

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

WESTERN DIGITAL TECHNOLOGIES, INC.,
Petitioner,

v.

GODO KAISHA IP BRIDGE 1,
Patent Owner.

Case No. IPR2024-01447
Patent No. 8,405,134

PATENT OWNER'S RESPONSE

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2016	Gleiter, H. “Nanostructured Materials: Basic Concepts and Microstructure,” <i>Acta Materialia</i> , vol. 48, no. 1, pp. 1-29 (2000)
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2019	Marrows, C.H. “Spin-polarised currents and magnetic domain walls,” <i>Advances in Physics</i> , vol. 52, no. 8, 2005, pp. 585-713
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2022	Nakatani, T., et al. “Read sensor technology for ultrahigh density magnetic recording,” <i>MRS Bulletin, Materials Research Society</i> , vol. 43, no. 2, 2018, pp. 106-111
2023	Jiang, B., et al. “Tunneling magnetoresistive devices as read heads in hard disk drives,” <i>Journal of Magnetism and Magnetic Materials</i> , vol. 571, 2023, p. 170546
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2026	2021 New Fellows, IEEE Japan Council, <i>available at</i> https://ieeelp.org/en/kaiin/fellow/fellow21.html
2027	JST owned patent wins Future Creative Invention Prize at the National Invention Award 2021, Japan Science and Technology Agency, <i>available at</i> https://www.jst.go.jp/report/2021/210525_e.html
2028	Dr. Shinji Yuasa profile, <i>available at</i> https://www.jst.go.jp/impact/sahashi/en/system/index.html
2029	AIST wins three Science and Technology Awards in the 2016 Minister of Education, Culture, Sports, Science and Technology Commendation for Science and Technology, <i>available at</i> https://www.aist.go.jp/aist_j/news/prize/pr20160412_3.html
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2036-2037	RESERVED
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2058	Powder diffraction file for Au, from Joint Committee of Powder Diffraction Standards (JCPDS), The International Centre for Diffraction Data, icdd.com
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2061	Boubeta, <i>et al.</i> , “Epitaxial Fe/MgO heterostructures on GaAs(001),” 226 <i>J. of Crystal Growth</i> 223-230 (2001); Exhibit EX1084 in IPR2024-01493
2062	Saito, Y., et al., “Correlation between barrier width, barrier height, and dc bias voltage dependences on the magnetoresistance ratio in Ir-Mn exchange biased single and double tunnel junctions,” <i>Jpn J. Appl. Phys.</i> 39, L1035–L1038 (2000)
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2068	Aboelfotoh, M. O., <i>Preferred orientations in MgO films deposited on amorphous substrates</i> , Applied Physics Letters, Vol. 24, No. 8, 347-349 (1974)
2069	L.E. Murr, <i>Handbook of Materials Structures, Properties, Processing and Performance</i> , Springer, 2015, pgs. 149-161
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I. INTRODUCTION

Patent No. 8,405,134 (“’134 Patent”) is directed to magnetic tunnel junction (“MTJ”) devices which are magnetoresistive devices having a tunnel barrier layer between two ferromagnetic electrodes.

The ’134 Patent’s claims 1-4 (“Challenged Claims”) all recite a magnetoresistive device comprising first and second ferromagnetic layers and a tunnel barrier layer in between. The tunnel barrier layer is “a single-crystalline or poly-crystalline magnesium oxide (MgO) in which (001) crystal plane is preferentially oriented” (hereafter “the claimed MgO(001) layer”). “(001) ... preferentially oriented” refers to a specific type of crystalline structure. Every claim also requires that the first ferromagnetic layer is “crystallized” (claims 1-2) or “entirely crystallized” (claims 3-4) and comprises a CoFeB (cobalt-iron-boron) alloy. The “first” ferromagnetic layer is the MTJ device’s bottom electrode because the claims require it be formed on a substrate.

This Patent Owner Response is supported by testimony from Dr. Caroline Ross, an MIT professor with decades of industry and research experience in MTJs. Dr. Ross is one of the world’s leading experts in the aspects of MTJ development that are critical to resolving the issues in this proceeding – materials science, thin film growth and crystal growth. EX2053 (“Ross”), ¶¶2-10. Conversely, Petitioner’s expert, Dr. Bokor, has limited expertise in materials science. EX2059, 42:6-21.

Worse yet, despite every Challenged Claim requiring a crystallized MgO(001) layer and a ferromagnetic layer that is “crystallized and comprises CoFeB alloy,” Dr. Bokor admitting he has *no* experience in forming crystalline materials. EX2018 (“Bokor-Depo”), 77:9-78:3 (“I’m no expert. I’m no crystal grower.”).

A. A POSA Never Would Have Combined the Prior Art Teachings In the Manner Alleged

Petitioner could find no teaching in the art of an MTJ device with a bottom ferromagnetic electrode that is crystallized *and* comprises CoFeB. The Petition’s two grounds are obviousness grounds.

Both grounds rely on primary references (Bowen or Nagahama) that discloses an MTJ device with *crystalline* electrodes that do not comprise CoFeB. Bowen and Nagahama were early attempts to test Butler’s and Mathon’s theory that an MTJ device formed with a perfectly crystalline MgO barrier layer and *perfectly crystalline electrodes* could yield a high tunnel magnetoresistance ratio (“TMR”)—a desired characteristic for commercial MTJ devices. Bowen and Nagahama had no boron in their electrodes because it was well known that boron “‘inhibited’ crystallization” (Petition, 37) and Bowen and Nagahama wanted crystalline electrodes.

Both grounds rely on the same two secondary references – Sunai and Parkin – to teach CoFeB electrodes. Sunai and Parkin took a different approach than Bowen and Nagahama. Sunai and Parkin used boron in their electrodes to make the

electrodes amorphous (*i.e.*, ***non***-crystalline) which Sunai and Parkin taught provided certain benefits.

