

UTILITY PATENT APPLICATION TRANSMITTAL (Only for new nonprovisional applications under 37 CFR 1.53(b))	Attorney Docket No.	HIT1P585/HJP920090046US1
	First Inventor	Kojiro Komagaki
	Title	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF
	Express Mail Label No.	

APPLICATION ELEMENTS See MPEP chapter 600 concerning utility patent application contents. 1. ☒ Fee Transmittal Form (e.g., PTO/SB/17) 2. ☐ Applicant claims small entity status. See 37 CFR 1.27. 3. ☒ Specification [Total Pages <u>26</u>] Both the claims and abstract must start on a new page (For information on the preferred arrangement, see MPEP 608.01(a)) 4. ☒ Drawing(s) (35 U.S.C. 113) [Total Sheets <u>03</u>] 5. Oath or Declaration [Total Sheets <u>03</u>] a. ☒ Newly executed (original or copy) b. ☐ A copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional with Box 18 completed) i. ☐ DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b). 6. ☒ Application Data Sheet. See 37 CFR 1.76 7. ☐ CD-ROM or CD-R in duplicate, large table or Computer Program (Appendix) ☐ Landscape Table on CD 8. Nucleotide and/or Amino Acid Sequence Submission (if applicable, items a. - c. are required) a. ☐ Computer Readable Form (CRF) b. ☐ Specification Sequence Listing on: i. ☐ CD-ROM or CD-R (2 copies); or ii. ☐ Paper c. ☐ Statements verifying identity of above copies	ADDRESS TO: Commissioner for Patents P.O. Box 1450 Alexandria VA 22313-1450 ACCOMPANYING APPLICATION PARTS 9. ☐ Assignment Papers (cover sheet & document(s)) Name of Assignee _____ 10. ☐ 37 CFR 3.73(b) Statement ☐ Power of Attorney (when there is an assignee) 11. ☐ English Translation Document (if applicable) 12. ☒ Information Disclosure Statement (PTO/SB/08 or PTO-1449) ☒ Copies of citations attached 13. ☐ Preliminary Amendment 14. ☐ Return Receipt Postcard (MPEP 503) (Should be specifically itemized) 15. ☐ Certified Copy of Priority Document(s) (if foreign priority is claimed) 16. ☐ Nonpublication Request under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent. 17. ☒ Other: PTO Form 8839
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18. If a CONTINUING APPLICATION, check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:

☐ Continuation	☐ Divisional	☐ Continuation-in-part (CIP)	of prior application No.: _____
---------------------------------------	-------------------------------------	---	---------------------------------

Prior application information: Examiner _____ Art Unit: _____

19. CORRESPONDENCE ADDRESS

☒ The address associated with Customer Number: 50535	OR ☐ Correspondence address below
Name _____	
Address _____	
City _____	State _____ Zip Code _____
Country _____	Telephone _____ Email _____

Signature	/Dominic M. Kotab/	Date	November 29, 2010
Name (Print/Type)	Dominic M. Kotab	Registration No. (Attorney/Agent)	42,762

This collection of information is required by 37 CFR 1.53(b). 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 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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Effective on 12/08/2004.
Fees pursuant to the Consolidated Appropriations Act, 2005 (H.R. 4818).

FEE TRANSMITTAL For FY 2009

☐ Applicant claims small entity status. See 37 CFR 1.27

TOTAL AMOUNT OF PAYMENT (\$) \$1,090.00

Complete if Known

Application Number	Unassigned
Filing Date	Herewith
First Named Inventor	Kojiro Komagaki
Examiner Name	Unassigned
Art Unit	Unassigned
Attorney Docket No.	HIT1P585/HJP920090046US1

METHOD OF PAYMENT (check all that apply)

☐ Check ☐ Credit Card ☐ Money Order ☐ None ☐ Other (please identify): _____
☒ Deposit Account Deposit Account Number: 50-2587 Deposit Account Name: _____

For the above-identified deposit account, the Director is hereby authorized to: (check all that apply)

☒ Charge fee(s) indicated below ☐ Charge fee(s) indicated below, except for the filing fee
☒ Charge any additional fee(s) or underpayments of fee(s) under 37 CFR 1.16 and 1.17 ☒ Credit any overpayments

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

FEE CALCULATION

1. BASIC FILING, SEARCH, AND EXAMINATION FEES

Application Type	FILING FEES		SEARCH FEES		EXAMINATION FEES		Fees Paid (\$)
	Fee (\$)	Small Entity Fee (\$)	Fee (\$)	Small Entity Fee (\$)	Fee (\$)	Small Entity Fee (\$)	
Utility	330	165	540	270	220	110	\$1090
Design	220	110	100	50	140	70	
Plant	220	110	330	165	170	85	
Reissue	330	165	540	270	650	325	
Provisional	220	110	0	0	0	0	

2. EXCESS CLAIM FEES

Fee Description	Fee (\$)	Small Entity Fee (\$)
Each claim over 20 (including Reissues)	52	26
Each independent claim over 3 (including Reissues)	220	110
Multiple dependent claims	390	195

Total Claims: 17 Extra Claims: 0 Fee (\$): \$52 Fee Paid (\$): \$0

HP = highest number of total claims paid for, if greater than 20.

Indep. Claims: 01 Extra Claims: 0 Fee (\$): \$220 Fee Paid (\$): \$0

HP = highest number of independent claims paid for, if greater than 3.

3. APPLICATION SIZE FEE

If the specification and drawings exceed 100 sheets of paper (excluding electronically filed sequence or computer listings under 37 CFR 1.52(e)), the application size fee due is \$270 (\$135 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).

Total Sheets: 100 Extra Sheets: 0 Number of each additional 50 or fraction thereof: 0 Fee (\$): \$0 Fee Paid (\$): \$0

4. OTHER FEE(S)

Non-English Specification, \$130 fee (no small entity discount)

Other (e.g., late filing surcharge):

SUBMITTED BY

Signature	/Dominic M. Kotab/	Registration No. (Attorney/Agent)	42,762	Telephone	408-971-2573
Name (Print/Type)	Dominic M. Kotab			Date	November 29, 2010

This collection of information is required by 37 CFR 1.136. 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 30 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.

Doc Code: PD.TO.AUTH

Document Description: Authorization to access Appl. by Trilateral Office

PTO/SB/39 (07-09)

Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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

AUTHORIZATION TO PERMIT ACCESS TO APPLICATION BY PARTICIPATING OFFICES

Send completed form to: Commissioner for Patents
P.O. Box 1450, Alexandria, VA 22313-1450

COMPLETE IF KNOWN

Application Number	Unassigned
Filing Date	Herewith
First Named Inventor	Kojiro Komagaki
Attorney Docket Number	HIT1P585/HJP920090046US1
Title (Required)	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF

The undersigned hereby grants the USPTO authority to provide the European Patent Office (EPO), the Japan Patent Office (JPO), the Korean Intellectual Property Office (KIPO), the World Intellectual Property Office (WIPO), and any other intellectual property offices in which a foreign application claiming priority to the above-identified patent application is filed access to the above-identified patent application. See 37 CFR 1.14(c) and (h).

In accordance with 37 CFR 1.14(h)(3), access will be provided to a copy of the above-identified application with respect to: 1) the above-identified patent application-as-filed; 2) any foreign application to which the above-identified patent application claims priority under 35 U.S.C. 119(a)-(d) if a copy of the foreign application that satisfies the certified copy requirement of 37 CFR 1.55 has been filed in the above-identified patent application; and 3) any U.S. application-as-filed from which benefit is sought in the above-identified patent application.

In accordance with 37 CFR 1.14(c), access may be provided to information concerning the date of filing the Authorization to Permit Access to Application by Participating Offices.

This written authorization should be submitted prior to the filing of a subsequent foreign application, in which priority is claimed to the above-identified patent application, with any intellectual property office (e.g., the EPO, JPO, KIPO, or DAS Accessing Office). However, if applicant does not wish the EPO, JPO, KIPO, WIPO, or other intellectual property office in which a foreign application claiming priority to the above-identified patent application is filed to have access to the above-identified patent application, this written authorization should not be filed.

No fee will be charged under 37 CFR 1.19(b)(1) for providing a participating intellectual property office with an electronic copy of the above-identified patent application.

This form must be signed by an authorized party in accordance with 37 CFR 1.14(c).

/Dominic M. Kotab/

Signature

November 29, 2010

Date

Dominic M. Kotab

Printed or Typed Name

408-971-2573

Telephone Number

Attorney for Applicant

Title

42,762

Registration Number, if applicable

This collection of information is required by 37 CFR 1.14(h). 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 6 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.

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		
	Filing Date		
	First Named Inventor	Kojiro Komagaki	
	Art Unit		
	Examiner Name	Unassigned	
	Attorney Docket Number	HIT1P585/HJP920090046US1	

U.S. PATENTS								
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
	1							
If you wish to add additional U.S. Patent citation information please click the Add button.								
U.S. PATENT APPLICATION PUBLICATIONS								
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
	1	20070195592	A1	2007-08-23	Yuasa			
	2	20060056115	A1	2006-03-16	Djayaprawira et al.			
If you wish to add additional U.S. Published Application citation information please click the Add button.								
FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T5
	1	04082711	JP	B2	2008-04-30			☐
	2	2006-080116	JP	A	2006-03-23	Canon Anvelva Corp Nat'l Inst. of Adv. Ind. & Tech		☒

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		
	Filing Date		
	First Named Inventor	Kojiro Komagaki	
	Art Unit		
	Examiner Name	Unassigned	
	Attorney Docket Number	HIT1P585/HJP920090046US1	

	3	2001-068760	JP		2001-03-16	Hitachi Ltd.	☒
	4	2004-071714	JP		2004-03-04	Sony Corp.	☒
	5	2006-134950	JP		2006-05-25	Toshiba Corp	☒
	6	2008-198792	JP		2008-08-28	Hitachi Ltd. Tohoku Univ.	☒
	7	2008-227388	JP		2008-09-25	Sony Corp.	☒
	8	2009-004784	JP		2009-01-08	Headway Technologies Inc.	☒

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵
	1	HAYAKAWA et al., "Dependence of Giant Tunnel Magnetoresistance of Sputtered CoFeB/MgO/CoFeB Magnetic Tunnel Junctions on MgO Barrier Thickness and Annealing Temperature," Japanese Journal of Applied Physics, Vol. 44, No. 19, 2005, p. L587-L589	☒

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

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

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT****(Not for submission under 37 CFR 1.99)**

Application Number	
Filing Date	
First Named Inventor	Kojiro Komagaki
Art Unit	
Examiner Name	Unassigned
Attorney Docket Number	HIT1P585/HJP920090046US1

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document.
⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

Application Number	
Filing Date	
First Named Inventor	Kojiro Komagaki
Art Unit	
Examiner Name	Unassigned
Attorney Docket Number	HIT1P585/HJP920090046US1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Dominic M. Kotab/	Date (YYYY-MM-DD)	2010-11-29
Name/Print	Dominic M. Kotab	Registration Number	42,762

This collection of information is required by 37 CFR 1.97 and 1.98. 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 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: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

**DECLARATION AND POWER OF ATTORNEY
FOR ORIGINAL U.S. PATENT APPLICATION**

Attorney's Docket No. HIT1P585/HIP920090046US1

As a below-named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name. I believe that I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter that is claimed and for which a patent is sought on the invention entitled: MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF the specification of which,

(check one)

1. ☒ is attached hereto.
2. ☐ was filed on _____ as
U.S. Application Serial No. _____
and was amended on _____.
3. ☐ was filed on _____ as
International PCT Application Serial No. _____
and was amended on _____.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose information which is material to the patentability of this application in accordance with Title 37, CFR § 1.56.

I hereby claim foreign priority benefits under Title 35, United States code, § 119(a)-(d) or § 365(b) of any foreign application(s) for patent or inventor's certificate, or § 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have identified below, by checking the box, any foreign application for patent or inventor's certificate, or PCT International application having a filing date before that of the application on which priority is claimed:

Prior Foreign Application(s)

2009-278388
(Appl. No.)

Japan
(Country)

12/8/2009
(Filing Date)

Priority Benefits Claimed?

☒ Yes ☐ No

(Appl. No.)

(Country)

(Filing Date)

☐ Yes ☐ No

(Appl. No.)

(Country)

(Filing Date)

☐ Yes ☐ No

I hereby claim the benefit under 35 U.S.C. § 119(e) of any United States provisional application(s) listed below:

(Application Serial No.)

(Filing Date)

(Application Serial No.)

(Filing Date)

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s), or § 365(c) of any PCT International application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information which is material to patentability as defined in Title 37, Code of Federal Regulations, § 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

Attiny Docket No. HIT1P585/HIP920090046US1

Page 1 of 3

Prior U.S. Application(s)

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

And I hereby appoint the following attorney(s) and/or agents associated with PTO Customer Number 50535 as my principal agents to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith:

Customer Number : 50535
Send Correspondence To: Zilka-Kotab, PC
P.O. Box 721120
San Jose, California 95172-1120

Direct Telephone Calls To: Dominic M. Kotab at telephone number (408) 971-2573

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these 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 issuing thereon.

Typewritten Full Name of
Sole or First Inventor: Kojiro Komagaki Citizenship: Japan

Inventor's signature: Kojiro Komagaki Date of Signature: 11/9/2010

Residence: (City) Odawara (State/Country) Japan

Post Office Address: 1-1-102, Yahagi, Odawara, Kanagawa, 250-0873, Japan

Full Name of Second Joint
Inventor (if any): Katsumi Hoshino Citizenship: Japan

Inventor's signature: Katsumi Hoshino Date of Signature: 11/9/2010

Residence: (City) Odawara (State/Country) Japan

Post Office Address: 2-17-16, Naka-cho, Odawara, Kanagawa, 250-0005, Japan

Full Name of Third Joint
Inventor (if any): Masashige Sato Citizenship: Japan

Inventor's signature: Masashige Sato Date of Signature: 11/12/2010

Residence: (City) Atsugi (State/Country) Japan

Post Office Address: 1-15-803, Atsugi-cho, Atsugi, Kanagawa, 243-0011, Japan

Full Name of Fourth Joint

Inventor (if any): Hiroyuki Hoshiva

Citizenship: Japan

Inventor's signature: Hiroyuki Hoshiva

Date of Signature: 11/12/2010

Residence: (City) Odawara

(State/Country) Japan

Post Office Address: 2-1-403, Yahagi, Odawara, Kanagawa, 250-0873, Japan

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

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	HIT1P585/HJP920090046US1
		Application Number	
Title of Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2

☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1				
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117
				☐ Party of Interest under 35 U.S.C. 118
Prefix	Given Name	Middle Name	Family Name	Suffix
	Kojiro		Komagaki	
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service				
City	Odawara, Kanagawa	Country Of Residence	JP	
Citizenship under 37 CFR 1.41(b)		JP		
Mailing Address of Applicant:				
Address 1	1-1-102, Yahagi			
Address 2				
City	Odawara, Kanagawa	State/Province		
Postal Code	250-0873	Country	JP	
Applicant 2				
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117
				☐ Party of Interest under 35 U.S.C. 118
Prefix	Given Name	Middle Name	Family Name	Suffix
	Katsumi		Hoshino	
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service				
City	Odawara, Kanagawa	Country Of Residence	JP	
Citizenship under 37 CFR 1.41(b)		JP		
Mailing Address of Applicant:				
Address 1	2-17-16, Naka-cho			
Address 2				
City	Odawara, Kanagawa	State/Province		
Postal Code	250-0005	Country	JP	
Applicant 3				
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117
				☐ Party of Interest under 35 U.S.C. 118
Prefix	Given Name	Middle Name	Family Name	Suffix
	Masashige		Sato	
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service				
City	Atsugi, Kanagawa	Country Of Residence	JP	

Application Data Sheet 37 CFR 1.76		Attorney Docket Number		HIT1P585/HJP920090046US1	
		Application Number			
Title of Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF				
Citizenship under 37 CFR 1.41(b)		JP			
Mailing Address of Applicant:					
Address 1		1-15-803, Atsugi-cho			
Address 2					
City	Atsugi, Kanagawa		State/Province		
Postal Code	243-0011		Country	JP	
Applicant 4					
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117	
				☐ Party of Interest under 35 U.S.C. 118	
Prefix	Given Name		Middle Name		Family Name
	Hiroyuki				Hoshiya
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service					
City	Odawara, Kanagawa		Country Of Residence		JP
Citizenship under 37 CFR 1.41(b)		JP			
Mailing Address of Applicant:					
Address 1		2-1-403, Yahagi			
Address 2					
City	Odawara, Kanagawa		State/Province		
Postal Code	250-0873		Country	JP	
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.					

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).	
☐ An Address is being provided for the correspondence information of this application.	
Customer Number	50535
Email Address	dom@zilkakotab.com
Add Email Remove Email	

Application Information:

Title of the Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF		
Attorney Docket Number	HIT1P585/HJP920090046US1	Small Entity Status Claimed ☐	
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	HIT1P585/HJP920090046US1
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Title of Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF		

Publication Information:

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Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
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Application Number	Country ¹	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
2009-278388	JP	2009-12-08	☒ Yes ☐ No
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Assignee 1	

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	HIT1P585/HJP920090046US1
		Application Number	
Title of Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF		

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Signature	/Dominic M. Kotab/		Date (YYYY-MM-DD)	2010-11-29	
First Name	Dominic	Last Name	Kotab	Registration Number	42762

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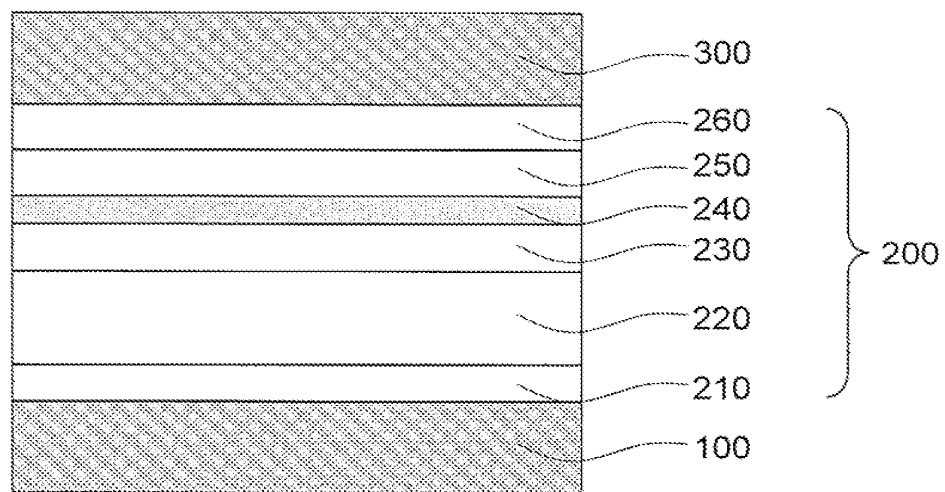


FIG. 1

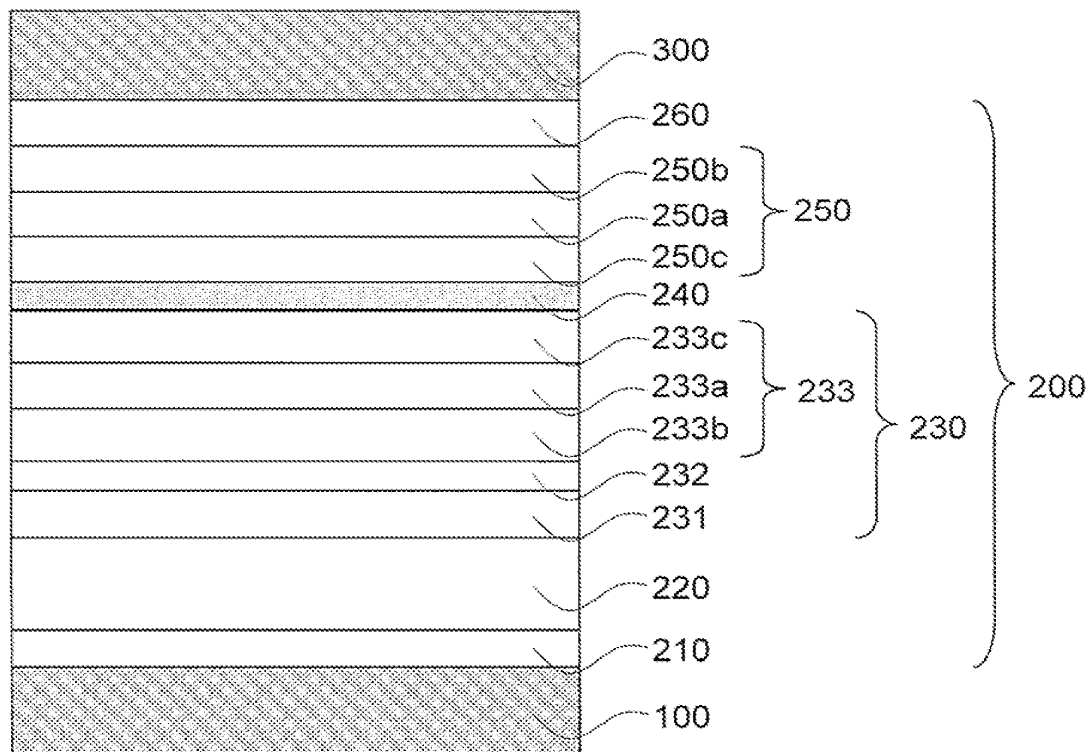


FIG. 2

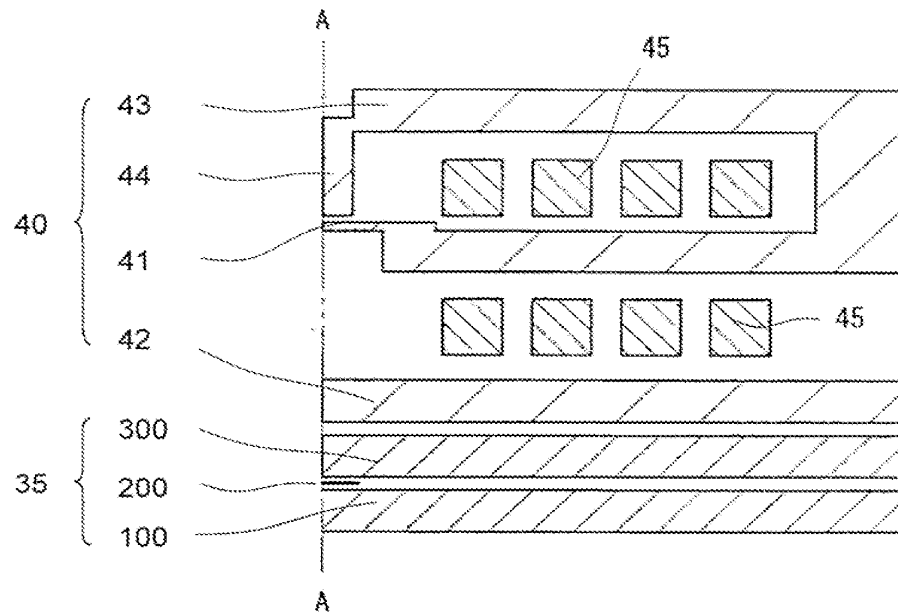


FIG. 3

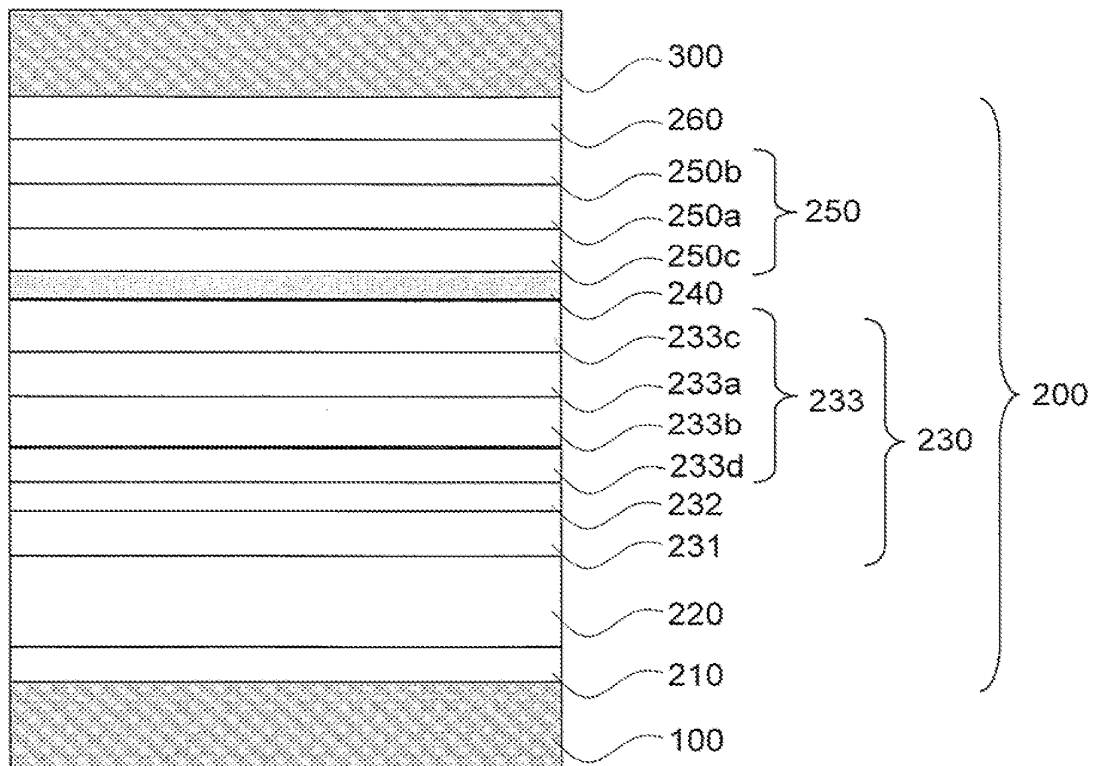


FIG. 4

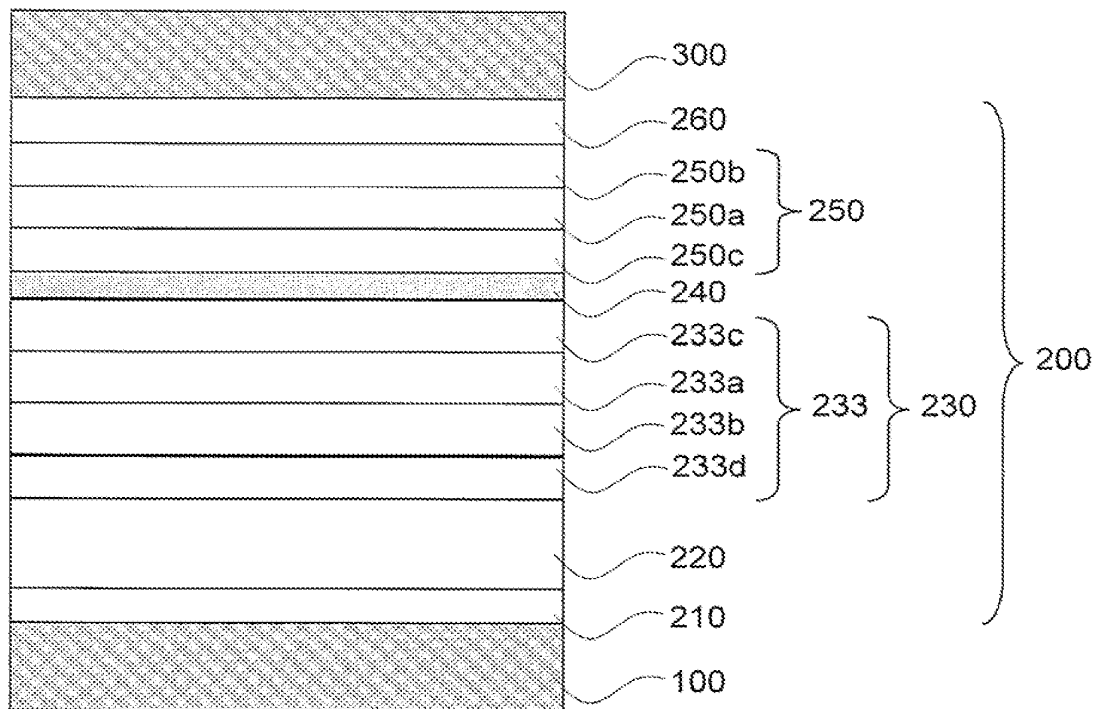


FIG. 5

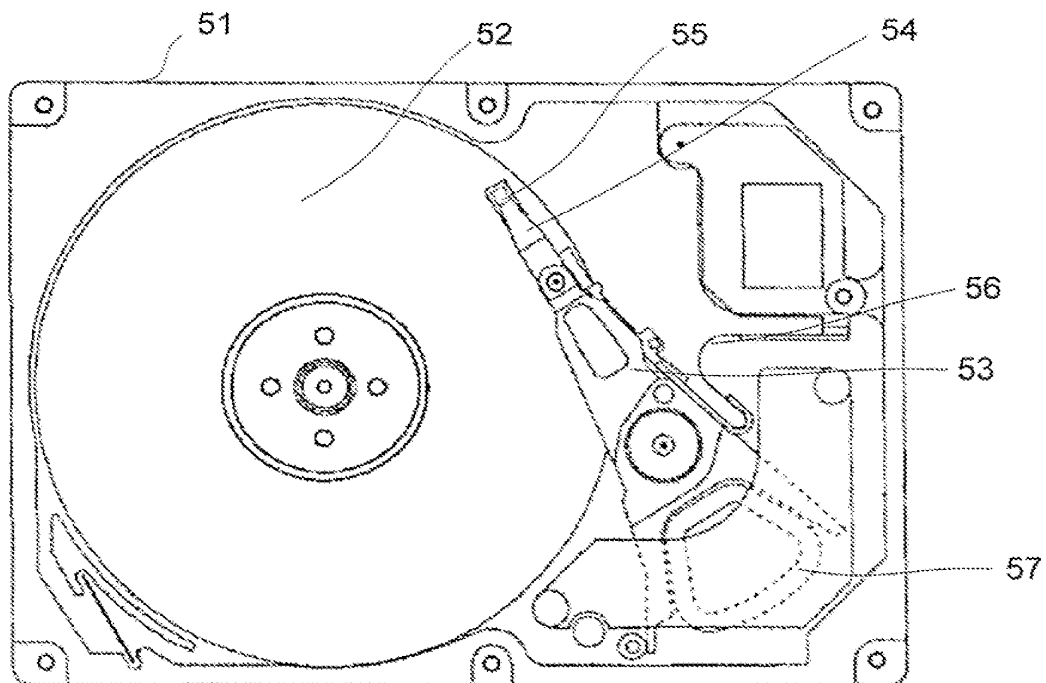


FIG. 6

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(11)Publication number : 2009-004784

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(51)Int.Cl. *H01L 43/08 (2006.01)*
H01L 43/10 (2006.01)
G11B 5/39 (2006.01)

(21)Application number : 2008-160607 (71)Applicant : HEADWAY TECHNOLOGIES INC

(22)Date of filing : 19.06.2008 (72)Inventor : ZHANG KUNLIANG
 WANG HUI-CHUAN
 ZHAO TONG
 LI MIN

(30)Priority

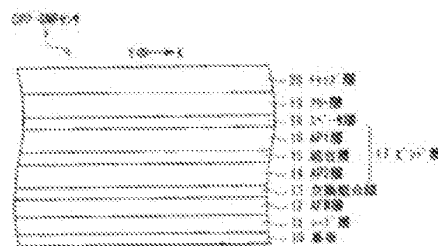
Priority number : 2007 820251 Priority date : 19.06.2007 Priority country : US

(54) EXCHANGE-COUPLING FILM, MAGNETORESISTANCE EFFECT ELEMENT USING THE SAME AND METHOD OF MANUFACTURING MAGNETORESISTANCE EFFECT ELEMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To provide an exchange-coupling film capable of increasing a Hex/Hc ratio between an AFM layer and an AP2 pinned layer without degrading an MR ratio and stably holding the magnetization of the AP2 layer in a fixed direction, and a magnetoresistance effect element using the same.

