



Western Digital v. Godo Kaisha IP Bridge

U.S. Patent No. 11,968,909 | IPR2024-01494

January 23, 2026

Judges Arbes, McShane, and Hamann

'909 Patent

Disclaimed **×**

~~Claim 1~~

~~Claim 2~~

~~Claim 3~~

~~Claim 4~~

~~Claim 7~~

~~Claim 8~~

0.1 to 0.85 eV

Claim 5

Claim 9

Claim 10

Claim 11

Claim 13

Claim 14

0.2 to 0.5 eV

Claim 6

Claim 12

Claim 15

Claim 16

Claim 17

Claim 18

Claim 19

Claim 20

Claim 5

- ✗ 1. [pre] A magnetoresistive device comprising a magnetic tunnel junction structure comprising a multi-layer material stack including:
- ✗ [a] first and second ferromagnetic material layer; and
- ✗ [b] a tunnel barrier layer between the first and second ferromagnetic material layers such that the tunnel barrier layer is above the first ferromagnetic material layer and below the second ferromagnetic material layer,
- ✗ [c] wherein said tunnel barrier layer comprises crystalline MgO_x (001) with oxygen vacancy defects and ($0 < x < 1$).
5. The magnetoresistive device of claim 1, wherein a barrier height of the tunnel barrier layer is in a range of 0.1 eV to 0.85 eV.

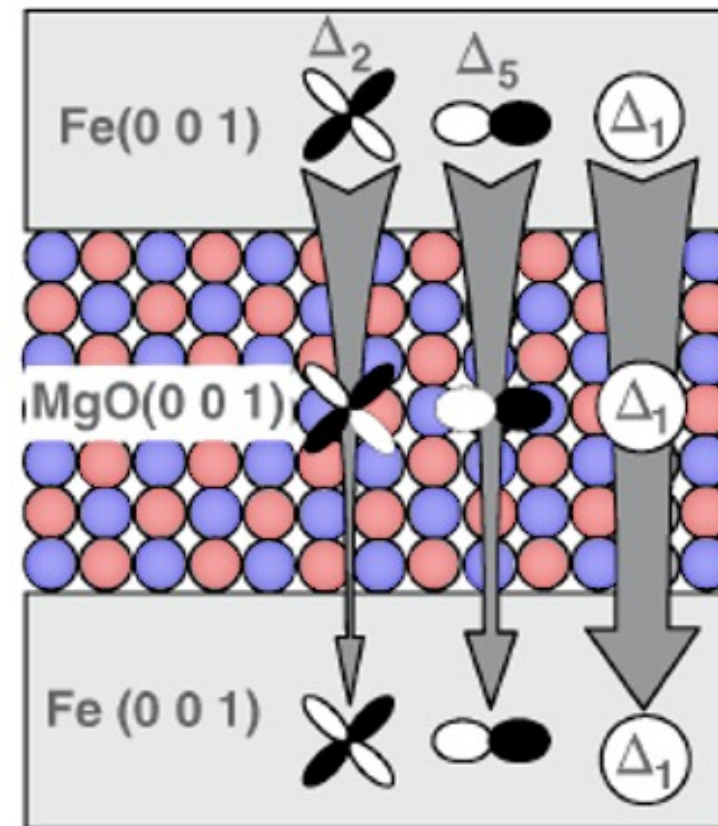
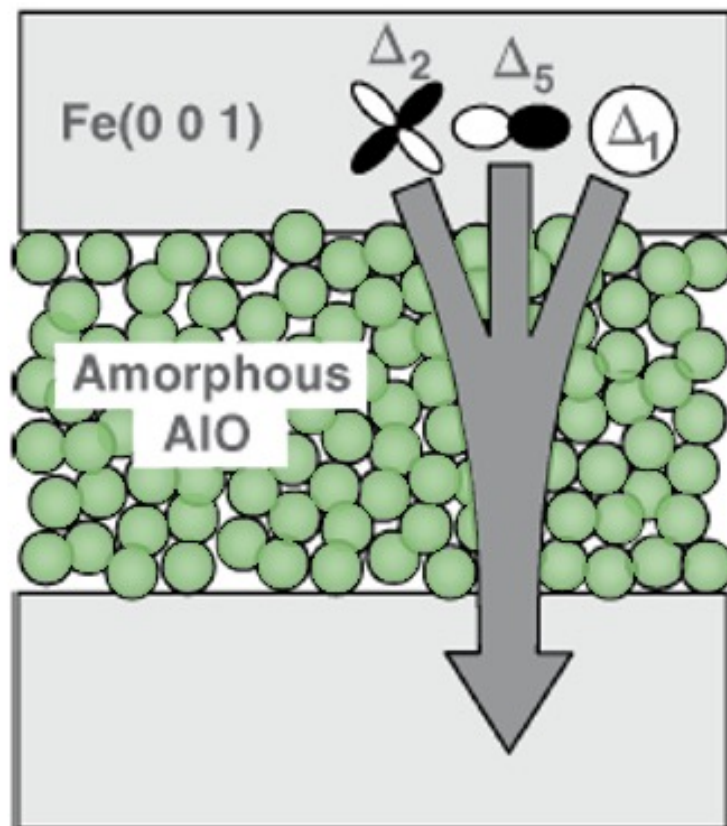
Claim 6