Petitioner's assertion that these disparate teachings in the art would have led a POSA to a ferromagnetic electrode layer that is crystallized and comprises CoFeB is baseless. Petitioner's obviousness combinations improperly pick and choose isolated teachings in the prior art in an attempt to reconstruct the claims in hindsight. Petitioner's secondary references (Sunai and Parkin) would not have motivated a POSA to modify either of Petitioner's primary references (Bowen and Nagahama) to use a ferromagnetic layer with boron because the secondary references teach that adding boron yielded a ***non***-crystalline electrode which was the exact opposite of what Bowen and Nagahama were trying to achieve. Moreover, after "picking" the teachings in Sunai and Parkin of an electrode with boron, Petitioner ignores the very reason why Sunai and Parkin used boron (to avoid crystallinity) and "chooses" a crystalline structure for the CoFeB electrode allegedly based on the primary references (Bowen and Nagahama), neither of which used a CoFeB electrode. Petitioner fails to establish that a POSA interested in retaining the crystalline structure of the electrodes in Bowen or Nagahama had any reason to introduce boron in the first place given that it was well known that boron would have inhibited the very crystallization Bowen and Nagahama sought.

Petitioner fails to establish that a POSA would have combined the teachings of the prior art in the manner claimed. Both grounds fail for that reason alone.

B. Petitioner Fails to Establish that Either Ground’s Combination Meets the Claimed MgO(001) Limitation

Even if the Board were to find that a POSA had some reason to combine the prior art teachings in the manner Petitioner alleges, Petitioner fails to establish that either of its modified MTJ devices—Bowen-Sunai/Parkin (Ground 1) or Nagahama-Sunai/Parkin (Ground 2)—meets the claimed MgO(001) layer.¹

Petitioner did not explain the contemplated workings of either combination and then map either independent claim (claims 1 and 3) to the combination. Instead, Petitioner mapped certain claim limitations to the *unmodified* primary reference (Bowen or Nagahama). The Petition implicitly assumes that the modified MTJ device (Bowen-Sunai/Parkin or Nagahama-Sunai/Parkin) would meet those claim limitations the same way the unmodified primary reference does. As Dr. Ross explains, that assumption was wrong for the claimed MgO(001) layer.

It was well-known that MgO crystallization is highly sensitive to certain conditions of the underlayer on which it is formed for the ultrathin layers used in MTJ devices like Bowen’s and Nagahama’s. Those conditions include whether the

¹ Patent Owner did not advance this argument in its POPR because it is best advanced with supporting expert testimony.

underlayer is crystalline or amorphous (*i.e.*, non-crystalline) and, if the underlayer is crystalline, the lattice spacing and orientation of the crystalline structure. The claims require that the MgO layer not only be crystalline but that it have a particular crystalline orientation – (001). Bowen and Nagahama have MgO(001) layers because they formed their MgO layers on a crystalline (001) underlayer – the bottom electrode was a crystalline (001) metal (Fe or CoFe) – that promoted MgO to form in an (001) orientation. But the Grounds modify Bowen and Nagahama to replace their bottom electrodes with CoFeB which is indisputably non-crystalline when formed. Petitioner fails to establish that either of its *modified* MTJ devices—Bowen-Sunai/Parkin (Ground 1) or Nagahama-Sunai/Parkin (Ground 2)—would have had the claimed MgO(001) layer.

Ground 2 is the more egregious example. The Petition only alleges that Nagahama alone, *unmodified* by Sunai and/or Parkin, meets the claimed MgO(001) layer. Petition, 56 and 63. Petitioner fails to even allege that **Ground 2's combination** meets the claimed MgO(001) limitation, let alone explain how or why that would have been so despite the fact that Ground 2's combination modifies Nagahama to use a CoFeB electrode instead of Nagahama's crystalline (001) electrode on which Nagahama's MgO(001) layer was formed. That should end the matter. Ground 2 fails to show that its *combination* meets the claimed MgO(001) layer.

Ground 1's showing for Limitation 1[d]'s² MgO(001) layer acknowledges that the combination replaces Bowen's crystalline (001) electrode – on which Bowen's MgO(001) layer was formed – with a CoFeB electrode. Petition, 33-34. But the Petition then simply alleges that the Bowen-Sunai/Parkin combination's MgO layer would “still have the same (001) orientation.” *Id.* No evidence supports that assertion. Indeed, Petitioner cites Parkin which teaches that it achieved an MgO(001) layer by forming the MgO layer on a crystalline (001) underlayer. Petitioner cites *no evidence* of a crystalline MgO(001) layer forming atop a CoFeB underlayer.

Both grounds fail because Petitioner fails to establish that the combination in either ground meets the claimed MgO(001) layer.

C. No Evidence Establishes that a POSA Would Have Reasonably Expected that Petitioner's Formation Techniques Would Have Yielded the Claimed MgO(001) Layer

To the extent Petitioner alleges in reply that a POSA would have reasonably expected that the formation techniques Petitioner describes for making Ground 1's Bowen-Sunai/Parkin's MTJ or Ground 2's Nagahama-Sunai/Parkin MTJ would have yielded an MTJ device with the claimed MgO(001) layer, any such assertion would fail. Dr. Ross explains in detail why a POSA would not have reasonably expected success in forming the claimed MgO(001) layer on a CoFeB underlayer

² This paper adopts the Petition's claim limitation labelling.

as in Petitioner's grounds. Dr. Ross's testimony is corroborated by extensive citation to teachings in the art and by evidence of the contemporaneous reaction of those in the field that were surprised by the unexpected results that the inventor, Dr. Yuasa, achieved.

To meet a *different* claim limitation requiring that the first ferromagnetic layer is "crystallized" and comprises CoFeB, Petitioner alleges a POSA would have annealed the CoFeB layer to crystallize it before forming the MgO layer on top of it. But Petitioner's expert admitted he did not know if the CoFeB electrode layer would crystallize at all.

Q So in Bowen's device now, if we modified Bowen's process, its fabrication method, and instead of depositing *iron* at room temperature for the bottom electrode, we deposited *cobalt iron boron* for the bottom electrode, what would happen when you then annealed that layer at 400 Celsius?

THE WITNESS: Right off the top of my head, *I can't answer that question*. We would I would have to go look through I don't if you if you are aware of a somewhere in all of the literature where somebody did that, we could I would be happy to look at that. But I can't *I'm unwilling to speculate just off the top of my head what would happen. I don't know* I don't know what what what that might what might happen in that situation. *I can't speculate*.