SOLUTION: The exchange-coupling film 13 is provided between the AFM layer 12 and the AP2 layer 14 constituting a pinned layer 17. The exchange-coupling film 13 is an amorphous magnetic layer comprised of at least one kind of an element selected from a group comprising Co, Fe, or Ni, and at least one kind of an element having an amorphous character selected from a group comprising B, Zr, Hf, Nb, Ta, Ti, Si, or P, or a non-



magnetic layer comprised of elements selected from a group comprising Cu, Ru, Mn, Hf, and Cr. Concretely, the exchange-coupling film 13 is composed of CoFeB, CoFeZr, CoFeNb, CoFeHf, CoFeNiZr, CoFeNiHf, or CoFeNiNbZr.

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2001-068760

(43)Date of publication of application : 16.03.2001

(51)Int.Cl.

H01L 43/08

G11B 5/39

H01F 10/30

(21)Application number : 11-244755

(71)Applicant : HITACHI LTD

(22)Date of filing : 31.08.1999

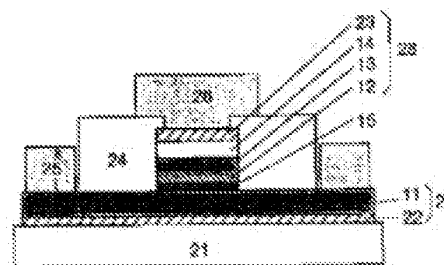
(72)Inventor : ARAI REIKO
KAWATO YOSHIAKI
WATANABE KATSURO

(54) FERROMAGNETIC TUNNEL JUNCTION ELEMENT

(57)Abstract:

PROBLEM TO BE SOLVED: To suppress the reduction in the magnetoresistance effect due to destruction of a tunnel barrier layer and thereby achieve uniformity and reproducibility, by arranging an amorphous ferromagnetic layer on at least the interface of one of a ferromagnetic layer and the tunnel barrier layer.

SOLUTION: A base film 22 for improving the orientability of a free layer 11 of a ferromagnetic tunnel junction, the layer 11, and an amorphous ferromagnetic layer 15 for improving heat resistance are formed on an oxide layer-



deposited silicon substrate 21. A tunnel barrier layer 12 is formed on the layer 15 by preparing an Al layer, and oxidizing the surface of the Al layer by a plasma oxidation method. Further, a fixed layer 13, an antiferromagnetic layer 14, and a protection film 23 are sequentially formed. Next, a lower electrode layer 26 and an upper electrode layer 27 are processed into predetermined configurations. Further, an Al₂O₃ insulating layer 24 for preventing contact between the layers 26 and 27 is formed, and then patterned, and for contact with the lower/upper electrode layers 27 and 28, Au layers are formed as lower/ upper electrode wiring layers 25 and 26, whereby a ferromagnetic tunnel junction element 20 is prepared.

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2004-071714

(43)Date of publication of application : 04.03.2004

(51)Int.Cl.

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G11C 11/15
H01F 10/13
H01F 10/32
H01L 27/105

(21)Application number : 2002-226520

(71)Applicant : SONY CORP

(22)Date of filing : 02.08.2002

(72)Inventor : OBA KAZUHIRO

KANO HIROSHI

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BESSHO KAZUHIRO

YAMAMOTO TETSUYA

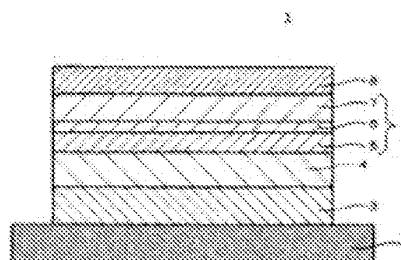
MIZUGUCHI TETSUYA

(54) MAGNETORESISTIVE EFFECT ELEMENT AND MAGNETIC MEMORY

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a magnetoresistive effect element exhibiting good magnetic characteristics by suppressing deterioration in the variation rate of the resistance due to heat treatment, and to provide a magnetic memory comprising the magnetoresistive effect element and exhibiting excellent writing characteristics.

SOLUTION: A pair of ferromagnetic layers (a pinned magnetization layer 5 and a free magnetization layer 7) are laid oppositely in a layer through an intermediate layer 6 and the resistance is varied by supplying a current perpendicularly to the film surface. The magnetoresistive element 1 comprises the pair of ferromagnetic layers 5 and 7 at least one of which containing an amorphous ferromagnetic material having a crystallization point of 623K or above, and the magnetic memory comprises the magnetoresistive element 1, and a bit line



and a word line sandwiching the magnetoresistive element 1 in the thickness direction.

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H O 1 L 43/10

H O 1 L 43/10 (2006.01)

H O 1 L 43/12

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 (33) 優先権主張国 日本国 (JP)

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最終頁に続く

(54) 【発明の名称】 磁気抵抗素子及びその製造方法

(57) 【特許請求の範囲】

【請求項1】

基板を準備する工程と、

該基板上にアモルファスC o F e B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M g O層を形成し、アニールにより該アモルファスM g O層を結晶化して(0 0 1)結晶面が優先配向した多結晶M g O_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C o F e B磁性合金からなる第2の強磁性体層を堆積する工程と、

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2】

基板を準備する工程と、

該基板上にアモルファスC o F e B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M g O層を形成し、アニールにより該アモルファスM g O層を結晶化して(0 0 1)結晶面が優先配向した多結晶M g O_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C o F e B磁性合金からなる第2の強磁性体層を堆積する工程と、

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アニールにより前記アモルファスCoFeB磁性合金からなる前記第1及び第2の強磁性体層を部分的あるいは全体的に結晶化する工程と、
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3】

前記(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において、MgO_xのx値を調整済みのターゲットを用いて前記アモルファスMgO層をスパッタリング法により堆積することを特徴とする請求項1又は2に記載の磁気抵抗素子の製造方法。

【請求項4】

アモルファスCoFeB磁性合金からなる第1の強磁性体層と、
(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と、
アモルファスCoFeB磁性合金からなる第2の強磁性体層と、
を有する磁気抵抗素子。

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【請求項5】

アモルファスCoFeB磁性合金からなる強磁性体層の上に形成された、(001)結晶面が優先配向した多結晶MgO_x (0<x<1) からなる、磁気抵抗素子のトンネル障壁層。

【請求項6】

アモルファスCoFeB磁性合金からなる第1の強磁性体層と、
(001)結晶面が優先配向した酸素欠損を有する多結晶MgOからなるトンネル障壁層と、
アモルファスCoFeB磁性合金からなる第2の強磁性体層と、
を有する磁気抵抗素子。

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【請求項7】

アモルファスCoFeB磁性合金からなる強磁性体層の上に形成された、(001)結晶面が優先配向した酸素欠損を有する多結晶MgOからなる、磁気抵抗素子のトンネル障壁層。

【請求項8】

1つのトランジスタと、前記トランジスタの負荷として用いられる請求項4または6に記載の磁気抵抗素子と、を有する記憶素子。

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【発明の詳細な説明】

【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、4 MbitのMRAMがサンプル出荷されたという実績がある。

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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

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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で、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(11)。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200mV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。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 (0<x<1)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性を示す図である。

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_{o, q}は(=バイアス電圧×(R_{ap}-R_p)/R_{ap})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Al₂O₃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L2₁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。

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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. Wulffhekel, 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することができるため、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。

$$\Delta R/R_p = (R_{ap} - R_p) / R_p$$

ここで、R_p及びR_{ap}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。Julliere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

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に表される。
MR比 = $(R_{ap} - R_p) / R_p = 2P_1 P_2 / (1 - P_1 P_2)$ 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。

ここで、P_αは、電極のスピンスピン分極率であり、D_{α↑}(E_F)とD_{α↓}(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、Julliere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。

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発明者は、酸化マグネシウム(MgO)の単結晶(001)あるいは(001)結晶面が優先配向した多結晶MgOをトンネル障壁として用いたTMR素子を成長するアプローチを試みている。従来のアモルファスのAl—O障壁とは異なり、酸化マグネシウムは結晶(原子が規則正しく配列した物質)であるため、電子が散乱されず、電子のコヒーレント状態がトンネル過程において保存されることが予測される。図1は、本実施の形態によるTMR素子構造(図1(B))と、強磁性体金属であるFe(001)のエネルギーバンド構造を示す図であり、波数空間の[001]方向に対するE—E_Fの関係を示す図(図1(A))である。図1(B)に示すように、本実施の形態によるTMR素子構造は、第1のFe(001)層1と、第2のFe(001)層5と、これらの間に挟まれた単結晶MgO_x(001)層あるいは(001)結晶面が優先配向した多結晶MgO_x(0 < x < 1)層3と、を有して構成されている。上記Julliere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たとすると、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

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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 Δ_1 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 Δ_1 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 Δ_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 (分子線エビタキシー法) により、単結晶MgO (001) 基板11の表面のモフォロジーを改善するため、MgO (001) シード層15を成長する。連続して、図1 (B) に示すように、50nm厚のエピタキシャルFe (001) 下部電極 (第1電極) 17をMgO (001) シード層15上に室温で成長し、次いで、超高真空中 (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上に室温でエビ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A1-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、0.7~2.5 eV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3.6 eVであり、実験値としては0.9~3.7 eV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、0.3 eV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($m = 9.11 \times 10^{-31}$ 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500 mV~1000 mV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})よりも、約0.5 nm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、100 mV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。

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

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、 $\Delta s \approx t_{MgO} - 0.5$ nm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(001)/Fe(001) TMR素子の典型的な磁気抵抗曲線を示す図である。測定温度20 KにおいてMR比14.6%であり、測定温度293 KにおいてMR比は8.8%であった。この値は、現在までに室温において得られた最も高いMR比である。このような高いMR比は、Fe(001)電極のスピン分極率によって説明することはできず、むしろ、コヒーレントなスピン偏極トンネリングに関連すると考えられる。160個のTMR素子を試作した結果、MR比とトンネル抵抗値とに関するばらつきは、20%以内であった。TMR素子の歩留まりも実験室段階で90%以上であった。このような高い値は、本アプローチの有効性を示唆している。TMR素子の抵抗-エリア積(RA)は、数 $k\Omega\mu m^2$ 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 $V_{H_{0.5}}$ は1250 mVという非常に高い値が得られている。尚、従来のA1-O系におけるMR比の半減する電圧 $V_{H_{0.5}}$ は300~600 mVである。図7(b)に、TMR素子の出力電圧 V_{out} は(=バイアス電圧×(RA

$p-Rp)/Rap)$ 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の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。

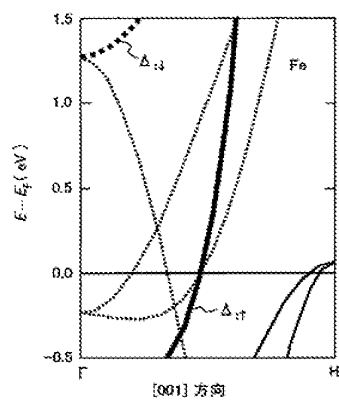
【産業上の利用可能性】

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MRAMに最適な低抵抗にすることができる。従って、TMR素子を用いたMRAMの高集積化が容易になる

という利点がある。MRAMの出力電圧値が従来の約2倍に向上し、ギガビット級の超高集積MRAMに適する。

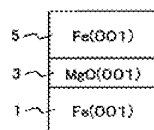
【図1(A)】

図1(A)



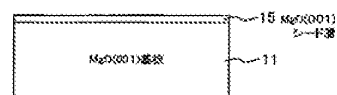
【図1(B)】

図1(B)



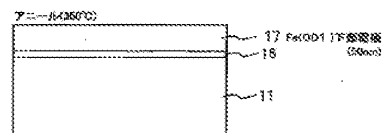
【図2(A)】

図2(A)



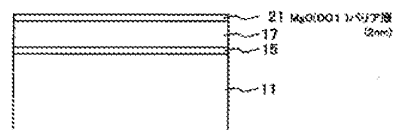
【図2(B)】

図2(B)



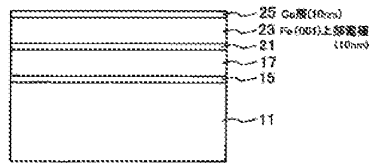
【図2(C)】

図2(C)



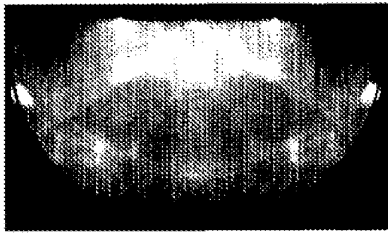
【図2 (D)】

図2 (D)



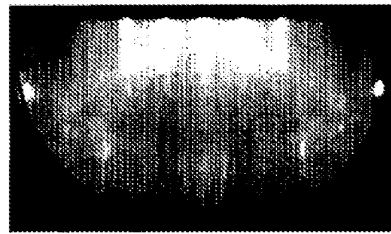
【図3 (A)】

図3 (A)



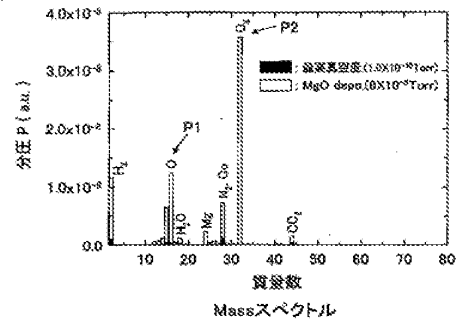
【図3 (B)】

図3 (B)



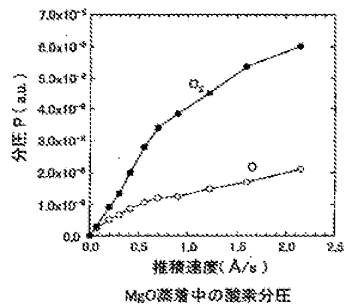
【図4】

図4



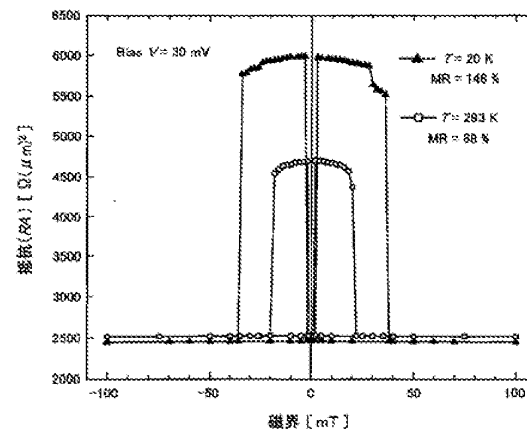
【図5】

図5



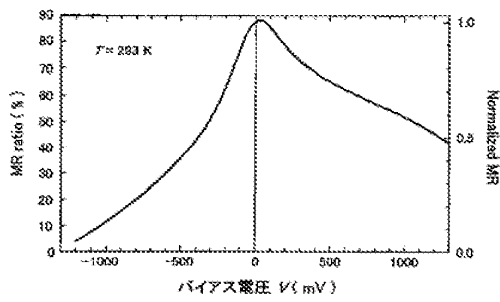
【図6】

図6



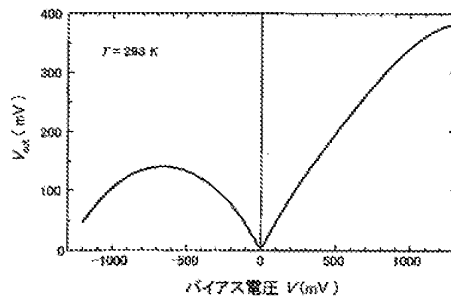
【図7(A)】

図7(A)



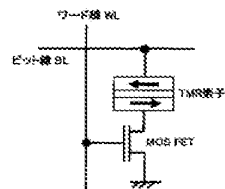
【図7(B)】

図7(B)



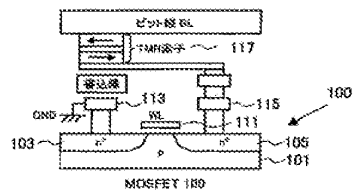
【図9(B)】

図9(B)



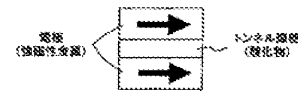
【図9(C)】

図9(C)



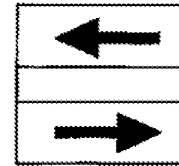
【図8(A)】

図8(A)



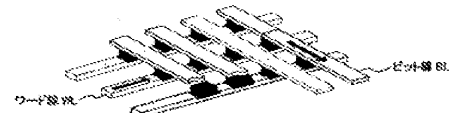
【図8(B)】

図8(B)



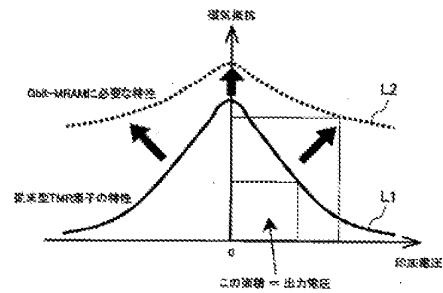
【図9(A)】

図9(A)



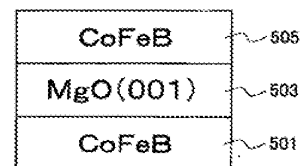
【図10】

図10



【図11】

図11



フロントページの続き

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審査官 川村 裕二

(56)参考文献 特開2002-289943 (JP, A)

特開2003-318465 (JP, A)

特開2002-204004 (JP, A)

特開2003-304010 (JP, A)

(58)調査した分野(Int.Cl., DB名)

H01L 43/08

H01L 27/105

H01L 43/10

H01L 43/12

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DETAIL

JAPANESE

LEGAL
STATUS

1 / 1

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2006-080116

(43)Date of publication of application : 23.03.2006

(51)Int.Cl.

H01L 43/08 (2006. 01)
 G11B 5/39 (2006. 01)
 H01L 43/10 (2006. 01)
 H01L 43/12 (2006. 01)
 H01L 27/105 (2006. 01)
 H01L 21/8246 (2006. 01)

(21)Application number : 2004-259280

(71)Applicant : CANON ANELVA CORP
 NATIONAL INSTITUTE OF
 ADVANCED INDUSTRIAL &
 TECHNOLOGY

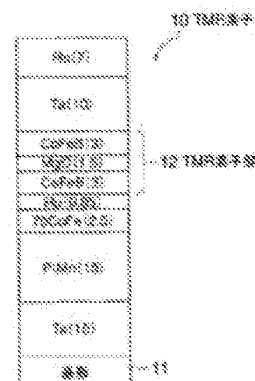
(22)Date of filing : 07.09.2004

(72)Inventor : DAVID DJAYAPRAWIRA
 TSUNEKAWA KOJI
 NAGAI MOTOMASA
 MAEHARA DAIKI
 YAMAGATA SHINJI
 WATANABE NAOKI
 YUASA SHINJI

(54) MAGNETORESISTIVE EFFECT ELEMENT AND ITS MANUFACTURING METHOD

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a magnetoresistive effect element which is superior in MR ratio and of which mass-productivity and practicality are improved, and to provide its manufacturing method.
 SOLUTION: The magnetoresistive effect element (TMR element 10) has a lamination structure (TMR element 12) which is formed of a pair of ferromagnetic layers and a barrier layer located at the middle position between them. At least one ferromagnetic layer is provided with such a portion in contact with the barrier layer that has an amorphous state, and the barrier layer is an MgO layer with a single crystal structure.



PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2006-134950

(43)Date of publication of application : 25.05.2006

(51)Int.Cl.

H01L 43/08 (2006. 01)
G11C 11/15 (2006. 01)
H01F 10/13 (2006. 01)
H01F 10/32 (2006. 01)
H01L 43/12 (2006. 01)
H01L 27/105 (2006. 01)
H01L 21/8246 (2006. 01)

(21)Application number : 2004-319604

(71)Applicant : TOSHIBA CORP

(22)Date of filing : 02.11.2004

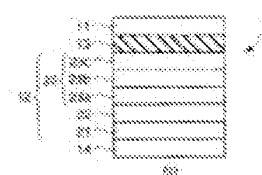
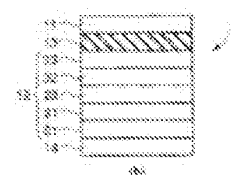
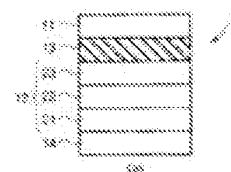
(72)Inventor : NAGASE TOSHIHIKO
 IKEGAWA SUMIO

(54) MAGNETORESISTIVE EFFECT ELEMENT, MANUFACTURING METHOD THEREOF, MAGNETIC RANDOM ACCESS MEMORY

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a magnetic random access memory capable of reducing shift of magnetizing inversion.

SOLUTION: A magnetic recording element comprises a first ferromagnetic layer 21 of which magnetizing direction is fixed and the value of magnetic moment per a unit area is m_1 . A non-magnetic layer 22 contacts the first ferromagnetic layer. The value of amplitude in roughness of the interface between the non-magnetic layer and the first ferromagnetic layer is h_1 . A second ferromagnetic layer 23 contacts the surface of non-magnetic layer which is opposite to the first ferromagnetic layer, whose magnetizing direction is fixed, and the value of magnetic moment per a unit area is m_2 which is smaller than m_1 . The value of amplitude in roughness of the interface between the second ferromagnetic layer 23 and the non-magnetic layer is h_2 . A barrier layer 13 contacts the surface of second ferromagnetic layer which is opposite to the non magnetic layer. The amplitude of roughness of the interface between the barrier and the second



ferromagnetic layer is h_3 which is smaller than h_1 and h_2 . A third ferromagnetic layer 11 faces the surface of the barrier layer which is opposite to the second ferromagnetic layer with its magnetizing direction being variable.

PATENT ABSTRACTS OF JAPAN

(11)Publication number : 2008-198792

(43)Date of publication of application : 28.08.2008

(51)Int.Cl.

H01L 43/08 (2006. 01)
H01L 43/10 (2006. 01)
H01L 21/8246 (2006. 01)
H01L 27/105 (2006. 01)
H01F 10/32 (2006. 01)

(21)Application number : 2007-032420

(71)Applicant : HITACHI LTD
 TOHOKU UNIV

(22)Date of filing : 13.02.2007

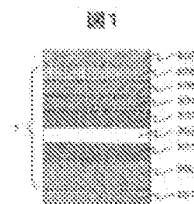
(72)Inventor : ONO HIDEO
 IKEDA SHOJI
 RI EIMIN
 HAYAKAWA JUN

(54) MAGNETORESISTANCE EFFECT ELEMENT AND MAGNETIC MEMORY CELL
 USING THE SAME, AND MAGNETIC RANDOM ACCESS MEMORY

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a high speed ultra-low power consumption nonvolatile memory, having a high temperature stability in a zero magnetic field.

SOLUTION: An insulating layer 304 and a non-magnetic conductive layer 305 are laminated to a ferromagnetic free layer 303 in a tunnel magnetoresistance effect film 1, comprising the non-volatile magnetic memory having a writing method by a spin transfer torque.



PATENT ABSTRACTS OF JAPAN

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(21)Application number : 2007-066907

(71)Applicant : SONY CORP

(22)Date of filing : 15.03.2007

(72)Inventor : YAMANE ICHIYO

HOSOMI MASAKATSU

OMORI HIROYUKI

YAMAMOTO TETSUYA

HIGO YUTAKA

OISHI TAKENORI

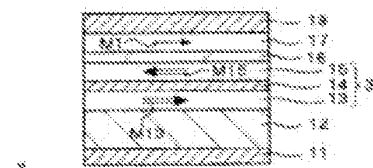
KANO HIROSHI

(54) MEMORY ELEMENT AND MEMORY

(57)Abstract:

PROBLEM TO BE SOLVED: To provide a memory element which improves thermal stability without increasing a writing current.

SOLUTION: A memory layer 17 retains information based on a magnetization state of a magnetic material. A fixed-magnetization layer 31 is formed on the memory layer 17 through an insulation layer 16. The information is recorded on the memory layer 17 with a change in a magnetization M1 direction of the memory layer 17 caused by injecting a spin-polarized electron in a stacked direction. A memory element 3 whose level of effective demagnetizing field which is received by the memory layer 17, is smaller than a saturation-magnetization level of the memory layer 17, is constituted thereby.



Electronic Patent Application Fee Transmittal				
Application Number:				
Filing Date:				
Title of Invention:		MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF		
First Named Inventor/Applicant Name:		Kojiro Komagaki		
Filer:		Dominic M. Kotab/April Skovmand		
Attorney Docket Number:		HIT1P585/HJP920090046US1		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Utility application filing	1011	1	330	330
Utility Search Fee	1111	1	540	540
Utility Examination Fee	1311	1	220	220
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				1090

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EFS ID:	8926552
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Confirmation Number:	8147
Title of Invention:	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF
First Named Inventor/Applicant Name:	Kojiro Komagaki
Customer Number:	50535
Filer:	Dominic M. Kotab/April Skovmand
Filer Authorized By:	Dominic M. Kotab
Attorney Docket Number:	HIT1P585/HJP920090046US1
Receipt Date:	29-NOV-2010
Filing Date:	
Time Stamp:	19:19:02
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$1090
RAM confirmation Number	6125
Deposit Account	502587
Authorized User	
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Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)					
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Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		HIT1P585_HJP920090046US1_ Appln_11-29-2010.pdf	9270395 57ed6cfd6fad1f8ecfb269aad13e581b34fd5a10	yes	43
	Multipart Description/PDF files in .zip description				
	Document Description	Start	End		
	Transmittal of New Application	1	1		
	Fee Worksheet (PTO-875)	2	2		
	Authorization to access Appl. by Trilateral Office	3	3		
	Information Disclosure Statement (IDS) Filed (SB/08)	4	7		
	Oath or Declaration filed	8	10		
	Appendix to the Specification	11	14		
	Specification	15	35		
	Claims	36	39		
	Abstract	40	40		
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New Applications Under 35 U.S.C. 111

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

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Electronic Acknowledgement Receipt	
EFS ID:	8926552
Application Number:	12955767
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Title of Invention:	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF
First Named Inventor/Applicant Name:	Kojiro Komagaki
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Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		HIT1P585_HJP920090046US1_Appln_11-29-2010.pdf	9270395 57ed6cfd6fad1f8ecfb269aad13e581b34fd5a10	yes	43
	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Transmittal of New Application		1	1	
	Fee Worksheet (PTO-875)		2	2	
	Authorization to access Appl. by Trilateral Office		3	3	
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	Appendix to the Specification		11	14	
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11	Fee Worksheet (PTO-875)	fee-info.pdf	33460	no	2
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MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF

RELATED APPLICATIONS

[0001] The present application claims priority to a Japanese Patent Application filed December 8, 2009 under Appl. No. 2009-278388, which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to a magnetoresistive effect head and a magnetic data storage system having the magnetoresistive effect head.

BACKGROUND OF THE INVENTION

[0003] Typically, a magnetic head used in a magnetic disk drive is provided with a playback head for reading information recorded on a recording medium. In the playback head, a magnetoresistive effect film changes resistance in response to a magnetization signal recorded on the recording medium.

[0004] The magnetoresistive effect film is typically provided with a magnetically pinned layer for pinning a direction of magnetization in one direction and a free magnetic layer which freely changes a direction of magnetization depending on a signal magnetic field from the medium, and detects the change in the magnetoresistance produced by changing the relative angle of the respective directions of magnetization of the free magnetic layer and the magnetically pinned layer by the action of the magnetization signal of the medium, and also reads the signal. Consequently, in order to improve the reading performance of the playback head, a magnetoresistive effect film exhibiting a large change in the magnetoresistive effect and a magnetoresistive effect element provided with the film are very useful.

HIT1P585/HJP920090046US1

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SUMMARY OF THE INVENTION

[0005] According to one embodiment, a magnetoresistive effect head includes a magnetically pinned layer having a direction of magnetization that is pinned, a free magnetic layer positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary, and a barrier layer comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer, wherein at least one of the magnetically pinned layer and the free magnetic layer has a layered structure, the layered structure including a crystal layer comprising one of: a CoFe magnetic layer or a CoFeB magnetic layer and an amorphous magnetic layer comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb, wherein the crystal layer is positioned closer to a tunnel barrier layer than the amorphous magnetic layer.

[0006] In another embodiment, a magnetic data storage system includes the magnetoresistive effect head described above, a magnetic medium, a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head, and a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

[0007] Any of these embodiments may be implemented in a magnetic data storage system such as a disk drive system, which may include a magnetic head, a drive mechanism for passing a magnetic storage medium (e.g., hard disk) over the head, and a control unit electrically coupled to the head for controlling operation of the head.

[0008] Other aspects and advantages of the present invention will become apparent from the following detailed description, which, when taken in conjunction with the drawings, illustrate by way of example the principles of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] FIG. 1 is a lateral cross-sectional view showing an example of a film structure of a conventional magnetoresistive effect element.

[0010] FIG. 2 is a lateral cross-sectional view showing a film structure of a magnetoresistive effect element according to one embodiment.

[0011] FIG. 3 is a structural diagram of a magnetic head provided with a tunnel magnetoresistive effect film according to one embodiment.

[0012] FIG. 4 is a lateral cross-sectional view showing a film structure of a magnetoresistive effect element according to one embodiment.

[0013] FIG. 5 is a lateral cross-sectional view showing a film structure of a magnetoresistive effect element according to one embodiment.

[0014] FIG. 6 is a top view of a magnetic recording and playback device according to one embodiment.

DETAILED DESCRIPTION

[0015] The following description is made for the purpose of illustrating the general principles of the present invention and is not meant to limit the inventive concepts claimed herein. Further, particular features described herein may be used in combination with other described features in each of the various possible combinations and permutations.

[0016] Unless otherwise specifically defined herein, all terms are to be given their broadest possible interpretation including meanings implied from the specification as well as meanings understood by those skilled in the art and/or as defined in dictionaries, treatises, etc.

[0017] It must also be noted that, as used in the specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless otherwise specified.

[0018] One film structure that may be used for the magnetoresistive effect element includes a structure having a tunnel barrier layer formed by placing an insulator between the magnetically pinned layer and the free magnetic layer. In U.S. Patent No. 4,082,711, a magnetoresistive effect element which uses MgO as the tunnel barrier layer and exhibits an extremely large magnetoresistance change ratio (TMR ratio) is described below.

[0019] In Japanese Unexamined Patent Appl. Pub. No. 2006-80116, a CoFeB/MgO/CoFeB-tunnel magnetoresistive element which uses a CoFeB magnetic layer and a MgO barrier layer, which were formed by a sputtering method widely used in industry, and exhibits a high TMR ratio exceeding 200% is described below.

[0020] In J. Hayakawa et al., Jpn. J. Appl. Phys., 44, L587 (2005), one reason for the appearance of a high TMR ratio in the CoFeB/MgO/CoFeB-tunnel magnetoresistive element is investigated. According to this reference, the reason for obtaining a high TMR ratio is believed to be that when the CoFeB layer, which is non-crystalline (amorphous), is subjected to thermal processing immediately after film deposition, (001) oriented crystals occur along the tunnel barrier layer which has (001) oriented crystals.

[0021] From these references, it may be ascertained that in order for the TMR element applicable to a playback head to obtain a high TMR, namely, a high playback output, the use of an insulation layer having (001) oriented crystallinity as the tunnel barrier layer, and the use of CoFeB layers in the magnetically pinned layer and the free magnetic layer are believed to be very effective.

[0022] Over the past few years, the bit widths on recording media have narrowed further and further, accompanying the higher recording density requirements of modern hard disk drives. Therefore, in order to read the magnetic signal recorded on the recording medium, the reading resolution must be improved by narrowing the read gap of the playback head. The read gap corresponds to the film thickness of the magnetoresistive effect film.

[0023] In order to thin the magnetoresistive effect film, it is effective to thin the film thickness of at least one of the CoFeB layer forming the magnetically pinned layer or the CoFeB layer forming the free magnetic layer which comprise most of the magnetoresistive effect film.

[0024] However, when the CoFeB layer is thin, the TMR ratio degrades substantially, in most heads. This is believed to be the result of the obstruction of the crystallization of the CoFeB layer along the atom arrangement of the tunnel barrier layer because of the epitaxial relationship originating in the compatibility of the nonmagnetic coupling layer or the antiferromagnetic layer adjacent to the magnetically pinned layer in the thermal processing executed after the magnetoresistive effect film is formed. The free magnetic layer is believed to be similarly connected to the epitaxial relationship due to the compatibility of the atom arrangement of the adjacent capping layer.

