMBLISS**
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME	)	
	)	
Attorney Docket No. HIRA.0236	)	

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

SUPPLEMENTAL PRELIMINARY AMENDMENT

Sir:

This is supplemental to the Preliminary Amendment filed on January 10, 2008 concurrently with the application. Prior to an examination on the merits, please amend the above-identified application as follows:

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IN THE CLAIMS:

Please cancel claims 1-4, 7, 15-16, 20-22, 26-27, 30, 35-37, and 40-65, and add new claims 66-119 as follows:

1-65. (Cancelled)

66. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline MgO_x (001) ($0 < x < 1$) or a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

67. (New) The magnetoresistive device according to claim 66, wherein a discontinuous value (to be hereafter referred to as "the tunnel barrier height") between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is in the range of 0.10 to 0.85 eV.

68. (New) The magnetoresistive device according to claim 67, wherein the tunnel barrier height is in the range of 0.2 to 0.5 eV.

69. (New) The magnetoresistive device according to claim 67, wherein said ferromagnetic material comprises a single-crystalline (001) of Fe or Fe-based alloy, or a poly-crystalline of Fe or Fe-based alloy in which (001) crystal plane is preferentially oriented.

70. (New) The magnetoresistive device according to claim 69, wherein the tunnel barrier height is in the range of 0.2 to 0.5 eV.

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71. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a single-crystalline MgO (001) or a poly-crystalline MgO in which (001) crystal plane is preferentially oriented, said MgO having oxygen vacancy defects and said tunnel barrier layer having the tunnel barrier height of 0.2 to 0.5 eV, and

an output voltage of said device is more than 200 mV at room temperature.

72. (New) A magnetoresistive device comprising:

a first ferromagnetic material layer of the BCC structure;

a second ferromagnetic material layer of the BCC structure; and

a magnesium oxide layer located between said first ferromagnetic material layer and said second ferromagnetic material layer, wherein

said magnesium oxide is a single-crystalline (001) or a poly-crystalline crystalline in which (001) crystal plane is preferentially oriented, and

said magnesium oxide has oxygen vacancy defects.

73. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier,

wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, and

the tunnel barrier height is in the range of 0.10 to 0.85 eV.

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74. (New) The magnetoresistive device according to claim 73, wherein the tunnel barrier height is in the range of 0.2 to 0.5 eV.

75. (New) The magnetoresistive device according to claim 73, wherein a magnetoresistance ratio of said device is more than 70 %.

76. (New) The magnetoresistive device according to claim 73, wherein an output voltage of said device is more than 200 mV at room temperature.

77. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a poly-crystalline MgO in which (001) crystal plane is preferentially oriented, said MgO having oxygen vacancy defects,

said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV,

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

an output voltage of said device is more than 200 mV at room temperature.

78. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a poly-crystalline magnesium oxide having oxygen vacancy defects in which (001) crystal plane is preferentially oriented,

said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV,

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

an output voltage of said device is more than 200 mV at room temperature.

79. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

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

said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV,

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

an output voltage of said device is more than 200 mV at room temperature.

80. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first amorphous ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second amorphous ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

81. (New) The magnetoresistive device according to claim 80, wherein said first and second amorphous ferromagnetic material layers comprise CoFeB alloy.

82. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

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a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said first and second ferromagnetic material layer comprise an amorphous CoFeB alloy and

said tunnel barrier layer comprises a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented, said magnesium oxide having oxygen vacancy defects.

83. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a first ferromagnetic material layer;

a tunnel barrier layer deposited on the first ferromagnetic material layer; and

a second ferromagnetic material layer formed on said tunnel barrier layer,

wherein

at least said first ferromagnetic material layer is amorphous and

said tunnel barrier layer comprises a poly-crystalline MgOx ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

84. (New) The magnetoresistive device according to claim 83, wherein said first ferromagnetic material layer comprises CoFeB alloy.

85. (New) The magnetoresistive device according to claim 83, wherein said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV.

86. (New) The magnetoresistive device according to claim 85, wherein said first ferromagnetic material layer comprises CoFeB alloy.

87. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a first ferromagnetic material layer;

a tunnel barrier layer deposited on the first ferromagnetic material layer; and

a second ferromagnetic material layer formed on said tunnel barrier layer, wherein

at least said first ferromagnetic material layer is amorphous and

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said tunnel barrier layer comprises a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented, said magnesium oxide having oxygen vacancy defects.

88. (New) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a first ferromagnetic material layer;

a tunnel barrier layer deposited on the first ferromagnetic material layer; and

a second ferromagnetic material layer formed on said tunnel barrier layer, wherein

at least said first ferromagnetic material layer is amorphous and

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

89. (New) A memory device comprising:

a transistor; and

a magnetoresistive device comprising a tunnel barrier layer; a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline [(001)] MgO_x (001) ($0 < x < 1$) or a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, wherein

the tunnel barrier height of said tunnel barrier layer is in the range of 0.2 to 0.5 eV and

said magnetoresistive device is used as a load for said transistor.

90. (New) A tunnel barrier layer comprising a poly-crystalline MgOx ($0 < x < 1$) in which (001) crystal plane is preferentially oriented and having the tunnel barrier height of 0.2 to 0.5 eV.

91. (New) A tunnel barrier layer used for a magnetoresistive device having an output voltage of more than 200 mV, wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in

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which (001) crystal plane is preferentially oriented and

the tunnel barrier height of said tunnel barrier layer is in the range of 0.2 to 0.5 eV.

92. (New) A tunnel barrier layer used for a magnetoresistive device having an output voltage of more than 200 mV, wherein

said tunnel barrier layer is formed by a poly-crystalline MgO in which (001) crystal plane is preferentially oriented, said MgO having oxygen vacancy defects and

the tunnel barrier height of said tunnel barrier layer is in the range of 0.2 to 0.5 eV.

93. (New) A tunnel barrier layer deposited on a ferromagnetic material layer, wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented and

the tunnel barrier height of said tunnel barrier layer is in the range of 0.2 to 0.5 eV.

94. (New) A tunnel barrier layer deposited on an amorphous ferromagnetic material layer, wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

95. (New) The tunnel barrier layer according to claim 94, wherein said amorphous ferromagnetic material is CoFeB alloy.

96. (New) The tunnel barrier layer according to claim 94, wherein said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV.

97. (New) The tunnel barrier layer according to claim 96, wherein said ferromagnetic material is CoFeB alloy.

98. (New) A tunnel barrier layer deposited on an amorphous ferromagnetic material layer, wherein

said tunnel barrier layer comprises a poly-crystalline magnesium oxide in which (001)

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Page 192

crystal plane is preferentially oriented, said magnesium oxide having oxygen vacancy defects.

99. (New) The tunnel barrier layer according to claim 98, wherein said ferromagnetic material comprises CoFeB alloy.

100. (New) A tunnel barrier layer deposited on an amorphous ferromagnetic material layer, wherein

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

101. (New) The tunnel barrier layer according to claim 100, wherein said ferromagnetic material comprises CoFeB alloy.

102. (New) A method of manufacturing a magnetoresistive device comprising:

preparing a substrate;

depositing a first amorphous ferromagnetic material layer on said substrate;

forming an amorphous MgO or MgO_x ($0 < x < 1$) layer on said first amorphous ferromagnetic material layer and then crystallizing said amorphous MgO or MgO_x ($0 < x < 1$) layer by annealing so as to form a tunnel barrier layer comprising a poly-crystalline MgO or MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented; and

depositing a second amorphous ferromagnetic material layer on said tunnel barrier layer.

103. (New) The method of manufacturing a magnetoresistive device according to claim 102, wherein the method further comprises an annealing step as to partially or entirely crystallize said amorphous ferromagnetic material layer or layers.

104. (New) A method of manufacturing a magnetoresistive device comprising;

preparing a substrate;

depositing a first amorphous ferromagnetic material layer on said substrate;

forming an amorphous magnesium oxide layer on said first amorphous ferromagnetic material layer and then crystallizing said amorphous magnesium oxide

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layer by annealing so as to form a tunnel barrier layer comprising a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented; and

depositing a second amorphous ferromagnetic material layer on said tunnel barrier layer.

105. (New) The method of manufacturing a magnetoresistive device according to claim 104, wherein the method further comprises an annealing step as to partially or entirely crystallize said amorphous ferromagnetic material layer or layers.

106. (New) A method of manufacturing a part of magnetoresistive device having a magnetic tunnel junction structure comprising:

preparing a substrate;

depositing a first amorphous ferromagnetic material layer on said substrate;

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

107. (New) The method of manufacturing a part of magnetoresistive device having a magnetic tunnel junction structure according to claim 106, wherein said poly-crystalline magnesium oxide has oxygen vacancy defects.

108. (New) The method of manufacturing a part of magnetoresistive device having a magnetic tunnel junction structure according to claim 106, wherein said ferromagnetic material is CoFeB alloy.

109. (New) The method of manufacturing a part of magnetoresistive device having a magnetic tunnel junction structure according to claim 108, wherein said poly-crystalline magnesium oxide has oxygen vacancy defects.

110. (New) A magnetic multilayer film comprising:

a first ferromagnetic material layer comprising an amorphous magnetic alloy;

a second ferromagnetic material layer comprising an amorphous magnetic alloy; and

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a crystalline magnesium oxide layer located between said first ferromagnetic material layer and said second ferromagnetic material layer.

111. (New) The magnetic multilayer film according to claim 110, wherein

said crystalline magnesium oxide is a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented.

112. (New) The magnetic multilayer film according to claim 110, wherein each of said ferromagnetic materials comprises CoFeB alloy.

113. (New) The magnetic multilayer film according to claim 112, wherein said crystalline magnesium oxide is a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented.

114. (New) A magnetic multilayer film comprising:

a first ferromagnetic material layer;

a second ferromagnetic material layer; and

a crystalline magnesium oxide layer located between said first ferromagnetic material layer and said second ferromagnetic material layer, said magnesium oxide layer has oxygen vacancy defects.

115. (New) A multilayer structure comprising:

a first ferromagnetic material layer comprising an amorphous CoFeB alloy;

a crystalline magnesium oxide layer deposited on said first ferromagnetic layer; and

a second ferromagnetic material layer deposited on said crystalline magnesium oxide layer.

116. (New) The multilayer structure according to claim 115, wherein said crystalline magnesium oxide is poly-crystalline magnesium oxide.

117. (New) The multilayer structure according to claim 115, wherein said crystalline magnesium oxide is poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented.

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118. (New)The multilayer structure according to claim 115, wherein said amorphous magnetic material layer have been partially or entirely crystallized by post-annealing.

119. (New) The multilayer structure according to claim 117, wherein said amorphous magnetic material layer have been partially or entirely crystallized by post-annealing.

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REMARKS

In view of the above amendments and Applicant's comments stated herein, Applicant respectfully requests an early and favorable action on the merits.

Claims 66-119 are under consideration in this application. Claims 1-4, 7, 15-16, 20-22, 26-27, 30, 35-37, and 40-65 are being cancelled without prejudice or disclaimer. New claims 66-119 are being added. All the new claims are supported by the specification. Applicant hereby submits that no new matter is being introduced into the application through the submission of this Supplemental Preliminary Amendment.

Favorable consideration 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 telephone number indicated below.

Respectfully submitted,

Stanley P. Fisher
Registration Number 24,344

Juan Carlos A. Marquez
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November 7, 2008
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PTO/SB/06 (07-06)
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 10/591,947	Filing Date 09/08/2006	☐ 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	
	11/07/2008	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	* 54	Minus	** 55	= 0	X $ =		OR	X $52=	0
	Independent (37 CFR 1.16(h))	* 21	Minus	***21	= 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:
/STANLEY JORDAN/

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
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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.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

38327 7590 05/12/2009

REED SMITH LLP
3110 FAIRVIEW PARK DRIVE, SUITE 1400
FALLS CHURCH, VA 22042

EXAMINER	
CHAMBLISS, ALONZO	
ART UNIT	PAPER NUMBER
2892	

MAIL DATE	DELIVERY MODE
05/12/2009	PAPER

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.

Office Action Summary	Application No.	Applicant(s)	
	10/591,947	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 1 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 *07 November 2008*.

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) *66-119* 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) _____ is/are rejected.

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

8)☒ Claim(s) *66-119* 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: _____.

Election/Restrictions

1. This application contains claims directed to the following patentably distinct species of the claimed invention:

Species of magnetoresistive device:

A1. A magnetoresistive device with a second ferromagnetic layer.

A2. A magnetoresistive device without a second ferromagnetic layer.

Applicant is required under 35 U.S.C. 121 to elect a single disclosed species for prosecution on the merits to which the claims shall be restricted if no generic claim is finally held to be allowable. Currently, no claims are generic.

Applicant is advised that a reply to this requirement must include an identification of the species that is elected consonant with this requirement, and a listing of all claims readable thereon, including any claims subsequently added. An argument that a claim is allowable or that all claims are generic is considered nonresponsive unless accompanied by an election.

Upon the allowance of a generic claim, applicant will be entitled to consideration of claims to additional species which are written in dependent form or otherwise include all the limitations of an allowed generic claim as provided by 37 CFR 1.141. If claims are added after the election, applicant must indicate which are readable upon the elected species. MPEP § 809.02(a).

Should applicant traverse on the ground that the species are not patentably distinct, applicant should submit evidence or identify such evidence now of record showing the species to be obvious variants or clearly admit on the record that this is the

case. In either instance, if the examiner finds one of the inventions unpatentable over the prior art, the evidence or admission may be used in a rejection under 35 U.S.C. 103(a) of the other invention.

Conclusion

2. 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.

/Alonzo Chambliss/
Primary Examiner, Art Unit 2892

AC/September 1, 2008

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	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	05/11/2009								
	66	÷								
	67	÷								
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	69	÷								
	70	÷								
	71	÷								
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Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	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	05/11/2009								
	102	÷								
	103	÷								
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Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	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	05/11/2009								
	138									
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Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
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	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	05/11/2009								
	174									
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JUN 12 2009
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	)	
	)	
YUASA	)	**Art Unit 2892**
	)	
Application Number: 10/591,947	)	
	)	**Examiner**
Filed: September 8, 2006	)	**Alonzo CHAMBLISS**
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME	)	
	)	
Attorney Docket No. HIRA.0236	)	

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

RESPONSE TO RESTRICTION REQUIREMENT

Sir:

This is in response to the Office Action mailed on May 12, 2009, the period of response to which is set to expire on June 12, 2009. Applicants hereby elect the continuing prosecution of Species A1 as recited in claims 66-89, 102-105 and 110-119, without traverse.