Bokor-Depo, 169:16-170:12 (Nagahama has a similar process for annealing the lower electrode).³

The claims do not require that the ferromagnetic layer that comprises CoFeB have any particular crystalline structure – they only require that the layer is “crystallized.” Thus, even if the Board were to find that Petitioner established that the CoFeB layer in its combinations would have crystallized in *some* form, Petitioner never even alleges, let alone establishes, that it would have crystallized with a top surface having the (001) orientation the prior art taught was needed for an underlayer to support formation of a thin MTJ MgO(001) layer.

Petitioner cites two references (Jimbo and Cardoso) as allegedly teaching that annealing a CoFeB layer resulted in crystallization. Even if Petitioner’s reliance on those references is credited, those references suggest that *if* crystallization occurred it had a (111) orientation. It is well-known that (111) orientation is dramatically different than the claimed (001) orientation. Ross, ¶¶131, 138. Indeed, Petitioner’s own cited evidence teaches that it is impossible to form the claimed MgO(001) layer atop a crystalline underlayer of (111) orientation. EX1057, 47, 127. Petitioner cites no evidence establishing that a POSA would have reasonably expected success in forming the claimed MgO(001) layer atop an annealed CoFeB layer as in Petitioner’s combinations.

³ Emphasis added except where noted.

In its Institution Decision (Paper, 10, “DI”), the Board noted Jimbo’s teaching of annealing CoFeB structures but “invite[d] additional briefing on” whether a POSA would have reasonably expected an annealing process to have achieved “a crystal CoFeB layer” in the combination used in either ground. DI, 20-22 and 31. Patent Owner (“PO”) presented only “attorney argument” pre-institution. *Id.* Now, Dr. Ross explains why neither Jimbo nor Cardoso teaches crystallization of a CoFeB layer that would support formation of the claimed MgO(001) layer atop it.

Lastly, Petitioner alleges that annealing the entire MTJ would have resulted in a crystalline CoFeB layer. Petitioner never even alleges that a POSA would have reasonably expected that annealing the MTJ would have yielded an MgO(001) layer—let alone submit evidence to establish that. The only reference used in either combination that teaches annealing the entire MTJ with an MgO tunnel barrier after formation was Parkin. But Parkin did not grow an MgO layer atop a CoFeB layer as in Petitioner’s combinations. Parkin did what every other prior art reference with an MgO(001) layer did—Parkin achieved an MgO(001) layer by

forming it on a crystalline ferromagnetic layer 119 with a (100)⁴ orientation that was known to promote MgO forming in (001) orientation. EX1062, 13:3-25, 16:41-46, 17:18-39, Fig. 3A (reproduced below with Petitioner's annotations); Petition, 39. Parkin does not teach that annealing an MTJ would yield a crystalline MgO(001) layer if the layer on which the MgO layer was formed was not crystalline (001).

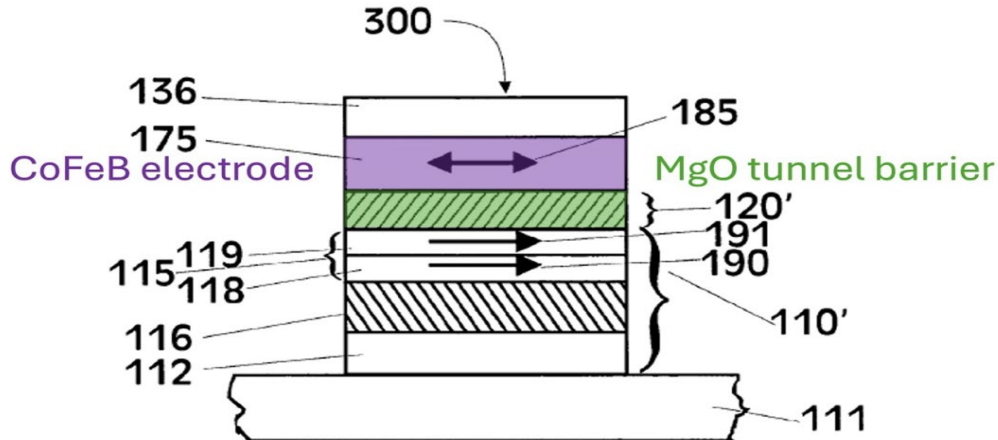


FIG. 3A

No prior art reference establishes that a POSA would have reasonably expected that annealing the MTJ in either of Petitioner's combinations would have yielded the claimed MgO(001) layer.

⁴ Petitioner admits that because MgO crystallizes in symmetric cubes its (001), (100), (010) planes are the same. Petition, 13, 33-34. Fe and CoFe similarly crystallize in symmetric cubes. Ross, ¶106.

D. Petitioner's Showing for Claims 3-4 is Facially Deficient

Claims 3-4 require that the first ferromagnetic layer is “*entirely* crystallized and comprises CoFeB alloy.” Petitioner’s showing for claims 3-4 fails for all the same reasons as its showing for claims 1-2 and for an additional reason. Petitioner identifies no ferromagnetic layer that comprise a CoFeB alloy and is “entirely crystallized” in the prior art and Petitioner’s expert offered no opinion that the modified MTJ device in either ground would have had such a layer. Petitioner cannot carry its burden to prove claims 3-4 obvious where no prior art evidence and no expert testimony supports Petitioner’s showing for claims 3-4.