[0025] One objective of the embodiments disclosed herein is to solve the above-described problems to provide a magnetoresistive effect head capable of suppressing degradation of the MR ratio caused by thinning of the film thickness of the magnetically pinned layer and/or the free magnetic layer.

[0026] According to one general embodiment, a magnetoresistive effect head includes a magnetically pinned layer having a direction of magnetization that is pinned, a free magnetic layer positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary, and a barrier layer

comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer, wherein at least one of the magnetically pinned layer and the free magnetic layer has a layered structure, the layered structure including a crystal layer comprising one of: a CoFe magnetic layer or a CoFeB magnetic layer and an amorphous magnetic layer comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb, wherein the crystal layer is positioned closer to a tunnel barrier layer than the amorphous magnetic layer.

[0027] In another general embodiment, a magnetic data storage system includes the magnetoresistive effect head described above, a magnetic medium, a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head, and a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

[0028] In a magnetoresistive effect head according to one embodiment, at least one of the magnetically pinned layer and the free magnetic layer has an amorphous magnetic layer on the side opposite the barrier layer. The amorphous magnetic layer maintains the non-crystalline state after passing through the magnetization thermal process of the antiferromagnetic layer and the crystallization thermal process of the insulation film and the magnetic film, which are generally conducted in the manufacturing process of the magnetoresistive effect head.

[0029] In a magnetoresistive effect head according to one embodiment, the epitaxial relationship from the amorphous magnetic layer side in the CoFeB magnetic layer is lost due to the non-crystalline nature of the amorphous magnetic layer. Thus, even when the film thickness of the CoFeB layer of at least one of the magnetically pinned layer or the free magnetic layer is thinned, the effect of the crystallinity from the side opposite the barrier layer side of the CoFeB magnetic layer is reduced, and the crystallization occurs along the atom arrangement on the barrier layer side. Consequently, even if the CoFeB magnetic layer is thinner, the degradation of the MR ratio may be suppressed, and a magnetoresistive effect head which achieves both a thinner magnetoresistive effect film and a high MR ratio may be constructed.

[0030] One embodiment for is described in detail with reference to the figures. In the description below, the figures illustrate representative examples and do not limit the

scope of the present invention. The figures illustrate a bottom spin valve structure, but the present invention may be applied to a top spin valve structure and/or a dual valve structure.

[0031] FIG. 1 is a lateral cross-sectional view showing an example of the film structure of a conventional magnetoresistive effect element. The example shown here is a film structure of a bottom tunnel magnetoresistive effect element.

[0032] A current-in-plane (CIP) element in which current flows in the plane of the magnetoresistive effect film and a current-perpendicular-to-the-plane (CPP) element in which the flow is in the direction perpendicular to the film plane are magnetoresistive effect elements.

[0033] The magnetoresistive effect element shown in FIG. 1 has a tunnel magnetoresistive effect film 200 between a lower shield layer 100 and an upper shield layer 300. The tunnel magnetoresistive effect film 200 has a lower ground layer 210, an antiferromagnetic layer 220, a magnetically pinned layer 230, a tunnel barrier layer 240, a free magnetic layer 250, and a capping layer 260. The read gap corresponds to the sum of the film thickness from the lower ground layer 210 to the capping layer 260.

[0034] In the film structure shown in FIG. 1, the antiferromagnetic layer 220 is positioned on the side opposite to the tunnel barrier layer 240 of the magnetically pinned layer 230. The capping layer 260 is positioned on the side opposite to the tunnel barrier layer 240 of the free magnetic layer 250.

[0035] From the epitaxial relationship of the antiferromagnetic layer 220 and the capping layer 260, the CoFeB layer of the magnetically pinned layer 230 or the free magnetic layer 250 is believed to obstruct the development of the (001) oriented crystals along the atom arrangement of the tunnel barrier layer 240.

[0036] According to one embodiment, and referring to FIG. 2, a lateral cross-sectional view of a magnetoresistive effect element is shown. For example, the lower shield layer 100 may be comprised of permalloy formed by a plating method.

[0037] The lower ground layer 210 above the lower shield layer 100 may become the layered structure of Ta and Ru from the lower shield layer 100 side (not shown), in one approach. Also, the antiferromagnetic layer 220 above the lower ground layer 210 is shown. The antiferromagnetic layer 220 fixes the direction of magnetization of the first

magnetically pinned layer 230 above the antiferromagnetic layer in one direction, and may comprise, for example, MnIr. The antiferromagnetic layer 220 may be constructed from MnPt, PdPtMn, NiMn, FeMn, RhMn, RuMn, RuRhMn, etc.

[0038] The magnetically pinned layer 230 above the antiferromagnetic layer 220 may become a layered ferri structure, in one approach. Specifically, the magnetically pinned layer 230 may be comprised of a three-layer structure of first magnetically pinned layer 231/nonmagnetic coupling layer 232/second magnetically pinned layer 233. The antiferromagnetic coupling is realized through the nonmagnetic coupling layer 232 between the first magnetically pinned layer 231 and the second magnetically pinned layer 233.

[0039] The first magnetically pinned layer 231 may comprise an alloy material having, for example, Co and Fe. The nonmagnetic coupling layer 232 may comprise an alloy having one or two or more of, for example, Ru, Cr, Ir, Rh, etc.

[0040] In one approach, the second magnetically pinned layer 233 may comprise a layered structure having the three layers: a CoFe magnetic layer 233c, a CoFeB magnetic layer 233a, and an amorphous magnetic layer 233b in order from the side in contact with the tunnel barrier layer 240. The amorphous magnetic layer 233b may be a layer which includes CoFeB and an element selected from the group composed of Ta, Hf, Zr, Nb.

[0041] The composition ratio of Co and Fe of the CoFe magnetic layer 233c may have a preferred composition range for Co:Fe of 75:25 to 100:0 in a face-centered cubic structure or a hexagonal close packed structure, in one embodiment. In addition, the film thickness of the CoFe magnetic layer 233c may preferably be about 0.5 nm to about 1.4 nm from the perspective of the TMR ratio, in one approach.

[0042] Preferably, the composition ratio of Co and Fe in the CoFeB magnetic layer 233a is a composition range of 100:0 to 75:25 which has the face centered cubic structure, or a composition range of 75:25 to 0:100 which has the body centered cubic structure after crystallization, in some approaches. In particular, the composition range of 75:25 to 0:100 which has the body centered cubic structure may be preferred.

[0043] Preferably, a film thickness of the amorphous magnetic layer 233b is about 0.25 nm to about 1.5 nm, in one embodiment.

[0044] The tunnel barrier layer 240 comprising an insulator is above the magnetically

pinned layer 230. The material forming the tunnel barrier layer 240 may be an insulation material such as oxides, nitrides, comprising one or two or more of, for example, Mg, Ca, Zn, Sr, Al, Ti, etc., according to various embodiments.

[0045] The tunnel barrier layer 240 may obtain an optimum effect when an insulator having the (001) oriented crystallinity of a halite structure is used, in one approach. This kind of tunnel barrier layer 240 may be obtained by oxidizing or nitriding a metal film formed by a sputtering method or a vapor deposition method. Alternatively, the layer may be formed by using an oxide or a nitride target, according to various embodiments.

[0046] The free magnetic layer 250 above the tunnel barrier layer 240 may have a layered structure comprising the three layers of: a CoFe magnetic layer 250c, a CoFeB magnetic layer 250a, an amorphous magnetic layer 250b in order from the tunnel barrier layer 240 side, in one embodiment. The amorphous magnetic layer 250b is a layer comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, Nb, in one approach.

[0047] Preferably, a composition ratio of Co and Fe of the CoFeB magnetic layer 250a has a composition range of 100:0 to 75:25 which has a face centered cubic structure or a composition range of 75:25 to 0:100 which has a body centered cubic structure after crystallization, according to various embodiments. In particular, a composition ratio within the range of 100:0 to 90:10 which has a face centered cubic structure may be preferred in one approach. In addition, preferably, a film thickness of the CoFe magnetic layer 250c may be about 0.5 nm to about 1.0 nm from the perspective of the TMR ratio, in one approach.

[0048] The free magnetic layer 250 may include, for example, a NiFe layer on the amorphous magnetic layer 250b (not shown) because magnetostriction may be preferably minimized.

[0049] The capping layer 260 above the topmost part of the tunnel magnetoresistive effect film 200 may comprise a layered structure of, for example, Ru and Ta, in one approach.

[0050] FIG. 3 is a structural diagram of a magnetic head provided with a tunnel magnetoresistive effect film, according to one embodiment. The view is the cross-sectional view in the plane direction perpendicular to the ABS plane (A-A line position).

[0051] The magnetic head has a playback head 35 and a recording head 40. The playback head 35 provides a magnetoresistive effect film 200 which is formed between the lower shield layer 100 and the upper shield layer 300.

[0052] The recording head 40 provides a main magnetic pole 41, a first return yoke 42, and a second return yoke 43. A trailing shield 44 is provided on the front end of the second return yoke 43. A coil 45 is wound around the back yoke member of the main magnetic pole 41.

[0053] The structures of the magnetoresistive effect film and the magnetic head were described above, according to various embodiments. An example of an amorphous magnetic layer placed in both the magnetically pinned layer 230 and the free magnetic layer 250 was described previously, but even if an amorphous magnetic layer is placed only on either of the layers, the effect corresponding to that part may be obtained, according to various embodiments.

[0054] As above, in the magnetoresistive effect film previously described, the second magnetically pinned layer 233 and the free magnetic layer 250 have layered structures comprising CoFe magnetic layer/CoFeB magnetic layer/amorphous magnetic layer in order from the tunnel barrier layer 240 side. It is believed that the epitaxial relationship from the amorphous magnetic layer side in the CoFeB magnetic layer is eliminated by the non-crystalline nature of the amorphous magnetic layer. Therefore, the CoFeB layer of the magnetically pinned layer 230 or the free magnetic layer 250 easily becomes (001) oriented crystals along the atom arrangement of the tunnel barrier layer 240, in one approach. Therefore, even if film thicknesses of the CoFeB magnetic layers of the magnetically pinned layer 230 and the free magnetic layer 250 are thinned, the degradation of the TMR ratio may be suppressed.

[0055] In addition, based on the magnetic head previously described, the degradation in the TMR ratio may be suppressed, and a high playback output may be obtained while continuing to narrow the read gap and improve the reading resolution by thinning the film thickness of the CoFeB magnetic layer.

[0056] FIG. 4 is a lateral cross-sectional view showing a film structure of a magnetoresistive effect element, according to one embodiment. The film structure shown in FIG. 4 includes a CoFe layer 223d between the nonmagnetic coupling layer 232 and

the amorphous magnetic layer 233b added to the structure described in FIG. 2. For example, the film thickness of the CoFe layer 233d may be about 0.5 nm to about 1.0 nm, according to various embodiments.

[0057] FIG. 5 is a lateral cross-sectional view showing a film structure of a magnetoresistive effect element, according to one embodiment. The film structure shown in FIG. 5 differs from that in FIG. 4 in that the magnetically pinned layer 230 comprises only the second magnetically pinned layer 233. The rest of the structure is the same as in FIG. 4, according to various embodiments.

[0058] In the structure of this tunnel magnetoresistive effect film, the magnetically pinned layer 230 is formed by only the second magnetically pinned layer 233. In other words, this has a single-pin structure. In the single-pin magnetoresistive effect film, a unidirectional anisotropic magnetic field H_p acting between the antiferromagnetic layer 220 and the second magnetically pinned layer 233 is directly reflected in the resistance to external magnetic fields of the magnetically pinned layer 230.

[0059] H_p is represented by the following equation (Equation 1) in terms of the unidirectional anisotropic constant J_k , the amount of saturated magnetization M_s , and the film thickness t of the second magnetically pinned layer 233.

$$H_p = J_k / (M_s \cdot t) \quad \text{Equation 1}$$

[0060] According to Equation 1 described above, it is clear that H_p increases as $(M_s \cdot t)$ decreases, and the second magnetically pinned layer 233 is firmly pinned.

[0061] In another embodiment, the magnetically pinned layer 230 may have a layered structure comprising the CoFe magnetic layer 233c, the CoFeB magnetic layer 233a, and the amorphous magnetic layer 233b in order from the side in contact with the tunnel barrier layer 240, according to one embodiment. The amorphous magnetic layer 233b has a small M_s compared to the CoFeB magnetic layer 233a. The $(M_s \cdot t)$ of the magnetically pinned layer 230 becomes smaller. Consequently, H_p is large compared to the conventional single-pin magnetoresistive effect film, which does not use the amorphous magnetic layer 233b, and the resistance to external magnetic fields of the magnetically

pinned layer 230 improves.

[0062] As described above, according to one embodiment, the magnetically pinned layer 230 may have the layered structure of the CoFe magnetic layer 233c, the CoFeB magnetic layer 233a, and the amorphous magnetic layer 233b in order from the tunnel barrier layer 240 side, and obtains effects similar to the other embodiments.

[0063] In the above-described embodiments, the thermal processing is applied after the tunnel magnetoresistive effect film was formed. For example, the thermal processing is applied from several tens of minutes to several hours at a temperature from about 240°C to about 350°C in the magnetic field of several KOe to several tens of KOe applied in a constant direction.

[0064] FIG. 6 shows a top view of a magnetic recording and playback device 50 according to another embodiment. The magnetic recording and playback device 50 provides a magnetic head having the structure of the magnetoresistive effect film 200 described in any one of the previous embodiments.

[0065] In one embodiment, a magnetic data storage system 50 includes at least one magnetoresistive effect head as described herein according to various embodiment, a magnetic medium 52, a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head and a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

[0066] The magnetic recording and playback device 50 provides a plurality of magnetic recording media 52 rotatably driven by a spindle motor in a casing 51 formed in a rectangular box shape. An actuator arm 53 supported to enable swinging parallel to the medium surface is positioned on the side of the magnetic recording media 52. A suspension 54 is mounted on the front end of the actuator arm 53 in the extension direction of the actuator arm 53. A head slider 55 is mounted on the front end of the suspension 54 towards the medium surface.

[0067] The magnetic head formed from the playback head 35 provided with the magnetoresistive effect film 200 described above is formed on a head slider 55.

[0068] The magnetic head is connected to a control circuit through wires formed on

the suspension 54 and a flexible cable 56 installed on the actuator arm 53. The control circuit records signals on the magnetic recording medium 52 and plays back signals recorded on the magnetic recording medium 52.

[0069] A process which records information on the magnetic recording medium 52 and plays back the information by the magnetic head acts with the operation (seek operation) which swings the actuator arm 53 to the specified position by using the actuator 57.

[0070] Working examples according to various embodiments and according to conventional art are described below.

[0071] In Working Example 1, an example which verifies the amorphous nature of the amorphous magnetic layer which constructs the tunnel magnetoresistive effect film is explained. In Working Example 1, CoFeBTa was adopted as the structure of the amorphous magnetic layer, and the amorphous nature before and after the thermal processing was examined experimentally. The film structure of the samples used in Working Example 1 is shown below. The left side corresponds to the substrate side (lower side in FIG. 1, etc.), and the film thickness of each layer is enclosed in the parentheses ().

[0072] In the layered structure of Ta (3 nm)/Ru (2 nm)/Mn₇₅Ir₂₅ (6 nm)/Ru (0.8 nm)/(Co₄₀Fe₄₀B₂₀)_{100-x}Ta_x (10 nm)/Ta (3 nm), the x in (Co₄₀Fe₄₀B₂₀)_{100-x}Ta_x which comprises the amorphous magnetic layer indicates the composition ratio as an atomic percentage (at.%). The (Co₄₀Fe₄₀B₂₀) in the parentheses indicates that Co, Fe, and B have the composition ratio of 40:40:20. The composition ratio of (Co₄₀Fe₄₀B₂₀) and Ta was converted from each film growth rate. The Ta composition x was changed to 3, 6, 9, 13, 17 at.%.

[0073] To identify the amorphous nature of the fabricated samples, a vibrating sample magnetometer (VSM) and an X-ray diffraction device (XRD) were used immediately after depositing the film to measure the saturated magnetization per unit area and the diffraction peaks after thermal processing at 280°C and thermal processing at 320°C.

[0074] When the CoFeB magnetic layer is crystallized by thermal processing, the amount of magnetization of the CoFeB magnetic layer increases under the influence of the diffusion of B. Consequently, by verifying that the saturated magnetization does not

change before and after the thermal processing of the CoFeBTa amorphous magnetic layer, the amorphous nature of the amorphous magnetic layer may be identified. In addition, the amorphous nature may be identified when the diffraction peaks by X-rays cannot be observed. In the two methods described above, the amorphous nature of the CoFeBTa amorphous magnetic layer was identified. Table 1 shows the effects. The T in the table represents Tesla.

Ta (at.%)	Saturated magnetization immediately after film deposition	Saturated magnetization after thermal processing at 280°C	Saturated magnetization after thermal processing at 320°C	Presence of diffraction peak after thermal processing at 320°C
3	1.264T	1.270T	1.272T	No
6	0.991T	1.00T	1.00T	No
9	0.758T	-	-	No
13	0.300T	-	-	No
17	0.032T	-	-	No

Table 1

[0075] As shown in Table 1, diffraction peaks could not be observed in any of the samples from the Ta composition of 3 at.% to 17 at.%. In addition, in the samples having the Ta compositions of 3 at.% and 6 at.%, the amount of change of the saturated magnetization after the 280°C thermal processing and 320°C thermal processing immediately after film deposition was less than 1%.

[0076] In other words, the CoFeBTa magnetic layer exhibits a good amorphous nature after at least thermal processing at 320°C in the Ta composition range from 3 at.% to 17 at.%.

[0077] Bulletin of the Japan Institute of Metals Materia, Vol. 37, No. 5, p. 339 (1998) describes an amorphous magnetic layer which exists stably as an amorphous alloy when the atomic radius ratio of the elements forming the alloy is at least 12%. Consequently, even if, for example, Hf, Zr, Nb, etc., are used instead of Ta shown in Working Example

1, it is easy to assume that similar effects result.

[0078] In Working Example 2, Sample 1 described below was created as a conventional tunnel magnetoresistive effect film.

[0079] Each layer was deposited as a film by using DC magnetron sputtering. The MgO of the tunnel barrier layer was formed by first accumulating a metal Mg film by a sputtering method, and then causing natural oxidation in a chamber having a mixture ratio of oxygen and argon set to 5:95 and a chamber gas pressure of 0.1 mTorr. The oxidation time was set to 10 seconds. The metal Mg film formed a tunnel barrier layer having different thicknesses in the substrate by film deposition at an incline with respect to the substrate so that different area resistances (RA) were obtained. After each layer was deposited, thermal processing was conducted at 50 kOe, 280°C for 3 hours in a thermal processing reactor in a magnetic field.

[0080] Sample 1 described below roughly corresponds to the removal of the amorphous magnetic layers 233b and 250b in Figure 4. “Ta (1 nm)/Ru (2 nm)” on the left side of Sample 1 corresponds to the lower ground layer 210 and corresponds to the layer one step higher when advancing to the right. “MgO (0.8 nm)” corresponds to the tunnel barrier layer 240. The right side of the tunnel barrier layer 240 corresponds to the free magnetic layer 250.

[0081] Sample 1 included: Si/Ta (1 nm)/Ru (2 nm)/Mn₇₅Ir₂₅ (5 nm)/Co₇₅Fe₂₅ (2 nm)/Ru (0.8 nm)/Co₉₀Fe₁₀ (0.5 nm)/Co₄₀Fe₄₀B₂₀ (2 nm)/Co₉₀Fe₁₀ (1.4 nm)/MgO (0.8 nm)/Co₉₀Fe₁₀ (0.9 nm)/Co₄₀Fe₄₀B₂₀ (3 nm)/Ru (3 nm)/Ta (3 nm)/Ru (4 nm)

[0082] A sample similar to Sample 1 was fabricated except the film thickness of the CoFeB magnetic layer 233a (Co₄₀Fe₄₀B₂₀ (2 nm)) was set to 1 nm, denoted as Sample 2.

[0083] A sample similar to Sample 1 was fabricated except the film thickness of the CoFeB magnetic layer 250a (Co₄₀Fe₄₀B₂₀ (3 nm)) was set to 2 nm, denoted as Sample 3.

[0084] Table 2 shows the results where the value of the TMR ratio was measured for each sample when the RA value was fixed. The measurement method was the current-in-plane tunneling (CIPT) method.

nm)/Ta (3 nm)/Ru (4 nm)

[0089] A sample (Sample 5) similar to Sample 4 was fabricated except the film thickness of the CoFeB magnetic layer 233a (Co₄₀Fe₄₀B₂₀ (0.5 nm)) was set to 1.0 nm.

[0090] A sample (Sample 6) similar to Sample 4 was fabricated except the film thickness of the CoFeB magnetic layer 233a (Co₄₀Fe₄₀B₂₀ (0.5 nm)) was set to 1.5 nm.

[0091] A sample (Sample 7) similar to Sample 4 was fabricated except the film thickness of the amorphous magnetic layer 233b ((Co₄₀Fe₄₀B₂₀)₉₄Ta₆) was set to 1.0 nm.

[0092] A sample (Sample 8) similar to Sample 4 was fabricated except the film thickness of the amorphous magnetic layer 233b ((Co₄₀Fe₄₀B₂₀)₉₄Ta₆) was set to 1.5 nm.

[0093] A sample (Sample 9) similar to Sample 4 was fabricated except the amorphous magnetic layer 233b was (Co₄₀Fe₄₀B₂₀)₉₇Ta₃.

[0094] A sample (Sample 10) similar to Sample 4 was fabricated except the amorphous magnetic layer 233b was (Co₄₀Fe₄₀B₂₀)₉₀Ta₁₀.

[0095] A sample (Sample 11) similar to Sample 4 was fabricated except the amorphous magnetic layer 233b was (Co₄₀Fe₄₀B₂₀)₈₇Ta₁₃.

[0096] A sample (Sample 12) similar to Sample 4 was fabricated except the amorphous magnetic layer 233b was (Co₄₀Fe₄₀B₂₀)₈₃Ta₁₇.

[0097] A sample (Sample 13) similar to Sample 4 was fabricated except the structure had the CoFeB magnetic layer 233a (Co₄₀Fe₄₀B₂₀ (0.5 nm)) removed from the second magnetically pinned layer 233.

[0098] A sample (Sample 14) similar to Sample 4 was fabricated except the amorphous magnetic layer 233b was (Co₄₀Fe₄₀)₈₅Ta₁₅.

[0099] Table 3 shows the results when the value of the TMR ratio was measured for each sample when the RA value was fixed. The measurement method was the CIPT method.

Sample No.	CoFeBTa film thickness	CoFeB film thickness	Film thickness of 2nd magnetically pinned layer	Ta composition	TMR ratio
1	-	2.0 nm	3.9 nm	-	80.5%
4	0.5 nm	0.5 nm	2.9 nm	6 at. %	90.3%
5	0.5 nm	1.0 nm	3.4 nm	6 at. %	86.2%
6	0.5 nm	1.5 nm	3.9 nm	6 at. %	87.3%
7	1.0 nm	0.5 nm	3.4 nm	6 at. %	101.0%
8	1.5 nm	0.5 nm	3.9 nm	6 at. %	103.9%
9	0.5 nm	0.5 nm	2.9 nm	3 at. %	83.7%
10	0.5 nm	0.5 nm	2.9 nm	10 at. %	85.4%
11	0.5 nm	0.5 nm	2.9 nm	13 at. %	82.4%
12	0.5 nm	0.5 nm	2.9 nm	17 at. %	65.6%
13	0.5 nm	-	2.4 nm	-	20.3%
14	CoFeTa 0.5 nm	0.5 nm	2.9 nm	15 at. %	50.2%

Table 3

[00100] As shown in Table 3, from comparisons of Sample 1 of the conventional example and Samples 4 to 8 of the present working examples, it is clear that the degradation of the TMR ratio is suppressed even when the film thickness of the second magnetically pinned layer 230 is thinned by forming the second magnetically pinned layer 230 in a layered structure of CoFe magnetic layer 233c/CoFeB magnetic layer 233a/CoFeBTa amorphous magnetic layer 233b from the tunnel barrier layer 240 side.

[00101] From the comparisons of Sample 9 to Sample 12, a high TMR ratio is seen in the Ta composition range from 3 at. % to 13 at. %, particularly, from 3 at. % to 10 at. %.

[00102] As shown in Table 1, in the composition range for the Ta composition from 3 at. % to 10 at. %, the CoFeBTa amorphous magnetic layer exhibits a high saturated magnetization from approximately 0.75T to 1.3T. The magnetic coupling between the CoFeBTa amorphous magnetic layer 233b and the CoFe magnetic layer 233c is believed to be strong.

[00103] Consequently, it is believed that the magnetic layers of the layered structure of

Sample No.	CoFeB film thickness of 2nd magnetically pinned layer	Film thickness of 2nd magnetically pinned layer	CoFeB film thickness of free magnetic layer	CoFeB film thickness of free magnetic layer	TMR ratio
1	2 nm	3.9	3 nm	3.9	80.5
2	1 nm	2.9	3 nm	3.9	40.4
3	2 nm	3.9	2 nm	2.9	72.1

Table 2

[0085] As shown in Table 2, compared to Sample 1, the TMR ratio decreased in Sample 2 and Sample 3. From the above results, in the conventional example, it is understood that when the film thickness of the CoFeB magnetic layer of at least one of the magnetically pinned layer and the free magnetic layer is thinned, the TMR ratio degrades.

[0086] In Working Example 3, Sample 4 described below having the amorphous magnetic layer 233b positioned on the magnetically pinned layer 230 was fabricated. In addition, Sample 5 to Sample 14 were fabricated for comparison. In Working Example 3, to verify the effect of placing the amorphous magnetic layer 233b on the magnetically pinned layer 230, the free magnetic layer 250 had the same structure as the conventional example.

[0087] The CoFeBTa amorphous magnetic layers in Sample 4 and Sample 9 to Sample 12 were identified to have a Ta composition of at least 3 at.% from the results of XRD and VSM and to maintain an amorphous structure after the 280°C thermal processing. In addition, Sample 14 had a portion of the second magnetically pinned layer 233 set to a CoFeTa amorphous magnetic layer compared to the CoFeTa amorphous magnetic layer.

[0088] Sample 4 included: Si/Ta (1 nm)/Ru (2 nm)/Mn75Ir25 (5 nm)/Co75Fe25 (2 nm)/Ru (0.8 nm)/Co90Fe10 (0.5 nm)/(Co40Fe40B20)₉₄Ta₆ (0.5 nm)/Co40Fe40B20 (0.5 nm)/Co90Fe10 (1.4 nm)/MgO (0.8 nm)/Co90Fe10 (0.9 nm)/Co40Fe40B20 (3 nm)/Ru (3

the CoFeBTa amorphous magnetic layer 233b and the CoFe magnetic layer 233c function well as one magnetic body; and the direction of magnetization of each layer acts independently, and the function as a magnetoresistive effect element is not damaged.

[00104] From the comparison of Sample 4 and Sample 13, the tunnel magnetoresistive effect film which has a second magnetically pinned layer 233 composed of only the CoFe magnetic layer 233c and the CoFeBTa amorphous magnetic layer 233b is known to have a large decrease in the TMR ratio. Thus, the effects of the present invention may be expected when the layered structure is a crystal layer, which is composed of CoFe magnetic layer 233c or CoFeB magnetic layer 233a, and an amorphous magnetic layer 233b. Consequently, the film structures disclosed in Japanese Unexamined Patent Appl. Pub. No. 2001-068760, Japanese Unexamined Patent Appl. Pub. No. 2004-071714, Japanese Unexamined Patent Appl. Pub. No. 2006-134950, Japanese Unexamined Patent Appl. Pub. No. 2008-198792, Japanese Unexamined Patent Appl. Pub. No. 2008-227388, Japanese Unexamined Patent Appl. Pub. No. 2009-004784 are not layered structures and are not believed to obtain the effects of the present invention.

[00105] From the comparison of Sample 4 and Sample 14, the CoFeTa amorphous magnetic layer, which does not contain the element B, has a large decrease in the TMR ratio. The reasons that the effects of the present invention are not obtained in the amorphous magnetic layer which does not contain the element B, namely, the reason that the effects of the present invention are obtained in the amorphous magnetic layer which contains the element B are as follows.

[00106] The epitaxial relationship from other than the tunnel barrier layer 240 is interrupted by the amorphous structure, and a portion of the B atoms diffused by the thermal processing is believed to contribute to the crystallization of the CoFeB magnetic layer 233a and the CoFe magnetic layer 233c. Thus, the amorphous magnetic layer 233b containing B is believed to obtain superior magnetization characteristics to those of the amorphous magnetic layer not containing B.

[00107] In Working Example 3, samples were fabricated with the film thickness of the amorphous magnetic layer 233b in the range of 0.5 nm to 1.5 nm. If the film thickness is approximately 0.25 nm, it is assumed that effects similar to those of Working Example 3 are exhibited.

[00108] In Working Example 3, Co₄₀Fe₄₀B₂₀ was adopted as the structure of the CoFeB magnetic layer 233a. It is assumed that the same effects as Working Example 3 are exhibited if within the composition range represented by (CoFe)_{100-x}B_x ($10 \leq x \leq 30$ at.%).

[00109] In Working Example 4, Samples 15, 16 which have an amorphous magnetic layer 250b placed in the free magnetic layer 250 were fabricated. The magnetically pinned layer 230 had the same structure as the conventional example. Table 4 shows the results when the value of the TMR ratio was measured for each sample when the RA value was fixed. The measurement method used the CIPT method.

Sample No.	CoFeB film thickness	CoFeBTa film thickness	Film thickness of free magnetic layer	Ta composition	TMR ratio
1	3.0 nm	-	3.9	-	80.5%
15	2.0 nm	0.5 nm	3.4	6 at. %	90.3%
16	1.0 nm	1.0 nm	2.9	6 at. %	86.2%

Table 4

[00110] As shown in Table 4, from the comparisons of Sample 1 in the conventional example and the Samples 15 and 16 in this working example, because the free magnetic layer 250 has the layered structure of CoFeB magnetic layer 250a/CoFeBTa amorphous magnetic layer 250b in order from the tunnel barrier layer 240 side, even if the film thickness of the free magnetic layer 250 is thinner, the degradation of the TMR ratio may be suppressed.

[00111] In Working Example 4, samples were fabricated with a film thickness of the amorphous magnetic layer 250b in the range of 0.5 nm to 1.0 nm. However, if the film thickness is approximately 0.25 nm to 1.5 nm, the effects equivalent to those of Working Example 4 are assumed.

[00112] In Working Example 4, the Co₄₀Fe₄₀B₂₀ was adopted similar to Working

Example 3 as the structure of the CoFeB layer 250a. However, it is assumed that effects equivalent to those of Working Example 4 are exhibited if within the composition range represented by $(\text{CoFe})_{100-x}\text{B}_x$ ($10 \leq x \leq 30$ at.%).

[00113] In Working Example 4, 6 at.% was adopted as the Ta composition ratio of the CoFeBTa amorphous magnetic layer 250b. However, it is assumed that effects equivalent to those of Working Example 4 are exhibited if within the range from 3 to 13 at.% as in Working Example 3.

[00114] While various embodiments have been described above, it should be understood that they have been presented by way of example only, and not limitation. Thus, the breadth and scope of an embodiment of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

CLAIMS

What is claimed is:

1. A magnetoresistive effect head, comprising:
 - a magnetically pinned layer having a direction of magnetization that is pinned;
 - a free magnetic layer positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary; and
 - a tunnel barrier layer comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer;wherein at least one of the magnetically pinned layer and the free magnetic layer has a layered structure, the layered structure comprising:
 - a crystal layer comprising one of: a CoFe magnetic layer or a CoFeB magnetic layer; and
 - an amorphous magnetic layer comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb,wherein the crystal layer is positioned closer to the tunnel barrier layer than the amorphous magnetic layer.
2. A magnetic data storage system, comprising:
 - at least one magnetoresistive effect head as recited in claim 1;
 - a magnetic medium;
 - a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
 - a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.
3. The magnetoresistive effect head as recited in claim 1, wherein the magnetically pinned layer has the layered structure.