IN THE CLAIMS:

Claim 66-89, 102-105 and 110-119 stand for consideration as follows, wherein claims 90-101 and 106-109 are hereby withdrawn from further consideration without prejudice or disclaimer, all as follows:

1-65. (Cancelled)

66. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline MgO_x (001) ($0 < x < 1$) or a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

67. (Previously Presented) The magnetoresistive device according to claim 66, wherein a discontinuous value (to be hereafter referred to as "the tunnel barrier height") between the bottom of the conduction band of said tunnel barrier layer and the Fermi energy of at least one of said first and said second ferromagnetic layers is in the range of 0.10 to 0.85 eV.

68. (Previously Presented) The magnetoresistive device according to claim 67, wherein the tunnel barrier height is in the range of 0.2 to 0.5 eV.

69. (Previously Presented) The magnetoresistive device according to claim 67, wherein said ferromagnetic material comprises a single-crystalline (001) of Fe or Fe-based alloy, or a poly-crystalline of Fe or Fe-based alloy in which (001) crystal plane is preferentially oriented.

70. (Previously Presented) The magnetoresistive device according to claim 69, wherein the tunnel barrier height is in the range of 0.2 to 0.5 eV.

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71. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of the BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a single-crystalline MgO (001) or a poly-crystalline MgO in which (001) crystal plane is preferentially oriented, said MgO having oxygen vacancy defects and said tunnel barrier layer having the tunnel barrier height of 0.2 to 0.5 eV, and

an output voltage of said device is more than 200 mV at room temperature.

72. (Previously Presented) A magnetoresistive device comprising:

a first ferromagnetic material layer of the BCC structure;

a second ferromagnetic material layer of the BCC structure; and

a magnesium oxide layer located between said first ferromagnetic material layer and said second ferromagnetic material layer, wherein

said magnesium oxide is a single-crystalline (001) or a poly-crystalline crystalline in which (001) crystal plane is preferentially oriented, and

said magnesium oxide has oxygen vacancy defects.

73. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier,

wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, and

the tunnel barrier height is in the range of 0.10 to 0.85 eV.

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74. (Previously Presented) The magnetoresistive device according to claim 73, wherein the tunnel barrier height is in the range of 0.2 to 0.5 eV.

75. (Previously Presented) The magnetoresistive device according to claim 73, wherein a magnetoresistance ratio of said device is more than 70 %.

76. (Previously Presented) The magnetoresistive device according to claim 73, wherein an output voltage of said device is more than 200 mV at room temperature.

77. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a poly-crystalline MgO in which (001) crystal plane is preferentially oriented, said MgO having oxygen vacancy defects,

said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV,

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

an output voltage of said device is more than 200 mV at room temperature.

78. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a poly-crystalline magnesium oxide having oxygen vacancy defects in which (001) crystal plane is preferentially oriented,

said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV,

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

an output voltage of said device is more than 200 mV at room temperature.

79. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

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

said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV,

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

an output voltage of said device is more than 200 mV at room temperature.

80. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first amorphous ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

a second amorphous ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

81. (Previously Presented) The magnetoresistive device according to claim 80, wherein said first and second amorphous ferromagnetic material layers comprise CoFeB alloy.

82. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and

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a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said first and second ferromagnetic material layer comprise an amorphous CoFeB alloy and

said tunnel barrier layer comprises a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented, said magnesium oxide having oxygen vacancy defects.

83. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a first ferromagnetic material layer;

a tunnel barrier layer deposited on the first ferromagnetic material layer; and

a second ferromagnetic material layer formed on said tunnel barrier layer, wherein

at least said first ferromagnetic material layer is amorphous and

said tunnel barrier layer comprises a poly-crystalline MgOx ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

84. (Previously Presented) The magnetoresistive device according to claim 83, wherein said first ferromagnetic material layer comprises CoFeB alloy.

85. (Previously Presented) The magnetoresistive device according to claim 83, wherein said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV.

86. (Previously Presented) The magnetoresistive device according to claim 85, wherein said first ferromagnetic material layer comprises CoFeB alloy.

87. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a first ferromagnetic material layer;

a tunnel barrier layer deposited on the first ferromagnetic material layer; and

a second ferromagnetic material layer formed on said tunnel barrier layer, wherein

at least said first ferromagnetic material layer is amorphous and

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said tunnel barrier layer comprises a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented, said magnesium oxide having oxygen vacancy defects.

88. (Previously Presented) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a first ferromagnetic material layer;

a tunnel barrier layer deposited on the first ferromagnetic material layer; and

a second ferromagnetic material layer formed on said tunnel barrier layer, wherein

at least said first ferromagnetic material layer is amorphous and

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

89. (Previously Presented) A memory device comprising:

a transistor; and

a magnetoresistive device comprising a tunnel barrier layer; a first ferromagnetic material layer formed on a first side of said tunnel barrier layer; and a second ferromagnetic material layer formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline [(001)] MgO_x (001) ($0 < x < 1$) or a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, wherein

the tunnel barrier height of said tunnel barrier layer is in the range of 0.2 to 0.5 eV and

said magnetoresistive device is used as a load for said transistor.

90. (Withdrawn) A tunnel barrier layer comprising a poly-crystalline MgOx ($0 < x < 1$) in which (001) crystal plane is preferentially oriented and having the tunnel barrier height of 0.2 to 0.5 eV.

91. (Withdrawn) A tunnel barrier layer used for a magnetoresistive device having an output voltage of more than 200 mV, wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in

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which (001) crystal plane is preferentially oriented and

the tunnel barrier height of said tunnel barrier layer is in the range of 0.2 to 0.5 eV.

92. (Withdrawn) A tunnel barrier layer used for a magnetoresistive device having an output voltage of more than 200 mV, wherein

said tunnel barrier layer is formed by a poly-crystalline MgO in which (001) crystal plane is preferentially oriented, said MgO having oxygen vacancy defects and

the tunnel barrier height of said tunnel barrier layer is in the range of 0.2 to 0.5 eV.

93. (Withdrawn) A tunnel barrier layer deposited on a ferromagnetic material layer, wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented and

the tunnel barrier height of said tunnel barrier layer is in the range of 0.2 to 0.5 eV.

94. (Withdrawn) A tunnel barrier layer deposited on an amorphous ferromagnetic material layer, wherein

said tunnel barrier layer is formed by a poly-crystalline MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented.

95. (Withdrawn) The tunnel barrier layer according to claim 94, wherein said amorphous ferromagnetic material is CoFeB alloy.

96. (Withdrawn) The tunnel barrier layer according to claim 94, wherein said tunnel barrier layer has the tunnel barrier height of 0.2 to 0.5 eV.

97. (Withdrawn) The tunnel barrier layer according to claim 96, wherein said ferromagnetic material is CoFeB alloy.

98. (Withdrawn) A tunnel barrier layer deposited on an amorphous ferromagnetic material layer, wherein

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said tunnel barrier layer comprises a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented, said magnesium oxide having oxygen vacancy defects.

99. (Withdrawn) The tunnel barrier layer according to claim 98, wherein said ferromagnetic material comprises CoFeB alloy.

100. (Withdrawn) A tunnel barrier layer deposited on an amorphous ferromagnetic material layer, wherein

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

101. (Withdrawn) The tunnel barrier layer according to claim 100, wherein said ferromagnetic material comprises CoFeB alloy.

102. (Previously Presented) A method of manufacturing a magnetoresistive device comprising:

preparing a substrate;

depositing a first amorphous ferromagnetic material layer on said substrate;

forming an amorphous MgO or MgO_x ($0 < x < 1$) layer on said first amorphous ferromagnetic material layer and then crystallizing said amorphous MgO or MgO_x ($0 < x < 1$) layer by annealing so as to form a tunnel barrier layer comprising a poly-crystalline MgO or MgO_x ($0 < x < 1$) in which (001) crystal plane is preferentially oriented; and

depositing a second amorphous ferromagnetic material layer on said tunnel barrier layer.

103. (Previously Presented) The method of manufacturing a magnetoresistive device according to claim 102, wherein the method further comprises an annealing step as to partially or entirely crystallize said amorphous ferromagnetic material layer or layers.

104. (Previously Presented) A method of manufacturing a magnetoresistive device comprising;

preparing a substrate;

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depositing a first amorphous ferromagnetic material layer on said substrate;

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

depositing a second amorphous ferromagnetic material layer on said tunnel barrier layer.

105. (Previously Presented) The method of manufacturing a magnetoresistive device according to claim 104, wherein the method further comprises an annealing step as to partially or entirely crystallize said amorphous ferromagnetic material layer or layers.

106. (Withdrawn) A method of manufacturing a part of magnetoresistive device having a magnetic tunnel junction structure comprising:

preparing a substrate;

depositing a first amorphous ferromagnetic material layer on said substrate;

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

107. (Withdrawn) The method of manufacturing a part of magnetoresistive device having a magnetic tunnel junction structure according to claim 106, wherein said poly-crystalline magnesium oxide has oxygen vacancy defects.

108. (Withdrawn) The method of manufacturing a part of magnetoresistive device having a magnetic tunnel junction structure according to claim 106, wherein said ferromagnetic material is CoFeB alloy.

109. (Withdrawn) The method of manufacturing a part of magnetoresistive device having a magnetic tunnel junction structure according to claim 108, wherein said poly-crystalline magnesium oxide has oxygen vacancy defects.

110. (Previously Presented) A magnetic multilayer film comprising:

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a first ferromagnetic material layer comprising an amorphous magnetic alloy;

a second ferromagnetic material layer comprising an amorphous magnetic alloy; and

a crystalline magnesium oxide layer located between said first ferromagnetic material layer and said second ferromagnetic material layer.

111. (Previously Presented) The magnetic multilayer film according to claim 110, wherein said crystalline magnesium oxide is a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented.

112. (Previously Presented) The magnetic multilayer film according to claim 110, wherein each of said ferromagnetic materials comprises CoFeB alloy.

113. (Previously Presented) The magnetic multilayer film according to claim 112, wherein said crystalline magnesium oxide is a poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented.

114. (Previously Presented) A magnetic multilayer film comprising:

a first ferromagnetic material layer;

a second ferromagnetic material layer; and

a crystalline magnesium oxide layer located between said first ferromagnetic material layer and said second ferromagnetic material layer, said magnesium oxide layer has oxygen vacancy defects.

115. (Previously Presented) A multilayer structure comprising:

a first ferromagnetic material layer comprising an amorphous CoFeB alloy;

a crystalline magnesium oxide layer deposited on said first ferromagnetic layer; and

a second ferromagnetic material layer deposited on said crystalline magnesium oxide layer.

116. (Previously Presented) The multilayer structure according to claim 115, wherein said crystalline magnesium oxide is poly-crystalline magnesium oxide.

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117. (Previously Presented) The multilayer structure according to claim 115, wherein said crystalline magnesium oxide is poly-crystalline magnesium oxide in which (001) crystal plane is preferentially oriented.

118. (Previously Presented)The multilayer structure according to claim 115, wherein said amorphous magnetic material layer have been partially or entirely crystallized by post-annealing.

119. (Previously Presented) The multilayer structure according to claim 117, wherein said amorphous magnetic material layer have been partially or entirely crystallized by post-annealing.

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REMARKS

The following remarks are being submitted as a full and complete response to the Office Action dated May 12, 2009. In view of the following remarks, the Examiner is respectfully requested to proceed with examination of the application on the merits, to indicate the allowability of the claims, and to pass this case to issue.

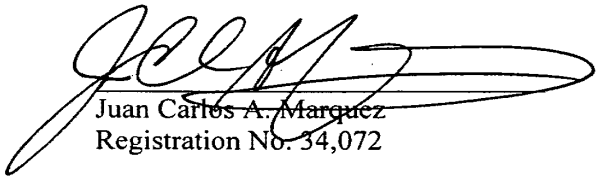
Restriction Requirement

In response to the Examiner's restriction requirement set forth in the above-mentioned Office Action, Applicants hereby elect the continued prosecution of the invention identified as Species A1 as recited in claims 66-89, 102-105 and 110-119, without traverse. Applicants understand that all the non-elected species and their corresponding claims are hereby withdrawn from further consideration in this pending application. Applicants hereby reserve the right to file divisional applications on such non-elected inventions.

Conclusion

Favorable consideration 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,



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Registration No. 34,072

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June 12, 2009

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Western Digital v IP Bridge
Page 219

OIPE
JUN 12 2009
PATENT & TRADEMARK OFFICE

IFW

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of

YUASA

Application Number: 10/591,947

Filed: September 8, 2006

For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

Attorney Docket No. HIRA.0236

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	54	54	34 (Over 20)	x $52	0
Independent Claims	26	26	23 (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). IF APPLICABLE, VERIFIED STATEMENT MUST BE ATTACHED				x ½	
			TOTAL		0

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

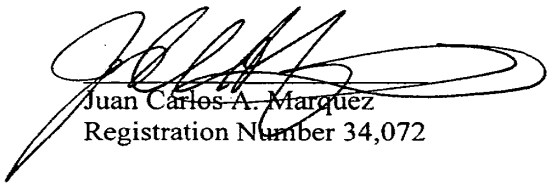
[x] Response/Amendment to Office Action (with Claim Election)
[ ] Preliminary Amendment
[ ] Substitute Specification
[ ] Terminal Disclaimer
[ ] Petition for __-month Extension of Time
[ ] Information Disclosure Statement w/ form 1449
[ ] Letter to Draftsperson
[ ] ___ sheets of replacement drawings
[ ] Request for Continued Examination

[ ] Please charge my **Deposit Account Number** _____ in the amount of _____ to cover the fees for _____. A duplicate copy of this paper is enclosed.

[ ] A check in the amount of **$**_____to cover the _____ fee is enclosed.