* * *

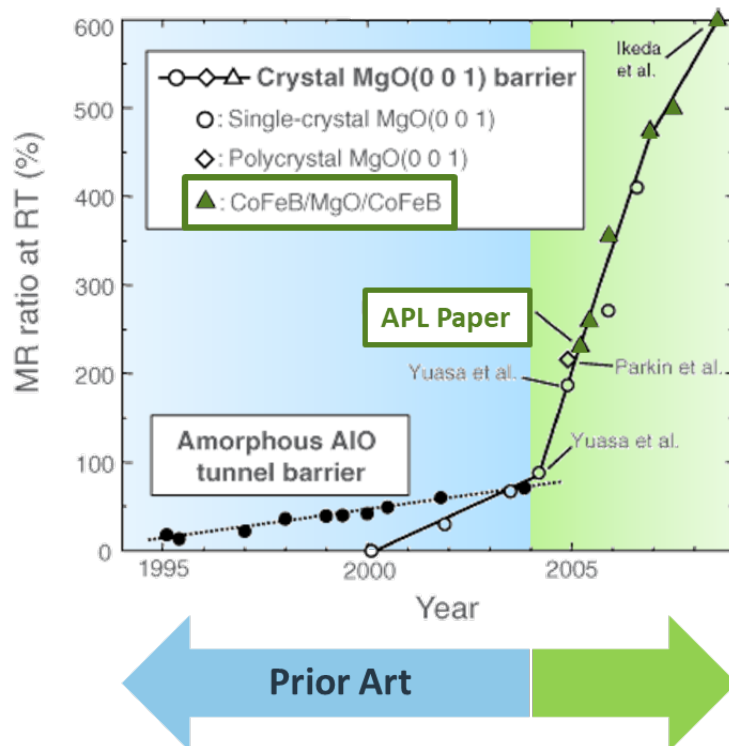
The technology at issue in this case is extremely complex. Prior to the inventor’s groundbreaking work, the technology was in its infancy and poorly understood even by the world’s leading experts. Petitioner’s grounds are based on nothing but hindsight and Petitioner fails to carry its burden to prove a reasonable expectation of success in achieving any Challenged Claim.

The contemporaneous reaction of those in the field reveals that the inventor achieved surprising and unexpected results that made a massive advance in making MTJ devices feasible for commercial applications. The record includes extensive objective evidence of non-obviousness. The inventor, Dr. Yuasa, received more than twenty scientific awards and extensive contemporaneous praise for his work

described in the '134 Patent. *See infra* §VII.A. Dr. Yuasa's work has been cited more than ***five thousand*** times by others and has appeared in the field's pre-eminent journals. Petitioner Western Digital's own employees contemporaneously praised Dr. Yuasa's work. The assertion now—two decades later—by Western Digital's attorneys and its paid expert that Dr. Yuasa's contributions to the art were “obvious” is belied by the ***contemporaneous*** reaction of those in the field – including Western Digital's own employees – who praised his work as groundbreaking.

The Petition itself cites—multiple times—a chapter from a 2017 textbook that Dr. Yuasa authored. Petition, 1, 6-7, 11-13 and 15 (citing EX1057). That chapter in turn cites Reference 33, which is a paper by Dr. Yuasa (the “APL paper”) disclosing the claimed invention. EX1057, 52. Figure 2.21 from the textbook shows graphically how the claimed device unleashed a new era of MTJs with skyrocketing TMRs. EX1057, 46; Ross, ¶262.

Figure 2.21 (Annotated)



Below, PO explains, with extensive citation to Dr. Ross’s testimony, admissions from Petitioner’s expert, and corroborating evidence, why Petitioner’s obviousness theories are baseless. PO also addresses any skepticism the Board expressed about PO’s arguments in instituting this trial. The more fully-developed record supports only one conclusion—Petitioner fails to carry its burden to prove any Challenged Claim obvious.

II. MAGNETIC TUNNEL JUNCTION DEVICES

A. Overview

An MTJ device has an insulator, called a tunnel barrier layer, between two ferromagnetic electrodes. EX1005, 1:38-42. Current can flow between the

electrodes, through the insulator layer, via a quantum phenomenon known as “tunneling.”

In 1975, Julliere (EX1033) observed that tunneling conductance and resistance through an Fe-Ge-Co junction was different when the electrode magnetizations were in parallel versus antiparallel. EX1033, 255-256. MTJs attracted attention in the mid-1990s when large differences between the parallel and antiparallel tunneling resistances were achieved through Al_2O_3 -based junctions. EX1057, 9-10, 27, 42-43, 51; EX1055, 2269, 2271; EX1035, 3273; EX1034, 231; Ross, ¶¶273-274.

In 2001, Butler (EX1044) and Mathon (EX1046) predicted the differences between the parallel and antiparallel resistances might be even greater in epitaxially-grown crystalline Fe-MgO-Fe structures because of a compatible crystal lattice match between Fe(001) and MgO(001). Ross, ¶106. Experimentalists worked for many years building MTJs attempting to realize the theory of whether an MTJ with an MgO insulating barrier layer could produce a commercially-useful device.

B. TMR

An MTJ device has parallel and antiparallel states corresponding to different relative magnetizations between its magnetic electrodes. The resistance R_{ap} in the

antiparallel state is higher than the resistance R_p in its parallel state. MTJ's are "magnetoresistive" because the magnetic state impacts the device's resistance.

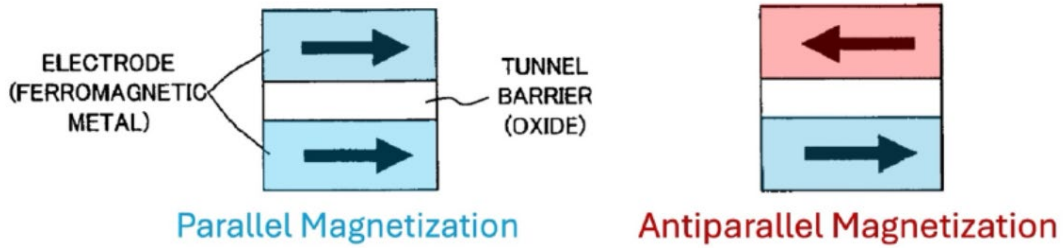


Fig. 8(A) (*Low Resistance*)

Fig. 8(B) (*High Resistance*)

Petition, 5 (annotating '134 Patent figures).

"Tunnel magnetoresistance ratio" ("TMR") is determined as shown by the Petition's below-reproduced formula. Petition, 5-6. A higher TMR facilitates determining which state the MTJ device is in because it reflects a larger difference between the antiparallel and parallel resistances. EX1005, 4:52-59.

$$\text{TMR} = \frac{\Delta R}{R_p} = \frac{R_{ap} - R_p}{R_p}$$

C. Butler's and Mathon's Theories on MgO Barriers

In 2001, Butler and Mathon presented a theoretical model predicting MTJs with a Fe-MgO-Fe junction—formed as a single perfect crystal—would produce a higher TMR than MTJs with Al₂O₃ barriers.⁵ EX1044, 1; EX1046, 1; Ross, ¶273.