4. The magnetoresistive effect head as recited in claim 3, wherein a film thickness of the amorphous magnetic layer is in a range from about 0.25 nm to about 1.5 nm.
5. The magnetoresistive effect head as recited in claim 3, wherein the crystal layer comprises the CoFeB magnetic layer, and wherein the CoFeB magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x$, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$.
6. A magnetic data storage system, comprising:
 - at least one magnetoresistive effect head as recited in claim 5;
 - a magnetic medium;
 - a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
 - a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.
7. The magnetoresistive effect head as recited in claim 3, wherein the amorphous magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x\phi_y$, wherein ϕ is the element selected from the group consisting of: Ta, Hf, Zr, Nb, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$, and with $3 \text{ at.}\% \leq y \leq 13 \text{ at.}\%$.
8. A magnetic data storage system, comprising:
 - at least one magnetoresistive effect head as recited in claim 7;
 - a magnetic medium;
 - a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
 - a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.
9. The magnetoresistive effect head as recited in claim 1, wherein the free magnetic

layer has the layered structure.

10. The magnetoresistive effect head as recited in claim 9, wherein a film thickness of the amorphous magnetic layer is in a range from about 0.25 nm to about 1.5 nm.

11. The magnetoresistive effect head as recited in claim 9, wherein the crystal layer comprises the CoFeB magnetic layer, wherein the CoFeB magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x$, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$.

12. A magnetic data storage system, comprising:
at least one magnetoresistive effect head as recited in claim 11;
a magnetic medium;
a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

13. The magnetoresistive effect head as recited in claim 9, wherein the amorphous magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x\phi_y$, wherein ϕ is the element selected from the group consisting of: Ta, Hf, Zr, Nb, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$, and with $3 \text{ at.}\% \leq y \leq 13 \text{ at.}\%$.

14. A magnetic data storage system, comprising:
at least one magnetoresistive effect head as recited in claim 13;
a magnetic medium;
a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

15. The magnetoresistive effect head as recited in claim 1, wherein the magnetically

pinned layer and the free magnetic layer have the layered structure.

16. The magnetoresistive effect head as recited in claim 15, wherein a film thickness of the amorphous magnetic layer in the pinned layer and the free magnetic layer is in a range from about 0.25 nm to about 1.5 nm.

17. The magnetoresistive effect head as recited in claim 15, wherein the crystal layer in the pinned layer and the free magnetic layer comprises the CoFeB magnetic layer, wherein the CoFeB magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x$, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$.

ABSTRACT

According to one embodiment, a magnetoresistive effect head includes a magnetically pinned layer having a direction of magnetization that is pinned, a free magnetic layer positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary, and a barrier layer comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer, wherein at least one of the magnetically pinned layer and the free magnetic layer has a layered structure, the layered structure including a crystal layer comprising one of: a CoFe magnetic layer or a CoFeB magnetic layer and an amorphous magnetic layer comprising CoFeB and an element selected from: Ta, Hf, Zr, and Nb, wherein the crystal layer is positioned closer to a tunnel barrier layer than the amorphous magnetic layer. In another embodiment, a magnetic data storage system includes the magnetoresistive effect head described above.

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	First Named Inventor	Kojiro Komagaki
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	Examiner Name	Unassigned
	Attorney Docket Number	HIT1P585/HJP920090046US1

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1	MATSUMOTO, "Flow In Studies Of Amorphous Metallic Materials," The Research Institute For Electric And Magnetic Materials, Sendai, 03/26/1998, 8 pgs., no translation	☐
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**INFORMATION DISCLOSURE
STATEMENT BY APPLICANT**
(Not for submission under 37 CFR 1.99)

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Filing Date	2010-11-29
First Named Inventor	Kojiro Komagaki
Art Unit	2627
Examiner Name	Unassigned
Attorney Docket Number	HIT1P585/HJP920090046US1

CERTIFICATION STATEMENT

Please see 37 CFR 1.97 and 1.98 to make the appropriate selection(s):

☐ That each item of information contained in the information disclosure statement was first cited in any communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(1).

OR

☐ That no item of information contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in 37 CFR 1.56(c) more than three months prior to the filing of the information disclosure statement. See 37 CFR 1.97(e)(2).

☐ See attached certification statement.

☐ Fee set forth in 37 CFR 1.17 (p) has been submitted herewith.

☒ None

SIGNATURE

A signature of the applicant or representative is required in accordance with CFR 1.33, 10.18. Please see CFR 1.4(d) for the form of the signature.

Signature	/Dominic M. Kotab/	Date (YYYY-MM-DD)	2010-12-08
Name/Print	Dominic M. Kotab	Registration Number	42,762

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アモルファス金属研究の流れ*

増 本 健**

1. はじめに

この度、金属分野の最高名誉である日本金属学会賞を受賞することになり、身に余る光栄である。この受賞の主な研究対象は、筆者が1969年以来約三十年近く精力を注いできたアモルファス金属の研究であるが、振り返って見れば、これまで永く研究を続けることができたのは、恩師の貴重な教訓、諸先輩の励ましと支援、共同研究者のたゆまぬ協力、多くの学生や研究生の若い力などの集積の賜であると言える。本誌を借りて深く感謝の意を表したい。

アモルファス物質と言えば無機ガラス(SiO_2)が古くから知られており、金属を除いた多くの無機・有機物質の分野においては決して珍しいものではない。しかし、金属分野においては、最近までアモルファス状態は実在しないと考えられてきた。従来の学術書には、“一般に、金属液体は急冷してもある温度(融点 T_m の約 $0.2 \sim 0.3 T_m$)以下には過冷されず、結晶として凝固する”と記述されていたのである。この一般的常識が覆されてその存在が明確にされたのは最近のことである。それは、原子スケールで物質の構造を解析し、分析することが可能になったからであり、今日ではアモルファス金属の種類によって原子の乱れ方が異なり、アモルファス相中には短範囲ばかりでなく中範囲での原子秩序が存在することが明らかにされつつある。

それでは最近になるまでアモルファス金属の存在が知られていなかったであろうか。実は、文献を調べてみると、古くは1940年代に表面処理に使われていたNi-Pめっき膜にアモルファスを暗示するデータが報告されていたし、また、透過電子顕微鏡の試料作製のために発達した蒸着技術を用いた

Te, Siなどの低温蒸着膜においてもアモルファス特有のハロー状のX線回折像が報告されていた。さらに古くは、強く機械的に磨耗した金属表面に形成される強加工層に、エッチングしても無組織の層があることが観察されていたのである。したがって、いつ誰が最初に金属合金にアモルファス相を見つけたかを確認することは極めて難し

いし、またこれを追究するのは余り意味のないことであろう。

しかしながら、アモルファス金属が新しい材料として注目され、さらに新しい学問分野を形成するきっかけとなった経緯をできるだけ正確に知っておく必要があるだろう。このためには、初期の段階から研究に携わってきた者として、その歴史と筆者らの役割をはっきりさせておきたい。そこで、この機会に「アモルファス金属研究の流れ」についてまとめることにした。なお、アモルファス金属の最近の動向に関しては、最近筆者により本誌に解説⁽¹⁾してあるので、これと重複を避けて記述することにした。

2. アモルファス金属研究の始まり(～1980年頃まで)

これまでの文献集⁽²⁾⁻⁽⁴⁾によれば、アモルファス金属の存在を示唆した研究はBrennerら(1948)⁽⁵⁾によるNi-Pめっき膜の報告であり、その後さらにBuckel(1954)⁽⁶⁾によるSi低温蒸着膜の報告である。しかしながら、一般には、アモルファス金属の存在を多くの研究者に認知させるきっかけとなっ



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た研究は、液体を急冷する方法で準安定結晶の生成について実験をしていた際に、共晶組成のAu-Si合金がハロー状のX線回折像を示すことを見出したDuwezら(1960)⁽⁷⁾の報告であり、さらに、その存在を熱力学的に考察したTurnbull(1961)⁽⁸⁾の報告であると言われている。筆者がこの物質に興味をもったのも、実はDuwezの解説論文⁽⁹⁾を一読した時であった。

ところが、1960年の当時は、今日のような精密な構造解析法が発達しておらず、X線のハロー状回折像のみからアモルファス相と微結晶相との区別を明確にすることが困難な時代であり、むしろ“微結晶の集合体である”と考える研究者の方が多く状況であった。当時の研究者がDuwezらの急冷金属を“デュエイの間抜けな合金”と呼んでいたのはこのためであったと思われる。このような構造上の論争は、物性の解釈と相まって、その後1970年後半頃まで続いたのである。とくに前半では、この奇妙な金属を微結晶の集合体であると考えて結晶を中心とした既成の学問で説明できるとした研究者が少なくなく、学会などで活発な議論が戦わされた時代であった。

ともかくも、Duwezらのグループによる金属液体の急冷に関する初期の研究は、アモルファス金属を我々の身近に引き寄せた点で高く評価されるべきであろう。しかしながら、1960年代におけるアモルファス金属に関する研究は、当時の超急冷技術で得られる試料が薄膜か不定形状の微小薄片であったために、X線回折、熱分析などの少量で試料形状が問題にならない幾つかの方法で実験することしかできなかった⁽¹⁰⁾。この点に着目したのが筆者らの研究⁽¹¹⁾である。筆者らは特殊な作製法⁽¹¹⁾によって一定形状のPd-Siリボン試料(およそ1mm幅、25μm厚さ、30cm長さ)を作製することに成功し、このリボン状試料を用いて初めてアモルファス金属の主な力学的物性を定量的に明らかにしたのである。この研究は、アモルファス金属が驚くほど高い強さをもち、しかも大きな塑性変形能をもつ高強靱性材料であることを明らかにした点で重要な成果であると共に、その後アモルファス金属が新材料として脚光を浴びるきっかけをつくった点で大きな役割を果たしたと言える。

図1は1960～1980年間のアモルファス金属に関する国内外の研究論文数の年代変化を示している。この図に見るように、世界で発表された論文数は1970年頃までは年間2～5件程度であったにも拘わらず、1974年前後を境として急激に増加している。このことから筆者らの報告が重要な役割を果たしたことは明らかであろう。その後、この分野の研究は、日本と米国を中心として基礎・応用の両面から活発に行われた⁽¹²⁾⁽¹³⁾。そして、1980年には、世界における論文数が1000件を超えるほどまでに急速に発展したのである。

アモルファス金属の基礎的研究に関しては、1980年頃までの初期において、理論・実験による構造解析、主要な物性(比熱、電気、磁性、拡散、超伝導、中性子照射など)の解

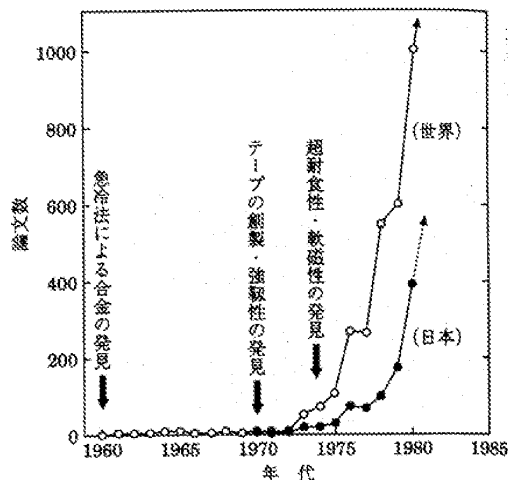


図1 アモルファス金属に関する学術論文数の年代変化。

明、工学的材料特性(安定性、結晶化、機械的性質、腐食、触媒など)の解明が精力的に行われ、アモルファス金属の概要がほぼ明らかにされた⁽¹²⁾⁽¹³⁾。また、これらの基礎的研究に加えて、多くの合金の探索と種々の作製法の開発が活発に行われ、短期間に新材料としての基盤が確立されたと言える。一方、企業による応用研究も活発に行われ、世界で初めてアモルファス金属を用いた製品開発に成功したのは、1978年に発表された軟磁性を利用したカートリッジ用コア部品(ソニー)である。このように、アモルファス金属の三大特性の発見と初めての実用化の成功が我が国において行われたことは、この分野における特筆すべきことであろう。

次に、1980年頃までに行われた作製法、合金組成、構造と物性についての研究の概要について述べよう。

(1) 液体急冷法によるアモルファス金属の作製

1970年に筆者によって作製されたアモルファス金属は、せいぜい0.5～2mm幅、25μm厚さの小さなリボン状試料であった⁽¹⁴⁾。その後、Chenによって双ロール法(1970)⁽¹⁵⁾が、また増本らによって単ロール法(1975)⁽¹⁶⁾が開発された。この中で、単ロール法は極めて簡単な原理であり、量産技術として最適であったことから広く世界に普及し、液体急冷実験装置として使用されており、また、企業における本格的な量産方式の基礎技術として利用されている。筆者らによるこの単ロール法の原理は、Allied Chemical社(旧名)による製法の特許出願(1976)の約半年前に筆者らにより発表⁽²¹⁾されたものであり、日本においてはすでに一年前から筆者らによって使用されていた公知の方法であった。しかし残念ながら、この技術の詳細についてはほとんど開示しなかったために、Allied Chemical社(旧)の日本特許が成立してしまい、日本国内では7mm幅以上の薄帯を製造することができな

くなってしまったのである。現在、我が国においても、この方式による 30 cm 幅程度の広幅薄帯の量産技術はすでに確立されている。

上述の薄帯の製造法の他に、アモルファス金属の細線と粉末の製造法も 1980 年代までに開発されている。細線製造についての初めての試みは Kavesh による水中鑄造法 (1975) (22) であったが、結局実用化されず、その後大中らによって考案された紡糸法 (1978) (23) の原理を応用した回転水中紡糸法 (1981) (24) が開発され、0.1~0.2 mm 径のアモルファス金属細線が生産され、実用化されている。粉末の製造としては、双ロール型キャピテーション法 (1981) (25) による粉末の製造法が実用化されている。また、数 10 μm 径の微粉末の製造法として一般のガスアトマイズ法が使用されていたが、しかし、通常の方法では冷却速度が十分でないために、細かい粉末のみがアモルファス化した結晶との混合粉末しか得られなかった。その後、アモルファス金属粉末が実用化されたのは、高圧アトマイズ法 (26) と扁平粉末法 (27) が開発される 1988 年まで待たなければならない。ともかくも、製法に関しては、薄帯を初めて細線と粉末の製造技術が我が国において開発されたことは注目し値する成果と言える。

(2) 液体急冷法による新たなアモルファス金属の探索

1960 年に Duwez ら (7) のグループが Au-Si 合金を見出し、その後、彼らのグループは、数種の遷移金属と P, C, B などの半金属との二・三元合金 (金属-半金属系合金) がアモルファス化し易いことを見出し、金属のアモルファス化の経験的規則として、(1) 深い共晶反応を示す合金系であること、(2) 半金属のような共有結合性の強い元素を含むこと、(3) 2 元系あるいはそれ以上の多元系であること、の条件を提案した。そして、Duwez ら (28) によって重要な Fe-P-C 合金 (1967) が、さらに Ray (29) により Zr-Cu, Zr-Ni などの金属-金属系合金 (1968) が新たに見出された。一方、我が国では、1971 年に山内ら (30) が (Fe, Ni)-P-B 系合金 (1971) を見出したが、この合金系は 1974 年にカタログ販売された Allied Chemical 社 (旧名) の商品「Metglas」の基本組成となった点で重要である。しかし、この P を含む Fe 系合金は、時効によって徐々に脆くなってしまうために問題となり、これに代わって増本ら (31) によって見出された (Fe, Co, Ni)-Si-B 系合金 (1975) が最も重要な組成となった。この合金は、筆者らが半金属元素 B, Si, P, C, Ge の詳細な各効果を調べた結果、鉄族基合金の中で Si-B 系合金が最もアモルファス化し易く、幅広い薄帯が製造でき、しかも材料特性が最も優れていることを見出したもので、現在世界で広く使用されているアモルファス軟磁性合金の基本組成となっている。一例として図 2 には、 $\text{Fe}_{80}\text{M}_{20}$ 二元合金のキュリー温度および飽和磁化におよぼす半金属元素 M の効果を調べた結果 (32) であり、磁性に対しては B, Si が好ましい元素であることを示している。他方、P は磁性には好ましくなく、Ge, C は材料を脆く

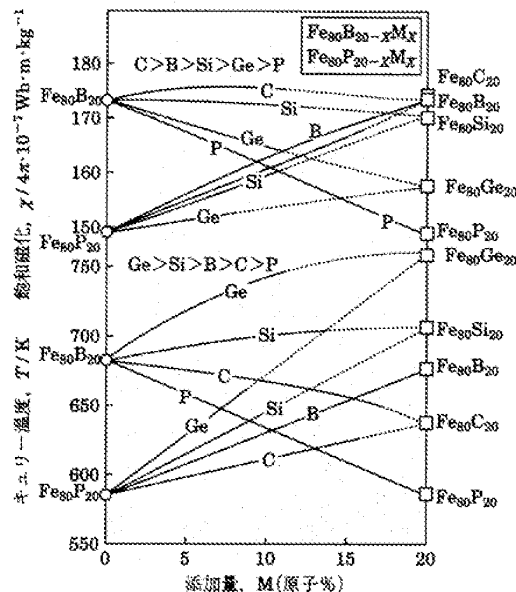


図2 アモルファス $\text{Fe}_{80}\text{M}_{20}$ 合金の飽和磁化およびキュリー温度におよぼす半金属元素 M の効果。

する元素である。この結果は、その後 1979 年に、Allied Chemical 社が Metglas の組成を P-B 系から Si-B 系の合金へ変更させることになるのである。

図 3 は初期における日本と米国におけるアモルファス軟磁性合金の組成の歴史的変遷を示している。現在、一般に使用されている合金系としては、(Fe, Co, Ni)-Si-B 系 (1975) (31) と (Fe, Co, Ni)-(Nb, Zr) 系 (1979) (33) の二種類に大別されている。この内、後者の金属-金属系の Co-Nb-Zr 合金は、軟磁性薄膜として広く磁気ヘッド磁心などに多用されている。

(3) アモルファス金属の構造と物性

今日では、アモルファス金属が非平衡準安定状態で存在することが知られているが、前述したように、Duwez のグループが液体を急冷することによってアモルファスが得られることを発表した当時は、アモルファス相を微結晶と明瞭に区別するだけの構造解析技術が無い時代であり、微結晶説に対して反論する確実な証拠を示すことが難しく、この論争は 1970 年後半まで続いたのである。しかし、最近では、新たに開発された X 線回折法、高分解能 TEM, FIM などの高精度構造解析法の発展により、アモルファス相中にはある程度の短範囲秩序性が存在すること、また最近では、強力パルス中性子散乱実験により、短範囲秩序性のみならず中範囲秩序性の構造も存在することが指摘されている (34)。この結果、これまで十分でなかった構造と物性との間の密接な関連についてもようやく明らかにされ始めつつあると言える。

一方、1960 年代におけるアモルファス金属の物性に関する

年 代	〔日本〕	〔米国〕
1967		Fe-P-C [Duwez]
1970		
1971	Fe-B-C, Ni-P-B, Fe-P-B, Co-P-B 〔溝口, 中川〕	
1972	Fe-Ni-P-C [増本]	アモルファス合金の特許 〔Chen〕
1973	(Fe, Co, Ni)-(Cr, Mo, V)-P-B [溝口]	[Allied Chem. Co.] 商品名: Metglas
1974	Fe-Co-P-C [寄賀, 増本] Fe-Co-P-C, (Fe, Co)-(Si-B) [野地, 増本]	Fe-Ni-P-B-Al [Met. 2826] Fe-P-C-B [Met. 2615] Fe-Ni-P-B [Met. 2826A] Fe-Ni-P-B-Si [Met. 2826B] Fe-Co-P-B-Al [Bell Lab.]
1975	Ni-Si-B, Co-Si-B [増本]	
1976	Fe-Si-B [増本] Fe-B, Co-B [増本] (Fe, Co, Ni)-Si-B [増本]	
1977	Fe-Si-B-C [増本]	Fe-B [Met. 2605]
1978	(Fe, Co, Ni)-(Cr, Mo, W)-C [増本] Co-Fe-Cr-Si-B [増本] Co-Fe-Ni-Mo-Si-B [増本]	Fe-B-C [U. Penn.] Co-Fe-Mo-B [Met. 2705] Fe-B-Si-C [Met. 2605C]
1979	(Fe, Co, Ni)-(Zr, Nb, Ta) [野地, 増本] Fe-Co-Zr [寄賀, 増本] Co-Mn-Fe-Si-B [増本] Co-Zr-B [大谷, 増本] (Fe, Co)-Hf [寄賀, 増本]	Fe-Si-B [Met. 2605S-2] Fe-Co-B-Si [Met. 2605CO] Fe-Si-B [Met. 2605S-3] Co-Fe-Mo-B-Si [Met. 2705X]
1980		
1981		
1982		

図3 日本におけるアモルファス磁性合金の年代的変遷と競争経過。

る研究は、当時の急冷技術で得られる試料が薄膜か不定形状の微小薄片であったために、X線回折、熱分析、比熱や電気抵抗測定などの少量で試料形状が問題にならない幾つかの物性を定性的に調べることしかできなかったが、この点に着目した筆者らの研究⁽¹⁰⁾により、アモルファス金属の主な機械的性質(弾性、引張強度、伸び、変形過程、破断形式、強度の歪み速度依存性と寸法依存性、結晶化過程と機械的性質の関係など)を総合的に明らかにした。この結果は、1970年に、当時のユーゴスラビアのブラホ市で開催された第1回準安定結晶金属合金に関する国際会議(後に液体急冷金属国際会議として名称が変更)において発表され、高い引張強度と明確な塑性変形の証拠が注目された。すなわち、強さがPd結晶(130 MPa)の約10倍である1320 MPaであり、アモルファス金属が高い強度と延性を持つ材料である可能性が示されたことと、結晶でないアモルファス金属においても塑性変形が起こることについて大きな興味をもたれた。この結果は、Leamyら⁽³⁵⁾によるほぼ同様な実験によって、再確認されている。次いで、筆者ら⁽³⁶⁾は高温における機械的性質(強度、変形・破断過程の温度依存性、クリープ挙動など)も明らかにした。

図4は、アモルファスPd-Si合金の引張試験のデータ⁽¹⁰⁾を示してある。ここに示す応力-歪み曲線はアモルファス金属の典型的図形であり、あたかも脆性破断が起こっているよ

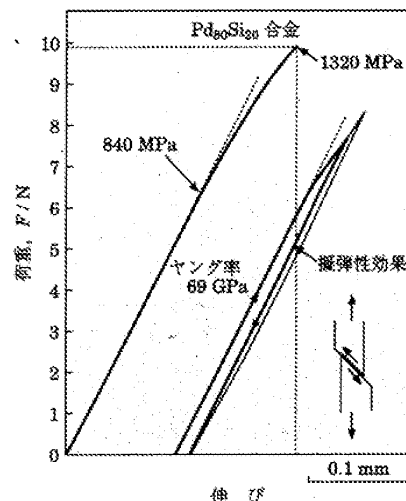


図4 アモルファスPd₈₀Si₂₀合金の引張曲線と破断形式。

うに見える。しかし、ここでは詳しくは述べないが、元来アモルファス金属は歪み硬化を起こさない理想的な弾塑性材料であり、この結果局所に応力集中が起こってその部分で破断するいわゆる不均一変形破断形式の材料であり、決して脆性材料ではないのである。また、引張試験の場合にはほとんど塑性伸びが見られないが、これはこの材料が脆性材料であることを示すのではなく、図中に模式図で示すように、一軸応力下では応力集中により塑性変形破断が局所で生じるために、見かけ上伸びが現れないだけであり、事実この材料は50%もの圧延加工や線引加工が可能である⁽⁴²⁾。また、応力歪み曲線には高応力側で直線からの偏倚が見られるが、これは材料自身が降伏したのではなく、アモルファス材料に特徴である大きな弾性効果のためである。この筆者らの研究は、アモルファス金属が驚くほど高い強さを持ち、しかも大きな塑性変形能をもつ強靱性材料であることを明らかにした点で極めて重要な発表であると共に、その後、アモルファス金属が新材料として一躍脚光を浴びるきっかけをつくった点で大きな役割を果たしたと言える。

さらに1973年には、筆者らによって実用的に重要な鉄基アモルファス合金(Fe-P-C, Fe-Si-Bなど)のリボン試料が作られ、多くの共同研究者と共に種々の材料物性の実験が実施された。そして1974年には、Fe基合金の高強靱性、高軟磁性、超耐食性を次々と発表したのである。これらの優れた特性の発見は、後に「アモルファス金属の三大特性」として高く評価されており、図1において1974年を境として急激に論文数が増加する原因となったと言っても過言ではない。すなわち、1975年に増本ら⁽³⁷⁾はFe-P-C合金の降伏強さが約3200 MPaであり、鉄鋼よりも強いことを発表した。また

1974年、藤森ら⁽³⁸⁾と Egami ら⁽³⁹⁾が磁気的性質を詳細に調べ、ほぼ同時にアモルファス鉄合金が高い飽和磁化と小さい保磁力を有する優れた軟磁性材料であることを発表し、そして1975年には、菊地ら⁽⁴⁰⁾が零磁歪組成の Co-Fe-Si-B 系合金が高透磁率材料であることを見出した。さらに1974年、奈賀ら⁽⁴¹⁾は、Fe-P-C 系合金に Cr 元素を少量添加すると現用の18-8 ステンレスの約100万倍の超耐食性が現れることを発表し、その機構を考察した。このように、当時、アモルファス金属研究において我が国が先行することができたのは、独自の製法によって容易に試料が作製できたためであったと言える⁽³¹⁾。

その後、世界において広い学問分野へと拡大し、精力的な研究が行われ、1980年頃までにアモルファス金属の基礎的物性がほぼ明らかにされた。例えば、靱性、加工性、疲労性、破壊機構、粘弾性、粘性などの機械的性質⁽⁴²⁾⁽⁴³⁾、磁歪、透磁率周波数特性、鉄損、メスbauer効果、スピングラスなどの磁気的性質⁽⁴⁴⁾⁻⁽⁴⁶⁾、腐食機構、水素脆性、応力腐食、触媒などの化学的性質⁽⁴⁷⁾、インバー効果、エリンバー効果など⁽⁴⁸⁾、超伝導性⁽⁴⁹⁾、その他照射効果、臨界冷却速度、粉末固化現象などの物性研究が行われた⁽⁵⁰⁾⁽⁵¹⁾。なお、当時の激烈な競争時代に記述された解説書⁽¹²⁾⁻⁽¹⁹⁾では、各々著者自身の立場で独自の解説を行っており、必ずしも一致しない点が見受けられる。このような歴史的な経過については、今後次第に明らかにされることであろう。

3. アモルファス金属研究の最近の進展(1980年～現在)

1980年以降のアモルファス金属の研究は、それまでのようなアモルファス相自身に関する研究だけではなく、図5に示すように、アモルファス相を結晶化させることによって新材料を生み出す研究へと拡がりを見せたのが特徴であろう。また、材料面では、鉄族基合金を中心とした材料から、Al, Mg, Ti を主体とする軽合金がトピックスとなっている。

実は、1980年代中頃は大きな変化の時代であった。1984年に、液体急冷した Al-Mn 2 元系合金に 5 回対称性構造をもつ新しい物質「準結晶」が発見⁽⁵²⁾され、また続いて高い超伝導転移温度を有するペロブスカイト型酸化物が発見⁽⁵³⁾され、材料研究に一大ブームを呼び起こしたために、多くの研究者がこれらの新しい研究課題に興味を移していった。このために、アモルファス金属の研究者人口が大きく低下したのである。しかしながら、常温で粉末混合するメカニカル・アロイイング法⁽⁵⁴⁾(1983)や水素吸収誘起法⁽⁵⁵⁾(1987)によってアモルファス相が生成することが報告され、続いて新しい観点からのアモルファス金属の研究が開拓されたことにより、再び脚光を浴び始めている。新材料としては、1988年に、アモルファス相を低温加熱することによって得られたナノ結晶合金(Fe-Si-B-Nb-Cu 系)が優れた軟磁性を示すことが

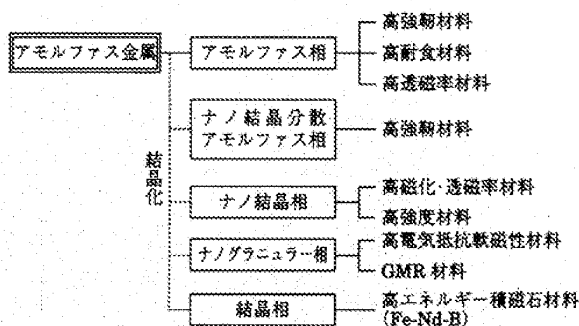


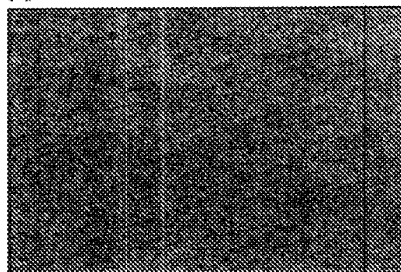
図5 アモルファス金属からナノ結晶相、ナノ結晶分散相、ナノグラニューラー相への展開と実用材料。

発見⁽⁵⁶⁾され、また、新しい高強度 Al 基⁽⁵⁷⁾および Mg 基⁽⁵⁸⁾アモルファス合金が開発され、さらに1988年にアモルファス相中にナノ Al 結晶が均一に分散した1600 MPaの強度を有する Al 基軽合金⁽⁵⁹⁾が発見され、最近には広い過冷却液体領域をもつ新しい金属ガラス⁽⁶⁰⁾が出現した。これらの先導的研究のほとんどは我が国において行われており、世界から注目を集めている。幾つかの解説⁽⁶¹⁾⁻⁽⁶⁶⁾があるので詳しくはそれらを参照されたい。

アモルファス相を結晶化させることによってナノ結晶が生成することは、1975年すでに増本ら⁽⁶⁷⁾によって報告されており、低温加熱によって約10ナノメートル径の結晶粒集合体が形成されることが明らかにされていた。最近の研究によれば、このナノ結晶は極めて安定であり、数100度におたつてほとんど成長しないことがわかっている。この理由は、アモルファス相中からナノ金属結晶粒が析出することによって、粒子からアモルファス形成元素が排出されて粒子界面に安定なアモルファス層が形成され、ナノ結晶の成長を抑制すると考えられている。したがって、アモルファス結晶化法はナノ結晶を作製する有力な方法と言えよう。図6には、その組織の模式図を示してある。

液体急冷による材料研究の進展に加えて、スパッター法による薄膜の分野でも大きな進展を見せている。例えば、軟磁性薄膜においては、アモルファス単相膜から種々の多層膜へと移行しており、ことに、1985年に唐門ら⁽⁶⁸⁾によって見出された新しい Fe-B-N 磁性薄膜が注目されている。最近ではグラニューラー相と呼ばれているが、この合金は高電気抵抗と強磁性を有し、MHz~GHz 高周波用軟磁性薄膜として期待されているもので、この機構は、図6に示すように、ナノ強磁性粒子間の数ナノ厚みの薄い絶縁層(窒化物、酸化物などのアモルファス層)を通したトンネル効果(強磁性トンネル接合)によると推測されている。このタイプの薄膜としては (Fe, Co)-M-O が有望であり、とくに (Fe, Co)-Al-O 系薄膜⁽⁶⁹⁾が注目されている。

[1] アモルファス単相



[1] アモルファス単相

- (1) 金属 (Fe, Co, Ni)-非金属 (B, C, P, Si...)
- (2) 金属 (Fe, Co, Ni)-IVa~Vla 族金属 (Zr, Hf, Nb...)
- (3) 金属 (Fe, Co, Ni)-希土類金属 (Nd, Gd, Tb, Sm, Y...)

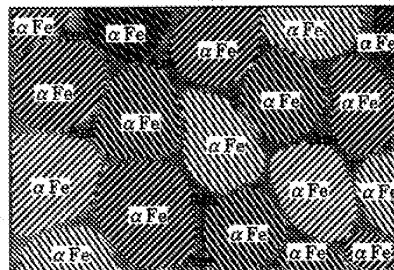
[2] ナノ結晶相

- (1) 金属 (Fe, Co, Ni)-非金属 (B, C, P, Si...)
- (2) 金属 (Fe, Co, Ni)-IVa~Vla 族金属 (Zr, Hf, Nb...)