[x] The Commissioner is hereby authorized to charge any additional fees associated with this communication, or credit any overpayment to **Deposit Account Number 08-1480**.

Respectfully submitted,



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June 12, 2009

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JUN 12 2009
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of

YUASA

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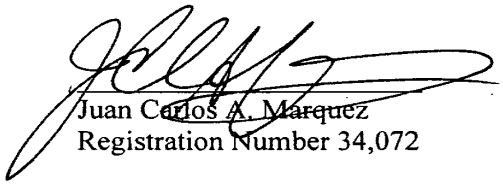
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Respectfully submitted,



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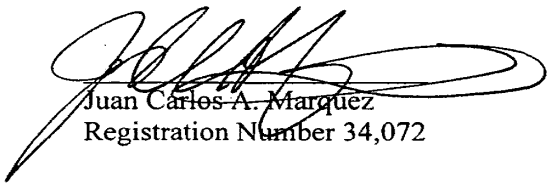
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Respectfully submitted,



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JUN 12 2009
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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of

YUASA

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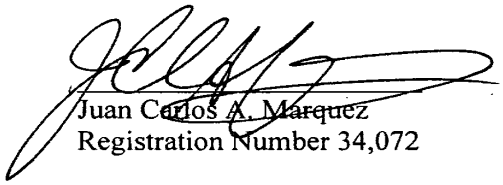
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Respectfully submitted,



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June 12, 2009

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PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number	Filing Date	☐ To be Mailed
10/591,947	09/08/2006	

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	
	06/12/2009	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	* 54	Minus	** 55	= 0	X $ =		OR	X $52=	0
	Independent (37 CFR 1.16(h))	* 24	Minus	***24	= 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:
/CAROLYN E. THOMAS/

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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APPLICATION NUMBER	PATENT NUMBER	GROUP ART UNIT	FILE WRAPPER LOCATION
10/591,947		2892	

OC000000036882029

Correspondence Address/Fee Address Change

The following fields have been set to Customer Number 38327 on 06/25/2009

- **Correspondence Address**
- **Maintenance Fee Address**
- **Power of Attorney Address**

The address of record for Customer Number 38327 is:

38327
REED SMITH LLP
3110 FAIRVIEW PARK DRIVE, SUITE 1400
FALLS CHURCH, VA 22042

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10/591,947		2892	

OC000000036883998

Correspondence Address/Fee Address Change

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- **Correspondence Address**
- **Maintenance Fee Address**
- **Power of Attorney Address**

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

38327 7590 11/23/2009

Juan Carlos A. Marquez
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1199 North Fairfax Street
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Alexandria, VA 22314-1437

EXAMINER	
CHAMBLISS, ALONZO	
ART UNIT	PAPER NUMBER
2892	

MAIL DATE	DELIVERY MODE
11/23/2009	PAPER

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.

Office Action Summary	Application No.	Applicant(s)	
	10/591,947	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 *12 June 2009*.

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) *66-89,102-105 and 110-119* 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) *66-89,102-105 and 110-119* 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 *08 September 2006* 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 *9/8/06,1/22/08,8/7/08*.
4) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .
5) ☐ Notice of Informal Patent Application
6) ☐ Other: _____.

DETAILED ACTION

Election/Restrictions

1. Applicant's election without traverse of claims 66-89, 102-105, and 110-119 in the reply filed on 6/12/09 is acknowledged.

Priority

2. Receipt is acknowledged of papers submitted under 35 U.S.C. 119(a)-(d), which papers have been placed of record in the file.

Information Disclosure Statement

3. The information disclosure statement (IDS) submitted on 9/8/06,1/22/08, and 8/7/08 was filed before the mailing date of the non-final rejection on 10/26/09. 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

4. Figures 8A, 8B, 9A, 9B, and 9C should be designated by a legend such as --Prior Art-- because only that which is old is illustrated. See MPEP § 608.02(g). Corrected drawings in compliance with 37 CFR 1.121(d) are required in reply to the Office action to avoid abandonment of the application. The replacement sheet(s) should be labeled "Replacement Sheet" in the page header (as per 37 CFR 1.84(c)) so as not to obstruct any portion of the drawing figures. 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.

5. 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.

Specification

6. The disclosure is objected to because of the following informalities: Figures 8A and 8B are missing from the Brief Description of the drawings.

Appropriate correction is required.

7. The title of the invention is not descriptive. A new title is required that is clearly indicative of the invention to which the claims are directed. The following title is suggested: " MAGNECTIC TUNNEL JUNCTION DEVICE ".

8. The following is a quotation of the second paragraph of 35 U.S.C. 112:

> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

9. Claim 71 is rejected under 35 U.S.C. 112, second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which applicant regards as the invention.

10. In claim 71, the phrase " an output voltage of the device " is vague and indefinite since it is not clear from the claim what structure creates the output voltage.

Claim Rejections - 35 USC § 112

11. The following is a quotation of the second paragraph of 35 U.S.C. 112:

> The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

12. Claims 66-70, 72, 80-88, 102-105, and 110-119 are rejected under 35 U.S.C. 112, second paragraph, as being incomplete for omitting essential elements, such omission amounting to a gap between the elements. See MPEP § 2172.01. The omitted elements are: the tunnel barrier height in a specified eV range.

13. Claims 72-89, 102-105, and 110-119 are rejected under 35 U.S.C. 112, second paragraph, as being incomplete for omitting essential elements, such omission amounting to a gap between the elements. See MPEP § 2172.01. The omitted elements are: the first and second ferromagnetic material layers having a BCC structure.

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

Conclusion

14. 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/October 26, 2009

/Alonzo Chambliss/
Primary Examiner, Art Unit 2892

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	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	05/11/2009	10/26/2009							
	66	÷	✓							
	67	÷	✓							
	68	÷	✓							
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Western Digital v IP Bridge
Page 237

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	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								
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	102	÷	✓							
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Page 238

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	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								
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Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	YUASA, SHINJI
	Examiner	Art Unit
	Alonzo Chambliss	2892

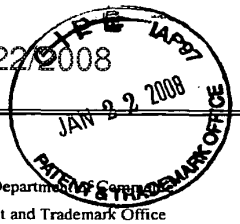
✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

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

CLAIM		DATE								
Final	Original	05/11/2009	10/26/2009							
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Western Digital v IP Bridge
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Receipt date: 01/22/2008



10591947 - GAU: 2892

Form PTO 1449 U.S. Department of Commerce Patent and Trademark Office Information Disclosure Statement by Applicant	ATTY. DOCKET NUMBER HIRA.0236	SERIAL NUMBER 10/591,947
	APPLICANT YUASA	
	FILING DATE September 8, 2006	GROUP 2827

U.S. Patent Documents

Examiner Initial		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB CLASS	FILING DATE
		2007/0128470	6/7/2007	Nagahama et al.			2/12/2007
		2004/0144995	7/29/2004	Nagahama et al.			5/24/2002
		2004/0245553	12/9/2004	Hosomi et al.			4/8/2003
		2006/0056115	3/16/2006	Djayaprawira et al.			9/7/2005

Foreign Patent Documents

Examiner Initial		DOCUMENT NUMBER	FILING DATE	COUNTRY	CLASS	SUB-CLASS	TRANSLATION	
							YES	NO
		2003-318465*	4/23/2002	Japan			Abstract	
		WO 2002/099905	5/24/2002	PCT			Abstract	
		EP 1 391 942	5/24/2002	EP			X	
		2002-204004	12/28/2000	Japan			Abstract	X
		2002-289943	3/26/2001	Japan			Abstract	X
		2003-304010**	4/9/2002	Japan			Abstract	
		WO 2003/085750	4/8/2003	PCT			Abstract	
		EP 1 494 295	4/8/2003	EP			X	
		2006-080116***	9/7/2004	Japan			Abstract	

* 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.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/ (10/26/2009)

Other Documents (Including Author, Title, Date Pertinent Pages, Etc.)

		Wolf, S.A. et al., "Spintronics: A Spin-Based Electronics Vision for the Future", Science, Vol. 294, November 16, 2001, pp. 1488-1495.
		Wulfhekel, W. et al., "Single-Crystal Magnetotunnel Junctions", Applied Physics Letters, Vol. 78, No. 4, January 22, 2001, pp. 509-511
		Julliere, M., "Tunneling Between Ferromagnetic Films", Physics Letters, Vol. 54A, No. 3, September 8, 1975, pp.225-226.
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		Simmons, John G., "Generalized Formula for the Electric Tunnel Effect between Similar Electrodes Separated by a Thin Insulating Film", Journal of Applied Physics, Vol. 34, NO. 6, June 1963, pp. 1793-1803.
		Vassent, J.L. et al., "A Study of Growth and the Relaxation of Elastic Strain in MgO on Fe(001)", J. Appl. Phys. Vol. 80, No. 10, November 15, 1996, pp. 5727-5735.
		Faure-Vincent, J. et al., "High Tunnel Magnetoresistance in Expitaxial Fe/MgO/Fe Tunnel Junctions", Applied Physics Letters, Vol. 82, No. 25, June 23, 2003, pp. 4507-4509.
		Meyerheim, H.L. et al., "Geometrical and Compositional Structure at Metal-Oxide Interfaces: MgO on Fe(001)", Physical Review Letters, Vol. 18, No. 7, August 13, 2001, pp. 076102-1 – 076102-4.
		Butler, W.H. et al., "Spin-dependent Tunneling Conductance of Fe[MgO]Fe Sandwiches", Physical Review B., Vol. 63, 054416, 2001, pp. 054416-1 – 054416-12.
		Mathon, J. et al., "Theory of Tunneling Magnetoresistance of an Epitaxial Fe/MgO/Fe(001) Junction", Physical Review B., Vol. 63, 220403(R), 2001, pp. 220403-1 – 220403-4.
		Zhang, X.-G. et al., "Effects of the Iron-Oxide Layer in Fe-FeO-MgO-Fe Tunneling Junctions", Physical Review B, Vol. 68, 092402, 2003, pp. 092402-1 – 092402-4.
		Zhang, X.-G. et al., "Large Magnetoresistance in bcc Co/MgO/Co and FeCo/MgO/FeCo Tunnel Junctions", Physical Review B., Vol. 70, 172407, 2004, pp. 172407-1 – 172407-4.
		Gibson, A. et al., "Stability of Vacancy Defects in MgO: The Role of Charge Neutrality", Physical Review B., Vol. 50, No. 4, July 15, 1994-II, pp. 2582-2592.
		Yuasa, S. et al., "High Tunnel Magnetoresistance at Room Temperature in Fully Expitaxial Fe/MgO/Fe Tunnel Junctions Due to Coherent Spin-Polarized Tunneling", Japanese Journal of Applied Physics, Vol. 43, No. 4B, 2004, pp. L588-L590.

EXAMINER	/Alonzo Chambliss/ (10/26/2009)	DATE CONSIDERED	

EXAMINER: Initial if citation is considered, whether or not citation is in conformance with MPEP 609; draw a line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

PTO1449

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/ (10/26/2009)

IAP9 Rec'd PCT/PTO 08 SEP 2006

Form PTO 1449	Atty. Docket Number	Serial Number
U.S. Department of Commerce Patent and Trademark Office	HIRA.0236	To be Assigned
	Applicant YUASA	
Information Disclosure Statement by Applicant	Filing Date Concurrently Herewith	Group

U.S. Patent Documents

Examiner Initial		Document Number	Date	Name	Class	Sub Class	Filing Date

Foreign Patent Documents

Examiner Initial		Document Number	Filing Date	Country	Class	Sub Class	Translation	
							Yes	No
		2003-318465	4/23/2002	Japan			Abstract	X
		2002-204004	12/28/2000	Japan			Abstract	X
		2002-289943	3/26/2001	Japan			Abstract	X
		2003-304010	4/9/2002	Japan			Abstract	X

Other Documents (Including Author, Title, Date Pertinent Pages, Etc.)

		International Search Report of PCT/JP2005/004720 mailed June 21, 2005

Examiner	/Alonzo Chambliss/ (10/26/2009)	Date Considered	

Examiner: Initial if citation is considered, whether or not citation is in conformance with MPEP 609; draw a line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

PTO1449

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

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Receipt date: 08/07/2008

10591947 - GAU: 2892



Form PTO 1449	ATTY. DOCKET NUMBER	SERIAL NUMBER
U.S. Department of Commerce Patent and Trademark Office	HIRA.0236	10/591,947
	APPLICANT YUASA	
Information Disclosure Statement by Applicant	FILING DATE September 8, 2006	GROUP 2892

U.S. Patent Documents

Examiner Initial		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB CLASS	FILING DATE

Foreign Patent Documents

Examiner Initial		DOCUMENT NUMBER	FILING DATE	COUNTRY	CLASS	SUB CLASS	TRANSLATION	
							YES	NO
		EP 1 633 007 A2	09/05/2005	Europe			X	
		EP 1 633 007 A3	09/05/2005	Europe			X	

Other Documents (Including Author, Title, Date Pertinent Pages, Etc.)

		Mitani, S., *et al.*, "Fe/MgO/FeCo (100) Epitaxial Magnetic Tunnel Junctions Prepared by Using *in situ* Plasma Oxidation", Journal of Applied Physics, Vol. 93, No. 10, Parts 2 and 3, May 15, 2003, pp. 8041-8043.
		Popova, E., *et al.*, "Epitaxial MgO Layer for Low-Resistance and Coupling-Free Magnetic Tunnel Junctions", Applied Physics Letters, Vol. 81, No. 6, August 5, 2002, pp.1035-1037.
		Boubeta, C. Martinez, et al., "Magnetic Coupling in Epitaxial TM/MgO/Fe(001) (TM=FeCo, Fe/Co, Fe) Macroscopic and MicroscopicTrilayers", Journal of Applied Physics, Vo. 94, No. 6, September 15, 2003, pp. 4006-4012.
		Supplementary European Search Report from European Patent Office for Application No. 05720955.3 2222, Patent No. 1737055, PCT/JP2005004720 dated July 2, 2008.