D. Resistance-Area Product

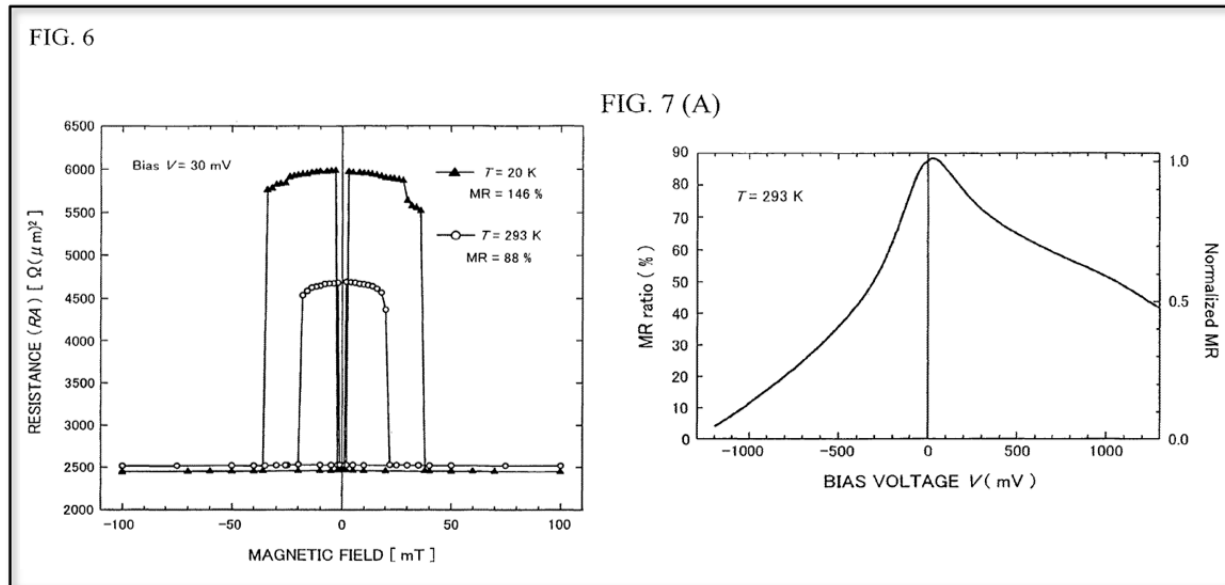
The resistance-area product (RA) of an MTJ device is the device's resistance R per unit area in ohms (Ω) per μm^2 . EX2008, 869; EX2060, 866-867, 864-865; Ross, ¶¶44-46, 273. An MTJ's RA is an important consideration for an MTJ device used in a circuit because it impacts the output voltage across the MTJ at a given current. Ross, ¶¶35-36. A too-high or too-low RA value would make it difficult for sensing circuitry to distinguish between an MTJ's parallel and antiparallel configurations. Ross, ¶273.

III. THE '134 PATENT

Dr. Yuasa recognized that Al₂O₃-based MTJs exhibited peak TMR values that were too low and decayed too rapidly for use in MRAM, and that Julliere's equation predicted TMR limits that would prevent realization of high-capacity MRAM. EX1005, 2:25-46, 5:1-14; Ross, ¶¶33-46.

⁵Al₂O₃ was predominantly used for tunnel barriers before Butler and Mathon. Ross, ¶273.

Dr. Yuasa understood the possibility of higher TMRs using ferromagnetic electrodes and MgO barrier layers. EX1005, 5:15-61, 8:56-9:10. Dr. Yuasa had the insight to use a ferromagnetic material layer that is crystallized and comprises CoFeB alloy, with a tunnel barrier layer that comprises a single-crystalline or polycrystalline MgO in which (001) crystal plane is preferentially oriented. *Id.* Dr. Yuasa's MTJ achieved "the highest MR ratios [*i.e.*, TMR] that [had] so far been obtained at room temperature" with small bias voltage dependency and a "resistance-area (*RA*) product ... suitable for MRAM." EX1005, 7:55-8:20; FIG. 6 (showing TMR and *RA* values), FIG. 7(A) (showing TMR and slow decay); EX2008, 869-870; Ross, ¶44.



Dr. Yuasa's discovery that an MTJ device with the claimed CoFeB ferromagnetic electrodes and MgO(001) layer could realize a device with a TMR and *RA* suitable for commercial applications was a ground-breaking advance, as

evidenced by the wide-spread acclaim Dr. Yuasa received. *Infra* §VII; Ross, ¶¶260-272.

IV. PETITIONER FAILS TO SHOW THAT THE MODIFIED MTJ IN EITHER GROUND HAD AN MGO(001) LAYER AS CLAIMED

In both grounds, the Petition maps its *unmodified* primary reference to certain claim limitations and then purports to modify the primary reference only when the Petition confronts a limitation the primary reference fails to meet. *See e.g.*, Petition, 28-41 (Ground 1: mapping Bowen to Limitations 1[pre]-1[d] and Bowen-Sunai/Parkin to Limitation 1[e]) and 50-61 (Ground 2: mapping Nagahama to Limitations 1[pre]-1[d] and Nagahama-Sunai/Parkin to Limitation 1[e]).

The Petition did not, for either ground, clearly explain the contemplated workings of its combination and then map a clearly-explained combination to the Challenged Claims. *Personal Web Techs. v. Apple*, 848 F.3d 987, 994 (Fed. Cir. 2017) (“a clear, evidence-supported account of the contemplated workings of the combination is a prerequisite to adequately explaining and supporting a conclusion that a [POSA] would have been motivated to make the combination and reasonably expect success in doing so.”). As explained below, Petitioner fails to establish that the alleged *combination* in either ground meets the claimed MgO(001) layer. Ross, ¶¶96-100.

A. Ground 2 Never Maps its Nagahama-Sunai/Parkin Combination to Limitation 1[d] or 3[d] that Require an MgO(001) Layer

Ground 2 alleges that Nagahama alone, *unmodified* by Sunai and/or Parkin, meets Limitations 1[d] and 3[d]. Petition, 56 and 63. Petitioner fails to even allege that **Ground 2's combination**—which modifies Nagahama based on Sunai and/or Parkin to replace Nagahama's (001)-highly-oriented lower ferromagnetic electrode with a CoFeB electrode (Petition, 56-61)—meets Limitation 1[d] or 3[d], let alone explain how or why that would have been so.