[3] ナノグラニューラー相

- (1) 金属 (Fe, Co, Ni)-金属 (Hf, Al, Si, 希土類...)-ガス元素 (N, O, F)

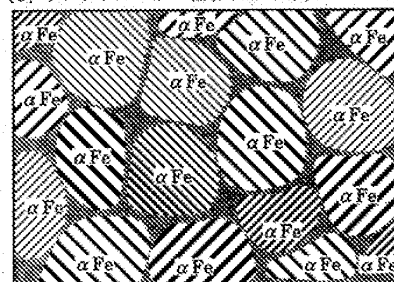
[2] ナノ結晶相 (Fe-Zr-B 系)



α -Fe α -Fe(B) 強磁性相

Zrリッチ Fe-B アモルファス相

[3] ナノグラニューラー相 (Fe-Al-O 系)



α -Fe α -Fe 強磁性相

Al-O ガラス状相

図6 アモルファス相, ナノ結晶相, ナノグラニューラー相の各組織の模式図と合金組成.

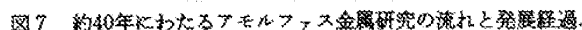
このように次々と生まれた新しい材料の出現によって、アモルファス金属分野の研究は再び大きく注目され始めている。図7はこの一連の研究の流れを示した図であり、1980年後半から、アモルファス相の研究からナノ結晶分散型アモルファス相、ナノ結晶相、グラニューラー構造相の研究へと領域が拡大していることを示している。ことに、金属ガラスの出現は従来のアモルファス金属のイメージを大きく変えた点で画期的であり、今後の研究の進展が大いに期待される。

4. 実用化を遅らせた日米間のハイテク紛争

アモルファス金属の実用化を大きく遅らせたのは、不幸にも二度に亘る日米間の紛争である(図7)⁽⁷⁰⁾。最初は1983年から1986年にかけて続いた特許紛争であり、Allied社(旧名)が米国でもつ特許を侵害し、製品を輸出して被害を与えたとして、日本、ドイツの5企業をITC(国際貿易委員会)に提訴した事件であった。3年にわたるITCの判決結果は、日本における筆者らの先行研究が認められて、Allied社の申し立てを無効としたのである。ところが、皮肉にも、このITCの判決が下される直前に、Allied社の合金基本組成に

関する日本特許が成立してしまうと言う皮肉な結果となった。これは日米間の特許制度の相違に基づくものであり、国では我々の先行成果が認められたにもかかわらず、日本先願制度と物質特許を認めない制度のために負けたと言える。ともかく、このために日本国内におけるアモルファス磁性合金の実用化の勢いが大きくそがれる結果となっていたのである。

続いて1990年には、再びAllied社(旧名)が、アモルファス合金の日本への輸出不振を理由に米国政府に訴えを起し、スーパー301条の問題として日米間の経済摩擦の一つ取り挙げられた。この問題の解決には、一緒に提出されていた半導体や米の輸入問題を優先的に検討するために、日本がアモルファス合金の輸入を無条件に承認してしまい、決られた台数の柱上トランス鉄心材料を毎年購入することで着してしまったのである。この二度にわたる日米間のハイテク戦争は我が国の敗北となり、このために日本におけるアモルファス磁性合金の大型応用製品の開発が大幅に遅れることになったのである。しかしながら、この応用分野は全体から見れば僅一部分であり、その他の大部分の応用分野では我が国の優位性が確保されているのが現状である。



最後に、これまで共同研究を行った方々および協力をいただいた方々に対し心から感謝を申し上げる。

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Confirmation Number:	8147
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First Named Inventor/Applicant Name:	Kojiro Komagaki
Customer Number:	50535
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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY. DOCKET NO	TOT CLAIMS	IND CLAIMS
12/955,767	11/29/2010	2627	1090	HIT1P585/HJP920090046US1	17	1

CONFIRMATION NO. 8147

50535
ZILKA-KOTAB, PC- HIT
P.O. BOX 721120
SAN JOSE, CA 95172-1120

FILING RECEIPT



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Date Mailed: 12/13/2010

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

Applicant(s)

Kojiro Komagaki, Odawara, JAPAN;
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Assignment For Published Patent Application

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The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/955,767**

Projected Publication Date: 06/09/2011

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Early Publication Request: No
Title

MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF

Preliminary Class

360

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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 12/955,767	
APPLICATION AS FILED - PART I						
(Column 1)		(Column 2)		SMALL ENTITY		OR
FOR	NUMBER FILED	NUMBER EXTRA	RATE(\$)	FEE(\$)	OTHER THAN SMALL ENTITY	
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A		N/A	330
SEARCH FEE (37 CFR 1.16(k), (l), or (m))	N/A	N/A	N/A		N/A	540
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A		N/A	220
TOTAL CLAIMS (37 CFR 1.16(j))	17	minus 20 = *			x 52 =	0.00
INDEPENDENT CLAIMS (37 CFR 1.16(h))	1	minus 3 = *			x 220 =	0.00
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is \$270 (\$135 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).					0.00
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))						0.00
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL		TOTAL	1090
APPLICATION AS AMENDED - PART II						
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY
AMENDMENT A	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)	OTHER THAN SMALL ENTITY
	Total (37 CFR 1.16(i))	*	Minus	**	=	RATE(\$)
	Independent (37 CFR 1.16(h))	*	Minus	***	=	ADDITIONAL FEE(\$)
	Application Size Fee (37 CFR 1.16(s))					x
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					=
			TOTAL		TOTAL	
			ADD'L FEE		ADD'L FEE	
(Column 1)		(Column 2)		(Column 3)		SMALL ENTITY
AMENDMENT B	CLAIMS REMAINING AFTER AMENDMENT	HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE(\$)	ADDITIONAL FEE(\$)	OTHER THAN SMALL ENTITY
	Total (37 CFR 1.16(i))	*	Minus	**	=	RATE(\$)
	Independent (37 CFR 1.16(h))	*	Minus	***	=	ADDITIONAL FEE(\$)
	Application Size Fee (37 CFR 1.16(s))					x
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					=
			TOTAL		TOTAL	
			ADD'L FEE		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 found in the appropriate box in column 1.						

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

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Date of Application: 2009年12月 8日

出 願 番 号
Application Number: 特願2009-278388

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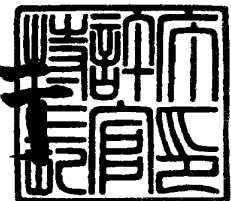
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出 願 人
Applicant(s): ヒタチグローバルストレージテクノロジーズネザーランドビービー

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特許庁長官
Commissioner,
Japan Patent Office

岩井良行



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【書類名】明細書

【発明の名称】磁気抵抗効果ヘッド、磁気記録再生装置

【技術分野】

【0001】

本発明は、磁気抵抗効果ヘッドと、磁気抵抗効果ヘッドを搭載した磁気記録再生装置に関するものである。

【背景技術】

【0002】

磁気ディスク装置に用いられる磁気ヘッドは、記録媒体に記録された情報を読み取る再生ヘッドを備える。再生ヘッドには、記録媒体に記録された磁化信号に応答して抵抗値が変化する磁気抵抗効果膜が用いられている。

【0003】

この磁気抵抗効果膜は、磁化方向が一方向に固定されている磁化固定層と、媒体からの信号磁界によって磁化方向が自由に変化する磁化自由層を備え、媒体の磁化信号の作用によって磁化自由層と磁化固定層それぞれの磁化方向の相対角度が変化することで生じる磁気抵抗変化を検出して信号を読み取る。したがって、再生ヘッドの読み取り性能を高めるためには、大きな磁気抵抗変化を示す磁気抵抗効果膜、およびそれを備えた磁気抵抗効果素子が必要となる。

【0004】

磁気抵抗効果素子の膜構成として、磁化固定層と磁化自由層の間に、絶縁体を用いて構成されたトンネルバリア層を配置した構成が知られている。

【0005】

下記特許文献1では、トンネルバリア層としてMgOを使用した磁気抵抗効果素子が非常に大きな磁気抵抗変化率（TMR比）を示すことが記載されている。

【0006】

下記特許文献2では、工業的に広く用いられているスパッタ法で作成されたCoFeB磁性層、およびMgOバリア層を用いたCoFeB/MgO/CoFeBトンネル磁気抵抗素子が、200%を超える高いTMR比を示したことが記載されている。

【0007】

下記非特許文献1では、CoFeB/MgO/CoFeBトンネル磁気抵抗素子で高いTMR比が発現する理由が考察されている。同文献によると、高いTMR比が得られる理由は、成膜直後では非結晶質（アモルファス）であるCoFeB層が、熱処理を実施した時に、（001）配向結晶を有するトンネルバリア層に沿って（001）配向結晶となるためであると考えられている。

【0008】

以上から、再生ヘッドに適用するTMR素子が高いTMR比すなわち高い再生出力を得るためには、トンネルバリア層として（001）配向結晶性を有する絶縁層を用い、さらに磁化固定層および磁化自由層にCoFeB層を用いることが非常に有効であると考えられる。

【先行技術文献】

【特許文献】

【0009】

【特許文献1】特許第4082711号公報

【特許文献2】特開2006-80116号公報

【非特許文献】

【0010】

【非特許文献1】J. Hayakawa et al., Jpn. J. Appl. Phys., 44 L587 (2005).

【発明の概要】

【発明が解決しようとする課題】

【0011】

近年は、ハードディスクドライブの高記録密度化にともない記録媒体上のビット幅がますます狭くなっている。このため、記録媒体上に記録されている磁気信号を読み取るためには、再生ヘッドのリードギャップを狭くすることにより、読み取り分解能を向上させることが必要となる。リードギャップは、磁気抵抗効果膜の膜厚に相当する。

【0012】

磁気抵抗効果膜を薄くするためには、磁気抵抗効果膜の多くを占める、磁化固定層を構成するC o F e B層、または磁化自由層を構成するC o F e B層のうち少なくとも一方の膜厚を薄くすることが有効である。

【0013】

しかしながら、C o F e B層を薄くするとTMR比が大きく劣化する可能性がある。これは、磁気抵抗効果膜を形成した後に実施する熱処理過程において、磁化固定層に隣接する非磁性結合層もしくは反強磁性層の整合性に起因するエピタキシャル関係により、C o F e B層がトンネルバリア層の原子配列に沿って結晶化されることが阻害されるためであると考えられる。磁化自由層については、隣接するキャッピング層の原子配列の整合性によるエピタキシャル関係が同様に関連していると思われる。

【0014】

本発明は、上記のような課題を解決するためになされたものであり、磁化固定層または磁化自由層の膜厚を薄くすることによるMR比の劣化を抑制することができる磁気抵抗効果ヘッド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】

【0015】

本発明に係る磁気抵抗効果ヘッドにおいて、磁化固定層または磁化自由層の少なくとも一方は、バリア層の反対側にアモルファス磁性層を有する。ここでいうアモルファス磁性層は、磁気抵抗効果ヘッドの製造過程で一般的に行われる、反強磁性層の着磁熱処理、絶縁膜・磁性膜の結晶化熱処理などを経た後に、非結晶質状態を保持しているもののことである。

【発明の効果】

【0016】

本発明に係る磁気抵抗効果ヘッドによれば、アモルファス磁性層の非結晶質性により、C o F e B磁性層におけるアモルファス磁性層側からのエピタキシャル関係が消失すると考えられる。これにより、磁化固定層もしくは磁化自由層の少なくとも一方のC o F e B層の膜厚を薄くした場合でも、C o F e B磁性層のバリア層側とは反対側からの結晶性の影響が低減され、バリア層側の原子配列に沿った結晶化が実現する。したがって、C o F e B磁性層を薄くしても、MR比の劣化を抑制し、磁気抵抗効果膜の薄膜化と高いMR比を両立する磁気抵抗効果ヘッドを構成することができる。

【図面の簡単な説明】

【0017】

【図1】従来の磁気抵抗効果素子の膜構成例を示す側断面図である。

【図2】実施の形態1に係る磁気抵抗効果素子の膜構成を示す側断面図である。

【図3】実施の形態1に係るトンネル磁気抵抗効果膜を備える磁気ヘッドの構成図である。

【図4】実施の形態2に係る磁気抵抗効果素子の膜構成を示す側断面図である。

【図5】実施の形態3に係る磁気抵抗効果素子の膜構成を示す側断面図である。

【図6】実施の形態4に係る磁気記録再生装置50の上面図である。

【発明を実施するための形態】

【0018】

以下、本発明を実施するための最良の形態について、図面を参照して詳細に説明する。なお、以下の説明においては、図面は代表的な例として示されたものであり、本発明の範囲を限定するものではない。図面はボトムタイプスピナバルブ構造を表しているが、本発明はトップタイプスピナバルブ構造、もしくはデュアルスピナバルブ構造にも適用可能で

ある。

【0019】

図1は、従来の磁気抵抗効果素子の膜構成例を示す側断面図である。ここでは、ボトムタイプトンネル磁気抵抗効果素子の膜構成例を示した。

【0020】

磁気抵抗効果素子には、電流を磁気抵抗効果膜面に流すCIP (Current in Plane) 型の素子と、膜面垂直方向に流すCPP (Current Perpendicular to the Plane) 型の素子がある。

【0021】

図1に示す磁気抵抗効果素子は、下部シールド層100と上部シールド層300との間にトンネル磁気抵抗効果膜200を有する。トンネル磁気抵抗効果膜200は、下地層210、反強磁性層220、磁化固定層230、トンネルバリア層240、磁化自由層250、キャッピング層260を有する。リードギャップは、下地層210からキャッピング層260までの膜厚を加えたものに相当する。

【0022】

図1に示す膜構成では、磁化固定層230のトンネルバリア層240とは反対側に反強磁性層220が配置され、磁化自由層250のトンネルバリア層240とは反対側にキャッピング層260が配置されている。

【0023】

反強磁性層220とキャッピング層260からのエピタキシャル関係により、磁化固定層230または磁化自由層250のCoFeB層が、トンネルバリア層240の原子配列に沿って(001)配向結晶化することが阻害されることが考えられる。

【0024】

<実施の形態1>

図2は、本発明の実施の形態1に係る磁気抵抗効果素子の膜構成を示す側断面図である。以下、図2の膜構成について説明する。

【0025】

下部シールド層100は、例えばメッキ法により形成されたパーマロイで構成される。

【0026】

下部シールド層100上に形成される下地層210は、下部シールド層100側からTaとRuとの積層構造となっている(図示せず)。

【0027】

下地層210上には、反強磁性層220が形成されている。反強磁性層220は、その上に形成される第1磁化固定層230の磁化方向を一方向に固定させるものであり、例えばMnIrにより構成される。反強磁性層220は、MnPt、PdPtMn、NiMn、FeMn、RhMn、RuMn、RuRhMnなどによって構成することもできる。

【0028】

反強磁性層220上に形成される磁化固定層230は、積層フェリ構造となっている。具体的には磁化固定層230は、第1磁化固定層231/非磁性結合層232/第2磁化固定層233の3層構造で構成される。第1磁化固定層231と第2磁化固定層233の間は、非磁性結合層232を介して反強磁性結合が実現している。

【0029】

第1磁化固定層231は、例えばCoとFeからなる合金材料により構成される。非磁性結合層232は、例えばRu、Cr、Ir、Rhのうち1種もしくは2種以上からなる合金を用いて構成することができる。

【0030】

第2磁化固定層233は、トンネルバリア層240と接する側から順に、CoFe磁性層233c、CoFeB磁性層233a、アモルファス磁性層233bの3層からなる積層構造で構成される。アモルファス磁性層233bは、CoFeBとTa、Hf、Zr、Nbからなる群から選択された元素とを含む層である。

【0031】

CoFe磁性層233cのCoとFeの組成比は、面心立方構造もしくは六方最密構造を有する、Co:Feが75:25から100:0の組成範囲が好適である。また、CoFe磁性層233cの膜厚は、TMR比の観点から、0.5nm~1.4nmとすることが好ましい。

【0032】

CoFeB磁性層233aのCoとFeの組成比は、結晶化後に面心立方構造を有する100:0から75:25の組成範囲、もしくは体心立方構造を有する75:25から0:100の組成範囲が好適である。特に、体心立方構造を有する75:25から0:100の組成範囲が好適である。

【0033】

アモルファス磁性層233bの膜厚は、0.25~1.5nm程度が好適である。

【0034】

磁化固定層230上には、絶縁体で構成されるトンネルバリア層240が形成されている。トンネルバリア層240を構成する材料としては、例えばMg、Ca、Zn、Sr、Al、Tiのうち1種もしくは2種以上からなる酸化物、窒化物等の絶縁材料を使用することができる。

【0035】

トンネルバリア層240は、岩塩構造の(001)配向結晶性を有する絶縁体を用いて構成するとき最良の効果を得ることができる。このようなトンネルバリア層240は、スパッタリング法や蒸着法により成膜された金属膜を酸化、または窒化することにより得ることができる。もしくは、酸化物、窒化物ターゲットを用いて形成することもできる。

【0036】

トンネルバリア層240上に形成される磁化自由層250は、トンネルバリア層240側から順に、CoFe磁性層250c、CoFeB磁性層250a、アモルファス磁性層250bの3層からなる積層構造で構成される。アモルファス磁性層250bは、CoFeBとTa、Hf、Zr、Nbからなる群から選択された元素とを含む層である。

【0037】

CoFeB磁性層250aのCoとFeの組成比は、結晶化後に面心立方構造を有する100:0から75:25の組成範囲、もしくは体心立方構造を有する75:25から0:100の組成範囲が好適である。特に、面心立方構造を有する100:0から90:10の範囲内が好適である。また、CoFe磁性層250cの膜厚は、TMR比の観点から0.5nm~1.0nm程度であることが好ましい。

【0038】

磁化自由層250は、磁歪を最小化することが好ましいため、例えばNiFe層をアモルファス磁性層250b上に形成することもできる(図示せず)。

【0039】

トンネル磁気抵抗効果膜200の最上部に形成されるキャッピング層260は、例えばRuとTaの積層構造からなる。

【0040】

図3は、本実施の形態1に係るトンネル磁気抵抗効果膜を備える磁気ヘッドの構成図である。ここでは、ABS面(A-A線位置)に対して垂直な面方向の断面図を示した。

【0041】

この磁気ヘッドは、再生ヘッド35と記録ヘッド40を有する。再生ヘッド35は、下部シールド層100と上部シールド層300に挟まれて形成されている磁気抵抗効果膜200を備える。

【0042】

記録ヘッド40は、主磁極41、第1リターンヨーク42、第2リターンヨーク43を備える。第2リターンヨーク43の前端部には、トレーリングシールド44が設けられている。主磁極41の後方のヨーク部にはコイル45が巻回されている。

【0043】

以上、本実施の形態1に係る磁気抵抗効果膜および磁気ヘッドの構成を説明した。本実施の形態1では、磁化固定層230と磁化自由層250の双方にアモルファス磁性層を配置した例を説明したが、いずれか一方のみにアモルファス磁性層を配置しても、その分に相応する効果を発揮することができる。

【0044】

以上のように、本実施の形態1に係る磁気抵抗効果膜において、第2磁化固定層233および磁化自由層250は、トンネルバリア層240側から順に、CoFe磁性層/CoFeB磁性層/アモルファス磁性層からなる積層構造を有する。アモルファス磁性層の非結晶質性により、CoFeB磁性層におけるアモルファス磁性層側からのエピタキシャル関係が消失すると考えられる。そのため、磁化固定層230または磁化自由層250のCoFeB層がトンネルバリア層240の原子配列に沿って(001)配向結晶になり易くなる。これにより、磁化固定層230と磁化自由層250のCoFeB磁性層の膜厚を薄くしても、TMR比の劣化を抑制することができる。

【0045】

また、本実施の形態1に係る磁気ヘッドによれば、CoFeB磁性層の膜厚を薄くすることによりリードギャップを小さくして読み取り分解能を向上させつつ、TMR比の劣化を抑制して高い再生出力を得ることができる。

【0046】

<実施の形態2>

図4は、本発明の実施の形態2に係る磁気抵抗効果素子の膜構成を示す側断面図である。図4に示す膜構成は、実施の形態1の図2で説明した構成に加え、非磁性結合層232とアモルファス磁性層233bの間にCoFe層233dを有する。CeFe層233dの膜厚は、例えば0.5nm~1.0nm程度である。

【0047】

本実施の形態2に係る膜構成を用いても、実施の形態1と同様の効果を発揮することができる。

【0048】

<実施の形態3>

図5は、本発明の実施の形態3に係る磁気抵抗効果素子の膜構成を示す側断面図である。図5に示す膜構成は、磁化固定層230が第2磁化固定層233のみで構成されている点が図4とは異なる。その他の構成は図4と同様である。

【0049】

このトンネル磁気抵抗効果膜の構成では、磁化固定層230が第2磁化固定層233のみで形成される、いわゆるシングルピンタイプ構造を有する。シングルピンタイプの磁気抵抗効果膜では、反強磁性層220と第2磁化固定層233の間にはたらく一方向異方性磁界Hpが磁化固定層230の外部磁界耐性に直接的に反映される。

【0050】

Hpは、一方向異方性定数Jk、第2磁化固定層233の飽和磁化量Ms、膜厚tを用いて、下記(式1)で表される。

【0051】

$$H_p = J_k / (M_s \cdot t) \quad \dots (式1)$$

【0052】

上記(式1)によれば、Hpは(Ms・t)が小さいほど大きくなり、第2磁化固定層233は強固に固着されることが分かる。

【0053】

本実施の形態3において、磁化固定層230は、トンネルバリア層240と接する側から順に、CoFe磁性層233c、CoFeB磁性層233a、アモルファス磁性層233bからなる積層構造を有する。アモルファス磁性層233bは、CoFeB層233aと比較してMsが小さい。そのため、本実施の形態4における磁化固定層230の(Ms

・t)は小さくなる。したがって、アモルファス磁性層233bを用いない従来のシングルピントタイプの磁気抵抗効果膜に比べて H_p が増大し、磁化固定層230の外部磁界耐性が向上する。

【0054】

以上のように、本実施の形態3によれば、磁化固定層230をトンネルバリア層240側から順に、CoFe磁性層233c、CoFeB磁性層233a、アモルファス磁性層233bの積層構造としたので、実施の形態1～2と同様の効果が得られる。

【0055】

なお、上記実施の形態1～2では、トンネル磁気抵抗効果膜を形成した後に熱処理が施される。例えば、数K Ω eから数10K Ω eの一定方向に印加された磁場中で、240℃から350℃程度の温度で数10分から数時間の熱処理が施される。

【0056】

<実施の形態4>

図6は、本発明の実施の形態4に係る磁気記録再生装置50の上面図である。磁気記録再生装置50は、実施の形態1～3いずれかで説明した磁気抵抗効果膜200の構成を有する磁気ヘッドを備える。

【0057】

磁気記録再生装置50は、矩形の箱状に形成されたケーシング51内に、スピンドルモータによって回転駆動される複数の磁気記録媒体52を備える。磁気記録媒体52の側方には、媒体面に平行に揺動可能に支持されたアクチュエータアーム53が配されている。アクチュエータアーム53の先端には、アクチュエータアーム53の延長方向にサスペンション54が取り付けられ、サスペンション54の先端にヘッドスライダ55が磁気ヘッドを媒体面に向けて取り付けられている。

【0058】

ヘッドスライダ55には、前述した磁気抵抗効果膜200を備える再生ヘッド35が形成された磁気ヘッドが形成されている。

【0059】

磁気ヘッドは、サスペンション54に形成された配線、およびアクチュエータアーム53に付設されたフレキシブルケーブル56を介して、制御回路に接続される。制御回路は、磁気記録媒体52に信号を記録し、磁気記録媒体52に記録された信号を再生する。

【0060】

磁気ヘッドにより磁気記録媒体52に情報を記録し、情報を再生する処理は、アクチュエータ57により、アクチュエータアーム53を所定位置に揺動させる操作（シーク動作）とともになされる。

【実施例】

【0061】

以下では、本発明の実施例および比較のための参考実施例を説明する。

【0062】

<実施例1>

本実施例1では、トンネル磁気抵抗効果膜を構成するアモルファス磁性層のアモルファス性を検証した例を説明する。本実施例1では、アモルファス磁性層の構成としてCoFeB T_a を採用し、その熱処理前後におけるアモルファス性を実験により調査した。下記に本実施例1で用いたサンプルの膜構成を示す。左側が基板側（図1等における下側）に相当し、（）内は各層の膜厚を示す。

【0063】

Ta(3nm)/Ru(2nm)/Mn₇₅Ir₂₅(6nm)/Ru(0.8nm)/
(Co₄₀Fe₄₀B₂₀)_{100-x}Ta_x(10nm)/Ta(3nm)

上記層構成のうち、アモルファス磁性層を構成する(Co₄₀Fe₄₀B₂₀)_{100-x}Ta_xのxは原子% (at. %)の組成比を示す。括弧内の(Co₄₀Fe₄₀B₂₀)はCoとFeとBが40:40:20の組成比であることを示している。(Co₄₀

Fe₄₀B₂₀)とTaの組成比は、それぞれの成膜レートから換算した。Taの組成xは、それぞれ3、6、9、13、17at.%と変化させた。

【0064】

作成したサンプルに対して、アモルファス性を同定するため、振動試料型磁力計(VSM)およびX線回折装置(XRD)を用いて成膜した直後、280℃熱処理後および320℃熱処理後それぞれの単位面積あたりの飽和磁化と回折ピークを測定した。

【0065】

CoFeB磁性層が熱処理により結晶化すると、Bの拡散の影響でCoFeB磁性層の磁化量が増加する。したがって、CoFeBTaアモルファス磁性層の熱処理前後での飽和磁化に変化がないことを確認することにより、アモルファス磁性層のアモルファス性を同定することができる。また、X線による回折ピークが観測されないことでもアモルファス性を同定することができる。上記2種類の手法でCoFeBTaアモルファス磁性層のアモルファス性を同定した。これらの結果を表1に示す。表中のTはテスラを表す。

【0066】

【表1】

Ta (at.%)	成膜直後の飽和磁化	280℃熱処理後の飽和磁化	320℃熱処理後の飽和磁化	320℃熱処理後回折ピーク有無
3	1.264T	1.270T	1.272T	無
6	0.991T	1.00T	1.00T	無
9	0.758T	—	—	無
13	0.300T	—	—	無
17	0.032T	—	—	無

【0067】

表1に示すように、Ta組成3at.%から17at.%すべてのサンプルで回折ピークは観測されなかった。また、Ta組成3at.%のサンプルと、6at.%のサンプルで、成膜直後に対する280℃熱処理後および320℃熱処理後の飽和磁化の変化量はいずれも1%以下であった。

【0068】

すなわち、CoFeBTa磁性層は、Ta組成3at.%から17at.%の範囲において、少なくとも320℃の熱処理後に良好なアモルファス性を発揮したといえる。

【0069】

なお、アモルファス磁性層に関して、下記非特許文献2には、合金を構成する元素の原子半径比が12%以上の場合にアモルファス合金として安定に存在することが記載されている。したがって、本実施例1に示したTaの代わりに、例えばHf、Zr、Nbなどを用いても、同様の結果になることが容易に推定される。

【0070】

非特許文献2：『日本金属学会報 までりあ』第37巻、第5号、p339(1998)

【0071】

<実施例2>

本実施例2では、従来のトンネル磁気抵抗効果膜として、下記サンプル1を作成した。

【0072】

各層はDCマグネトロンスパッタ法を用いて成膜した。トンネルバリア層のMgOは、

まず金属Mg膜をスパッタ法により堆積させ、その後酸素とアルゴンの混合比を5：95とし、チャンバースペース圧を0.1mTorrとしたチャンバー内で自然酸化させることにより形成した。酸化時間は10秒とした。金属Mg膜は基板に対して傾斜をつけて成膜することにより基板内で異なる膜厚のトンネルバリア層を形成し、異なる面積抵抗(RA)が得られるようにした。各層を成膜した後に、磁場中熱処理炉で、50kOe、280℃、3時間の熱処理を施した。

【0073】

下記サンプル1は、図4におけるアモルファス磁性層233bおよび250bを削除したものに概ね相当する。サンプル1の左側の「Ta(1nm)/Ru(2nm)」が下地層210に相当し、右に進むにつれて1段ずつ上の層に相当する。「MgO(0.8nm)」は、トンネルバリア層240に相当する。トンネルバリア層240の右側は磁化自由層250に相当する。

【0074】

(サンプル1)

Si/Ta(1nm)/Ru(2nm)/Mn75Ir25(5nm)/Co75Fe25(2nm)/Ru(0.8nm)/Co90Fe10(0.5nm)/Co40Fe40B20(2nm)/Co90Fe10(1.4nm)/MgO(0.8nm)/Co90Fe10(0.9nm)/Co40Fe40B20(3nm)/Ru(3nm)/Ta(3nm)/Ru(4nm)

【0075】

(サンプル2)

CoFeB磁性層233a(Co40Fe40B20(2nm))の膜厚を1nmとした以外は、サンプル1と同様に作製した。

【0076】

(サンプル3)

CoFeB磁性層250a(Co40Fe40B20(3nm))の膜厚を2nmとした以外は、サンプル1と同様に作製した。

【0077】

表2に、RA値を固定したときのTMR比の値をサンプル毎に測定した結果を示す。測定方法は、CIPT(Current in plane tunneling)法を用いた。

【0078】

【表2】

サンプル番号	第2磁化固定層 CoFeB膜厚 (nm)	第2磁化固定層 膜厚 (nm)	磁化自由層 CoFeB膜厚 (nm)	磁化自由層 CoFeB膜厚 (nm)	TMR比(%)
1	2nm	3.9	3nm	3.9	80.5
2	1nm	2.9	3nm	3.9	40.4
3	2nm	3.9	2nm	2.9	72.1

【0079】

表2に示すように、サンプル1に比べて、サンプル2およびサンプル3ではTMR比が減少した。以上の結果から、従来例においては、磁化固定層、磁化自由層の少なくとも一方のCoFeB磁性層の膜厚を薄くすると、TMR比が劣化することが分かる。

【0080】

<実施例3>

本実施例3では、磁化固定層230にアモルファス磁性層233bを配置した下記サンプル4を作成した。また、比較のためのサンプル5～14を作成した。本実施例3では、磁化固定層230にアモルファス磁性層233bを配置することの効果を検証するため、磁化自由層250は従来例と同様の構成とした。

【0081】

サンプル4、およびサンプル9～12におけるCoFeBTaアモルファス磁性層は、XRDおよびVSMの結果からTa組成が3 at. %以上であり、280℃熱処理後においてアモルファス構造を保持していることが同定されている。また、サンプル14は、CoFeBTaアモルファス磁性層との比較のため、第2磁化固定層233の一部をCoFeTaアモルファス磁性層とした。

【0082】

(サンプル4)

Si/Ta (1 nm) / Ru (2 nm) / Mn₇₅Ir₂₅ (5 nm) / Co₇₅Fe₂₅ (2 nm) / Ru (0.8 nm) / Co₉₀Fe₁₀ (0.5 nm) / (Co₄₀Fe₄₀B₂₀)₉₄Ta₆ (0.5 nm) / Co₄₀Fe₄₀B₂₀ (0.5 nm) / Co₉₀Fe₁₀ (1.4 nm) / MgO (0.8 nm) / Co₉₀Fe₁₀ (0.9 nm) / Co₄₀Fe₄₀B₂₀ (3 nm) / Ru (3 nm) / Ta (3 nm) / Ru (4 nm)

【0083】

(サンプル5)

CoFeB磁性層233a (Co₄₀Fe₄₀B₂₀ (0.5 nm)) の膜厚を1.0 nmとした以外はサンプル4と同様に作製した。

【0084】

(サンプル6)

CoFeB磁性層233a (Co₄₀Fe₄₀B₂₀ (0.5 nm)) の膜厚を1.5 nmとした以外はサンプル4と同様に作製した。

【0085】

(サンプル7)

アモルファス磁性層233b ((Co₄₀Fe₄₀B₂₀)₉₄Ta₆) の膜厚を1.0 nmとした以外はサンプル4と同様に作製した。

【0086】

(サンプル8)