1. [pre] A magnetoresistive device comprising a magnetic tunnel junction structure comprising a multi-layer material stack including:
- [a] first and second ferromagnetic material layer; and
 - [b] a tunnel barrier layer between the first and second ferromagnetic material layers such that the tunnel barrier layer is above the first ferromagnetic material layer and below the second ferromagnetic material layer,
 - [c] wherein said tunnel barrier layer comprises crystalline MgO_x (001) with oxygen vacancy defects and ($0 < x < 1$).
6. The magnetoresistive device of claim 5, wherein the barrier height of the tunnel barrier layer is in a range of 0.2 eV to 0.5 eV.

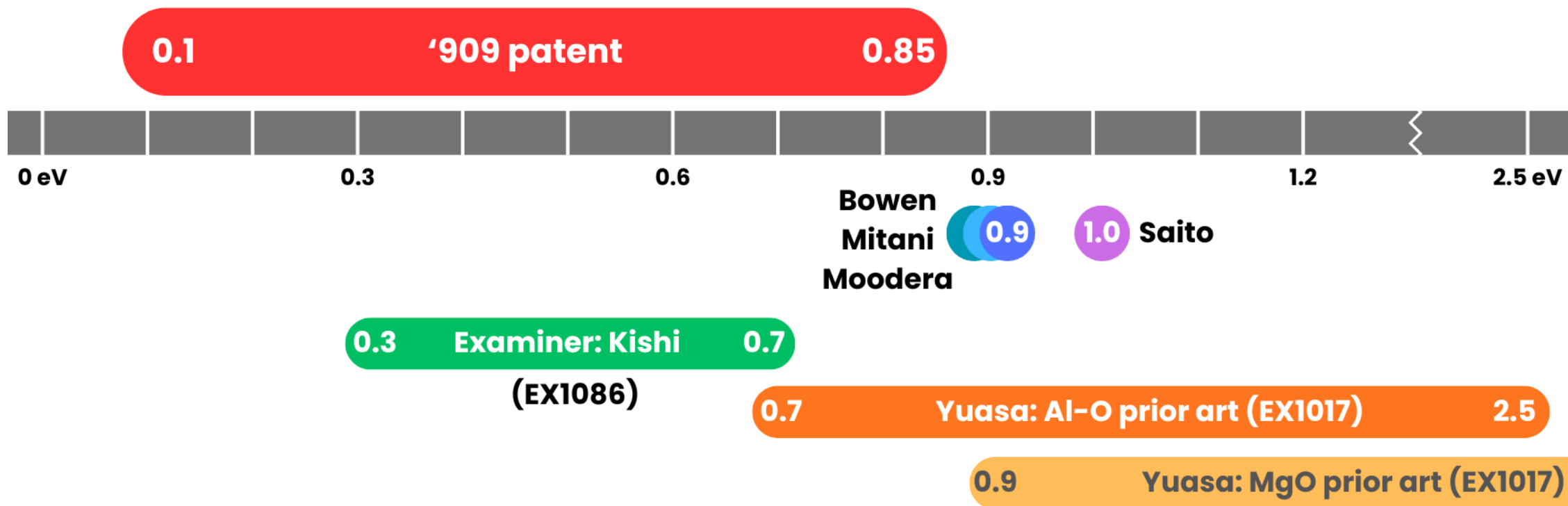
What is the Density of States (DOS)?

barrier. The number of electrons available for tunneling is described in quantum mechanics by the density of states (DOS) that describes the number of electron states per interval of energy around each energy level available to be occupied by electrons. For purposes of providing a simple illustration, spin-dependent tunneling