As explained *infra* §IV.C.2, it was well-known that MgO crystallization is highly sensitive to the conditions of the underlayer on which it is formed for the ultrathin layers used in MTJ devices like Bowen's and Nagahama's. *See also* Ross ¶¶140-171; EX1026, 1656 (MgO barrier layer of 20 Angstroms (2 nm)); EX1062, 18:34-39, 17:21-37 (MgO barrier layer range of 5-50 Angstroms (0.5-5 nm)).⁶ These conditions include the crystallinity (or lack thereof) in the underlayer and, if the underlayer is crystalline, the lattice spacing and crystalline orientation of the underlayer. *Id.*; *see also infra* §IV.C.2.c. Fe and CoFe were known to have crystal lattice spacing and (001) crystal orientations that promoted MgO to grow in an (001) orientation. *Id.*; Ross ¶¶113-114, 106. That is because MgO was known to form a crystalline structure having close symmetry in the orientation and lattice

⁶ Nagahama does not report a thickness for its MgO barrier layer.

spacing to that of a crystalline underlayer like Fe(001) and CoFe(001). Id., *see also infra* §IV.C.1.

Nagahama – like every reference Petitioner cites with an MgO(001) layer – achieved its MgO(001) layer by depositing the MgO layer on a highly-oriented (001) ferromagnetic electrode. EX1027, ¶73 (“magnetoresistive element ... includes a (001)-highly-oriented lower ferromagnetic electrode layer, a (001)-highly-oriented MgO barrier layer, and a (001)-highly-oriented upper ferromagnetic electrode layer”), ¶62 (describing the process for making the device), ¶65 (the “Fe diffraction . . . shows that high quality crystals have grown in the (001) direction”); Ross, ¶115; Bokor-Depo, 196:4-200-4; Petition, 51 (Nagahama’s lower electrode is “(001)-highly oriented”); *infra* §IV.C.1 (discussing Bowen and Parkin).

But Nagahama’s highly-oriented (001) electrode is **not** used in Ground 2’s combination—it is “replace[d]” by an CoFeB electrode that Petitioner never even alleges is of (001) crystalline structure. Petition, 57 (Nagahama’s (001) ferromagnetic layer is “replace[d] ... with CoFeB”). That Nagahama achieved an MgO(001) layer provides no evidence of what MgO structure would have formed on the CoFeB electrode – which Petitioner never alleges is crystalline with an (001) orientation—in Ground 2’s *Nagahama-Sunai/Parkin combination*. Ross, ¶¶116-117.

For Ground 1's Bowen-Sunai/Parkin combination, Petitioner's showing for Limitations 1[d] and 3[d] acknowledges that replacing Bowen's (001) lower electrode could impact the structure of the resulting MgO layer and advances an argument for why the ***Bowen-Sunai/Parkin combination's*** MgO layer would have been (001). Petition, 33-34 and 45. Petitioner made no such argument for Ground 2's Nagahama-Sunai/Parkin combination.

The Petition's failure to explain how or why its Nagahama-Sunai/Parkin combination allegedly meets the claimed MgO(001) layer in Limitations 1[d] and 3[d] is far from a harmless oversight because a POSA would have expected the MgO layer in this combination to ***not*** have an (001) orientation for the reasons discussed *infra* §IV.B-C. Given the "complexity ... of the technology," Petitioner needed to provide a detailed explanation of the "contemplated workings" of its Ground 2 combination as a prerequisite to showing obviousness of any Challenged Claim. *Personal Web*, 848 F.3d at 994. The Petition's failure to do so is fatal to Ground 2.

If the Board were to read the Petition's argument for why its Ground 1 combination allegedly meets the claimed MgO(001) layer to apply to Ground 2 (which the Petition never alleges), that argument fails for the reasons below.

B. Ground 1 Fails to Show that a POSA Would Have Reasonably Expected the Bowen-Sunai/Parkin Combination to Meet the Claimed MgO(001) Layer

In Ground 1's Bowen-Sunai/Parkin Combination, the MgO layer is formed on a CoFeB layer rather than on Bowen's crystalline Fe(001) layer. Petition, 34-41 (Bowen's Fe layer is "replaced" with a CoFeB layer). Petitioner admits boron inhibits crystallization. *Id.*, 37. Petitioner fails to show that a POSA would have reasonably expected the MgO layer in its Bowen-Sunai/Parkin combination to meet the MgO(001) limitation despite being formed on a CoFeB layer. Ross, ¶101.

Ground 1's showing for Limitations 1[d] and 3[d] makes the following conclusory assertion:

if Sunai's or Parkin's CoFeB electrodes are used as described in Claims 1[e] and 2 in this Ground, one of skill would understand that the MgO could be polycrystalline or single-crystal but would still have the *same (001) orientation*. *EX1024* ¶129; *EX1062* at 9:58-10:2 (describing use of polycrystalline or single-crystal MgO), 18:49-51 ("highly textured (100) MgO tunnel barriers"); *EX1005* at 4:30-32 (MgO (001), (100), (010) planes are the same).

Petition, 33-34 and 45 (3[d]'s showing relies on 1[d]'s showing).

None of the cited evidence supports Petitioner's conclusory assertion that a POSA "would understand that the MgO ... would still have the same (001) orientation" despite being formed on a CoFeB layer. *Id.*; Ross, ¶102.

“EX1005” is the ’134 Patent, which cannot establish obviousness of its disclosed invention. *Orexo v. Actavis*, 903 F.3d 1265, 1271 (Fed. Cir. 2018) (“It is inappropriate to use the template provided by the inventor, to render the inventor’s contribution obvious.”). Moreover, Petitioner only cites the ’134 Patent to support its assertion that MgO planes (001), (100) and (010) planes “are the same.” Petition, 33-34. Petitioner argues that (001) and (100) are “the same” for MgO – which PO does not dispute – because Petitioner cites sections of Parkin referring to (100) instead of (001) as claimed. Ross, ¶103.