EXAMINER	/Alonzo Chambliss/ (10/26/2009)	DATE CONSIDERED	

EXAMINER: Initial if citation is considered, whether or not citation is in conformance with MPEP 609; draw a line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant

PTO1449

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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	0	tunnel adj3 barrier and first adj3 ferromagnectic and second adj3 ferromagnetic and crystalline	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/10/26 09:42
L2	587	tunnel adj3 barrier and ferromagnetic and crystalline	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2009/10/26 09:43

10/26/2009 9:43:51 AM
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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	YUASA, SHINJI
	Examiner	Art Unit
	Alonzo Chambliss	2892

SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES		
Search Notes	Date	Examiner
East text search only - see attached printout	10/26/09	AC

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

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USPTO
PATENT & TRADEMARK OFFICE

Form PTO 1449	ATTY. DOCKET NUMBER	SERIAL NUMBER
U.S. Department of Commerce Patent and Trademark Office	ASAM.0236	10/591,947
	APPLICANT	
	YUASA	
Information Disclosure Statement by Applicant	FILING DATE	GROUP
	September 8, 2006	2827

U.S. Patent Documents

Examiner Initial		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB CLASS	FILING DATE

Foreign Patent Documents

Examiner Initial		DOCUMENT NUMBER	FILING DATE	COUNTRY	CLASS	SUB-CLASS	TRANSLATION	
							YES	No
		EP 1 085 586 A2	9/15/2000	EPO			X	

Other Documents (Including Author, Title, Date Pertinent Pages, Etc.)

		Office Action from the European Patent Office dated November 6, 2009

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PATENT & TRADEMARK OFFICE

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	)	
	)	
YUASA	)	**Art Unit 2827**
	)	
Application Number: 10/591,947	)	
	)	
Filed: September 8, 2006	)	
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME	)	
	)	
ATTORNEY DOCKET NO. HIRA.0236	)	

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(s)
( ) Credit Card form payment

☒ 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
December 4, 2009

156629:1:ALEXANDRIA

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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 2827**
	)	
Application Number: 10/591,947	)	
	)	
Filed: September 8, 2006	)	
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME	)	
	)	
ATTORNEY DOCKET NO. HIRA.0236	)	

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 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

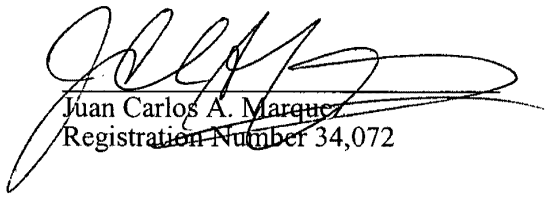
This Information Disclosure Statement is submitted after three months from the filing date of the above-identified U.S. patent application and after the mailing date of the first Office Action on the merits of the above-identified application, but prior to issuance of the earlier of any Final Action or Notice of Allowance sent in such application.

It is also hereby certified that each item of information contained in this statement was cited in a communication from a foreign patent office in a counterpart foreign application not more than three months from the date of this filing. Therefore, no fee is due 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
December 4, 2009

156630:1:ALEXANDRIA

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Western Digital v IP Bridge
Page 250

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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: 10/591,947	**Examiner**
Filed: September 8, 2006	**Alonzo Chambliss**
For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME (AS AMENDED)	
ATTORNEY DOCKET NO. HIRA.0236	

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 November 23, 2009, the period of response to which is set to expire on March 23, 2010, with the payment of the appropriate extension fees for an extension of time of one month. Please amend the above-referenced application as follows:

IN THE DRAWINGS:

Please amend/replace Figures 8(A)-9(C) with the substitute Figures 8(A)-9(C) provided in the replacement sheets of drawings submitted herewith. Each of Figures 8(A)-9(C) is being designated with a legend indicating that the illustration therein is prior art.

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IN THE SPECIFICATION:

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

MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING~~METHOD OF MANUFACTURING~~ THE SAME

Please amend/replace paragraphs [0006] and [0023] of the instant application as follows:

[0006] 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]]103 and a drain region [[103]]105 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]]103 is grounded via a source junction 113, and the drain region 105 is connected to a bit line BL via a drain junction 115 and the MTJ device. A word line WL is connected to the gate electrode 111 in a region that is not shown.

[0023] ~~Fig. 8~~Figs. 8(A) and 8(B) show[[s]] the structure of the MTJ device and its operating principle.

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IN THE CLAIMS

Claims 68, 69, 72, 75, 77, 78, 84, and 89 are pending in this application, wherein claims 66, 67, 70, 71, 73, 74, 76, 79-83, 85-88, and 90-119 are being canceled without prejudice or disclaimer, and wherein claims 68, 69, 72, 75, 77, 78, 84, and 89 are being amended to improve form, as follows:

1-67. (Canceled)

68. (Currently Amended) [[The]]A magnetoresistive device ~~according to claim 67,~~having a tunnel barrier junction structure, the magnetoresistive device comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of a BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline MgOx (001) ($0 < x < 1$) or a poly-crystalline MgOx ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, and

wherein [[the]]a tunnel barrier height between a bottom of a conduction band of said tunnel barrier layer and a Fermi energy of at least one of said first and second ferromagnetic layers is a discontinuous value in [[the]]a range of 0.2 to 0.5 eV.

69. (Currently Amended) The magnetoresistive device according to claim [[67]]68, wherein said ferromagnetic material comprises a single-crystalline (001) of Fe or Fe-based alloy, or a poly-crystalline of Fe or Fe-based alloy in which (001) crystal plane is preferentially oriented.

70-71. (Canceled).

72. (Currently Amended) A magnetoresistive device, comprising:

a first ferromagnetic material layer of [[the]]a BCC structure;

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a second ferromagnetic material layer of the BCC structure; and

a magnesium oxide layer located between said first ferromagnetic material layer and said second ferromagnetic material layer, wherein

said magnesium oxide is a single-crystalline (001) or a poly-crystalline crystalline in which (001) crystal plane is preferentially oriented,[[and]]

wherein said magnesium oxide has oxygen vacancy defects, and

wherein said magnesium oxide has a tunnel barrier height in a range of 0.2 to 0.5 eV.

73-74. (Canceled).

75. (Currently Amended) The magnetoresistive device according to claim [[73]]68, wherein a magnetoresistance ratio of said magnetoresistive device is more than 70 %.

76. (Canceled).

77. (Currently Amended) A magnetoresistive device having a magnetic tunnel junction structure comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of a BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a poly-crystalline MgO in which (001) crystal plane is preferentially oriented, said MgO having oxygen vacancy defects,

wherein said tunnel barrier layer has [[the]]a tunnel barrier height of 0.2 to 0.5 eV, and

wherein a magnetoresistance ratio of said device is more than 70 %~~, and an output voltage of said device is more than 200 mV at room temperature~~.

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78. (Currently Amended) A magnetoresistive device having a magnetic tunnel junction structure, the magnetoresistive device comprising:

a tunnel barrier layer;

a first ferromagnetic material layer of a BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer comprises a poly-crystalline magnesium oxide having oxygen vacancy defects in which (001) crystal plane is preferentially oriented,

said tunnel barrier layer has [[the]]a tunnel barrier height of 0.2 to 0.5 eV, and

a magnetoresistance ratio of said device is more than 70 ~~%, and an output voltage of said device is more than 200 mV at room temperature~~.

79-83. (Canceled).

84. (Currently Amended) The magnetoresistive device according to claim [[83]]68, wherein said first ferromagnetic material layer comprises CoFeB alloy.

85-88. (Canceled).

89. (Currently Amended) A memory device comprising:

a transistor; and

a magnetoresistive device comprising a tunnel barrier layer;

a first ferromagnetic material layer of a BCC structure formed on a first side of said tunnel barrier layer; and

a second ferromagnetic material layer of the BCC structure formed on a second side of said tunnel barrier layer, wherein

said tunnel barrier layer is formed by a single-crystalline ~~[(001)]~~ MgOx (001) ($0 < x < 1$) or a poly-crystalline MgOx ($0 < x < 1$) in which (001) crystal plane is preferentially oriented, wherein

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[[the]]a tunnel barrier height of said tunnel barrier layer is in [[the]]a range of 0.2 to 0.5 eV and

said magnetoresistive device is used as a load for said transistor.

90-119. (Canceled).

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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 November 23, 2009 (U.S. Patent Office Paper No. 20091026). 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 68, 69, 72, 75, 77, 78, 84, and 89 stand for consideration in this application, wherein claims 66, 67, 70, 71, 73, 74, 76, 79-83, 85-88, and 90-119 are being canceled without prejudice or disclaimer, and wherein claims 68, 69, 72, 75, 77, 78, 84, and 89 are being amended to improve form.

All amendments to the application are fully supported therein. For example, the amendments to the claims are supported by paragraphs [0015], [0027]-[0028], [0032]-[0033], and [0036]-[0039], as well as by Figures 1(A)-2(D) and 5. 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 Figures 8(A)-9(C) of the drawings, stating that these figures should each be designated by a legend indicating that the illustration is prior art. As set forth above, a set of replacement sheets of corrected drawings, in which each of Figures 8(A)-9(C) are designated by a legend indicating that the illustration is prior art, thereby rendering moot and/or obviating this objection.

The Examiner also objected to the drawings as failing to comply with 37 CFR 1.84(p)(5) for including reference character "113" not mentioned in the description. As set forth above, paragraph [0006] of the specification is being amended to correctly indicate that reference character "113" refers to "a source junction," thereby rendering moot and/or obviating this objection.

The Examiner objected to the specification for failing to reference Figures 8A and 8B in the Brief Description of the Drawings. As set forth above, paragraph [0023] of the specification

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is being amended to specifically reference Figures 8A and 8B, thereby rendering moot and/or obviating this objection.

The Examiner also objected to the specification for having a Title of the Invention that is not sufficiently descriptive of the invention to which the claims are directed. As set forth above, the Title of the Invention is being amended to "Magnetic Tunnel Junction Device and Memory Device Including the Same," thereby rendering moot and/or obviating this objection.

The Examiner rejected claim 71 under 35 U.S.C. §112, second paragraph, as being indefinite. In particular, the Examiner stated that the phrase "an output voltage of the device" recited in claim 71 is vague. As set forth above, claim 71 is being canceled without prejudice or disclaimer, thereby rendering moot and/or obviating this rejection.

The Examiner also rejected claims 66-70, 72, 80-88, 102-105, and 110-119 under 35 U.S.C. §112, second paragraph, as being indefinite. In particular, the Examiner stated that these claims are incomplete for failure to recite "a tunnel barrier height in a specified eV range." As set forth above, each of these claims is either being canceled without prejudice or disclaimer, amended to explicitly recite a limitation of a tunnel barrier height of a specified eV range, or amended to depend from another claim that explicitly recites a limitation of a tunnel barrier height of a specified eV range, thereby rendering moot and/or obviating this rejection of claims 66-70, 72, 80-88, 102-105 and 110-119.

The Examiner also rejected claims 72-89, 102-105, and 110-119 under 35 U.S.C. §112, second paragraph, as being indefinite. In particular, the Examiner stated that these claims are incomplete for failure to recite "first and second ferromagnetic layers having a BCC structure." As set forth above, each of these claims is either being canceled without prejudice or disclaimer, amended to explicitly recite first and second ferromagnetic layers having a BCC structure, or amended to depend from another claim that explicitly recites first and second ferromagnetic layers having a BCC structure, thereby rendering moot and/or obviating this rejection of claims 72-89, 102-105, and 110-119.

Conclusion

In view of all the above, Applicants respectfully submit that the present application is now in condition for allowance. Favorable reconsideration of this application as amended is

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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

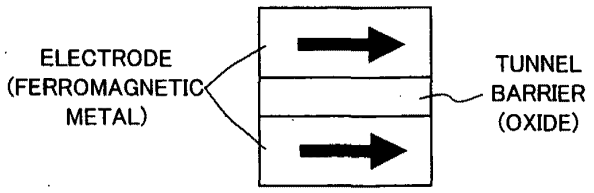
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Alexandria, VA 22314-1437
(703) 739-4900 Voice
(703) 739-9577 Fax
Customer No. 38327

March 23, 2010

2355LT:00236:166305:1:ALEXANDRIA

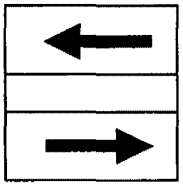
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Page 260

FIG. 8 (A)



Prior Art

FIG. 8 (B)



Prior Art

FIG. 9 (A) Prior Art

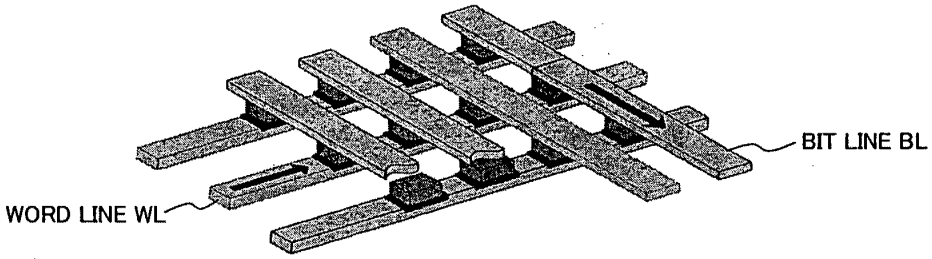


FIG. 9 (B) Prior Art

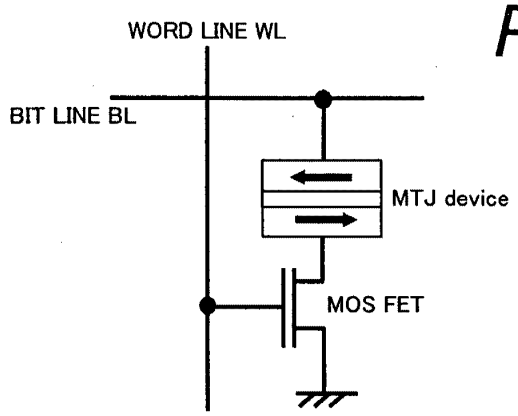
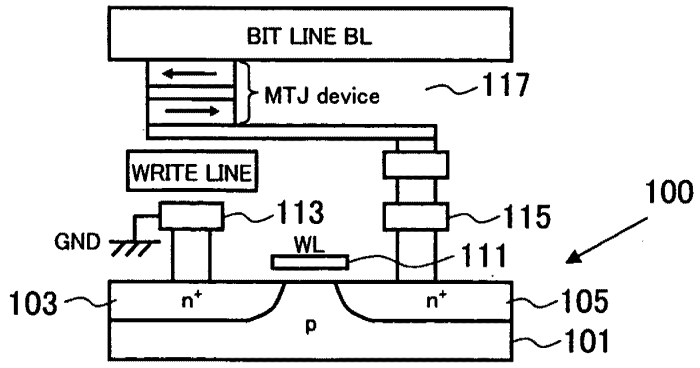


FIG. 9 (C) Prior Art



MOSFET 100

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OPAP
MAR 23 2010
IAP20
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of

YUASA

Application Number: 10/591,947

Filed: September 8, 2006

For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME (AS AMENDED)

ATTORNEY DOCKET NO. HIRA.0236

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	8	54	34 (Over 20)	x $52	0
Independent Claims	5	26	23 (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 Spec. & marked-up copy
[ ] Preliminary Amendment
[ ] Other: _____

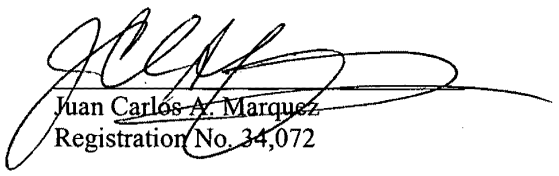
[x] Petition for Extension of Time 1 month
[ ] Information Disclosure Statement
[x] 2 sheets of replacement drawings
[ ] RCE

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

[x] Credit card information for **$130.00** to cover the 1-month extension of time fee is enclosed.