Al₂O₃ v. MgO



The Claimed Barrier Height Is Obvious



Sources: EX1017 ('909 Pat.); EX1026 (Bowen); EX1038 (Moodera); EX1053 (Mitani); EX2037 (Saito); EX1086 (Kishi FH); see also Pet. (Paper 1) at 33; POR (Paper 18) at 15; Reply (Paper 24) at 1. Demonstrative Exhibit - Not Evidence

Bowen



The magnetoresistance of magnetic tunnel junctions (MTJs)¹ is of uncontested interest for important applications with, in particular, promising perspectives for the fabrication of nonvolatile memories (Magnetic RAM).² Up to now, most studies have been performed on MTJs with a layer of amorphous alumina as insulating barrier between the ferromagnetic electrodes, yielding large and reproducible tunneling magnetoresistance (TMR). However, from a fundamental

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taxially grown structures. Towards this end, much work has been expended to characterize the growth and electrical behavior of ultrathin MgO layers.⁷ In this letter, we present experimental results showing large TMR values in Fe(001)/MgO(001)/FeCo(001) epitaxial tunnel junctions.

Source: EX1026 (Bowen) at 1655 (highlighted); see also Pet. (Paper 1) at 26, 34.

Demonstrative Exhibit - Not Evidence

TMR effect

$$\Delta \text{DOS} \Rightarrow \Delta \text{TMR}$$

The TMR effect is known to originate from the spin polarization of the electrodes, i.e. the difference between the densities of states (DOSs) of the up- and down-spin subbands in the two electrodes. According to Julliere's simplified

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AIP | Applied Physics Letters

assisted processes. The temperature dependence of $I(V)$ curves places¹² the barrier height at $\phi = 0.9$ eV. Simmons' equations¹³ yield $\phi \sim 1.1$ eV for a barrier thickness $d \sim 15$ Å, in good agreement with previous transport studies using epitaxial MgO(111) by Kiyomura *et al.*,¹⁴ and polycrystalline MgO by Moodera *et al.*,¹⁵ who both report $\phi \sim 0.9$ eV using this method. This value is lower than half of the 5.5 eV MgO band gap calculated for an ultrathin layer.⁵ This difference may be due to metal-induced gap states in the MgO barrier⁴ although we cannot completely rule out the presence of stoichiometric and/or thickness inhomogeneities in the insulating film. A somewhat higher value of ϕ has

Source: EX1026 (Bowen) at 1656 (highlighted); see also Pet. (Paper 1) at 24, 33.

Demonstrative Exhibit - Not Evidence

Tunnel Barrier Height

Δ Fermi energy $\Rightarrow$ Δ Barrier height

F. Tunnel Barrier Height

An MTJ's "tunnel barrier height" is the energy difference in electron volts (eV) between the Fermi energy (E_F) of the electrode material and the bottom of the conduction band of the barrier material so tunnel barrier height depends on the

Bowen



junction electrodes. Numerically, the TMR values calculated by Butler *et al.* are much higher (2000% for 20 Å MgO) than our experimental value of 60% (with a FeCo top electrode), as is generally the case when comparing theory with experiment. More interestingly, in future experiments we will aim to confirm the predicted relative increase of the TMR with MgO barrier thickness.

⁵W. H. Butler, X. G. Zhang, T. C. Schultess, and J. M. MacLaren, Phys. Rev. B **63**, 54416 (2001).

Soukup

TABLE I. Summary of device data.

Device No.	S^a	S_0^b	ϕ_1^c	ϕ_2^d	$P_{O_2}^e$
PY-G-11(1)	80	200	0.714	0.33	
PY-G-16(3)	105	...	0.721	...	...
PY-G-17(1)	200	194	0.721	0.33	...
PY-G-18(1)	105	...	0.694	0.34	...
PY-G-18(2)	105	222	0.700	0.35	...
PY-G-19(2)	70	133	0.710	0.33	...
PY-G-20(1)	680	...	0.695	...	...
PY-G-20(3)	680	...	0.695	...	...
PY-G-21(3)	90	...	0.732	0.34	...
PY-G-22(2)	90	209	0.780	0.21	10^{-8}
PY-G-25(3)	60	200	0.823	0.11	10^{-7}
PY-G-38(1)	120	...	1.9, 1.74 ^f	...	10^{-6} , ...

^a S = oxide thickness, in Å.

^b S_0 = overlayer thickness, in Å.

^c ϕ_1 = barrier obtained by zero intercept method, in eV.

^d ϕ_2 = barrier obtained from slope of Arrhenius plot, in eV.

^e P_{O_2} = pressure of admitted O_2 during MgO deposition, in Torr.