アモルファス磁性層233b ((Co₄₀Fe₄₀B₂₀)₉₄Ta₆) の膜厚を1.5 nmとした以外はサンプル4と同様に作製した。

【0087】

(サンプル9)

アモルファス磁性層233bを(Co₄₀Fe₄₀B₂₀)₉₇Ta₃とした以外はサンプル4と同様に作製した。

【0088】

(サンプル10)

アモルファス磁性層233bを(Co₄₀Fe₄₀B₂₀)₉₀Ta₁₀とした以外はサンプル4と同様に作製した。

【0089】

(サンプル11)

アモルファス磁性層233bを(Co₄₀Fe₄₀B₂₀)₈₇Ta₁₃とした以外はサンプル4と同様に作製した。

【0090】

(サンプル12)

アモルファス磁性層233bを(Co₄₀Fe₄₀B₂₀)₈₃Ta₁₇とした以外はサンプル4と同様に作製した。

【0091】

(サンプル13)

第2磁化固定層233からCoFeB磁性層233a (Co₄₀Fe₄₀B₂₀ (0.5 nm)) を除いた構造とした以外はサンプル4と同様に作製した。

【0092】

(サンプル14)

アモルファス磁性層233bを(Co40Fe40)₈₅Ta₁₅とした以外はサンプル4と同様に作製した。

【0093】

表3に、RA値を固定したときのTMR比の値をサンプル毎に測定した結果を示す。測定方法は、CIP T法を用いた。

【0094】

【表3】

サンプル番号	CoFeBTa膜 (nm)	CoFeB膜厚 (nm)	第2磁化固定層膜厚(nm)	Ta組成(at.%)	TMR比(%)
1	—	2.0nm	3.9nm	—	80.5%
4	0.5nm	0.5nm	2.9nm	6at%	90.3%
5	0.5nm	1.0nm	3.4nm	6at%	86.2%
6	0.5nm	1.5nm	3.9nm	6at%	87.3%
7	1.0nm	0.5nm	3.4nm	6at%	101.0%
8	1.5nm	0.5nm	3.9nm	6at%	103.9%
9	0.5nm	0.5nm	2.9nm	3at%	83.7%
10	0.5nm	0.5nm	2.9nm	10at. %	85.4%
11	0.5nm	0.5nm	2.9nm	13at. %	82.4%
12	0.5nm	0.5nm	2.9nm	17at. %	65.6%
13	0.5nm	—	2.4nm	—	20.3%
14	CoFeTa 0.5nm	0.5nm	2.9nm	15at. %	50.2%

【0095】

表3に示すように、従来例のサンプル1と本実施例のサンプル4～サンプル8の比較から、第2磁化固定層230をトンネルバリア層240側から順にCoFe磁性層233c/CoFeB磁性層233a/CoFeBTaアモルファス磁性層233bの積層構造とすることにより、第2磁化固定層230の膜厚を薄くしてもTMR比の劣化が抑制されることがわかる。

【0096】

また、サンプル9～サンプル12の比較から、Ta組成が3at.%～13at.%、特に3at.%～10at.%の範囲において高いTMR比を示していることがわかる。

【0097】

なお表1に示すように、Ta組成3at.%から10at.%の組成範囲では、CoFeBTaアモルファス磁性層は約0.75Tから1.3Tの高い飽和磁化を示し、CoFeBTaアモルファス磁性層233bとCoFe磁性層233cの間の磁氣的結合は強いものと考えられる。

【0098】

したがって、CoFeBTaアモルファス磁性層233bとCoFe磁性層233cの積層構造とする磁性層はひとつの磁性体として良好に機能し、各層の磁化方向が単独に動作して磁気抵抗効果素子としての機能が損なわれることはないものと考えられる。

【0099】

なお、サンプル4とサンプル13の比較から、第2磁化固定層233がCoFe磁性層233cとCoFeBTaアモルファス磁性層233bのみからなるトンネル磁気抵抗効果膜は、TMR比が大きく減少することが分かる。よって、CoFe磁性層233cあるいはCoFeB磁性層233aからなる結晶層とアモルファス磁性層233bとの積層構造を有する場合に本発明の効果が期待できる。したがって、以下の特許文献3から特許文献8に開示されている膜構造は積層構造ではないので、本発明の効果は得られないと考えられる。

【0100】

特許文献3：特開2001-068760号公報

特許文献4：特開2004-071714号公報

特許文献5：特開2006-134950号公報

特許文献6：特開2008-198792号公報

特許文献7：特開2008-227388号公報

特許文献8：特開2009-004784号公報

【0101】

また、サンプル4とサンプル14との比較から、B元素を含まないCoFeTaアモルファス磁性層は、TMR比が大きく低下することが分かる。B元素を含まないアモルファス磁性層で本発明の効果が得られない理由、すなわちB元素を含むアモルファス磁性層で本発明の効果が得られる理由として、次の点が挙げられる。

【0102】

アモルファス構造によってトンネルバリア層240以外からのエピタキシャル関係を切り、かつ熱処理により拡散するB原子の一部が、CoFeB磁性層233aおよびCoFe磁性層233cの結晶化に寄与すると考えられる。したがって、Bを含むアモルファス磁性層233bは、Bを含まないアモルファス磁性層よりも優れた磁化特性が得られるものと考えられる。

【0103】

本実施例3では、アモルファス磁性層233bの膜厚として0.5nm～1.5nmの範囲のサンプルを作成したが、0.25nm程度の膜厚であれば本実施例3と同等の効果を発揮するものと想定される。

【0104】

また、本実施例3では、CoFeB層233aの構成としてCo₄₀Fe₄₀B₂₀を採用したが、(CoFe)_{100-x}B_x (10≤x≤30at.%)で表される組成の範囲内であれば、本実施例3と同等の効果を発揮するものと想定される。

【0105】

<実施例4>

本実施例4では、磁化自由層250にアモルファス磁性層250bを配置したサンプル15、16を作成した。磁化固定層230は従来例と同様の構成とした。表4に、RA値を固定したときのTMR比の値をサンプル毎に測定した結果を示す。測定方法は、CIP法を用いた。

【0106】

【表4】

サンプル番号	CoFeB膜 (nm)	CoFeBTa膜厚 (nm)	磁化自由層膜厚(nm)	Ta組成(at.%)	TMR比(%)
1	3.0nm	—	3.9	—	80.5
15	2.0nm	0.5nm	3.4	6	90.3
16	1.0nm	1.0nm	2.9	6	86.2

【0107】

表4に示すように、従来例であるサンプル1と、本実施例のサンプル15、16との比較から、磁化自由層250をトンネルバリア層240側から順にCoFeB磁性層250a/CoFeBTaアモルファス磁性層250bの積層構造とすることで、磁化自由層250の膜厚を薄くしても、TMR比の劣化が抑制されることがわかる。

【0108】

なお、本実施例4において、アモルファス磁性層250bの膜厚として0.5nm～1.0nmの範囲のサンプルを作成したが、0.25nm～1.5nm程度の膜厚であれば本実施例4と同等の効果を発揮するものと想定される。

【0109】

また、本実施例4では、 CoFeB 層250aの構成として実施例3と同様に $\text{Co}_{40}\text{Fe}_{40}\text{B}_{20}$ を採用したが、 $(\text{CoFe})_{100-x}\text{B}_x$ ($10 \leq x \leq 30 \text{ at. \%}$)で表される組成の範囲内であれば、本実施例4と同等の効果を発揮するものと想定される。

【0110】

また、本実施例4では、 CoFeBTa アモルファス磁性層250bのTa組成比として6 at. %を採用したが、実施例3と同様に3～13 at. %の範囲内であれば、本実施例4と同等の効果を発揮するものと想定される。

【符号の説明】

【0111】

35：再生ヘッド、40：記録ヘッド、41：主磁極、42：第1リターンヨーク、43：第2リターンヨーク、44：トレーリングシールド、45：コイル、50：磁気記録再生装置、51：ケーシング、52：磁気記録媒体、53：アクチュエータアーム、54：サスペンション、55：ヘッドスライダ、56：フレキシブルケーブル、57：アクチュエータ、100：下部シールド層、200：トンネル磁気抵抗効果膜、210：下地層、220：反強磁性層、230：磁化固定層、231：第1磁化固定層、232：非磁性結合層、233：第2磁化固定層、233a： CoFeB 磁性層、233b：アモルファス磁性層、233c： CoFe 磁性層、233d： CoFe 層、240：トンネルバリア層、250：磁化自由層、250a： CoFeB 磁性層、250b：アモルファス磁性層、250c： CoFe 磁性層、260：キャッピング層、300：上部シールド層。

【書類名】特許請求の範囲

【請求項 1】

磁化方向が固定されている磁化固定層と、
磁化方向が変化する磁化自由層と、
前記磁化固定層と前記磁化自由層の間に配置され絶縁体を用いて形成されているバリア層と、
を備え、
前記磁化固定層または前記磁化自由層の少なくとも一方は、前記バリア層側から順に、
C o F e 磁性層もしくはC o F e B 磁性層からなる結晶層と、
C o F e B と、T a、H f、Z r、N b からなる群から選択された元素と、を含むアモルファス磁性層と、
を有する積層構造になっている
ことを特徴とする磁気抵抗効果ヘッド。

【請求項 2】

前記磁化固定層は前記積層構造を有することを特徴とする請求項 1 記載の磁気抵抗効果ヘッド。

【請求項 3】

前記磁化固定層を構成する前記アモルファス磁性層の膜厚は0.25nm～1.5nmの範囲であることを特徴とする請求項 2 記載の磁気抵抗効果ヘッド。

【請求項 4】

前記磁化固定層を構成する前記C o F e B 磁性層は、 $(\text{C o F e})_{100-x}\text{B}_x$ ($10 \leq x \leq 30 \text{ a t. \%}$) で表される組成を有することを特徴とする請求項 2 記載の磁気抵抗効果ヘッド。

【請求項 5】

前記磁化固定層を構成する前記アモルファス磁性層は、 $(\text{C o F e})_{100-x}\text{B}_x\text{A}_y$ (AはT a、H f、Z r、N b からなる群から選択された元素、 $10 \leq x \leq 30$ 、 $3 \leq y \leq 13 \text{ a t. \%}$) で表される組成を有することを特徴とする請求項 2 記載の磁気抵抗効果ヘッド。

【請求項 6】

前記磁化自由層は前記積層構造を有することを特徴とする請求項 1 記載の磁気抵抗効果ヘッド。

【請求項 7】

前記磁化自由層を構成する前記アモルファス磁性層の膜厚は0.25nm～1.5nmの範囲であることを特徴とする請求項 6 記載の磁気抵抗効果ヘッド。

【請求項 8】

前記磁化自由層を構成する前記C o F e B 磁性層は、 $(\text{C o F e})_{100-x}\text{B}_x$ ($10 \leq x \leq 30 \text{ a t. \%}$) で表される組成を有することを特徴とする請求項 6 記載の磁気抵抗効果ヘッド。

【請求項 9】

前記磁化自由層を構成する前記アモルファス磁性層は、 $(\text{C o F e})_{100-x}\text{B}_x\text{A}_y$ (AはT a、H f、Z r、N b からなる群から選択された元素、 $10 \leq x \leq 30$ 、 $3 \leq y \leq 13 \text{ a t. \%}$) で表される組成を有することを特徴とする請求項 6 記載の磁気抵抗効果ヘッド。

【請求項 10】

請求項 1 から 9 までのいずれか 1 項に記載の磁気抵抗効果ヘッドを搭載した磁気記録再生装置。

【書類名】 要約書

【要約】

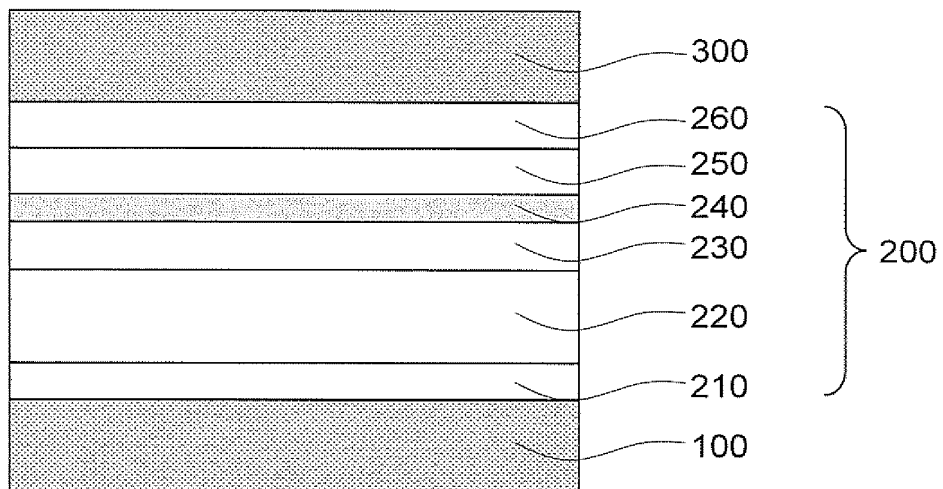
【課題】 磁化固定層または磁化自由層の膜厚を薄くすることによるMR比の劣化を抑制することができる磁気抵抗効果ヘッドを提供する。

【解決手段】 本発明に係る磁気抵抗効果ヘッドにおいて、磁化固定層または磁化自由層の少なくとも一方は、バリア層の反対側にアモルファス磁性層を有する。

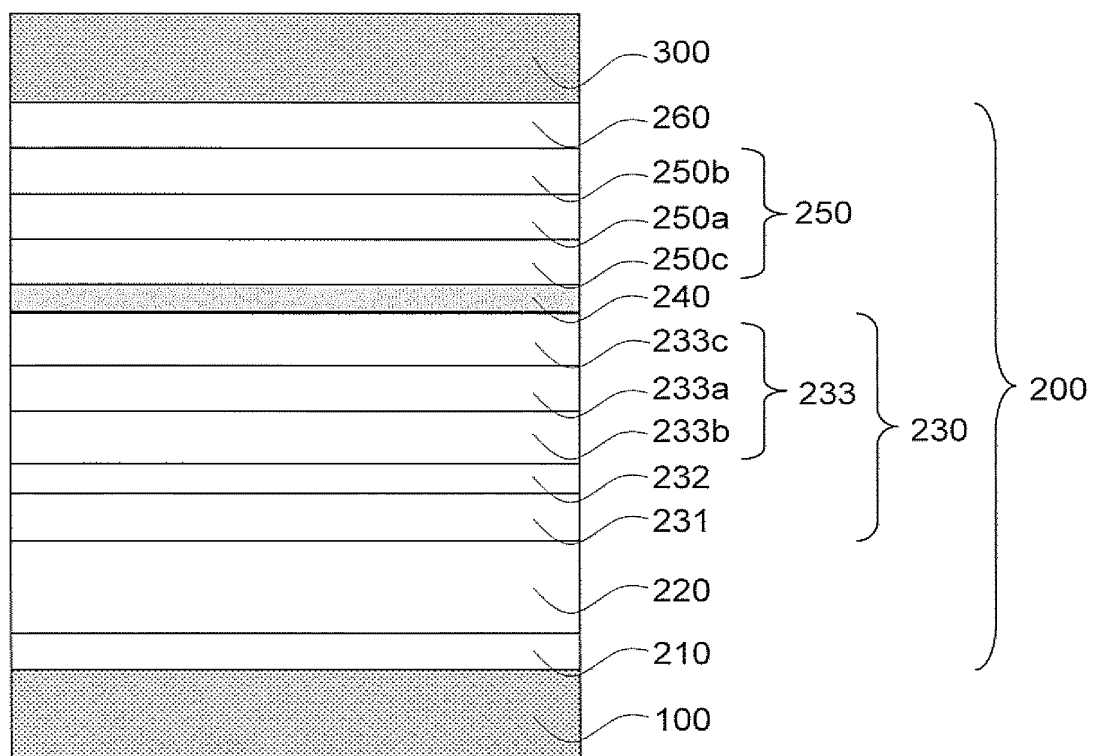
【選択図】 図2

【書類名】 図面

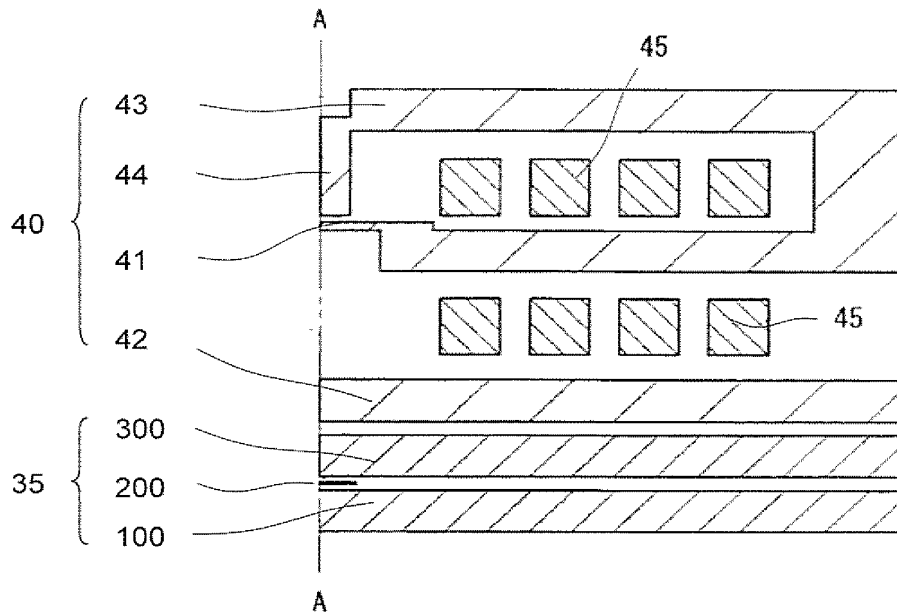
【図 1】



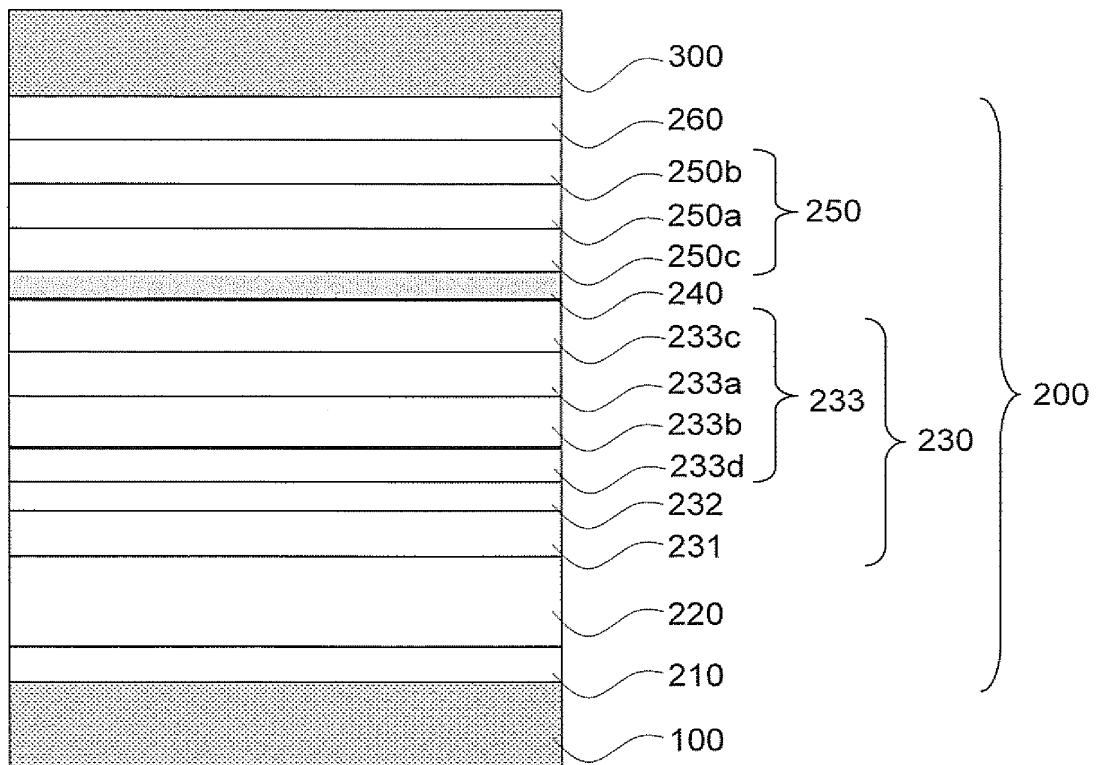
【図 2】



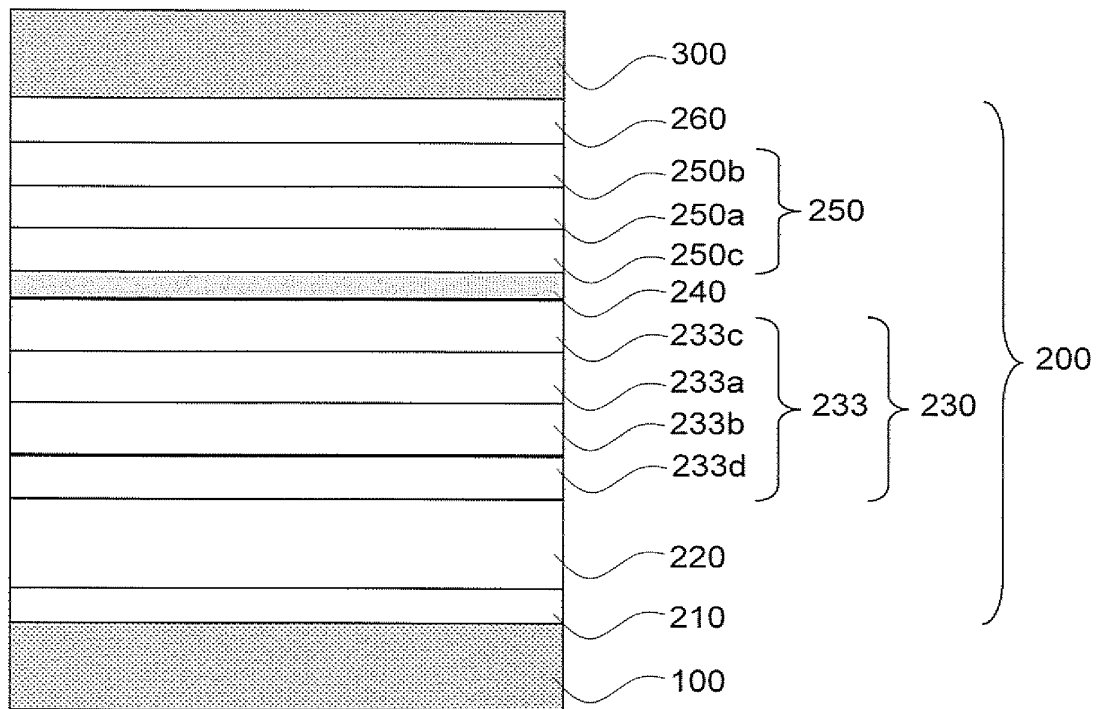
【図3】



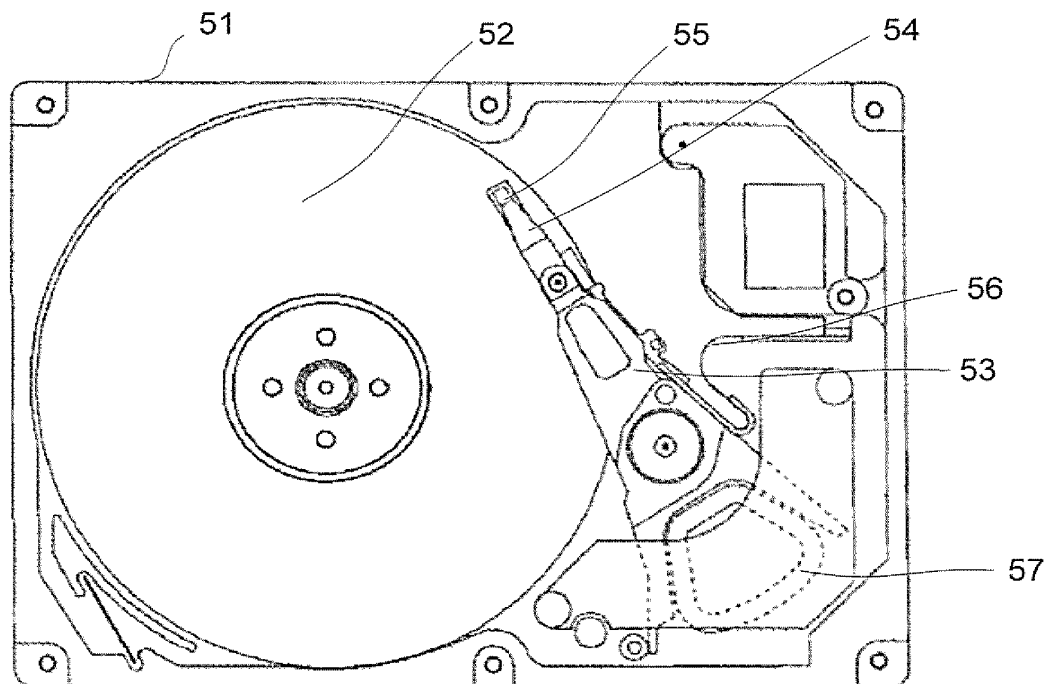
【図4】



【図5】



【図6】



出願人履歴

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住所変更

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			CONFIRMATION NO. 8147
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Title:MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF

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10/04/2012

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)		
	12/955,767	KOMAGAKI ET AL.		
	Examiner	Art Unit		
JEFFERSON EVANS				2627

-- 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 ____.

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

3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ____; the restriction requirement and election have been incorporated into this action.

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

Disposition of Claims

5) ☒ Claim(s) 1-17 is/are pending in the application.

5a) Of the above claim(s) ____ is/are withdrawn from consideration.

6) ☐ Claim(s) ____ is/are allowed.

7) ☒ Claim(s) 1,2 and 9-12 is/are rejected.

8) ☒ Claim(s) 3-8 and 13-17 is/are objected to.

9) ☐ Claim(s) ____ are subject to restriction and/or election requirement.

Application Papers

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

11) ☒ The drawing(s) filed on 29 November 2010 is/are: a) ☐ accepted or b) ☒ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

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

Priority under 35 U.S.C. § 119

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

a) ☒ All b) ☐ Some c) ☐ None of:

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

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

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

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

Attachment(s)

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

Claims 1-17 are pending.

1. The title of the invention is not adequately descriptive. A new title is required that is more clearly indicative of the invention to which the claims are directed by, for example, making reference to the pinned layer and/or free layer including a crystal layer and an amorphous layer.

Drawings

2. Figure 1 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.

Claim Rejections - 35 USC § 102

3. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

4. Claims 1, 2, 9-12 are rejected under 35 U.S.C. 102(b) as being anticipated by Gill (U.S. 2009/0155629). Gill discloses a magnetoresistive effect head, comprising: a magnetically pinned layer 408 having a direction of magnetization that is pinned; a free magnetic layer 410 positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary; and a tunnel barrier layer 412 comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer; wherein the free magnetic layer has a layered structure, the layered structure comprising: a crystal layer 436 comprising one of: a CoFe magnetic layer or a CoFeB magnetic layer; and an amorphous magnetic layer 442 comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb (paragraph 0043) wherein the crystal layer is positioned closer to the tunnel barrier layer than the amorphous magnetic layer. The layer 442 will be within the 0.5 to 3 nm range (note the last 6 lines of paragraph 0043). The layer 438 may become crystalline during annealing and is CoFeB with B being in the 15-25 at% range (note the first 5 lines of paragraph 0043).

Allowable Subject Matter

5. Claims 3-8 and 13-17 are objected to as being dependent upon a rejected base claim, but would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims.

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to JEFFERSON EVANS whose telephone number is (571)272-7574. The examiner can normally be reached on weekdays, 11:00am to 7:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Wayne Young can be reached on 571-272-7582. 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 PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Jefferson Evans/
Primary Examiner, Art Unit 2627
Monday, October 1, 2012

Notice of References Cited	Application/Control No. 12/955,767	Applicant(s)/Patent Under Reexamination KOMAGAKI ET AL.	
	Examiner JEFFERSON EVANS	Art Unit 2627	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-2008/0112093	05-2008	Sato et al.	360/324.2
*	B	US-2008/0179699	07-2008	Horng et al.	257/421
*	C	US-2008/0191251	08-2008	Ranjan et al.	257/295
*	D	US-2008/0217710	09-2008	Horng et al.	257/421
*	E	US-2009/0155629	06-2009	Gill, Hardayal Singh	428/828.1
*	F	US-2010/0009467	01-2010	Horng et al.	438/3
*	G	US-2011/0164448	07-2011	Sato et al.	365/158
*	H	US-2011/0303997	12-2011	Wang et al.	257/421
*	I	US-2012/0148735	06-2012	Zhou, Yuchen	427/129
*	J	US-2012/0018823	01-2012	Huai et al.	257/421
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

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

NON-PATENT DOCUMENTS

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

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

EAST Search History**EAST Search History (Prior Art)**

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	845	(360/324.1).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/01 11:57
L2	1002	(360/324.11).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/01 11:58
L3	1333	(360/324.12).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/01 11:58
L4	1016	(360/324.2).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2012/10/01 11:58
L10	25	komagaki near3 kojiro	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/01 11:59
L11	130	hoshino near3 katsumi	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/01 11:59
L12	4	sato near3 masahige	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/01 11:59
L13	219	hoshiya near3 hiroyuki	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/01 11:59
L14	16	((pinned or fixed) and free and tunnel\$4 and crystal\$4 and amorphous\$4 and cofeb).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/01 12:02
L15	0	((pinned or fixed) and free and tunnel\$4 and crystal\$4 and amorphous\$4 and cofebx).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/01 12:17
L16	5	(pinned or fixed) and free and tunnel\$4 and crystal\$4 and amorphous\$4 and cofebx	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2012/10/01 12:18

10/ 1/ 2012 12:26:09 PM

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		
	Filing Date		
	First Named Inventor	Kojiro Komagaki	
	Art Unit	12955767 - GAU: 2627	
	Examiner Name	Unassigned	
	Attorney Docket Number	HIT1P585/HJP920090046US1	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. //J.E./

U.S. PATENTS								
Examiner Initial*	Cite No	Patent Number	Kind Code ¹	Issue Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
	1							
If you wish to add additional U.S. Patent citation information please click the Add button.								
U.S. PATENT APPLICATION PUBLICATIONS								
Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
	1	20070195592	A1	2007-08-23	Yuasa			
	2	20060056115	A1	2006-03-16	Djayaprawira et al.			
If you wish to add additional U.S. Published Application citation information please click the Add button.								
FOREIGN PATENT DOCUMENTS								
Examiner Initial*	Cite No	Foreign Document Number ³	Country Code ²	Kind Code ⁴	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear	T5
	1	04082711	JP	B2	2008-04-30			☐
	2	2006-080116	JP	A	2006-03-23	Canon Anvelva Corp Nat'l Inst. of Adv. Ind. & Tech		☒

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12955767 - GAU: 2627	
	Filing Date			
	First Named Inventor	Kojiro Komagaki		
	Art Unit			
	Examiner Name	Unassigned		
Attorney Docket Number		HIT1P585/HJP920090046US1		

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.E./

	3	2001-068760	JP		2001-03-16	Hitachi Ltd.	☒
	4	2004-071714	JP		2004-03-04	Sony Corp.	☒
	5	2006-134950	JP		2006-05-25	Toshiba Corp	☒
	6	2008-198792	JP		2008-08-28	Hitachi Ltd. Tohoku Univ.	☒
	7	2008-227388	JP		2008-09-25	Sony Corp.	☒
	8	2009-004784	JP		2009-01-08	Headway Technologies Inc.	☒

If you wish to add additional Foreign Patent Document citation information please click the Add button

NON-PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.	T ⁵
	1	HAYAKAWA et al., "Dependence of Giant Tunnel Magnetoresistance of Sputtered CoFeB/MgO/CoFeB Magnetic Tunnel Junctions on MgO Barrier Thickness and Annealing Temperature," Japanese Journal of Applied Physics, Vol. 44, No. 19, 2005, p. L587-L589	☒

If you wish to add additional non-patent literature document citation information please click the Add button

EXAMINER SIGNATURE

Examiner Signature	/Jefferson Evans/	Date Considered	10/01/2012
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*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.E./

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number		12955767 - GAU: 2627
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	First Named Inventor	Kojiro Komagaki	
	Art Unit		
	Examiner Name	Unassigned	
	Attorney Docket Number	HIT1P585/HJP920090046US1	

¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /J.E./

<i>Search Notes</i> 	Application/Control No. 12955767	Applicant(s)/Patent Under Reexamination KOMAGAKI ET AL.
	Examiner JEFFERSON EVANS	Art Unit 2627

SEARCHED			
Class	Subclass	Date	Examiner
360	324.1	10-1-2012	JAE
360	324.11	10-1-2012	JAE
360	324.12	10-1-2012	JAE
360	324.2	10-1-2012	JAE

SEARCH NOTES		
Search Notes	Date	Examiner
EAST (see attached)	10-1-2012	JAE

INTERFERENCE SEARCH			
Class	Subclass	Date	Examiner

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Doc code: IDS

Doc description: Information Disclosure Statement (IDS) Filed

PTO/SB/08a (01-10)

Approved for use through 07/31/2012. OMB 0651-0031

U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT (Not for submission under 37 CFR 1.99)	Application Number	12955767
	Filing Date	2010-11-29
	First Named Inventor	Kojiro Komagaki
	Art Unit	2627
	Examiner Name	Unassigned
	Attorney Docket Number	HIT1P585/HJP920090046US1

U.S. PATENTS								
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Examiner Initial*	Cite No	Publication Number	Kind Code ¹	Publication Date	Name of Patentee or Applicant of cited Document	Pages, Columns, Lines where Relevant Passages or Relevant Figures Appear		
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NON-PATENT LITERATURE DOCUMENTS								
Examiner Initials*	Cite No	Include name of the author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc), date, pages(s), volume-issue number(s), publisher, city and/or country where published.						T ⁵

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	First Named Inventor	Kojiro Komagaki		
	Art Unit	2627		
	Examiner Name	Unassigned		
	Attorney Docket Number	HIT1P585/HJP920090046US1		

/J.E./	1	MATSUMOTO, "Flow In Studies Of Amorphous Metallic Materials," The Research Institute For Electric And Magnetic Materials, Sendai, 03/26/1998, 8 pgs., no translation	☐
If you wish to add additional non-patent literature document citation information please click the Add button			
EXAMINER SIGNATURE			
Examiner Signature	/Jefferson Evans/		Date Considered 10/01/2012
*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through a citation if not in conformance and not considered. Include copy of this form with next communication to applicant.			
¹ See Kind Codes of USPTO Patent Documents at www.USPTO.GOV or MPEP 901.04. ² Enter office that issued the document, by the two-letter code (WIPO Standard ST.3). ³ For Japanese patent documents, the indication of the year of the reign of the Emperor must precede the serial number of the patent document. ⁴ Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. ⁵ Applicant is to place a check mark here if English language translation is attached.			