[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

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1199 North Fairfax Street, Suite 900
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Telephone: (703) 739-4900
Facsimile: (703) 739-9577
Customer No. 38327
March 23, 2010

166418:1:ALEXANDRIA

OPAP
MAR 2 3 2010
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	)	
	)	
YUASA	)	
	)	**Art Unit 2892**
Application Number: 10/591,947	)	
	)	**Examiner**
Filed: September 8, 2006	)	**Alonzo Chambliss**
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME (AS AMENDED)	)	
	)	
ATTORNEY DOCKET NO. **HIRA.0236**	)	

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

PETITION FOR EXTENSION OF TIME

Sir:

Applicants request that the time for taking action in this case be extended pursuant to 37 C.F.R. § 1.136(a) for **one (1) month**. The fee set in 37 C.F.R. § 1.17 for the extension of time is **$130.00** for a large entity.

Please charge any additional fee required for this extension of time to Deposit Account 12-0555.

Also filed is a *Response/Amendment to Office Action.*

Respectfully submitted,

Juan Carlos A. Marquez
Registration Number 34,072

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1199 North Fairfax Street, Suite 900
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Telephone: (703) 739-4900
Facsimile: (703) 739-9577
Customer No.: 38327
March 23, 2010

03/24/2010 JADD01 00000100 10591947
01 FC:1251 130.00 OP

166417:1:ALEXANDRIA

PTO/SB/06 (07-06)
Approved for use through 1/31/2007. OMB 0651-0032
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 10/591,947	Filing Date 09/08/2006	☐ 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	
	03/23/2010	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)		RATE ($)	ADDITIONAL FEE ($)
AMENDMENT	Total (37 CFR 1.16(i))	* 8	Minus	** 54	= 0	X $ =		OR	X $52=	0
	Independent (37 CFR 1.16(h))	* 5	Minus	***26	= 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:
/GAIL D. D. WOOTEN/

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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NOTICE OF ALLOWANCE AND FEE(S) DUE

38327 7590 07/02/2010

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: 07/02/2010

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$300	$0	$1810	10/04/2010

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. 08/07) Approved for use through 08/31/2010.

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 07/02/2010

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.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE AND METHOD OF MANUFACTURING THE SAME

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$300	$0	$1810	10/04/2010

EXAMINER	ART UNIT	CLASS-SUBCLASS
CHAMBLISS, ALONZO	2892	257-421000

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 EX1002
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Page 269

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.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

38327 7590 07/02/2010

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: 07/02/2010

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 565 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 565 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. 08/07) Approved for use through 08/31/2010.

Notice of Allowability	Application No.	Applicant(s)	
	10/591,947	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 amendment filed on 3/23/10*.

2. ☒ The allowed claim(s) is/are *68,69,72,75,77,78,84 and 89*.

3. ☒ 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.

4. ☐ 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.

5. ☐ 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).

6. ☐ 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 12/4/09
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 _____.

DETAILED ACTION

1. The amendment filed on 3/23/10 has been fully considered and made of record in the instant application.

Drawings

2. The drawings were received on 3/23/10. These drawings are approved by the examiner.

Information Disclosure Statement

3. The information disclosure statement (IDS) submitted on 3/23/10 was filed before the mailing date of the notice of allowance on 6/1910. 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, 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/June 19, 2010

/Alonzo Chambliss/
Primary Examiner, Art Unit 2892

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

BIB DATA SHEET

CONFIRMATION NO. 8009

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/591,947	09/08/2006 RULE	365	2892	HIRA.0236

APPLICANTS
Shinji Yuasa, Ibaraki, JAPAN;

**** CONTINUING DATA ***************************
This application is a 371 of PCT/JP05/04720 03/10/2005

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

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ****
05/12/2007

Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /ALONZO CHAMBLISS/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		JAPAN	10	39	12

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	FEES: Authority has been given in Paper	
7440	No._____ to charge/credit DEPOSIT ACCOUNT No._____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

Receipt date: 12/04/2009 DEC 04 2009 USPTO PATENT & TRADEMARK OFFICE

10591947 - GAU: 2892

Form PTO 1449	ATTY. DOCKET NUMBER	SERIAL NUMBER
U.S. Department of Commerce Patent and Trademark Office	ASAM.0236	10/591,947
	APPLICANT	
	YUASA	
Information Disclosure Statement by Applicant	FILING DATE	GROUP
	September 8, 2006	2827

U.S. Patent Documents

Examiner Initial		DOCUMENT NUMBER	DATE	NAME	CLASS	SUB CLASS	FILING DATE

Foreign Patent Documents

Examiner Initial		DOCUMENT NUMBER	FILING DATE	COUNTRY	CLASS	SUB-CLASS	TRANSLATION	
							YES	No
		EP 1 085 586 A2	9/15/2000	EPO			X	

Other Documents (Including Author, Title, Date Pertinent Pages, Etc.)

		Office Action from the European Patent Office dated November 6, 2009

/Alonzo Chambliss/ (06/18/2010)

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

156631:1:ALEXANDRIA

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	YUASA, SHINJI
	Examiner	Art Unit
	Alonzo Chambliss	2892

SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES		
Search Notes	Date	Examiner
East text search only - see attached printout	10/26/09	AC
Updated previous East text search only - see attached printout	6/19/10	AC

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
257	4,295,421,427	6/19/10	AC
365	171	6/19/10	AC

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	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)	
		G 1 1 C 11 / 14 (2006.01.01)	

CROSS REFERENCE(S)					
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

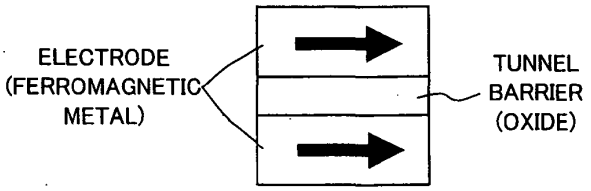
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	11		27		43		59	3	75						
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	14		30		46		62	7	78						
	15		31		47		63		79						
	16		32		48		64		80						

		Total Claims Allowed:	
NONE		8	
(Assistant Examiner)	(Date)		
/Alonzo Chambliss/ Primary Examiner.Art Unit 2892	6/19/10	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1B

WD EX1002
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Page 277

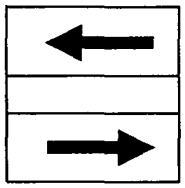
APPROVED: /AC/ (06/19/2010)

FIG. 8 (A)



Prior Art

FIG. 8 (B)



Prior Art

FIG. 9 (A) Prior Art

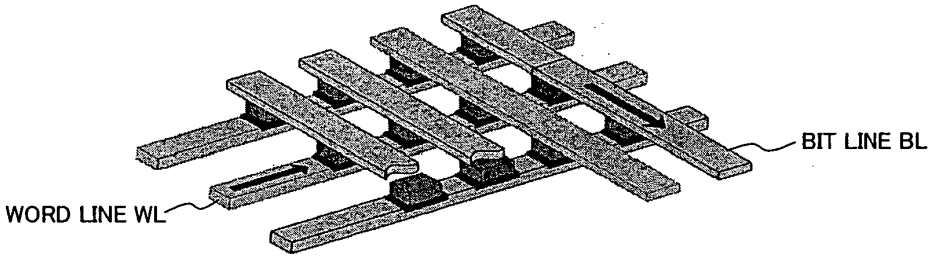


FIG. 9 (B) Prior Art

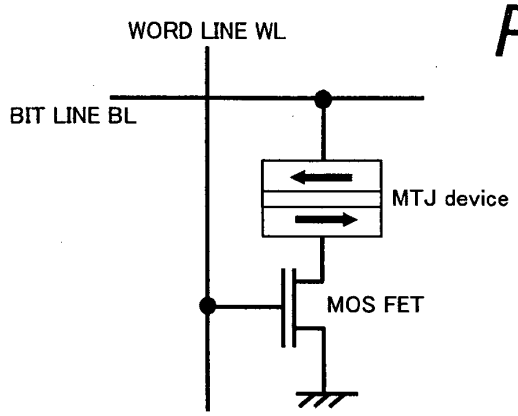
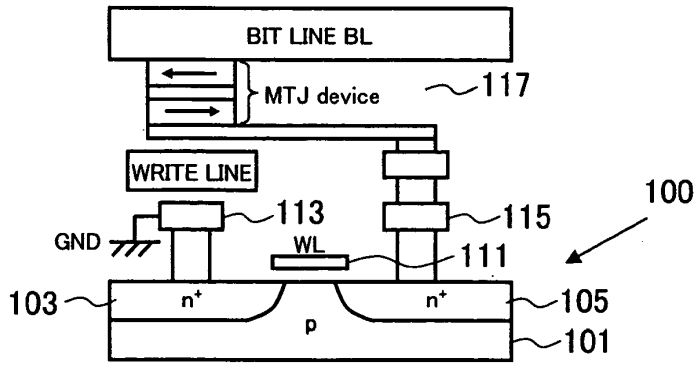


FIG. 9 (C) Prior Art



MOSFET 100

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L2	235	yuasa.in. and ferromagnetic	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/19 19:15
L3	51	yuasa.in. and ferromagnetic and MgO	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/19 19:16
L4	1822	"257"/$.ccls. and (Fe ferromagnetic) and MgO	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/19 19:17
L5	431	"257"/$.ccls. and (Fe ferromagnetic) and MgO and magnetic adj3 device	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/19 19:18
L6	319	"365"/$.ccls. and (Fe ferromagnetic) and MgO and magnetic adj3 device	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/19 19:23
L7	186	257/E27.104	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/19 19:38
L8	58	257/E29.164	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/19 19:38

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Page 280

L9	76	257/E21.208	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/19 19:38
L10	265	257/E29.323	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/06/19 19:38

6/19/2010 7:38:53 PM
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OPAP IAP16 JUL 06 2010 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 #	10/591,947
Confirmation #	8009
Filing Date	September 8, 2006
First Inventor	YUASA
Art Unit	2892
Examiner	Alonzo Chambliss
Docket #	HIRA.0236

U.S. PATENT DOCUMENTS

Exam. Initial*	Document No. Number – Kind Code	Publ. Date MM-DD-YYYY	Name Patentee or Applicant	Relevance Passages/Figs.
	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.	Translation
	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
	JP 2002-246567	8/30/2002	Toshiba Corp		Abstract
	WO 2005/088745 A1	9/22/2005	Japan Science and Technology Agency; National Institute of Advanced Industrial Science and 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		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.*

175022:1:ALEXANDRIA

OPAP IAP16 JUL 06 2010 PATENT & TRADEMARK OFFICE

B/F/G

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	
YUASA	
	Art Unit 2892
Application Number: 10/591,947	
	Examiner
Filed: September 8, 2006	**Alonzo Chambliss**
For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME (AS AMENDED)	
ATTORNEY DOCKET NO. HIRA.0236	

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
July 6, 2010

Juan Carlos A. Marquez
Registration Number 34,072

QPAP
JUL 06 2010
IAP16
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	
YUASA	
Application Number: 10/591,947	**Art Unit 2892**
Filed: September 8, 2006	**Examiner Alonzo Chambliss**
For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME (AS AMENDED)	
ATTORNEY DOCKET NO. HIRA.0236	

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 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 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 issuance of the earlier of any Final Action or Notice of Allowance sent in such application.

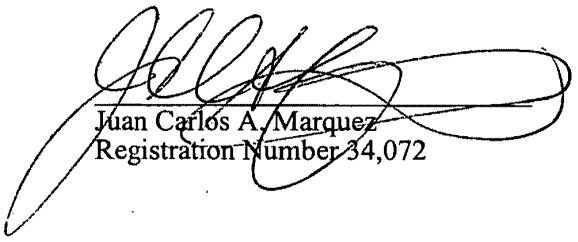
It is also hereby certified that each item of information contained in this statement was cited in a communication from a foreign patent office in a counterpart foreign application not more than three months from the date of this filing. Accordingly, no fee is due or payable at this

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
July 6, 2010

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Page 285

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

Bib Data Sheet

CONFIRMATION NO. 8009

SERIAL NUMBER	FILING OR 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
10/591,947	09/08/2006 RULE	257	2892	HIRA.0236

APPLICANTS

Shinji Yuasa, Ibaraki, JAPAN;

**** CONTINUING DATA ***************************

This application is a 371 of PCT/JP05/04720 03/10/2005

**** FOREIGN APPLICATIONS *********************

JAPAN 2004-071186 03/12/2004
JAPAN 2004-313350 10/28/2004

IF REQUIRED, FOREIGN FILING LICENSE GRANTED
** 05/12/2007

Foreign Priority claimed	STATE OR COUNTRY	SHEETS DRAWING	TOTAL CLAIMS	INDEPENDENT CLAIMS
☐ yes ☐ no	JAPAN	10	39	12
35 USC 119 (a-d) conditions met ☐ yes ☐ no ☐ Met after Allowance				
Verified and Acknowledged _____ Examiner's Signature Initials				

PNP 7/20/10

ADDRESS
38327

TITLE

MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME

FILING FEE RECEIVED		
7440	FEES: Authority has been given in Paper No. _____ to charge/credit DEPOSIT ACCOUNT No. _____ for following:	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time) ☐ 1.18 Fees (Issue) ☐ Other _____ ☐ Credit

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

38327 7590 07/21/2010

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	

MAIL DATE	DELIVERY MODE
07/21/2010	PAPER

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.