^f The barrier was obtained from the slope of the Fowler-Nordheim plot.

Sources: EX1028 (Soukup) at 3233 (annotated); see *also* Pet. (Paper 1) at 33.

Demonstrative Exhibit - Not Evidence

Soukup

near the underlayer. These results are consistent with the hypothesis that admitting oxygen gas during deposition of the MgO film increases the stoichiometry of the film as seen by an increased barrier height. The data is plotted on a Fowler–Nordheim plot in Fig. 7 and it can be seen that the injection mechanism could now be tunneling, i.e., a higher barrier.

2024: 909 Patent Allowed

<i>Applicant-Initiated Interview Summary</i>	Application No. 18/219,320	Applicant(s) YUASA, Shinji		
	Examiner ALONZO CHAMBLISS	Art Unit 2897	AIA (First Inventor to File) Status No	Page 1 of 1

Date of Interview: 02 February 2024

Issues Discussed:

35 U.S.C. 103

Debrosse et I.(US2004/0109347) as stated by applicant's attorney fails to disclose a tunnel barrier made of MgO with a barrier height between .1eV to .85eV. The examiner agrees with the applicant since the prior art shows a barrier height of .9ev which is outside the claimed range of .1eV to .85eV. However, the double patenting rejection of claims 3-10 and 17-22 are maintain by the examiner.

2025: 909 Child Application Rejected

Examiner withdrew allowance, rejected claims over Kishi:

3. Applicant is advised that the Notice of Allowance mailed **11/15/2023** is vacated.

* * *

7. Claims 11, 14, 16, 17, and 22 are rejected under pre-AIA 35 U.S.C. 102b as being clearly anticipated by Kishi et al. (JP2000-106462).

With respect to Claims 11, 14, and 17, Kishi teaches a first ferromagnetic material layer 2 and a second ferromagnetic material layer 4. A tunnel barrier layer 3 between the first ferromagnetic material layer 2 and the second ferromagnetic material layer 3. The tunnel barrier layer 3 comprises magnesium oxide and has a barrier height in a range of .3eV to .7eV (i.e. for example .4eV) (see paragraphs 20, 32, and 38; Fig. 1). Thus, Kishi teaches a barrier height of (0.1 eV to 0.85 eV) and (.2eV to .5eV).

Notice of Abandonment	Application No. 18/232,576 Examiner ALONZO CHAMBLISS	Applicant(s) YUASA, Shinji Art Unit 2897
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-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

This application is abandoned in view of:

- ☒ Applicant's failure to timely file a proper reply to the Office letter mailed on 26 June 2024.
 - ☐ A reply was received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the period for reply (including a total extension of time of _____ month(s)) which expired on _____.
 - ☐ A proposed reply was received on _____, but it does not constitute a proper reply under 37 CFR 1.113 to the final rejection. (A proper reply under 37 CFR 1.113 to a final rejection consists only of: (1) a timely filed amendment which places the application in condition for allowance; (2) a timely filed Notice of Appeal (with appeal fee); or (3) if this is utility or plant application, a timely filed Request for Continued Examination (RCE) in compliance with 37 CFR 1.114. Note that RCEs are not permitted in design applications.)
 - ☐ A reply was received on _____ but it does not constitute a proper reply, or a *bona fide* attempt to prosecute, to the non-final rejection. See 37 CFR 1.85(a) and 1.111. (See explanation in box 8 below).
 - ☒ No reply has been received.
- ☐ Applicant's failure to timely pay the required issue fee and publication fee, if applicable, within a statutory period of three months from the mailing date of the Notice of Allowance (PTOL-85).
 - ☐ The issue fee and publication fee, if applicable, was not paid on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the statutory period for payment of the issue fee and publication fee to the Office of Allowance (PTOL-85).
 - ☐ The submitted fee of \$_____ is insufficient. A balance of \$_____ is due.
 - ☐ The issue fee and publication fee, if applicable, was not paid on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the statutory period for payment of the issue fee and publication fee to the Office of Allowance (PTOL-85).
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- ☐ Applicant's failure to timely file a proper reply to the Office letter mailed on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the period for reply (including a total extension of time of _____ month(s)) which expired on _____.
 - ☐ A proposed reply was received on _____, but it does not constitute a proper reply under 37 CFR 1.113 to the final rejection. (A proper reply under 37 CFR 1.113 to a final rejection consists only of: (1) a timely filed amendment which places the application in condition for allowance; (2) a timely filed Notice of Appeal (with appeal fee); or (3) if this is utility or plant application, a timely filed Request for Continued Examination (RCE) in compliance with 37 CFR 1.114. Note that RCEs are not permitted in design applications.)
 - ☐ A reply was received on _____ but it does not constitute a proper reply, or a *bona fide* attempt to prosecute, to the non-final rejection. See 37 CFR 1.85(a) and 1.111. (See explanation in box 8 below).
 - ☒ No reply has been received.
- ☐ The fee of \$_____ for an appeal which is payable to the attorney or agent of record or other party authorized under 37 CFR 1.33 (b). See 37 CFR 1.36(b).
- ☐ The letter expressing abandonment which is signed by an attorney or agent (acting in a representative capacity under 37 CFR 1.34) upon the expiration of the period for seeking court review of the decision has expired and there are no allowed claims.
- ☐ The dismissal of the appeal in an application having no allowed claims. (When an appeal is dismissed in an application having no allowed claims the application stands abandoned. See MPEP 1215.04 subsections I-V for an explanation of the reasons why an appeal is dismissed.)
- ☒ The reason(s) below:
The attorney of record (Andrzej Malacz) informed the examiner on 10/20/24 that the case has gone abandon.