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Kojiro Komagaki et al.

Application No.: 12/955,767

Filed: 11/29/2010

For: MAGNETORESISTIVE EFFECT
HEAD HAVING A MULTILAYERED
PINNED LAYER AND/OR FREE
LAYER HAVING AMORPHOUS AND
CRYSTALLINE LAYERS, AND
SYSTEMS THEREOF (AS AMENDED)

Customer No.: 50535

Confirmation No.: 8147

Examiner: EVANS, JEFFERSON A.

Art Unit: 2688

Atty. Docket No.: HIT1P585/HJP920090046US1

Date: January 4, 2013

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 2233-1450

Sir:

Transmitted herewith is an amendment in the above-identified application.

- ☒ Applicant(s) believe that no Extension of Time is required; however, if it is determined that such an extension is required, Applicant(s) hereby petition that such an extension be granted and authorize the Commissioner to charge the required fees for an Extension of Time under 37 CFR 1.136 to Deposit Account No. 50-2587.
- ☒ If the required fees are missing or any additional fees are required to facilitate filing the enclosed response, please charge such fees or credit any overpayment to Deposit Account No. 50-2587 (Order No. HJP920090046US1).

Respectfully submitted,
Zilka-Kotab, PC

/Dominic M. Kotab/

Dominic M. Kotab
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(Revised 12/2010)

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Kojiro Komagaki et al.

Application No.: 12/955,767

Filed: 11/29/2010

For: MAGNETORESISTIVE EFFECT
HEAD HAVING A MULTILAYERED
PINNED LAYER AND/OR FREE
LAYER HAVING AMORPHOUS AND
CRYSTALLINE LAYERS, AND
SYSTEMS THEREOF (AS AMENDED)

Customer No.: 50535

Confirmation No.: 8147

Examiner: EVANS, JEFFERSON A.

Art Unit: 2688

Atty. Docket No.: HIT1P585/HJP920090046US1

Date: January 4, 2013

AMENDMENT A

Commissioner for Patents
P.O. Box 1450
Alexandria, VA22313-1450

Dear Examiner:

In response to the communication mailed October 4, 2012 (hereafter “Non-Final Office Action” or “NFOA”), please consider the following amendments and/or remarks believed to place the claims in condition for allowance.

HIT1P585/HJP920090046US1

- 1 -

IN THE SPECIFICATION:

Please amend title as follows:

-- MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED
PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND
CRYSTALLINE LAYERS, AND SYSTEMS THEREOF --.

AMENDMENT TO THE CLAIMS:

This listing of claims will replace all prior versions of claims in the application:

LISTING OF CLAIMS:

1. (CURRENTLY AMENDED) A magnetoresistive effect head, comprising:
 - a magnetically pinned layer having a direction of magnetization that is pinned;
 - a free magnetic layer positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary; and
 - a tunnel barrier layer comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer;wherein at least one of the magnetically pinned layer and the free magnetic layer has a layered structure, the layered structure comprising:
 - a crystal layer comprising ~~one of: a CoFe magnetic layer or a CoFeB~~ magnetic layer; and
 - an amorphous magnetic layer comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb,wherein the crystal layer is positioned closer to the tunnel barrier layer than the amorphous magnetic layer.
2. (ORIGINAL) A magnetic data storage system, comprising:
 - at least one magnetoresistive effect head as recited in claim 1;
 - a magnetic medium;
 - a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
 - a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.
3. (CURRENTLY AMENDED) ~~The magnetoresistive effect head as recited in~~

claim 1, A magnetoresistive effect head, comprising:

a magnetically pinned layer having a direction of magnetization that is pinned;
a free magnetic layer positioned above the magnetically pinned layer, the free
magnetic layer having a direction of magnetization that is free to vary; and
a tunnel barrier layer comprising an insulator positioned between the
magnetically pinned layer and the free magnetic layer;

wherein the magnetically pinned layer has ~~the~~ a layered structure, the layered
structure comprising:

a crystal layer comprising one of: a CoFe magnetic layer or a CoFeB
magnetic layer; and

an amorphous magnetic layer comprising CoFeB and an element
selected from a group consisting of: Ta, Hf, Zr, and Nb,

wherein the crystal layer is positioned closer to the tunnel barrier layer
than the amorphous magnetic layer.

4. (ORIGINAL) The magnetoresistive effect head as recited in claim 3, wherein a film thickness of the amorphous magnetic layer is in a range from about 0.25 nm to about 1.5 nm.

5. (ORIGINAL) The magnetoresistive effect head as recited in claim 3, wherein the crystal layer comprises the CoFeB magnetic layer, and wherein the CoFeB magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x$, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$.

6. (ORIGINAL) A magnetic data storage system, comprising:

at least one magnetoresistive effect head as recited in claim 5;

a magnetic medium;

a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and

a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

7. (ORIGINAL) The magnetoresistive effect head as recited in claim 3, wherein the amorphous magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x\text{ }_y$, wherein is the element selected from the group consisting of: Ta, Hf, Zr, Nb, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$, and with $3 \text{ at.}\% \leq y \leq 13 \text{ at.}\%$.
8. (ORIGINAL) A magnetic data storage system, comprising:
at least one magnetoresistive effect head as recited in claim 7;
a magnetic medium;
a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.
9. (ORIGINAL) The magnetoresistive effect head as recited in claim 1, wherein the free magnetic layer has the layered structure.
10. (ORIGINAL) The magnetoresistive effect head as recited in claim 9, wherein a film thickness of the amorphous magnetic layer is in a range from about 0.25 nm to about 1.5 nm.
11. (ORIGINAL) The magnetoresistive effect head as recited in claim 9, wherein the crystal layer comprises the CoFeB magnetic layer, wherein the CoFeB magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x$, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$.
12. (ORIGINAL) A magnetic data storage system, comprising:
at least one magnetoresistive effect head as recited in claim 11;
a magnetic medium;
a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and

a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

13. (CURRENTLY AMENDED) ~~The magnetoresistive effect head as recited in claim 9,~~ A magnetoresistive effect head, comprising:

a magnetically pinned layer having a direction of magnetization that is pinned;
a free magnetic layer positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary; and
a tunnel barrier layer comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer;

wherein the free magnetic layer has a layered structure, the layered structure comprising:

a crystal layer comprising one of: a CoFe magnetic layer or a CoFeB magnetic layer; and

an amorphous magnetic layer comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb,

wherein the crystal layer is positioned closer to the tunnel barrier layer than the amorphous magnetic layer,

wherein the amorphous magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x\text{Y}_y$, wherein Y is the element selected from the group consisting of: Ta, Hf, Zr, Nb, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$, and with $3 \text{ at.}\% \leq y \leq 13 \text{ at.}\%$.

14. (ORIGINAL) A magnetic data storage system, comprising:

at least one magnetoresistive effect head as recited in claim 13;

a magnetic medium;

a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and

a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

15. (CURRENTLY AMENDED) The magnetoresistive effect head as recited in claim 1, wherein the ~~magnetically pinned layer and~~ the free magnetic layer ~~have~~ also has the layered structure.
16. (ORIGINAL) The magnetoresistive effect head as recited in claim 15, wherein a film thickness of the amorphous magnetic layer in the pinned layer and the free magnetic layer is in a range from about 0.25 nm to about 1.5 nm.
17. (ORIGINAL) The magnetoresistive effect head as recited in claim 15, wherein the crystal layer in the pinned layer and the free magnetic layer comprises the CoFeB magnetic layer, wherein the CoFeB magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x$, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$.
18. (NEW) A magnetic data storage system, comprising:
at least one magnetoresistive effect head as recited in claim 3;
a magnetic medium;
a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.
19. (NEW) The magnetoresistive effect head as recited in claim 1, wherein the magnetically pinned layer has the layered structure.
20. (NEW) The magnetoresistive effect head as recited in claim 1, wherein the magnetically pinned layer and the free magnetic layer have the layered structure.

AMENDMENT TO THE DRAWINGS:

The attached sheets of drawings include changes to Fig. 1. This sheet replaces the original sheet for Figs. 1-2.

In Fig. 1, the words --(prior art)-- have been added to the legends of the Fig.

REMARKS:

In the Specification

The title has been objected to. The title has been amended to reflect the general subject matter of one or more claims. Withdrawal of the objection is respectfully requested.

In the Drawings:

The drawings have been objected to. The words --(prior art)-- have been added to Fig. 1 in the attached replacement sheet. Withdrawal of the objection is respectfully requested.

Claims 1, 2 and 9-12:

Claims 1, 2 and 9-12 have been rejected under 35 U.S.C. § 102(b) as being anticipated by Gill (U.S. 2009/0155629 hereafter "Gill").

While Applicant respectfully disagrees with the rejection, and solely in order to expedite prosecution, claim 1 has been amended to further differentiate the claim from the cited reference. Particularly, claim 1 has been amended to require "a crystal layer comprising a CoFeB magnetic layer."

In sharp contrast, none of the art of record in any combination discloses the unique combination of features claimed. For example, Gill 0043 indicates that layer 438, of CoFeB is amorphous. Accordingly, the art of record does not anticipate claim 1 and the rejection thereof must be withdrawn. Reconsideration and allowance of claim 1 is respectfully requested.

For the reasons discussed above, claim 1 is believed to be distinguishable from, and therefore in condition for allowance over, the art of record. Claims depending from claim 1 are believed to be allowable by virtue of their dependence. Reconsideration and allowance thereof is respectfully requested.

Applicant does not concede that the subject matter encompassed by claim 1 and its dependents as originally presented is anticipated by the art cited in the rejection. Rather, claim 1 was amended solely to facilitate expeditious prosecution thereof, and the right to pursue additional claims, including the subject matter originally encompassed by claim 1 and its dependents, in this or future applications is reserved. Moreover, Applicant does not concede or assent to the Examiner's arguments as applied to claim 1 and any claim depending from claim 1 in the previous communication(s). Rather, the rejection of claim 1 and any claim depending from claim 1 is deemed improper at least by virtue of the reasons set forth herein and/or claim dependency, and Applicant reserves the right to further address the grounds of rejection in this or future actions and/or applications.

Claims 3-8 and 13-17:

Claims 3-8 and 13-17 have been objected to as being dependent upon a rejected base claim. Such objection is deemed avoided by virtue of the arguments set forth herein.

Claim 3 has been amended to include all limitations of the parent claim and any intervening claim.

Claim 13 has been amended to include all limitations of the parent claim and any intervening claim.

For any one of the foregoing reasons, the rejection(s) have been overcome. Accordingly, Applicant respectfully requests reconsideration and allowance of all claims.

New Claims

New claims have been added to further define and vary the scope of the present invention. The claims are fully supported in the present application and drawings as

originally filed. No new matter has been added. Moreover, Applicant believes the new claims to require subject matter not shown, expressly or inherently, in any combination of art currently of record. Allowance of the new claims is respectfully requested.

In the event a telephone conversation would expedite the prosecution of this application, the Examiner may reach the undersigned at (408) 971-2573. For payment of any additional fees due in connection with the filing of this paper, the Commissioner is authorized to charge such fees to Deposit Account No. 50-2587 (Order No. HJP920090046US1).

Respectfully submitted,

By: /Dominic M. Kotab/
Dominic M. Kotab
Reg. No. 42,762

Date: January 4, 2013

Zilka-Kotab, PC
P.O. Box 721120
San Jose, California 95172-1120
Telephone: (408) 971-2573
Facsimile: (408) 971-4660

REPLACEMNENT SHEET

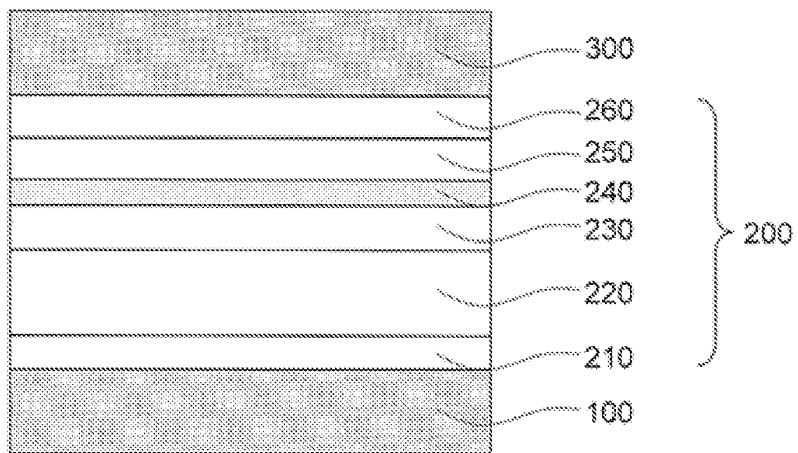


FIG. 1
(PRIOR ART)

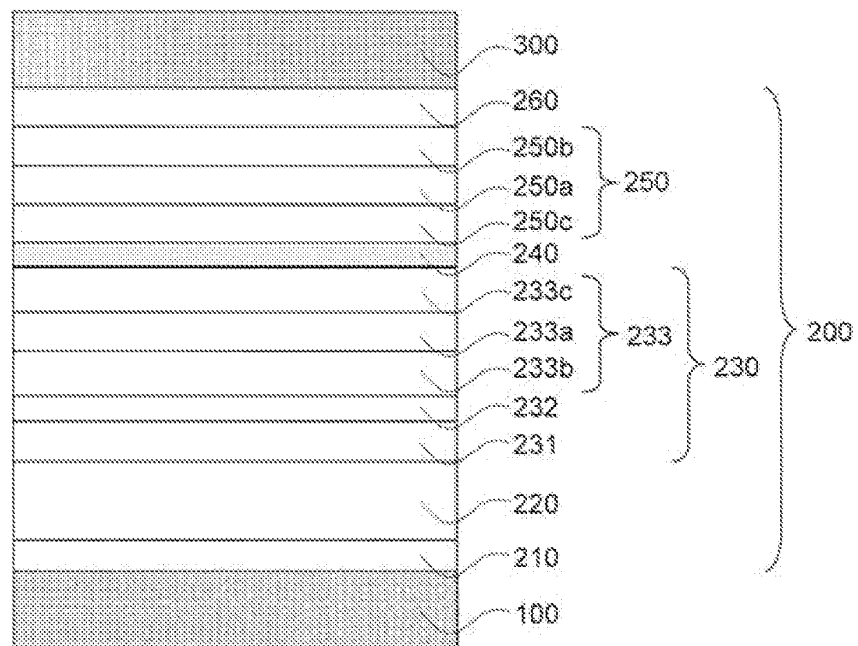


FIG. 2

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	HIT1P585/HJP920090046US1
		Application Number	
Title of Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF		
The application data sheet is part of the provisional or nonprovisional application for which it is being submitted. The following form contains the bibliographic data arranged in a format specified by the United States Patent and Trademark Office as outlined in 37 CFR 1.76. This document may be completed electronically and submitted to the Office in electronic format using the Electronic Filing System (EFS) or the document may be printed and included in a paper filed application.			

Secrecy Order 37 CFR 5.2

- ☐ Portions or all of the application associated with this Application Data Sheet may fall under a Secrecy Order pursuant to 37 CFR 5.2 (Paper filers only. Applications that fall under Secrecy Order may not be filed electronically.)

Applicant Information:

Applicant 1					Remove
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117	☐ Party of Interest under 35 U.S.C. 118
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Kojiro		Komagaki		
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service					
City	Odawara, Kanagawa		Country Of Residenceⁱ	JP	
Citizenship under 37 CFR 1.41(b)ⁱ		JP			
Mailing Address of Applicant:					
Address 1		1-1-102, Yahagi			
Address 2					
City	Odawara, Kanagawa		State/Province		
Postal Code	250-0873		Countryⁱ	JP	
Applicant 2					Remove
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117	☐ Party of Interest under 35 U.S.C. 118
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Katsumi		Hoshino		
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service					
City	Odawara, Kanagawa		Country Of Residenceⁱ	JP	
Citizenship under 37 CFR 1.41(b)ⁱ		JP			
Mailing Address of Applicant:					
Address 1		2-17-16, Naka-cho			
Address 2					
City	Odawara, Kanagawa		State/Province		
Postal Code	250-0005		Countryⁱ	JP	
Applicant 3					Remove
Applicant Authority		☒ Inventor		☐ Legal Representative under 35 U.S.C. 117	☐ Party of Interest under 35 U.S.C. 118
Prefix	Given Name	Middle Name	Family Name	Suffix	
	Masashige		Sato		
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service					
City	Atsugi, Kanagawa		Country Of Residenceⁱ	JP	

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	HIT1P585/HJP920090046US1
		Application Number	
Title of Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF		

Citizenship under 37 CFR 1.41(b) i		JP	
Mailing Address of Applicant:			
Address 1		1-15-803, Atsugi-cho	
Address 2			
City	Atsugi, Kanagawa	State/Province	
Postal Code	243-0011	Countryⁱ	JP
Applicant 4			Remove
Applicant Authority		☒ Inventor ☐ Legal Representative under 35 U.S.C. 117 ☐ Party of Interest under 35 U.S.C. 118	
Prefix	Given Name	Middle Name	Family Name
	Hiroyuki		Hoshiya
Residence Information (Select One) ☐ US Residency ☒ Non US Residency ☐ Active US Military Service			
City	Odawara, Kanagawa	Country Of Residenceⁱ	JP
Citizenship under 37 CFR 1.41(b) i		JP	
Mailing Address of Applicant:			
Address 1		2-1-403, Yahagi	
Address 2			
City	Odawara, Kanagawa	State/Province	
Postal Code	250-0873	Countryⁱ	JP
All Inventors Must Be Listed - Additional Inventor Information blocks may be generated within this form by selecting the Add button.			Add

Correspondence Information:

Enter either Customer Number or complete the Correspondence Information section below. For further information see 37 CFR 1.33(a).	
☐ An Address is being provided for the correspondence Information of this application.	
Customer Number	50535
Email Address	dom@zilkakotab.com
Add Email Remove Email	

Application Information:

Title of the Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF		
Attorney Docket Number	HIT1P585/HJP920090046US1	Small Entity Status Claimed ☐	
Application Type	Nonprovisional		
Subject Matter	Utility		
Suggested Class (if any)		Sub Class (if any)	
Suggested Technology Center (if any)			
Total Number of Drawing Sheets (if any)	03	Suggested Figure for Publication (if any)	02

Application Data Sheet 37 CFR 1.76		Attorney Docket Number	HIT1P585/HJP920090046US1
		Application Number	
Title of Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF		

Publication Information:

☐	Request Early Publication (Fee required at time of Request 37 CFR 1.219)
☐	Request Not to Publish. I hereby request that the attached application not be published under 35 U.S.C. 122(b) and certify that the invention disclosed in the attached application has not and will not be the subject of an application filed in another country, or under a multilateral international agreement, that requires publication at eighteen months after filing.

Representative Information:

Representative information should be provided for all practitioners having a power of attorney in the application. Providing this information in the Application Data Sheet does not constitute a power of attorney in the application (see 37 CFR 1.32). Enter either Customer Number or complete the Representative Name section below. If both sections are completed the Customer Number will be used for the Representative Information during processing.			
Please Select One:	☒ Customer Number	☐ US Patent Practitioner	☐ Limited Recognition (37 CFR 11.9)
Customer Number	50535		

Domestic Benefit/National Stage Information:

This section allows for the applicant to either claim benefit under 35 U.S.C. 119(e), 120, 121, or 365(c) or indicate National Stage entry from a PCT application. Providing this information in the application data sheet constitutes the specific reference required by 35 U.S.C. 119(e) or 120, and 37 CFR 1.78(a)(2) or CFR 1.78(a)(4), and need not otherwise be made part of the specification.			
Prior Application Status		Remove	
Application Number	Continuity Type	Prior Application Number	Filing Date (YYYY-MM-DD)
Additional Domestic Benefit/National Stage Data may be generated within this form by selecting the Add button.			Add

Foreign Priority Information:

This section allows for the applicant to claim benefit of foreign priority and to identify any prior foreign application for which priority is not claimed. Providing this information in the application data sheet constitutes the claim for priority as required by 35 U.S.C. 119(b) and 37 CFR 1.55(a).			
			Remove
Application Number	Country ⁱ	Parent Filing Date (YYYY-MM-DD)	Priority Claimed
2009-278388	JP	2009-12-08	☒ Yes ☐ No
Additional Foreign Priority Data may be generated within this form by selecting the Add button.			Add

Assignee Information:

Providing this information in the application data sheet does not substitute for compliance with any requirement of part 3 of Title 37 of the CFR to have an assignment recorded in the Office.	
Assignee 1	Remove

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Application Data Sheet 37 CFR 1.76		Attorney Docket Number	HIT1P585/HJP920090046US1
		Application Number	
Title of Invention	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF		

If the Assignee is an Organization check here. ☒			
Organization Name	Hitachi Global Storage Technologies Netherlands B.V.		
Mailing Address Information:			
Address 1	Locatellikade 1		
Address 2	Parnassustoren		
City	1076 AZ Amsterdam	State/Province	
Country ⁱ		Postal Code	
Phone Number		Fax Number	
Email Address			
Additional Assignee Data may be generated within this form by selecting the Add button. Add			

Signature:

A signature of the applicant or representative is required in accordance with 37 CFR 1.33 and 10.18. Please see 37 CFR 1.4(d) for the form of the signature.					
Signature	/Dominic M. Kotab/			Date (YYYY-MM-DD)	2013-01-04
First Name	Dominic	Last Name	Kotab	Registration Number	42762

This collection of information is required by 37 CFR 1.76. 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 23 minutes to complete, including gathering, preparing, and submitting the completed application data sheet 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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5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Electronic Acknowledgement Receipt	
EFS ID:	14623620
Application Number:	12955767
International Application Number:	
Confirmation Number:	8147
Title of Invention:	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER OR FREE LAYER AND SYSTEMS THEREOF
First Named Inventor/Applicant Name:	Kojiro Komagaki
Customer Number:	50535
Filer:	Dominic M. Kotab/April Skovmand
Filer Authorized By:	Dominic M. Kotab
Attorney Docket Number:	HIT1P585/HJP920090046US1
Receipt Date:	04-JAN-2013
Filing Date:	29-NOV-2010
Time Stamp:	19:48:58
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		HIT1P585_HJP920090046US1_AmendOA_01-04-2013.pdf	105143 647bc6fbfd00264c21b6550e8b52711313d54b5e	yes	13

Multipart Description/PDF files in .zip description					
Document Description			Start	End	
Amendment/Req. Reconsideration-After Non-Final Reject			1	2	
Specification			3	3	
Claims			4	8	
Drawings-only black and white line drawings			9	9	
Applicant Arguments/Remarks Made in an Amendment			10	12	
Drawings-only black and white line drawings			13	13	
Warnings:					
Information:					
2	Application Data Sheet	HIT1P585_HJP920090046US1_Updated_ADS_01-04-2013.pdf	1031645	no	5
			92b68164fe61bbe4595cc8ee825f9b6f4cbb14		
Warnings:					
Information:					
Total Files Size (in bytes):			1136788		
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875					Application or Docket Number 12/955,767		Filing Date 11/29/2010		☐ To be Mailed		
APPLICATION AS FILED – PART I					SMALL ENTITY ☐		OR		OTHER THAN SMALL ENTITY		
(Column 1)		(Column 2)									
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 \$ =			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					SMALL ENTITY		OR		OTHER THAN SMALL ENTITY		
(Column 1)		(Column 2)		(Column 3)							
AMENDMENT	01/04/2013	CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)		RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	* 20	Minus	** 20	= 0	X \$ =			X \$62=	0	
	Independent (37 CFR 1.16(h))	* 3	Minus	*** 3	= 0	X \$ =			X \$250=	0	
	☐ Application Size Fee (37 CFR 1.16(s))										
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE			TOTAL ADD'L FEE	0	
AMENDMENT		CLAIMS REMAINING AFTER AMENDMENT		HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA	RATE (\$)	ADDITIONAL FEE (\$)		RATE (\$)	ADDITIONAL FEE (\$)	
	Total (37 CFR 1.16(i))	*	Minus	**	=	X \$ =			X \$ =		
	Independent (37 CFR 1.16(h))	*	Minus	***	=	X \$ =			X \$ =		
	☐ Application Size Fee (37 CFR 1.16(s))										
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))										
						TOTAL ADD'L FEE			TOTAL ADD'L FEE		
* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.					Legal Instrument Examiner:						
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".					/KAREN VESTAL/						
*** 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.											

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/955,767	11/29/2010	Kojiro Komagaki	HIT1P585/HJP920090046US1	8147

50535 7590 01/31/2013
ZILKA-KOTAB, PC- HIT
P.O. BOX 721120
SAN JOSE, CA 95172-1120

EXAMINER

EVANS, JEFFERSON A

ART UNIT	PAPER NUMBER
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2688

MAIL DATE	DELIVERY MODE
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01/31/2013

PAPER

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

Office Action Summary	Application No.	Applicant(s)	
	12/955,767	KOMAGAKI ET AL.	
	Examiner	Art Unit	
	JEFFERSON EVANS	2688	

-- 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 04 January 2013.

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

3) ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on ____; the restriction requirement and election have been incorporated into this action.

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

Disposition of Claims

5) ☒ Claim(s) 1-17 is/are pending in the application.

5a) Of the above claim(s) ____ is/are withdrawn from consideration.

6) ☒ Claim(s) 3-8 and 13-20 is/are allowed.

7) ☒ Claim(s) 1,2 and 9-12 is/are rejected.

8) ☐ Claim(s) ____ is/are objected to.

9) ☐ Claim(s) ____ are subject to restriction and/or election requirement.

Application Papers

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

11) ☐ The drawing(s) filed on ____ is/are: a) ☐ accepted or b) ☐ objected to by the Examiner.
Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).
Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

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

Priority under 35 U.S.C. § 119

13) ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
a) ☐ All b) ☐ Some * c) ☐ None of:
1. ☐ Certified copies of the priority documents have been received.
2. ☐ Certified copies of the priority documents have been received in Application No. ____.
3. ☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).
* See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

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

Claims 1-20 are pending.

Claim Rejections - 35 USC § 102

1. The following is a quotation of the appropriate paragraphs of 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

A person shall be entitled to a patent unless –

(b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

2. Claims 1, 2, 9-12 are rejected under 35 U.S.C. 102(b) as being anticipated by Gill (U.S. 2009/0155629). Gill discloses a magnetoresistive effect head, comprising: a magnetically pinned layer 408 having a direction of magnetization that is pinned; a free magnetic layer 410 positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary; and a tunnel barrier layer 412 comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer; wherein the free magnetic layer has a layered structure, the layered structure comprising: a crystal layer 436 comprising one of: a CoFe magnetic layer or a CoFeB magnetic layer; and an amorphous magnetic layer 442 comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb (paragraph 0043 and figure 4) wherein the crystal layer is positioned closer to the tunnel barrier layer than the amorphous magnetic layer. The layer 442 will be within the 0.5 to 3 nm range (note the last 6 lines of paragraph 0043). The layer 438 may become crystalline during annealing

and is CoFeB with B being in the 15-25 at% range (note the first 5 lines of paragraph 0043).

Allowable Subject Matter

3. Claims 3-8 and 13-20 are allowed.
4. **THIS ACTION IS MADE FINAL.** Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

5. Response to Arguments filed 1-4-2013

Applicant's amendment to claim 1 does not overcome the rejection because Gill discloses a CoFeB layer 438 which may be at least partially crystalline and an amorphous CoFeBX layer 442, with layer 438 being closer to the tunnel barrier layer than layer 442.

Art Unit: 2688

6. Any inquiry concerning this communication or earlier communications from the examiner should be directed to JEFFERSON EVANS whose telephone number is (571) 272-7574. The examiner can normally be reached on week days 11:00am to 7:00pm.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Wayne Young can be reached on 571-272-7582. 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 PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see <http://pair-direct.uspto.gov>. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

/Jefferson Evans/
Primary Examiner, Art Unit 2627
Monday, January 28, 2013

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Kojiro Komagaki et al.

Application No.: 12/955,767

Filed: 11/29/2010

For: MAGNETORESISTIVE EFFECT
HEAD HAVING A MULTILAYERED
PINNED LAYER AND/OR FREE
LAYER HAVING AMORPHOUS AND
CRYSTALLINE LAYERS, AND
SYSTEMS THEREOF

Customer No.: 50535

Confirmation No.: 8147

Examiner: EVANS, JEFFERSON A.

Art Unit: 2688

Atty. Docket No.: HIT1P585/HJP920090046US1

Date: April 17, 2013

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 2233-1450

Sir:

Transmitted herewith is an amendment in the above-identified application.

- ☒ Applicant(s) believe that no Extension of Time is required; however, if it is determined that such an extension is required, Applicant(s) hereby petition that such an extension be granted and authorize the Commissioner to charge the required fees for an Extension of Time under 37 CFR 1.136 to Deposit Account No. 50-2587.
- ☒ If the required fees are missing or any additional fees are required to facilitate filing the enclosed response, please charge such fees or credit any overpayment to Deposit Account No. 50-2587 (Order No. HJP920090046US1).

Respectfully submitted,
Zilka-Kotab, PC

/Dominic M. Kotab/

Dominic M. Kotab
Registration No. 42,762

P.O. Box 721120
San Jose, CA 95172-1120
Telephone: (408) 971-2573

(Revised 12/2010)

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Kojiro Komagaki et al.