UNITED STATES DEPARTMENT OF COMMERCE
U.S. Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450

APPLICATION NO./ CONTROL NO.	FILING DATE	FIRST NAMED INVENTOR / PATENT IN REEXAMINATION	ATTORNEY DOCKET NO.
10591947	9/8/2006	YUASA, SHINJI	HIRA.0236

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

EXAMINER	
Alonzo Chambliss	
ART UNIT	**PAPER**
2892	20100717

DATE MAILED:

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

Commissioner for Patents

The IDS filed on 7/6/10 has been fully considered and made of record in the instant application. The references in the IDS fail to read on the claims of this application.

/Alonzo Chambliss/
Primary Examiner, Art Unit 2892

PTO-90C (Rev.04-03)

Receipt date: 07/06/2010



10591947 - GAU: 2892

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

Substitute for Form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Sheet 1 of 1

Application #	10/591,947
Confirmation #	8009
Filing Date	September 8, 2006
First Inventor	YUASA
Art Unit	2892
Examiner	Alonzo Chambliss
Docket #	HIRA.0236

U.S. PATENT DOCUMENTS

Exam. Initial*	Document No. Number – Kind Code	Publ. Date MM-DD-YYYY	Name Patentee or Applicant	Relevance Passages/Figs.
	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 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
	JP 2002-246567	8/30/2002	Toshiba Corp		Abstract
	WO 2005/088745 A1	9/22/2005	Japan Science and Technology Agency; National Institute of Advanced Industrial Science and 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/ (07/17/2010)	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.*

175022:1:ALEXANDRIA

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /AC/

PART B - ISSUE FEE (S) TRANSMITTAL

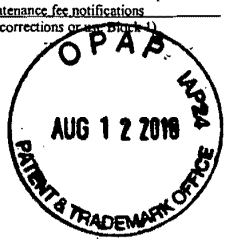
Complete and mail this form, together with applicable fees, to:

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, PLCC
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.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

TITLE OF INVENTION: **MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME**

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$300	$1810	10/04/2010

EXAMINER	ART UNIT	CLASS – SUBCLASS
CHAMBLISS, ALONSO	2892	257-421000

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: 3

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) **August 12, 2010**

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

08/13/2010 SHOHAMM1 00000039 10591947

01 FC:1501 1510.00 OP
02 FC:1504 300.00 OP
03 FC:8001 9.00 OP

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

WD EX1002
Western Digital v IP Bridge
Page 290

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.
10/591,947	09/21/2010	7800149	HIRA.0236	8009

38327 7590 09/01/2010

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 901 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;

OPAP
SEP 0 2 2010
PATENT & TRADEMARK OFFICE
1AP18

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	)	
	)	
YUASA	)	
	)	**Art Unit 2892**
Application Number: 10/591,947	)	
	)	**Examiner**
Filed: September 8, 2006	)	**Alonzo Chambliss**
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME (AS AMENDED)	)	
	)	
ATTORNEY DOCKET NO. HIRA.0236	)	

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

PETITION TO WITHDRAW FROM ISSUE UNDER 37 C.F.R. §1.313(c)(2) AFTER PAYMENT OF ISSUE FEE

Sir:

Applicant respectfully petitions that the above identified application be withdrawn from issue. Withdrawal from issue is necessary in order to consider a Request for Continued Examination (RCE) under 37 CFR § 1.313(c)(2).

The issue fee was paid on August 12, 2010. However, Applicant is submitting a new Information Disclosure Statement with references presented to the Applicants on August 10, 2010. We hereby file a Request for Continued Examination in conjunction with filing an Information Disclosure Statement. We respectfully request the application be withdrawn from issue in order to permit the Examiner to consider the new references.

09/03/2010 AWONDAF1 00000083 10591947
02 FC:1464 130.00 OP

Enclosed is a credit card form for $130.00 to cover the required petition fee. The commission is hereby authorized to charge any insufficiency or credit any overpayment to Deposit Account No. 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
Customer No. 38327
September 2, 2010

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Western Digital v IP Bridge
Page 293

OPAP IAP18
SEP 0 2 2010
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	
YUASA	**Art Unit 2892**
Application Number: 10/591,947	**Examiner**
Filed: September 8, 2006	**Alonzo Chambliss**
For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME (AS AMENDED)	
ATTORNEY DOCKET NO. HIRA.0236	

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

INFORMATION DISCLOSURE STATEMENT

Sir:

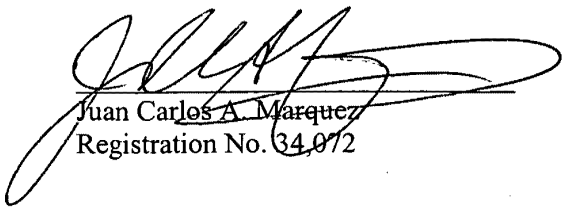
Pursuant to 37 C.F.R. §§ 1.56 and 1.97, this Information Disclosure Statement is submitted in the above-identified patent application. A listing of documents to be published on the face of any patent granted from this application is submitted herewith on Form PTO-1449. Any other documents or information 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, submitted herewith.

This Information Disclosure Statement is submitted with the initial filing of the RCE. 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 No. 34,072

STITES & HARBISON, PLLC
1199 North Fairfax Street, Suite 900
Alexandria, VA 22314
Telephone: (703) 739-4900
Customer No. 38327
September 2, 2010

OPAP IAP18 SEP 0 2 2010 PATENT & TRADEMARK OFFICE

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

Substitute for Form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Application #	10/591,947
Confirmation #	8009
Filing Date	September 8, 2006
First Inventor	YUASA
Art Unit	2892
Examiner	Alonzo Chambliss
Sheet 1 of 1	Docket # HIRA.0236

U.S. PATENT DOCUMENTS

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

FOREIGN PATENT DOCUMENTS

Exam. Initial*	Country-Number-Kind Code if known	Publ. Date MM-DD-YYYY	Name Patentee or Applicant	Relevance Passages/Figs.	Translation
	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
	F. ERNULT et al., "Preparation of Nanometer-Scale Iron Dots on Insulating Layer", Science and Technology of Advanced Materials, Vol. 4, (2003), pp. 383-389	Yes
	DAVID J. SMITH et al., "Structural Characterization of Thin Film Ferromagnetic Tunnel Junctions", Journal of Applied Physics, Vol. 83, No. 10, 15 May 1998, pp. 5154-5158	Yes
	X. W. LI et al., "Fabrication and Properties of Heteroepitaxial Magnetite (Fe_3O_4) Tunnel Junctions", Applied Physics Letters, Vol. 73, No. 22, 30 November 1998, pp.3282-3284	Yes
	C. L. PLATT, et al., "Spin Polarized Tunneling in Reactively Sputtered Tunnel Junctions", Journal of Applied Physics, Vol. 81, No. 8, 15 April 1997, pp. 5523-5525	Yes
	P. TURBAN et al., "Growth and Characterization of Single Crystalline NiMnSb Thin Films and Epitaxial NiMnSb/MgO/NiMnSb(001) Trilayers", 2002 The American Physical Society, Physical Review B., Vol. 65, pp. 134417-1 to 134417-13	Yes
	T. MORIYAMA et al., "Preparation and Magnetoresistance in Single-Crystal and Polycrystal Fe/MgO/FeCo Tunnel Junctions", The Physical Society of Japan, 2003 Spring meeting, Abstracts Book 58(1-3), 460, (2003-03-06)	Yes
	JAGADEESH S. MOODERA et al., "Ferromagnetic-Insulator-Ferromagnetic Tunneling: Spin-Dependent Tunneling and Large Magnetoresistance in Trilayer Junctions (Invited), Journal of Applied Physics, Vol. 79, No. 8, 15 April 1996, pp. 4724-4729	Yes
	MASAYOSHI TONOUCHI et al., "Epitaxial Growth of NbN on an Ultrathin MgO/Semiconductor System", Journal of Applied Physics, Vol. 62, No. 3, 1 August 1987, pp. 961-966	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.*

OPAP IAP16 SEP 0 2 2010 PATENT & TRADEMARK OFFICE

Customized PTO/SB/30 (04-09)

REQUEST FOR CONTINUED EXAMINATION (RCE) Transmittal

Mail Stop RCE

Application #	10/591,947
Confirmation #	8009
Filing Date	September 8, 2006
First Inventor	YUASA
Art Unit	2892
Examiner	Alonzo Chambliss
Docket #	HIRA.0236

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**
- ☐ Amendment/Response to Office Action
- ☐ Affidavit(s)/Declaration
- ☒ Information Disclosure Statement
- ☒ Other: Petition to Withdraw from Issue under 37 C.F.R. §1.313(c)(2) after Payment of Issue Fee

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 _____.

☐ Other:

FEES calculated below (after reduction for an amendment if noted above).

	NOW	*Basic/Previous Number*	*Present Extra*	*Rate*	$
☐ TOTAL CLAIMS	8	8		X $ 52 =	
☐ INDEPENDENT CLAIMS	5	5		X $ 220 =	
☒ RCE fee required under 37 CFR 1.17(e)				$ 810 =	810
				TOTAL OF ABOVE CALCULATIONS =	810
☐ Reduction by ½ for small entity status of applicant				–	
				SUBTOTAL =	
☐ Extension of time fee __ months				=	
☒ Other fee for Petition to Withdraw from Issue (37 CFR §§1.136 and 1.17)				=	130
				TOTAL OF ALL FEES =	**940**

☒ Payment of **$940** 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.

09/03/2010 AWONDAF1 00000003 10591947
01 FC:1801 810.00 OP

Date: September 2, 2010

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

179920:1:ALEXANDRIA

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

Date : September 10, 2010

TO : Director, Office of Patent Publication

FROM : Office of the Deputy Commissioner
for Patent Examination Policy

SUBJECT : Withdrawal from Issue of Application No. 10/591,947

Applicant(s) : Shinji Yuasa
Application No. : 10/591,947
Filed : September 8, 2006

The above-identified application has been assigned Patent No. 7,800,149 and an issue date of September 21, 2010.

It is hereby directed that this application be withdrawn from issue at the request of the applicant.

Do not refund the issue fee.

The following erratum should be published in the Official Gazette if the above-identified application is published in the OG of: September 21, 2010.

> "All reference to Patent No. 7,800,149 to Shinji Yuasa of Japan for MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME appearing in the Official Gazette of September 21, 2010 should be deleted since no patent was granted."

/Irvin Dingle/
Irvin Dingle
Petitions Examiner
Office of Petitions

cc: Paul Harrison
Deneise Boyd (DMB)
Mary Louise McAskill
Niomi Farmer
Mary E. Johnson (Cookie)
Duane Davis (CDS)
Bradley Harris
Kimberly Terrell
Kay Pinkney
Betty Powell
Lamont Fletcher

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
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JUAN CARLOS A. MARQUEZ
C/O STITES & HARBISON PLLC
1199 NORTH FAIRFAX STREET
SUITE 900
ALEXANDRIA, VA 22314-1437

MAILED

SEP 10 2010

OFFICE OF PETITIONS

In re Application of :
Shinji Yuasa :
Application No. 10/591,947 : ON PETITION
Filed: September 8, 2006 :
Attorney Docket No. HIRA.0236

This is a decision on the petition, filed September 2, 2010 under 37 CFR 1.313(c)(2) to withdraw the above-identified application from issue after payment of the issue fee.

The petition is **GRANTED**.

The above-identified application is withdrawn from issue for consideration of a submission under 37 CFR 1.114 (request for continued examination). See 37 CFR 1.313(c)(2).

Petitioner is advised that the issue fee paid on August 12, 2010 in the above-identified application cannot be refunded. If, however, the above-identified application is again allowed, petitioner may request that it be applied towards the issue fee required by the new Notice of Allowance.[1]

Telephone inquiries should be directed to Irvin Dingle at (571) 272-3210.

This matter is being referred to Technology Center AU 2892 for processing of the request for continued examination under 37 CFR 1.114 and for consideration of the concurrently filed Information Disclosure Statement.

/Irvin Dingle/
Irvin Dingle
Petitions Examiner
Office of Petitions

---

[1] The request to apply the issue fee to the new Notice may be satisfied by completing and returning the new Issue Fee Transmittal Form PTOL-85(b), which includes the following language thereon: Commissioner for Patents is requested to apply the Issue Fee and Publication Fee (if any) or re-apply any previously paid issue fee to the application identified above. Petitioner is advised that, whether a fee is indicated as being due or not, the Issue Fee Transmittal Form **must** be completed and timely submitted to avoid abandonment. Note the language in bold text on the first page of the Notice of Allowance and Fee(s) Due (PTOL-85).

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

PATENT WITHDRAWAL NOTICE

DATE WITHDRAWN	WITHDRAWAL NUMBER
9/14/10	18558

The following application has been **WITHDRAWN** from the

Tuesday, September 21, 2010 issue.

SERIAL NO.	PATENT NUMBER
10/591,947	7,800,149
DRAWINGS	**CLASS**
010	257/421

TITLE

MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME

NAME AND ADDRESS

SHINJI YUASA
IBARAKI, JAPAN

REASON FOR WITHDRAWAL

Office of Petitions granted applicant's request to withdraw patent from issue.

APPROVED

/Kimberly Terrell/, Manager

Patent Publication Branch
Office of Data Management

FORM PTO-302 -- (REV. 05-2009)

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 09/17/2010

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: 09/17/2010

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$0	$1510	$1510	12/17/2010

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. 08/07) Approved for use through 08/31/2010.