Examiner
ALONZO CHAMBLISS

1.181, should be promptly filed to minimize
Part of Paper No. 20250109

**IPB abandoned app.
1/14/2025**

Alleged Secondary Considerations

Read sensor technology for ultrahigh density magnetic recording

Tomoya Nakatani, Zheng Gao, and Kazuhiro Hono

This article reviews progress in magnetoresistive (MR) read sensor technology for hard-disk drives (HDDs). MR reader technology has progressed from the anisotropic magnetoresistance sensor, to the current-in-plane giant magnetoresistive (CIP-GMR) sensor, to today's current-perpendicular-to-plane (CPP) tunneling magnetoresistance (TMR) sensor. This evolution has

EX2022

Credits Butler,
not Yuasa



EX2024

“Yuasa’s pioneering work on magnetic tunnel junctions... which have a large room temperature magnetoresistance (MR) ratio”



EX2029

Yuasa: “a giant tunnel magnetoresistance effect of approximately 200% at room temperature was realized for the first time”

Sources: EX2022 (Nakatani) at 107; EX2024 at 2; EX2029 at 2; see *also* Reply (Paper 24) at 3-4.

Demonstrative Exhibit - Not Evidence

EX2022 Nakatini article

Tunnel MR sensors

Current TMR readers utilize an MgO(001) crystalline tunnel barrier. In 2001, Butler and Mathon independently proposed a large TMR ratio from a Fe(001)/MgO(001)/Fe(001) epitaxial magnetic tunnel junction (MTJ).^{5,6}

* * *

through the Fe-MgO interfaces. With this coherent tunneling mechanism, the effective barrier height can also be smaller than the case of noncoherent tunneling, which makes a TMR sensor with low resistance and high MR ratio possible.

Tunnel MR sensors

Current TMR readers utilize an MgO(001) crystalline tunnel barrier. In 2001, Butler and Mathon independently proposed a large TMR ratio from a Fe(001)/MgO(001)/Fe(001) epitaxial magnetic tunnel junction (MTJ).^{5,6} In this configuration, electrons with certain band asymmetry (Δ_1 band) can coherently tunnel through a crystalline MgO barrier, which acts as a spin filter allowing only majority-spin (up-spin) electrons to tunnel (i.e., spin polarization $P \sim 1$) of tunnel electrons. Since TMR ratio is expected to follow Julliere's equation,⁷ $\text{TMR ratio} = 2P_1P_2/(1-P_1P_2)$, where P_1 and P_2 are the spin polarizations of each magnetic electrode of MTJ, large TMR enhancement is expected when P approaches 1 by the spin filtering effect through the Fe-MgO interfaces. With this coherent tunneling mechanism, the effective barrier height can also be smaller than the case of noncoherent tunneling, which makes a TMR sensor with low resistance and high MR ratio possible. Yuasa et al. demonstrated, in 2004, a 180% MR ratio with a fully epitaxial MBE-grown single-crystalline Fe(001)/MgO(001)/Fe(001) MTJ based on this theoretical prediction.⁸ Parkin et al.⁹ demonstrated an MR ratio of 220% with fully integrated polycrystalline TMR stack of CoFe/MgO/CoFe. This result motivated many researchers in industry and academia to further pursue the potential of MgO-based TMR to meet process and design requirements for read sensors.

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