Application No.: 12/955,767

Filed: 11/29/2010

For: MAGNETORESISTIVE EFFECT
HEAD HAVING A MULTILAYERED
PINNED LAYER AND/OR FREE
LAYER HAVING AMORPHOUS AND
CRYSTALLINE LAYERS, AND
SYSTEMS THEREOF

Customer No.: 50535

Confirmation No.: 8147

Examiner: EVANS, JEFFERSON A.

Art Unit: 2688

Atty. Docket No.: HIT1P585/HJP920090046US1

Date: April 17, 2013

AMENDMENT B

Commissioner for Patents
P.O. Box 1450
Alexandria, VA22313-1450

Dear Examiner:

In response to the communication mailed Jan. 31, 2013 (hereafter "Office Action" or "OA"), please consider the following amendments and/or remarks believed to place the claims in condition for allowance.

HIT1P585/HJP920090046US1

- 1 -

AMENDMENT TO THE CLAIMS:

This listing of claims will replace all prior versions of claims in the application:

LISTING OF CLAIMS:

1. (CURRENTLY AMENDED) A magnetoresistive effect head, comprising:
 - a magnetically pinned layer having a direction of magnetization that is pinned;
 - a free magnetic layer positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary; and
 - a tunnel barrier layer comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer;wherein at least one of the magnetically pinned layer and the free magnetic layer has a layered structure, the layered structure comprising:
 - a crystal layer comprising a CoFeB magnetic layer; and
 - an amorphous magnetic layer comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb,wherein the crystal layer is positioned closer to the tunnel barrier layer than the amorphous magnetic layer,
wherein the magnetically pinned layer has the layered structure.
2. (ORIGINAL) A magnetic data storage system, comprising:
 - at least one magnetoresistive effect head as recited in claim 1;
 - a magnetic medium;
 - a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
 - a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.
3. (PREVIOUSLY PRESENTED) A magnetoresistive effect head, comprising:

a magnetically pinned layer having a direction of magnetization that is pinned;
 a free magnetic layer positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary; and
 a tunnel barrier layer comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer;
 wherein the magnetically pinned layer has a layered structure, the layered structure comprising:
 a crystal layer comprising one of: a CoFe magnetic layer or a CoFeB magnetic layer; and
 an amorphous magnetic layer comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb,
 wherein the crystal layer is positioned closer to the tunnel barrier layer than the amorphous magnetic layer.

4. (ORIGINAL) The magnetoresistive effect head as recited in claim 3, wherein a film thickness of the amorphous magnetic layer is in a range from about 0.25 nm to about 1.5 nm.
5. (ORIGINAL) The magnetoresistive effect head as recited in claim 3, wherein the crystal layer comprises the CoFeB magnetic layer, and wherein the CoFeB magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x$, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$.
6. (ORIGINAL) A magnetic data storage system, comprising:
 at least one magnetoresistive effect head as recited in claim 5;
 a magnetic medium;
 a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
 a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

7. (ORIGINAL) The magnetoresistive effect head as recited in claim 3, wherein the amorphous magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x\text{Y}_y$, wherein Y is the element selected from the group consisting of: Ta, Hf, Zr, Nb, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$, and with $3 \text{ at.}\% \leq y \leq 13 \text{ at.}\%$.
8. (ORIGINAL) A magnetic data storage system, comprising:
at least one magnetoresistive effect head as recited in claim 7;
a magnetic medium;
a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.
9. (ORIGINAL) The magnetoresistive effect head as recited in claim 1, wherein the free magnetic layer has the layered structure.
10. (ORIGINAL) The magnetoresistive effect head as recited in claim 9, wherein a film thickness of the amorphous magnetic layer is in a range from about 0.25 nm to about 1.5 nm.
11. (ORIGINAL) The magnetoresistive effect head as recited in claim 9, wherein the crystal layer comprises the CoFeB magnetic layer, wherein the CoFeB magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x$, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$.
12. (ORIGINAL) A magnetic data storage system, comprising:
at least one magnetoresistive effect head as recited in claim 11;
a magnetic medium;
a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and

a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

13. (PREVIOUSLY PRESENTED) A magnetoresistive effect head, comprising:
a magnetically pinned layer having a direction of magnetization that is pinned;
a free magnetic layer positioned above the magnetically pinned layer, the free magnetic layer having a direction of magnetization that is free to vary; and
a tunnel barrier layer comprising an insulator positioned between the magnetically pinned layer and the free magnetic layer;

wherein the free magnetic layer has a layered structure, the layered structure comprising:

a crystal layer comprising one of: a CoFe magnetic layer or a CoFeB magnetic layer; and

an amorphous magnetic layer comprising CoFeB and an element selected from a group consisting of: Ta, Hf, Zr, and Nb,

wherein the crystal layer is positioned closer to the tunnel barrier layer than the amorphous magnetic layer,

wherein the amorphous magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x\text{Y}_y$, wherein Y is the element selected from the group consisting of: Ta, Hf, Zr, Nb, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$, and with $3 \text{ at.}\% \leq y \leq 13 \text{ at.}\%$.

14. (ORIGINAL) A magnetic data storage system, comprising:

at least one magnetoresistive effect head as recited in claim 13;

a magnetic medium;

a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and

a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

15. (PREVIOUSLY PRESENTED) The magnetoresistive effect head as recited in

claim 3, wherein the the free magnetic layer also has the layered structure.

16. (ORIGINAL) The magnetoresistive effect head as recited in claim 15, wherein a film thickness of the amorphous magnetic layer in the pinned layer and the free magnetic layer is in a range from about 0.25 nm to about 1.5 nm.

17. (ORIGINAL) The magnetoresistive effect head as recited in claim 15, wherein the crystal layer in the pinned layer and the free magnetic layer comprises the CoFeB magnetic layer, wherein the CoFeB magnetic layer has a composition represented by $(\text{CoFe})_{100-x}\text{B}_x$, with $10 \text{ at.}\% \leq x \leq 30 \text{ at.}\%$.

18. (PREVIOUSLY PRESENTED) A magnetic data storage system, comprising:
at least one magnetoresistive effect head as recited in claim 3;
a magnetic medium;
a drive mechanism for passing the magnetic medium over the at least one magnetoresistive effect head; and
a controller electrically coupled to the at least one magnetoresistive effect head for controlling operation of the at least one magnetoresistive effect head.

19. (CANCELED)

20. (PREVIOUSLY PRESENTED) The magnetoresistive effect head as recited in claim 1, wherein the magnetically pinned layer and the free magnetic layer have the layered structure.

REMARKS:

Allowable Subject Matter

Any rejected claims have either been made to depend from an allowable independent claim or canceled.

Allowance of all pending claims is respectfully requested.

Certain claims have been amended and/or canceled. Applicant does not concede that the subject matter encompassed by any claim as originally presented is unpatentable over the art cited in the rejection. Nor does Applicant agree with or acquiesce to any of the rejections. Rather, said claims have been canceled and/or amended solely to facilitate expeditious prosecution of the remaining claims, and the right to pursue additional claims, including the subject matter originally encompassed by such claims in this or future applications is reserved.

Claims 1, 2 and 9-12:

Claims 1, 2 and 9-12 have been rejected under 35 U.S.C. § 102(b) as being anticipated by Gill (U.S. 2009/0155629 hereafter “Gill”).

While Applicant respectfully disagrees with the rejection, and solely in order to expedite prosecution, claim 1 has been amended to further differentiate the claim from the cited reference. Particularly, claim 1 has been amended to require the limitations of allowable claim 19.

In sharp contrast, none of the art of record in any combination discloses the unique combination of features claimed. Accordingly, the art of record does not anticipate claim 1 and the rejection thereof must be withdrawn. Reconsideration and allowance of claim 1 is respectfully requested.

For the reasons discussed above, claim 1 is believed to be distinguishable from, and therefore in condition for allowance over, the art of record. Claims depending from claim 1 are believed to be allowable by virtue of their dependence. Reconsideration and allowance thereof is respectfully requested.

Applicant does not concede that the subject matter encompassed by claim 1 and its dependents as originally presented is anticipated by the art cited in the rejection. Rather, claim 1 was amended solely to facilitate expeditious prosecution thereof, and the right to pursue additional claims, including the subject matter originally encompassed by claim 1 and its dependents, in this or future applications is reserved. Moreover, Applicant does not concede or assent to the Examiner's arguments as applied to claim 1 and any claim depending from claim 1 in the previous communication(s). Rather, the rejection of claim 1 and any claim depending from claim 1 is deemed improper at least by virtue of the reasons set forth herein and/or claim dependency, and Applicant reserves the right to further address the grounds of rejection in this or future actions and/or applications.

In the event a telephone conversation would expedite the prosecution of this application, the Examiner may reach the undersigned at (408) 971-2573. For payment of any additional fees due in connection with the filing of this paper, the Commissioner is authorized to charge such fees to Deposit Account No. 50-2587 (Order No. HJP920090046US1).

Respectfully submitted,

By: /Dominic M. Kotab/
Dominic M. Kotab
Reg. No. 42,762

Date: April 17, 2013

Zilka-Kotab, PC
P.O. Box 721120

HIT1P585/HJP920090046US1

- 8 -

San Jose, California 95172-1120
Telephone: (408) 971-2573
Facsimile: (408) 971-4660

Electronic Acknowledgement Receipt	
EFS ID:	15547617
Application Number:	12955767
International Application Number:	
Confirmation Number:	8147
Title of Invention:	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF
First Named Inventor/Applicant Name:	Kojiro Komagaki
Customer Number:	50535
Filer:	Dominic M. Kotab/April Skovmand
Filer Authorized By:	Dominic M. Kotab
Attorney Docket Number:	HIT1P585/HJP920090046US1
Receipt Date:	17-APR-2013
Filing Date:	29-NOV-2010
Time Stamp:	20:03:48
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no
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File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		HIT1P585_HJP920090046US1_AmendOA_04-17-2013.pdf	36521 672189ca1484eeec511f6ad82c220eb8653fb6838	yes	10

	Multipart Description/PDF files in .zip description		
	Document Description	Start	End
	Amendment After Final	1	2
	Claims	3	7
	Applicant Arguments/Remarks Made in an Amendment	8	10
Warnings:			
Information:			
Total Files Size (in bytes):		36521	
This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503. <u>New Applications Under 35 U.S.C. 111</u> If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application. <u>National Stage of an International Application under 35 U.S.C. 371</u> If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course. <u>New International Application Filed with the USPTO as a Receiving Office</u> If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.			

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

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875				Application or Docket Number 12/955,767		Filing Date 11/29/2010		☐ To be Mailed	
ENTITY: ☒ LARGE ☐ SMALL ☐ MICRO									
APPLICATION AS FILED – PART I									
		(Column 1)		(Column 2)					
FOR		NUMBER FILED		NUMBER EXTRA		RATE (\$)		FEE (\$)	
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))		N/A		N/A		N/A			
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))		N/A		N/A		N/A			
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))		N/A		N/A		N/A			
TOTAL CLAIMS (37 CFR 1.16(i))		minus 20 =		*		X \$ =			
INDEPENDENT CLAIMS (37 CFR 1.16(h))		minus 3 =		*		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 \$310 (\$155 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			
APPLICATION AS AMENDED – PART II									
		(Column 1)		(Column 2)		(Column 3)			
AMENDMENT	04/17/2013		CLAIMS REMAINING AFTER AMENDMENT			HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		
	Total (37 CFR 1.16(i))		* 19		Minus	** 20	= 0		
	Independent (37 CFR 1.16(h))		* 3		Minus	*** 3	= 0		
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
	TOTAL ADD'L FEE								
		(Column 1)		(Column 2)		(Column 3)			
AMENDMENT			CLAIMS REMAINING AFTER AMENDMENT			HIGHEST NUMBER PREVIOUSLY PAID FOR	PRESENT EXTRA		
	Total (37 CFR 1.16(i))		*		Minus	**	=		
	Independent (37 CFR 1.16(h))		*		Minus	***	=		
	☐ Application Size Fee (37 CFR 1.16(s))								
	☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))								
	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.									

LIE
/DEBRA SAVOY/

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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NOTICE OF ALLOWANCE AND FEE(S) DUE

50535 7590 04/26/2013
ZILKA-KOTAB, PC- HIT
P.O. BOX 721120
SAN JOSE, CA 95172-1120

EXAMINER

EVANS, JEFFERSON A

ART UNIT

PAPER NUMBER

2688

DATE MAILED: 04/26/2013

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/955,767	11/29/2010	Kojiro Komagaki	HIT1P585/HJP920090046US1	8147

TITLE OF INVENTION: MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$1780	\$300	\$0	\$2080	07/26/2013

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 ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

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.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: **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)

50535 7590 04/26/2013
ZILKA-KOTAB, PC- HIT
P.O. BOX 721120
SAN JOSE, CA 95172-1120

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/955,767	11/29/2010	Kojiro Komagaki	HIT1P585/HJP920090046US1	8147

TITLE OF INVENTION: MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$1780	\$300	\$0	\$2080	07/26/2013

EXAMINER	ART UNIT	CLASS-SUBCLASS
EVANS, JEFFERSON A	2688	360-324120

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, 1 _____
- (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. 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)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see form PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

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.



UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/955,767	11/29/2010	Kojiro Komagaki	HIT1P585/HJP920090046US1	8147

50535	7590	04/26/2013
ZILKA-KOTAB, PC- HIT		
P.O. BOX 721120		
SAN JOSE, CA 95172-1120		

EXAMINER	
EVANS, JEFFERSON A	

ART UNIT	PAPER NUMBER
2688	

DATE MAILED: 04/26/2013

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 249 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 249 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.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 12/955,767	Applicant(s) KOMAGAKI ET AL.	
	Examiner JEFFERSON EVANS	Art Unit 2688	AIA (First Inventor to File) Status No

-- 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 AF Amendment filed 4-17-2013.
☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

3. ☒ The allowed claim(s) is/are 1-18 and 20. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
Certified copies:
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: _____.

Interim copies:
a) ☐ All b) ☐ Some c) ☐ None of the: Interim copies of the priority documents have been received.

Applicant has **THREE MONTHS FROM THE "MAILING DATE"** of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in **ABANDONMENT** of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ **CORRECTED DRAWINGS** (as "replacement sheets") must be submitted.
☐ 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)	5. ☐ Examiner's Amendment/Comment
2. ☐ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date _____	6. ☐ Examiner's Statement of Reasons for Allowance
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material	7. ☐ Other _____
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____	

/JEFFERSON EVANS/ Primary Examiner, Art Unit 2688	
--	--



UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
 United States Patent and Trademark Office
 Address: COMMISSIONER FOR PATENTS
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BIB DATA SHEET

CONFIRMATION NO. 8147

SERIAL NUMBER	FILING or 371(c) DATE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.		
12/955,767	11/29/2010	360	2688 HIT1	P585/HJP920090046US1		
APPLICANTS Kojiro Komagaki, Odawara, JAPAN; Katsumi Hoshino, Odawara, JAPAN; Masashige Sato, Atsugi, JAPAN; Hiroyuki Hoshiya, Odawara, JAPAN; ** CONTINUING DATA ***** ** FOREIGN APPLICATIONS ***** JAPAN 2009-278388 12/08/2009 ** IF REQUIRED, FOREIGN FILING LICENSE GRANTED ** 12/09/2010						
Foreign Priority claimed ☒ Yes ☐ No 35 USC 119(a-d) conditions met ☒ Yes ☐ No Verified and /JEFFERSON A EVANS/ Acknowledged Examiner's Signature		☐ Met after Allowance Initials	STATE OR COUNTRY JAPAN	SHEETS DRAWINGS 3	TOTAL CLAIMS 17	INDEPENDENT CLAIMS 1
ADDRESS ZILKA-KOTAB, PC- HIT P.O. BOX 721120 SAN JOSE, CA 95172-1120 UNITED STATES						
TITLE MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF						
FILING FEE RECEIVED 1090	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		

OK TO ENTER: /J.E./

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Kojiro Komagaki et al.

Application No.: 12/955,767

Filed: 11/29/2010

For: MAGNETORESISTIVE EFFECT
HEAD HAVING A MULTILAYERED
PINNED LAYER AND/OR FREE
LAYER HAVING AMORPHOUS AND
CRYSTALLINE LAYERS, AND
SYSTEMS THEREOF

Customer No.: 50535

Confirmation No.: 8147

Examiner: EVANS, JEFFERSON A.

Art Unit: 2688

Atty. Docket No.: HIT1P585/HJP920090046US1

Date: April 17, 2013

OK TO ENTER: /J.E./

AMENDMENT B

Commissioner for Patents
P.O. Box 1450
Alexandria, VA22313-1450

Dear Examiner:

In response to the communication mailed Jan. 31, 2013 (hereafter "Office Action" or "OA"), please consider the following amendments and/or remarks believed to place the claims in condition for allowance.

OK TO ENTER: /J.E./

HIT1P585/HJP920090046US1

- 1 -

Issue Classification 	Application/Control No. 12955767	Applicant(s)/Patent Under Reexamination KOMAGAKI ET AL.
	Examiner JEFFERSON EVANS	Art Unit 2688

CPC		
Symbol	Type	Version

CPC Combination Sets				
Symbol	Type	Set	Ranking	Version

US ORIGINAL CLASSIFICATION						INTERNATIONAL CLASSIFICATION													
CLASS		SUBCLASS				CLAIMED					NON-CLAIMED								
360		324.11				G	1	1	B	5 / 39 (2006.01.01)									
CROSS REFERENCE(S)																			
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)																		
360	324.12	324.2																	

NONE		Total Claims Allowed:	
(Assistant Examiner)		19	
(Date)			
/JEFFERSON EVANS/ Primary Examiner.Art Unit 2688		4-21-2013	
(Primary Examiner)		(Date)	
		O.G. Print Claim(s)	O.G. Print Figure
		1	2

Issue Classification 	Application/Control No. 12955767	Applicant(s)/Patent Under Reexamination KOMAGAKI ET AL.
	Examiner JEFFERSON EVANS	Art Unit 2688

NONE		Total Claims Allowed:	
		19	
(Assistant Examiner)	(Date)		
/JEFFERSON EVANS/ Primary Examiner.Art Unit 2688	4-21-2013	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	2

Issue Classification 	Application/Control No. 12955767	Applicant(s)/Patent Under Reexamination KOMAGAKI ET AL.
	Examiner JEFFERSON EVANS	Art Unit 2688

☐ 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	1	16	17												
2	2	17	18												
8	3		19												
9	4	7	20												
10	5														
11	6														
12	7														
13	8														
3	9														
4	10														
5	11														
6	12														
18	13														
19	14														
14	15														
15	16														

NONE (Assistant Examiner) _____ (Date) _____		Total Claims Allowed: 19	
/JEFFERSON EVANS/ Primary Examiner. Art Unit 2688 (Primary Examiner) _____ (Date) _____		O.G. Print Claim(s) 1	O.G. Print Figure 2

Search Notes 	Application/Control No. 12955767	Applicant(s)/Patent Under Reexamination KOMAGAKI ET AL.
	Examiner JEFFERSON EVANS	Art Unit 2627

CPC- SEARCHED		
Symbol	Date	Examiner

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
360	324.1	10-1-2012	JAE
360	324.11	10-1-2012	JAE
360	324.12	10-1-2012	JAE
360	324.2	10-1-2012	JAE
360	324.1	4-21-2013	JAE
360	324.11	4-21-2013	JAE
360	324.12	4-21-2013	JAE
360	324.2	4-21-2013	JAE

SEARCH NOTES		
Search Notes	Date	Examiner
EAST (see attached)	10-1-2012	JAE
EAST (see attached)	4-21-2013	JAE

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
360	324.1	4-21-2013	JAE
360	324.11	4-21-2013	JAE
3603	324.12	4-21-2013	JAE
360	324.2	4-21-2013	JAE

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	860	(360/324.1).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/04/21 19:42
L2	1024	(360/324.11).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/04/21 19:43
L3	1364	(360/324.12).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/04/21 19:43
L4	1053	(360/324.2).CCLS.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/04/21 19:43
L10	27	komagaki near3 kojiro	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/04/21 19:44
L11	130	hoshino near3 katsumi	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/04/21 19:44
L12	132	sato near3 masashige	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/04/21 19:45
L13	221	hoshiya near3 hiroyuki	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/04/21 19:45
L14	89	((magnetoresist\$4 or magneto-resist\$4 or gmr or tmr or (spin adj	US-PGPUB; USPAT; USOCR;	OR	ON	2013/04/21 19:46

		valve) or tunnel\$4 or barrier) and free and pinned and crystal\$4 and amorphous\$4).clm.	FPRS; EPO; JPO; DERWENT; IBM_TDB			
L15	791	((magnetoresist\$4 or magneto- resist\$4 or gmr or tmr or (spin adj valve) or tunnel\$4 or barrier) and free and pinned and (cofe or cofeb)).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/04/21 19:47
L16	222	((magnetoresist\$4 or magneto- resist\$4 or gmr or tmr or (spin adj valve) or tunnel\$4 or barrier) and free and pinned and cofeb).clm.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/04/21 19:47
L17	563	((magnetoresist\$4 or magneto- resist\$4 or gmr or tmr or (spin adj valve) or tunnel\$4 or barrier) and free and pinned and crystal\$4 and amorphous\$4 and (cofeb or co-fe-b))	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2013/04/21 19:48

4/ 21/ 2013 7:49:14 PM

5. **Change in Entity Status** (from status indicated above)

☐ Applicant certifying micro entity status. See 37 CFR 1.29

☐ Applicant asserting small entity status. See 37 CFR 1.27

☐ Applicant changing to regular undiscounted fee status.

NOTE: Absent a valid certification of Micro Entity Status (see form PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.

NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.

NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

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 /Dominic M. Kotab/

Date July 17, 2013

Typed or printed name Dominic M. Kotab

Registration No. 42,762

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450.

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Alexandria, VA 22313-1450

Fax to:
571-273-6500

- OR -

INSTRUCTIONS: The issue fee must have been paid for application(s) listed on this form. In addition, only an address represented by a Customer Number can be established as the fee address for maintenance fee purposes (hereafter, fee address). A fee address should be established when correspondence related to maintenance fees should be mailed to a different address than the correspondence address for the application. **When to check the first box below:** If you have a Customer Number to represent the fee address. **When to check the second box below:** If you have no Customer Number representing the desired fee address, in which case a completed Request for Customer Number (PTO/SB/125) must be attached to this form. For more information on Customer Numbers, see the Manual of Patent Examining Procedure (MPEP) § 403.

For the following listed application(s), please recognize as the "Fee Address" under the provisions of 37 CFR 1.363 the address associated with:

☒ Customer Number: 36023

OR

☐ The attached Request for Customer Number (PTO/SB/125) form.

PATENT NUMBER (if known)	APPLICATION NUMBER
	12/955,767

Completed by (check one):

☐ Applicant/Inventor	/Dominic M. Kotab/ Signature
☒ Attorney or Agent of record <u>42,762</u> (Reg. No.)	Dominic M. Kotab Typed or printed name
☐ Assignee of record of the entire interest. See 37 CFR 3.71. Statement under 37 CFR 3.73(b) is enclosed. (Form PTO/SB/96)	408-971-2573 Requester's telephone number
☐ Assignee recorded at Reel _____ Frame _____	July 17, 2013 Date

NOTE: Signatures of all the inventors or assignees of record of the entire interest or their representative(s) are required. Submit multiple forms if more than one signature is required, see below*.

☒ * Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.363. 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 5 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 COMPLETED FORMS TO THIS ADDRESS.

SEND TO: Mail Stop M Correspondence, 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.

Electronic Patent Application Fee Transmittal				
Application Number:		12955767		
Filing Date:		29-Nov-2010		
Title of Invention:		MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF		
First Named Inventor/Applicant Name:		Kojiro Komagaki		
Filer:		Dominic M. Kotab/April Skovmand		
Attorney Docket Number:		HIT1P585/HJP920090046US1		
Filed as Large Entity				
Utility under 35 USC 111(a) Filing Fees				
Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl Issue Fee	1501	1	1780	1780
Publ. Fee- Early, Voluntary, or Normal	1504	1	300	300

Description	Fee Code	Quantity	Amount	Sub-Total in USD(\$)
Extension-of-Time:				
Miscellaneous:				
Total in USD (\$)				2080

Electronic Acknowledgement Receipt	
EFS ID:	16347087
Application Number:	12955767
International Application Number:	
Confirmation Number:	8147
Title of Invention:	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF
First Named Inventor/Applicant Name:	Kojiro Komagaki
Customer Number:	50535
Filer:	Dominic M. Kotab/April Skovmand
Filer Authorized By:	Dominic M. Kotab
Attorney Docket Number:	HIT1P585/HJP920090046US1
Receipt Date:	17-JUL-2013
Filing Date:	29-NOV-2010
Time Stamp:	19:58:52
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Deposit Account
Payment was successfully received in RAM	\$2080
RAM confirmation Number	6473
Deposit Account	502587
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows: Charge any Additional Fees required under 37 C.F.R. Section 1.16 (National application filing, search, and examination fees) Charge any Additional Fees required under 37 C.F.R. Section 1.17 (Patent application and reexamination processing fees)	

Charge any Additional Fees required under 37 C.F.R. Section 1.19 (Document supply fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.20 (Post Issuance fees)

Charge any Additional Fees required under 37 C.F.R. Section 1.21 (Miscellaneous fees and charges)

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		HIT1P585_HJP920090046US1_IssueFee_07-17-2013.pdf	140870 45d4abc286c203d270d9d5796d37c6cfd9e31ab	yes	4

Multipart Description/PDF files in .zip description

Document Description	Start	End
Issue Fee Payment (PTO-85B)	1	2
Change of Address	3	4

Warnings:

Information:

2	Fee Worksheet (SB06)	fee-info.pdf	32291 379827132c2e1ca37f8429f818bcb1bbd89fe475c	no	2
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Warnings:

Information:

Total Files Size (in bytes): 173161

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

New Applications Under 35 U.S.C. 111

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

National Stage of an International Application under 35 U.S.C. 371

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

New International Application Filed with the USPTO as a Receiving Office

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

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re application of:

Kojiro Komagaki et al.

Application No.: 12/955,767

Filed: 11/29/2010

For: MAGNETORESISTIVE EFFECT
HEAD HAVING A MULTILAYERED
PINNED LAYER AND/OR FREE
LAYER HAVING AMORPHOUS AND
CRYSTALLINE LAYERS, AND
SYSTEMS THEREOF

Customer No.: 50535

Confirmation No.: 8147

Examiner: EVANS, JEFFERSON A.

Art Unit: 2688

Atty. Docket No.: HIT1P585/HJP920090046US1

Date: July 17, 2013

Issue Fee Payment Transmittal

Mail Stop Issue Fee
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

Transmitted herewith are the following items:

- 1) Part B- Issue Fee Transmittal
- 2) Fee Address Indication Form

Respectfully submitted,
Zilka-Kotab, PC

/Dominic M. Kotab/

Dominic M. Kotab
Reg. No. 42,762

P.O. Box 721120
San Jose, CA 95172-1120
(408) 971-2573

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)

50535 7590 04/26/2013
ZILKA-KOTAB, PC- HIT
P.O. BOX 721120
SAN JOSE, CA 95172-1120

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/955,767	11/29/2010	Kojiro Komagaki	HIT1P585/HJP920090046US1	8147

TITLE OF INVENTION: MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	UNDISCOUNTED	\$1780	\$300	\$0	\$2080	07/26/2013

EXAMINER	ART UNIT	CLASS-SUBCLASS
EVANS, JEFFERSON A	2688	360-324120

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 Zilka-Kotab, PC

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)

HGST Netherlands B.V.

Amsterdam, The Netherlands

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 50-2587 (enclose an extra copy of this form).



UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
12/955,767	08/20/2013	8514527	HIT1P585/HJP920090046US1	8147

50535 7590 07/31/2013
ZILKA-KOTAB, PC- HIT
P.O. BOX 721120
SAN JOSE, CA 95172-1120

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 249 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):

Kojiro Komagaki, Odawara, JAPAN;
Katsumi Hoshino, Odawara, JAPAN;
Masashige Sato, Atsugi, JAPAN;
Hiroyuki Hoshiya, Odawara, JAPAN;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Patent Number: 8,514,527
Issued: 08/20/2013
Name of Patentee: Kojiro Komagaki
Title of Invention: Magnetoresistive Effect Head Having A Multilayered Pinned Layer And/Or Free Layer
Having Amorphous And Crystalline Layers, And Systems Thereof

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

REQUEST FOR CERTIFICATE OF CORRECTION OF PATENT
FOR PTO MISTAKE (37 C.F.R. § 1.322(a))

1. Attached is PTO/SB/44 in a form suitable for printing.
2. The exact page and line number where the errors are shown correctly in the application file are:

In the listed publications (page 2):

replace prior art listing "JP 2008-277388 9/2008" with --JP 2008-227388 9/2008--.

In the Specification:

col. 4, lines 66-67 replace "anti ferromagnetic" with --antiferromagnetic--;

col. 4, lines 67 replace "in," with --in--.

3. It is noted that the above identified errors were typographical errors that apparently occurred during the printing process. Accordingly, it is believed that no fees are due in connection with the filing of this Request for Certificate of Correction. However, if it is determined that any fees are due, the Commissioner is hereby authorized to charge such fees to Deposit Account 50-2587 (Order No. HJP920090046US1).
4. Please send the Certificate to:

Name: Dominic M. Kotab
Address: Zilka-Kotab, PC
P.O. Box 721120
San Jose, CA 95172
USA

/Dominic M. Kotab/
Dominic M. Kotab, Attorney of Record

UNITED STATES PATENT AND TRADEMARK OFFICE CERTIFICATE OF CORRECTION

PATENT NO. : 8,514,527 B2
DATED : 08/20/2013
INVENTOR(S) : Komagaki et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the listed publications (page 2):

replace prior art listing "JP 2008-277388 9/2008" with --JP 2008-227388 9/2008--.

In the Specification:

col. 4, lines 66-67 replace "anti ferromagnetic" with --antiferromagnetic--;

col. 4, lines 67 replace "in," with --in--.

MAILING ADDRESS OF SENDER:

Zilka-Kotab, PC
P.O. Box 721120
San Jose, CA. 95172

PATENT NO. 8,514,527 B2

No. of additional copies

 1

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 2.

Electronic Acknowledgement Receipt	
EFS ID:	16817711
Application Number:	12955767
International Application Number:	
Confirmation Number:	8147
Title of Invention:	MAGNETORESISTIVE EFFECT HEAD HAVING A MULTILAYERED PINNED LAYER AND/OR FREE LAYER HAVING AMORPHOUS AND CRYSTALLINE LAYERS, AND SYSTEMS THEREOF
First Named Inventor/Applicant Name:	Kojiro Komagaki
Customer Number:	50535
Filer:	Dominic M. Kotab/April Skovmand
Filer Authorized By:	Dominic M. Kotab
Attorney Docket Number:	HIT1P585/HJP920090046US1
Receipt Date:	10-SEP-2013
Filing Date:	29-NOV-2010
Time Stamp:	19:54:43
Application Type:	Utility under 35 USC 111(a)

Payment information:

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

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Certificate of Correction	HIT1P585_HJP920090046US1_ReqCerCorr_09-10-2013.pdf	52065 73e96f5232413a640dfbdf5d3ce9df4bd8ea8224	no	2

Warnings:

Information:

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

New Applications Under 35 U.S.C. 111

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

National Stage of an International Application under 35 U.S.C. 371

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

New International Application Filed with the USPTO as a Receiving Office

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

UNITED STATES PATENT AND TRADEMARK OFFICE
CERTIFICATE OF CORRECTION

PATENT NO. : 8,514,527 B2
APPLICATION NO. : 12/955767
DATED : August 20, 2013
INVENTOR(S) : Komagaki et al.

Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

On the Title Page:

Item (56) in the listed publications (page 2):

replace prior art listing “JP 2008-277388 9/2008” with --JP 2008-227388 9/2008--.

In the Specification:

col. 4, lines 66-67 replace “anti ferromagnetic” with --antiferromagnetic--;

col. 4, lines 67 replace “in,” with --in--.

Signed and Sealed this
Eighth Day of October, 2013



Teresa Stanek Rea
Deputy Director of the United States Patent and Trademark Office