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 09/17/2010

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.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$0	$1510	$1510	12/17/2010

EXAMINER	ART UNIT	CLASS-SUBCLASS
CHAMBLISS, ALONZO	2892	257-421000

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.

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Page 302

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/591,947	09/08/2006	Shinji Yuasa	HIRA.0236	8009

38327 7590 09/17/2010

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: 09/17/2010

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 565 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 565 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. 08/07) Approved for use through 08/31/2010.

Notice of Allowability	Application No.	Applicant(s)	
	10/591,947	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 RCE filed on 9/2/10*.

2. ☒ The allowed claim(s) is/are *68,69,72,75,77,78,84 and 89*.

3. ☒ 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.

4. ☐ 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.

5. ☐ 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).

6. ☐ 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 9/2/10
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 9/2/10 has been entered.

Information Disclosure Statement

2. The information disclosure statement (IDS) submitted on 9/2/10 was filed after the mailing date of the notice of allowance on 7/2/10. The submission is in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner.

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, 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/September 11, 2010

/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	10	(("20020159203") or ("20050207071") or ("20020191355") or ("20020149962") or ("20070195592")).PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2010/09/11 11:24
L2	2	"2003318465"	JPO; DERWENT; IBM_TDB	OR	OFF	2010/09/11 11:48
L3	454	"257"/$.ccls. and (Fe ferromagnetic) and MgO and magnetic adj3 device	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/09/11 11:53
L4	329	"365"/$.ccls. and (Fe ferromagnetic) and MgO and magnetic adj3 device	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/09/11 11:54
L5	215	257/E27.104	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/09/11 11:54
L6	69	257/E29.164	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/09/11 11:54
L7	83	257/E21.208	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/09/11 11:54

L8	315	257/E29.323	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/09/11 11:55

9/11/2010 11:55:32 AM
C:\ Documents and Settings\ AChambliss\ My Documents\ EAST\ Workspaces\ 11232499.wsp

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	YUASA, SHINJI
	Examiner	Art Unit
	Alonzo Chambliss	2892

SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES		
Search Notes	Date	Examiner
East text search only - see attached printout	10/26/09	AC
Updated previous East text search only - see attached printout	6/19/10	AC
Updated previous East text search only - see attached printout	9/11/10	AC

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
257	4,295,421,427	6/19/10	AC
365	171	6/19/10	AC
257	4,295,421,427	9/11/10	AC
365	171	9/11/10	AC

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	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)	
		G 1 1 C 11 / 14 (2006.0)	

CROSS REFERENCE(S)					
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
	1		17		33		49		65		81				
	2		18		34		50		66		82				
	3		19		35		51		67		83				
	4		20		36		52	1	68	4	84				
	5		21		37		53	2	69		85				
	6		22		38		54		70		86				
	7		23		39		55		71		87				
	8		24		40		56	5	72		88				
	9		25		41		57		73	8	89				
	10		26		42		58		74						
	11		27		43		59	3	75						
	12		28		44		60		76						
	13		29		45		61	6	77						
	14		30		46		62	7	78						
	15		31		47		63		79						
	16		32		48		64		80						

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	8	
/Alonzo Chambliss/ Primary Examiner.Art Unit 2892	9/11/10	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	1B

OPAP
SEP 0 2 2010
PATENT & TRADEMARK OFFICE

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

Substitute for Form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Application #	10/591,947
Confirmation #	8009
Filing Date	September 8, 2006
First Inventor	YUASA
Art Unit	2892
Examiner	Alonzo Chambliss
Sheet 1 of 1	Docket # HIRA.0236

U.S. PATENT DOCUMENTS

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

FOREIGN PATENT DOCUMENTS

Exam. Initial*	Country-Number-Kind Code If known	Publ. Date MM-DD-YYYY	Name Patentee or Applicant	Relevance Passages/Figs.	Translation
	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
	F. ERNULT et al., "Preparation of Nanometer-Scale Iron Dots on Insulating Layer", Science and Technology of Advanced Materials, Vol. 4, (2003), pp. 383-389	Yes
	DAVID J. SMITH et al., "Structural Characterization of Thin Film Ferromagnetic Tunnel Junctions", Journal of Applied Physics, Vol. 83, No. 10, 15 May 1998, pp. 5154-5158	Yes
	X. W. LI et al., "Fabrication and Properties of Heteroepitaxial Magnetite (Fe_3O_4) Tunnel Junctions", Applied Physics Letters, Vol. 73, No. 22, 30 November 1998, pp.3282-3284	Yes
	C. L. PLATT, et al., "Spin Polarized Tunneling in Reactively Sputtered Tunnel Junctions", Journal of Applied Physics, Vol. 81, No. 8, 15 April 1997, pp. 5523-5525	Yes
	P. TURBAN et al., "Growth and Characterization of Single Crystalline NiMnSb Thin Films and Epitaxial NiMnSb/MgO/NiMnSb(001) Trilayers", 2002 The American Physical Society, Physical Review B., Vol. 65, pp. 134417-1 to 134417-13	Yes
	T. MORIYAMA et al., "Preparation and Magnetoresistance in Single-Crystal and Polycrystal Fe/MgO/FeCo Tunnel Junctions", The Physical Society of Japan, 2003 Spring meeting, Abstracts Book 58(1-3), 460, (2003-03-06)	Yes
	JAGADEESH S. MOODERA et al., "Ferromagnetic-Insulator-Ferromagnetic Tunneling: Spin-Dependent Tunneling and Large Magnetoresistance in Trilayer Junctions (Invited), Journal of Applied Physics, Vol. 79, No. 8, 15 April 1996, pp. 4724-4729	Yes
	MASAYOSHI TONOUCHI et al., "Epitaxial Growth of NbN on an Ultrathin MgO/Semiconductor System", Journal of Applied Physics, Vol. 62, No. 3, 1 August 1987, pp. 961-966	Yes

Examiner Signature	/Alonzo Chambliss/ (09/11/2010)	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/

PART B - ISSUE FEE (S) TRANSMITTAL

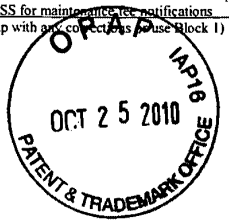
Complete and mail this form, together with applicable fees, to:

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, PLCC
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.
10/591,947	09/08/2006	Shinji Yuasa .	HIRA.0236	8009

TITLE OF INVENTION: **MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME**

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$0	$0	$0	12/17/2010

EXAMINER	ART UNIT	CLASS – SUBCLASS
CHAMBLISS, ALONSO	2892	257-421000

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**

10/26/2010 SMOHAMM1 00000061 10591947
01 FC:1501 1510.00 OP

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 – See explanation below.

☒ 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 25, 2010**

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

Commissioner for Patents is requested to apply the Issue Fee and Publication Fee previously paid on August 12, 2010 to the application identified above

Adjustment date: 10/26/2010 SMOHAMM1
08/13/2010 SMOHAMM1 00000039 10591947
01 FC:1501 -1510.00 OP

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

WD EX1002
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Page 312

PATENT & TRADEMARK OFFICE
NOV 10 2010
IAP19

4fw RCE #

Customized PTO/SB/30 (04-09)

REQUEST FOR CONTINUED EXAMINATION (RCE) Transmittal

Mail Stop RCE

Application #	10/591,947
Confirmation #	8009
Filing Date	September 8, 2006
First Inventor	YUASA
Art Unit	2892
Examiner	Alonzo Chambliss
Docket #	HIRA.0236

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 previously filed on August 12, 2009
- ☐ Other:

☒ **Enclosed**
- ☐ Amendment/Reply
- ☐ Affidavit(s)/Declaration(s)
- ☒ Information Disclosure Citation
- ☒ Other: Petition to Withdraw from Issue under 37 C.F.R. §1.313(c)(2) after Payment of Issue Fee

Miscellaneous

☐ **Suspension of action** on the above-identified application is requested under 37 CFR § 1.103(c) for a period of months *(Period of suspension shall not exceed 3 months; Fee under 37 CFR§ 1.17(i) required)*

☐ Other:

FEES calculated below (after reduction for an amendment if noted above).

	NOW	*Basic/Previous Number*	*Present Extra*	*Rate*	
☐ TOTAL CLAIMS	8	8		X $ 52 =	
☐ INDEPENDENT CLAIMS	5	5		X $ 220 =	
☒ RCE fee required under 37 CFR 1.17(e)				$ 810 =	$810
				TOTAL OF ABOVE CALCULATIONS =	810
☐ Reduction by ½ for small entity status of applicant				–	
				SUBTOTAL =	
☐ Extension of time fee				+ $ =	
☒ Other fee for Petition to Withdraw from Issue (37 CFR 1.136 and 1.17)				+ $ =	130
				TOTAL OF ALL FEES =	**940**

☒ Payment of **$940** 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: November 10, 2010

Douglas E. Jackson POR #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

11/12/2010 AWONDAF1 00000007 10591947
810.00 OP
01 FC:1801

185985:1:ALEXANDRIA

OPAP
NOV 10 2010
IAP19
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	)	
	)	
YUASA	)	
	)	**Art Unit 2892**
Application Number: 10/591,947	)	
	)	**Examiner**
Filed: September 8, 2006	)	**Alonzo Chambliss**
	)	
For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME (AS AMENDED)	)	
	)	
ATTORNEY DOCKET NO. HIRA.0236	)	

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

PETITION TO WITHDRAW FROM ISSUE UNDER 37 C.F.R. §1.313(c)(2) AFTER PAYMENT OF ISSUE FEE

Sir:

Applicant respectfully petitions that the above identified application be withdrawn from issue. Withdrawal from issue is necessary in order to consider a Request for Continued Examination (RCE) under 37 CFR § 1.313(c)(2).

The issue fee was paid on October 25, 2010. However, Applicant is submitting a new Information Disclosure Statement with a reference presented to the Applicants on October 27, 2010. We hereby file a Request for Continued Examination in conjunction with filing an Information Disclosure Statement. We respectfully request the application be withdrawn from issue in order to permit the Examiner to consider the new references.

11/12/2010 AWONDAF1 00000007 10591947
02 FC:1464 130.00 OP

Enclosed is a credit card form for $130.00 to cover the required petition fee. The commission is hereby authorized to charge any insufficiency or credit any overpayment to Deposit Account No. 12-0555.

Respectfully submitted,

Douglas E Jacobson for #28,548

Juan Carlos A. Marquez
Registration No. 34,072

STITES & HARBISON, PLLC
1199 North Fairfax Street, Suite 900
Alexandria, VA 22314
Telephone: (703) 739-4900
Customer No. 38327
November 10, 2010

OPAP
NOV 10 2010
IAP19
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of	
YUASA	**Art Unit 2892**
Application Number: 10/591,947	**Examiner**
Filed: September 8, 2006	**Alonzo Chambliss**
For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME (AS AMENDED)	
ATTORNEY DOCKET NO. HIRA.0236	

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, submitted herewith.

This Information Disclosure Statement is submitted with the initial filing of the RCE. 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,

Douglas E Jeschon FOR
#28,548

Juan Carlos A. Marquez
Registration No. 34,072

STITES & HARBISON, PLLC
1199 North Fairfax Street, Suite 900
Alexandria, VA 22314
Telephone: (703) 739-4900
Customer No. 38327
November 10, 2010

OPAP IAP19
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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 #	10/591,947
Confirmation #	8009
Filing Date	September 8, 2006
First Inventor	YUASA
Art Unit	2892
Examiner	Alonzo Chambliss
Docket #	HIRA.0236

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	

FOREIGN PATENT DOCUMENTS

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

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.*

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.
10/591,947	12/07/2010	7847327	HIRA-0236	8009

38327 7590 11/17/2010

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 881 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;

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

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

MAILED

NOV 19 2010

OFFICE OF PETITIONS

In re Application of	:	
Shinji Yuasa	:	
Application No. 10/591,947	:	DECISION GRANTING PETITION
Filed: September 8, 2006	:	UNDER 37 CFR 1.313(c)(2)
Attorney Docket No. HIRA-0236	:	

This is a decision on the petition under 37 CFR 1.313(c)(2), filed, November 10, 2010 to withdraw the above-identified application from issue after payment of the issue fee.

The petition is **GRANTED**.

The above-identified application is withdrawn from issue for consideration of a submission under 37 CFR 1.114 (request for continued examination). *See* 37 CFR 1.313(c)(2).

Petitioner is advised that the issue fee paid on October 25, 2010 cannot be refunded. If, however, this application is again allowed, petitioner may request that it be applied towards the issue fee required by the new Notice of Allowance.[1]

Telephone inquiries should be directed to Terri Johnson at (571) 272-2991.

This application is being referred to Technology Center AU 2892 for processing of the request for continued examination under 37 CFR 1.114 and for consideration of the concurrently filed information disclosure statement.

/Terri Johnson/
Terri Johnson
Petitions Examiner
Office of Petitions

[1] *The request to apply the issue fee to the new Notice may be satisfied by completing and returning the new Part B – Fee(s) Transmittal Form (along with any balance due at the time of submission). Petitioner is advised that the Issue Fee Transmittal Form must be completed and timely submitted to avoid abandonment of the application.*

UNITED STATES PATENT AND TRADEMARK OFFICE

Commissioner for Patents
United States Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450
www.uspto.gov

Date : November 19, 2010

TO : Director, Office of Data Management

FROM : Office of Petitions

SUBJECT : Withdrawal from Issue of **Application No. 10/591,947**

Applicant(s) : Shinji Yuasa
Application No. : 10/591,947
Filed : September 8, 2006

The above-identified application has been assigned Patent No. 7,847,327 and an issue date of December 7, 2010.

It is hereby directed that this application be withdrawn from issue at the request of the applicant. Do not refund the issue fee.

The following erratum should be published in the Official Gazette if the above-identified application is published in the OG of December 7, 2010:

"All reference to Patent No. 7,847,327 to Shinji Yuasa of Japan for MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME appearing in the Official Gazette of December 7, 2010 should be deleted since no patent was granted."

/Terri Johnson/
Terri Johnson
Petitions Examiner
Office of Petitions

cc: Paul Harrison
Deneise Boyd
Mary Louise McAskill
Niomi Farmer
Mary E. Johnson (Cookie)
Brad Harris
Kim Terrell
Lamont Fletcher

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE

PATENT WITHDRAWAL NOTICE

DATE WITHDRAWN	WITHDRAWAL NUMBER
11/19/10	18770

The following application has been **WITHDRAWN** from the

Tuesday, December 07, 2010 issue.