Parkin (“EX1062”), 18:49-51 says the MgO layer is (100) but says nothing about why that is so. Ross, ¶104. The other cited Parkin section explains that “the method of forming the MgO ... tunnel barrier described herein can also be applied to the growth of epitaxial single crystalline film structures, wherein the structures are prepared on a face of a single crystalline substrate chosen so that the crystalline spacing and crystalline cell is compatible with the growth of a *bcc ferromagnetic metal layer oriented in the (100) growth direction and the subsequent growth of a MgO* ... tunnel barrier according one of the preferred embodiments described herein.” EX1062, 9:58-10:2. This teaches that the ferromagnetic layer on which the MgO layer is grown has (100) orientation so that the MgO will similarly have (100) orientation. Ross, ¶104.

The description of Parkin's Fig. 3A embodiment (reproduced below with Petitioner's annotations (Petition, 24)) confirms that Parkin achieves an MgO(100) layer by depositing it on a "crystalline" (100) layer 115 comprised of crystalline (100) CoFe layers 118-119. EX1062, 13:3-25 ("the ferromagnetic electrodes ...have a bcc crystalline structure and are also textured in the (100) orientation"), 17:18-39; Ross, ¶105.

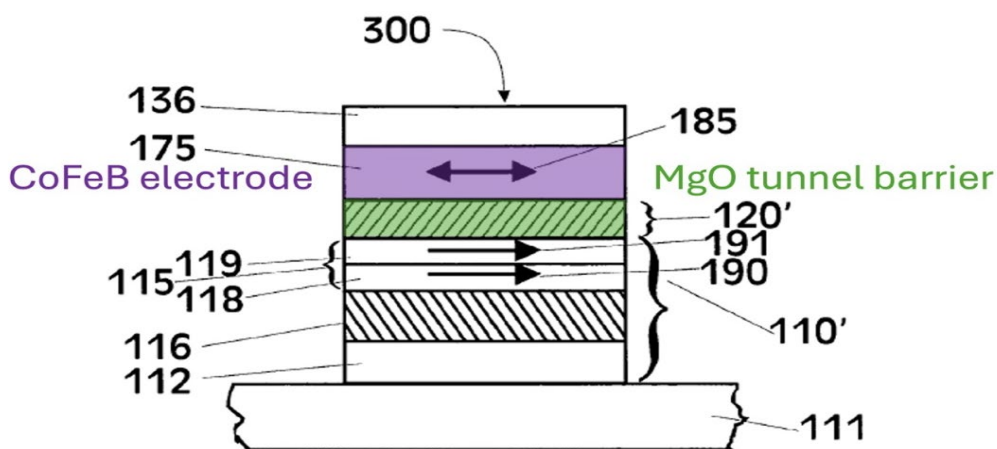


FIG. 3A

Thus, Parkin achieved a crystalline MgO(100) layer because Parkin deposited the MgO layer on top of a CoFe(100) layer. Ross, ¶¶106-107. That is consistent with the teachings in the art that MgO crystallization is highly sensitive to the conditions of the underlayer on which it is formed for the ultrathin layers used in MTJ devices. EX1062, 13:3-25; *infra* §§IV.C.1, IV.C.2.c; Ross, ¶¶140-171.

Parkin provides no support for Petitioner's assertion that a POSA "would understand that the MgO ... would still have the same (001) orientation" (Petition,

33-34) despite being formed on a CoFeB layer because that is not what Parkin did. Ross, ¶¶108. Indeed, Parkin teaches away from Petitioner’s combinations and the claimed invention because Parkin is explicit that it was important to deposit MgO on a crystalline (100) electrode to achieve an MgO(100) layer and Petitioner cites no prior art reference disclosing a crystalline CoFeB layer of (001) or equivalent orientation. *Id.*

The remaining evidence Petitioner cites is Dr. Bokor’s declaration at EX1024, ¶129. Here, Dr. Bokor repeats the Petition’s conclusory assertion virtually word-for-word and purports to support that conclusory assertion only with citation to the same Parkin sections (EX1062, 9:58-10:2 and 18:49-51). *Compare* Petition, 33-34 *with* EX1024, ¶129. Because Dr. Bokor’s testimony parrots the Petition’s conclusory assertion, does not explain the basis for the conclusion, and only cites prior art evidence that fails to support the conclusion, it warrants no weight. Bokor-Depo, 94:1-10, 96:22-97:4, 103:22-104:13, 109:2-6, 118:11-24; *Xerox v. Bytemark*, IPR2022-00624, Paper 9, 15 (Aug. 24, 2022) (precedential) (“[T]he cited declaration testimony is conclusory and unsupported, adds little to the conclusory assertion for which it is offered to support, and is entitled to little weight.”); *see also id.* (quoting 37 C.F.R. § 42.65(a): “Expert testimony that does not disclose the underlying facts or data on which the opinion is based is entitled to little or no weight.”).

The hindsight assertion today by Petitioner and Dr. Bokor, two decades after Dr. Yuasa's discovery, that a POSA would have "understood" that the claimed MgO(001) layer could be formed on CoFeB (Petition, 33; EX1024, ¶129) is refuted by the contemporaneous teachings in the art. *See, e.g.*, EX1055, 2270 ("amorphous CoFeB does not support any crystalline grain growth"); Ross, ¶¶110-112; *see also infra* §IV.C.2.

After Dr. Yuasa discovered that the claimed MgO(001) layer could be formed atop a CoFeB electrode, he published his 2005 article in Applied Physics Letters and explained that this result was "surprising[]." EX2006, 092502-2 ("***Surprisingly***, the MgO layer, grown on the amorphous CoFeB layer, showed a good crystalline structure with a (001) fiber texture."). Applied Physics Letters is a prestigious peer-reviewed journal and this paper has been cited more than ***1,200 times***. EX2052, 1; Ross, ¶111. Dr. Yuasa also explained that these results were surprising in the above-discussed 2017 textbook that Petitioner itself relies on. EX1057, 47 ("***Surprisingly***, the MgO barrier layer grown on the amorphous CoFeB is a (001)-oriented polycrystal (textured structure)."). Petitioner's expert described EX1057 as "a well-known textbook" and "very good comprehensive text" that is "a comprehensive book... intending to be a comprehensive sort of treatise" that Dr. Bokor himself uses "as a reference source" that "is relatively up to date." EX2017 ("Bokor-Depo2"), 138:23-140:11.