SERIAL NO.	PATENT NUMBER
10/591,947	7,847,327
DRAWINGS	**CLASS**
010	257/421

TITLE

MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME

NAME AND ADDRESS

SHINJI YUASA
IBARAKI, JAPAN

REASON FOR WITHDRAWAL

Office of Petitions granted applicant's request to withdraw patent from issue.

APPROVED

/Kimberly Terrell/, Manager

Patent Publication Branch
Office of Data Management

FORM PTO-302 -- (REV. 05-2009)

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 12/13/2010

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: 12/13/2010

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/591,947	09/08/2006	Shinji Yuasa	HIRA-0236	8009

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$0	$1510	$1510	03/14/2011

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. 08/07) Approved for use through 08/31/2010.

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 12/13/2010

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.
10/591,947	09/08/2006	Shinji Yuasa	HIRA-0236	8009

TITLE OF INVENTION: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME

APPLN. TYPE	SMALL ENTITY	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$0	$1510	$1510	03/14/2011

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 EX1002
Western Digital v IP Bridge
Page 324

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.
10/591,947	09/08/2006	Shinji Yuasa	HIRA-0236	8009

38327 7590 12/13/2010

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: 12/13/2010

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 565 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 565 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. 08/07) Approved for use through 08/31/2010.

WD EX1002
Western Digital v IP Bridge
Page 325

Notice of Allowability	Application No.	Applicant(s)	
	10/591,947	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 RCE filed on 11/10/10*.

2. ☒ The allowed claim(s) is/are *66,69,72,75,77,78,84 and 89*.

3. ☒ 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.

4. ☐ 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.

5. ☐ 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).

6. ☐ 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 11/10/10
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 _____.

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 11/10/10 has been entered.

Information Disclosure Statement

2. The information disclosure statement (IDS) submitted on 11/10/10 was filed before the mailing date of the notice of allowance on 11/29/10. The submission is in compliance with the provisions of 37 CFR 1.97. Accordingly, the information disclosure statement is being considered by the examiner.

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, 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 28, 2010

/Alonzo Chambliss/
Primary Examiner, Art Unit 2892

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	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)	
		G 1 1 C 11 / 14 (2006.0)	

CROSS REFERENCE(S)

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
	1		17		33		49		65		81				
	2		18		34		50		66		82				
	3		19		35		51		67		83				
	4		20		36		52	1	68	4	84				
	5		21		37		53	2	69		85				
	6		22		38		54		70		86				
	7		23		39		55		71		87				
	8		24		40		56	5	72		88				
	9		25		41		57		73	8	89				
	10		26		42		58		74						
	11		27		43		59	3	75						
	12		28		44		60		76						
	13		29		45		61	6	77						
	14		30		46		62	7	78						
	15		31		47		63		79						
	16		32		48		64		80						

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 8	
/Alonzo Chambliss/ Primary Examiner.Art Unit 2892 (Primary Examiner)	11/28/10 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 1B

WD EX1002
Western Digital v IP Bridge
Page 329

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	10591947	YUASA, SHINJI
	Examiner	Art Unit
	Alonzo Chambliss	2892

SEARCHED			
Class	Subclass	Date	Examiner

SEARCH NOTES		
Search Notes	Date	Examiner
East text search only - see attached printout	10/26/09	AC
Updated previous East text search only - see attached printout	6/19/10	AC
Updated previous East text search only - see attached printout	9/11/10	AC
Updated previous East text search only - see attached printout	11/28/10	AC

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner
257	4,295,421,427	6/19/10	AC
365	171	6/19/10	AC
257	4,295,421,427	9/11/10	AC
365	171	9/11/10	AC
257	4,295,421,427	11/28/10	AC
365	171	11/28/10	AC

Receipt date: 11/10/2010



10591947 - GAU: 2892

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

Substitute for Form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

Sheet 1 of 1

Application #	10/591,947
Confirmation #	8009
Filing Date	September 8, 2006
First Inventor	YUASA
Art Unit	2892
Examiner	Alonzo Chambliss
Docket #	HIRA.0236

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	

FOREIGN PATENT DOCUMENTS

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

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/ (11/28/2010)	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
L23	467	"257"/$.ccls. and (Fe ferromagnetic) and MgO and magnetic adj3 device	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2010/11/28 21:53

11/28/2010 9:58:44 PM

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, PLCC
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.
10/591,947	09/08/2006	Shinji Yuasa	HIRA-0236	8009

TITLE OF INVENTION: **MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME**

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1510	$0	$1510	03/14/2011

EXAMINER	ART UNIT	CLASS – SUBCLASS
CHAMBLISS, ALONSO	2892	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

JAPAN SCIENCE AND TECHNOLOGY AGENCY

NATIONAL INSTITUTE OF ADVANCED INDUSTRIAL SCIENCE AND TECHNOLOGY

(B) RESIDENCE: (CITY and STATE OR COUNTRY)

Saitama

Adjustment date: 12/29/2010 SMOHAMM1
10/26/2010 SMOHAMM1 00000061 10591947
01 FC:1501 -1510.00 OP

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 – see explanation below.

☒ 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) **December 28, 2010**

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

Commissioner for Patents is requested to apply the Issue Fee and Publication Fee previously paid on August 12, 2010 to the application identified above.

12/29/2010 SMOHAMM1 00000051 10591947
01 FC:1501 1510.00 OP

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

US_ACTIVE-100195432.1 12/28/10 2:04 PM

2355LT:00236:190583:1:ALEXANDRIA

WD EX1002
Western Digital v IP Bridge
Page 333

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.
10/591,947	02/08/2011	7884403	HIRA-0236	8009

38327 7590 01/19/2011

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 881 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;

OPAP
MAY 02 2012
PATENT & TRADEMARK OFFICE

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of

YUASA

Patent No. 7,884,403
Date of Patent: February 8, 2011

Application Number: 10/591,947
Filed: September 8, 2006

For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME

Attorney Docket No. HIRA-0236

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 to correct an oversight by the USPTO.

One Foreign reference and 8 non-patent references filed on September 2, 2010 were considered by the Examiner but all of them were inadvertently omitted. Please add to the cover page of the patent under (56) References Cited, Foreign Patent Documents, the following:

"JP 11-097766 4/1999"

Please add to the cover page of the patent under (56) References Cited, Other Publications, the following:

- "F. ERNULT et al., "Preparation of Nanometer-Scale Iron Dots on Insulating Layer", Science and Technology of Advanced Materials, Vol. 4, (2003), pp. 383-389
- DAVID J. SMITH et al., "Structural Characterization of Thin Film Ferromagnetic Tunnel Junctions", Journal of Applied Physics, Vol. 83, No. 10, 15 May 1998, pp. 5154-5158

- X. W. LI et al., "Fabrication and Properties of Heteroepitaxial Magnetite (Fe3O4) Tunnel Junctions", Applied Physics Letters, Vol. 73, No. 22, 30 November 1998, pp.3282-3284

- C. L. PLATT, et al., "Spin Polarized Tunneling in Reactively Sputtered Tunnel Junctions", Journal of Applied Physics, Vol. 81, No. 8, 15 April 1997, pp. 5523-5525

- P. TURBAN et al., "Growth and Characterization of Single Crystalline NiMnSb Thin Films and Epitaxial NiMnSb/MgO/NiMnSb(001) Trilayers", 2002 The American Physical Society, Physical Review B., Vol. 65, pp. 134417-1 to 134417-13

- T. MORIYAMA et al., "Preparation and Magnetoresistance in Single-Crystal and Polycrystal Fe/MgO/FeCo Tunnel Junctions", The Physical Society of Japan, 2003 Spring meeting, Abstracts Book 58(1-3), 460, (2003-03-06)

- JAGADEESH S. MOODERA et al., "Ferromagnetic-Insulator-Ferromagnetic Tunneling: Spin-Dependent Tunneling and Large Magnetoresistance in Trilayer Junctions (Invited), Journal of Applied Physics, Vol. 79, No. 8, 15 April 1996, pp. 4724-4729

- MASAYOSHI TONOUCHI et al., "Epitaxial Growth of NbN on an Ultrathin MgO/Semiconductor System", Journal of Applied Physics, Vol. 62, No. 3, 1 August 1987, pp. 961-966"

No fee is required as this was an oversight by the Patent Office.

The Commissioner is hereby respectfully requested to grant a Certificate of Correction in accordance with the attached Certificate of Correction.

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,

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
May 2, 2012

245401:1:ALEXANDRIA

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
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(Also Form PTO-1050)

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 7,884,403 B2

DATED : February 8, 2011

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:

On the face of the patent, please add under Item (56) under References Cited, Foreign Patent Documents:

"JP 11-097766 4/1999"

On the face of the patent, please add under item (56) References Cited, Other Publications, the following:

- "F. ERNULT et al., "Preparation of Nanometer-Scale Iron Dots on Insulating Layer", Science and Technology of Advanced Materials, Vol. 4, (2003), pp. 383-389
- DAVID J. SMITH et al., "Structural Characterization of Thin Film Ferromagnetic Tunnel Junctions", Journal of Applied Physics, Vol. 83, No. 10, 15 May 1998, pp. 5154-5158
- X. W. LI et al., "Fabrication and Properties of Heteroepitaxial Magnetite (Fe3O4) Tunnel Junctions", Applied Physics Letters, Vol. 73, No. 22, 30 November 1998, pp.3282-3284
- C. L. PLATT, et al., "Spin Polarized Tunneling in Reactively Sputtered Tunnel Junctions", Journal of Applied Physics, Vol. 81, No. 8, 15 April 1997, pp. 5523-5525
- P. TURBAN et al., "Growth and Characterization of Single Crystalline NiMnSb Thin Films and Epitaxial NiMnSb/MgO/NiMnSb(001) Trilayers", 2002 The American Physical Society, Physical Review B., Vol. 65, pp. 134417-1 to 134417-13
- T. MORIYAMA et al., "Preparation and Magnetoresistance in Single-Crystal and Polycrystal Fe/MgO/FeCo Tunnel Junctions", The Physical Society of Japan, 2003 Spring meeting, Abstracts Book 58(1-3), 460, (2003-03-06)
- JAGADEESH S. MOODERA et al., "Ferromagnetic-Insulator-Ferromagnetic Tunneling: Spin-Dependent Tunneling and Large Magnetoresistance in Trilayer Junctions (Invited), Journal of Applied Physics, Vol. 79, No. 8, 15 April 1996, pp. 4724-4729

- MASAYOSHI TONOUCHI et al., "Epitaxial Growth of NbN on an Ultrathin MgO/Semiconductor System", Journal of Applied Physics, Vol. 62, No. 3, 1 August 1987, pp. 961-966"

MAILING ADDRESS OF SENDER:
Juan Carlos A. Marquez, Esq.
STITES & HARBISON, PLLC
1199 N. Fairfax Street
Alexandria, Virginia 22314

PATENT NO. **7,884,403**

This collection of information is required by 37 CFR 1.322, 1.323, and 1.324. 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 1.0 hour 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: Attention Certificate of Corrections Branch, 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

OPAP MAY 02 2012 PATENT & TRADEMARK OFFICE

C of C

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re U.S. Patent Application of)
)
YUASA)
)
Patent No. 7,884,403)
Date of Patent: February 8, 2011)
)
Application Number: 10/591,947)
Filed: September 8, 2006)
)
For: MAGNETIC TUNNEL JUNCTION DEVICE AND MEMORY DEVICE INCLUDING THE SAME)
)
Attorney Docket No. HIRA-0236)

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) 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
(703) 739-4900
Customer No.: 38327
May 2, 2012

Juan Carlos A. Marquez
Registration Number 34,072

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,884,403 B2
APPLICATION NO. : 10/591947
DATED : February 8, 2011
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:

On the face of the patent, please add under Item (56) under References Cited, Foreign Patent Documents:

"JP 11-097766 4/1999"

On the face of the patent, please add under item (56) References Cited, Other Publications, the following:

- "F. ERNULT et al., "Preparation of Nanometer-Scale Iron Dots on Insulating Layer", Science and Technology of Advanced Materials, Vol. 4, (2003), pp. 383-389
- DAVID J. SMITH et al., "Structural Characterization of Thin Film Ferromagnetic Tunnel Junctions", Journal of Applied Physics, Vol. 83, No. 10, 15 May 1998, pp. 5154-5158
- X. W. LI et al., "Fabrication and Properties of Heteroepitaxial Magnetite (Fe3O4) Tunnel Junctions", Applied Physics Letters, Vol. 73, No. 22, 30 November 1998, pp. 3282-3284
- C. L. PLATT, et al., "Spin Polarized Tunneling in Reactively Sputtered Tunnel Junctions", Journal of Applied Physics, Vol. 81, No. 8, 15 April 1997, pp. 5523-5525
- P. TURBAN et al., "Growth and Characterization of Single Crystalline NiMnSb Thin Films and Epitaxial NiMnSb/MgO/NiMnSb(001) Trilayers", 2002 The American Physical Society, Physical Review B., Vol. 65, pp. 134417-1 to 134417-13

Signed and Sealed this
Fifth Day of June, 2012

David J. Kappos
Director of the United States Patent and Trademark Office

- T. MORIYAMA et al., "Preparation and Magnetoresistance in Single-Crystal and Polycrystal Fe/MgO/FeCo Tunnel Junctions", The Physical Society of Japan, 2003 Spring meeting, Abstracts Book 58(1-3), 460, (2003-03-06)

- JAGADEESH S. MOODERA et al., "Ferromagnetic-Insulator-Ferromagnetic Tunneling: Spin-Dependent Tunneling and Large Magnetoresistance in Trilayer Junctions (Invited), Journal of Applied Physics, Vol. 79, No. 8, 15 April 1996, pp. 4724-4729

- MASAYOSHI TONOUCHI et al., "Epitaxial Growth of NbN on an Ultrathin MgO/Semiconductor System", Journal of Applied Physics, Vol. 62, No. 3, 1 August 1987, pp. 961-966"