Two decades after Dr. Yuasa’s surprising discovery, Petitioner’s expert – who was not working in the field at the time and admits he is “no expert” in forming crystal materials (Bokor-Depo, 77:9-78:3) – now offers the naked conclusion that a POSA would have reasonably expected the results Dr. Yuasa achieved. That assertion is not only unsupported by a single piece of corroborating evidence, it is refuted by evidence establishing the contemporaneous reaction of those who were working in the field. Ross, ¶112.

* * *

Petitioner fails to establish that a POSA would have reasonably expected the MTJ device in either of Petitioner’s combinations to meet the MgO(001) layer required by every Challenged Claim. That is fatal to both obviousness grounds. *Medtronic v. Teleflex*, 70 F.4th 1331, 1345 (Fed. Cir. 2023) (“An obviousness determination *requires* finding that a person of ordinary skill in the art would have been motivated to combine or modify the ... prior art and would have had a reasonable expectation of success in doing so.”).

C. No Evidence Establishes that a POSA Would Have Reasonably Expected the Petition’s Formation Techniques for Its Modified MTJs to Have Yielded the Claimed MgO(001) Layer

It is not PO’s burden to prove that Petitioner’s combinations do not meet the claimed MgO(001) layer—it is Petitioner’s burden to prove that they do. Above, PO addressed the *only* arguments the Petition advances for how and why either

combination allegedly meets the claimed MgO(001) layer in Limitations 1[d] and 3[d]. They are facially deficient and that should end the matter. To the extent Petitioner alleges in reply that a POSA would have reasonably expected the formation techniques the Petition describes for its modified MTJs to have yielded the claimed MgO(001) layer, any such assertion would fail for the reasons explained below.

Petitioner's showing is the same for Grounds 1 and 2. Petitioner alleges a POSA would have “*replace[d]* either or both of *Bowen's [or Nagahama's] electrodes with CoFeB*” and *annealed the CoFeB electrode* to crystallize it. Petition, 36-37 and 58-59. Petitioner also alleges a POSA would have “*anneal[ed] Bowen's [or Nagahama's] MTJ* with CoFeB to obtain a crystalline ferromagnetic layer.” Petition, 38 and 59. Petitioner proposes no other change to Bowen's or Nagahama's manufacturing process. Ross, ¶119.

Petitioner is unclear about whether it proposes both annealing the CoFeB electrode *and* annealing the MTJ, or whether these are alternative ways of allegedly achieving a crystalline CoFeB electrode. Regardless, Petitioner fails to demonstrate that a POSA would have reasonably expected the claimed MgO(001) layer to result if the CoFeB electrode is annealed, the entire MTJ is annealed, or both. Ross, ¶120.

1. No Evidence Supports that a POSA Would Have Reasonably Expected that Annealing the Bowen-Sunai/Parkin or Nagahama-Sunai/Parkin MTJ Would Have Yielded the Claimed MgO(001) Layer

Every Challenged Claim requires that the first ferromagnetic layer that comprises CoFeB be “deposited on a substrate.” *See* Limitations 1[a], 1[e], 3[a], and 3[e]. Thus, Petitioner maps the claimed first ferromagnetic layer to the *bottom* electrode in Bowen’s and Nagahama’s MTJ. Petition, 29 (Ground 1) and 51 (Ground 2). As a result, both grounds rely on an MgO layer formed atop a CoFeB layer.

Bowen’s MgO layer is ultrathin. EX1026, 1656 (using MgO barrier layer of 2 nm (20 Å)). While Nagahama does not identify the thickness of the barrier layer in its MgO embodiment (¶¶0074-0075), it was well known that MTJ MgO barrier layers were on the order of 10 nm or less. Ross, ¶¶121-122; EX1062, 17:21-39 (discussing MTJ barrier layer thickness of 0.5-5 nm); EX1046, 3 (“is also clear that *after some ten atomic planes* of MgO [i.e., after 2.2 nm] *conductances decreases[e] exponentially* with MgO thickness.”).

As discussed *infra* §IV.C.2.c, it was well known that MgO crystallization is highly sensitive to the conditions of the underlayer on which it is formed—including the underlayer’s crystallinity (or lack thereof) and the lattice spacing and orientation when the underlayer is crystalline—especially for ultrathin MgO layers in MTJ devices like Bowen’s and Nagahama’s. Ross, ¶123. Fe and CoFe were

known to have lattice spacing and (001) crystal orientation that promoted MgO growing in an (001) orientation. *Id.*; EX1044, 1-2; EX1046, 1; EX1062, 3:34-41, 9:1-15, 12:3-10, 13:3-15; EX1057, 16, 28.

Bowen, Nagahama, and Parkin all formed an MgO(001) layer on top of a *crystallized (001)* ferromagnetic layer of Fe or CoFe. Ross, ¶124; Petition, 34 (admitting Bowen’s annealed lower Fe electrode had “high quality” with 001 orientation before depositing MgO on it) and 51 (Nagahama’s lower electrode was “(001)-highly oriented”); EX1026 (**Bowen**), 1655 (“we present experimental results showing large TMR values in *Fe(001)*/MgO(001)/FeCo(001) epitaxial tunnel junctions”); EX1027 (**Nagahama**), ¶73 (“magnetoresistive element was prepared which includes a *(001)-highly-oriented lower ferromagnetic electrode layer*, a (001)-highly-oriented MgO barrier layer, and a (001)-highly-oriented upper ferromagnetic electrode layer) and ¶¶60-61 (“Fe(001)” lower electrode)⁷; EX1062 (**Parkin**), 13:3-25 (crystalline *CoFe(100)* layer 115). Both Bowen and Nagahama describe the lower electrode as Fe. Ross, ¶124.

⁷ Nagahama describes an Fe electrode for its Al-O barrier layer embodiment and identifies no different bottom electrode material for its MgO barrier layer embodiment in ¶73. A POSA understood Nagahama to disclose the use of the Fe electrode for the MgO embodiment. Ross, ¶125.

Thus, every one of Petitioner's references, used in the grounds that describes a crystallized MgO(001) layer,⁸ formed that MgO layer on a *crystallized Fe(001) or CoFe(001)* ferromagnetic layer. Ross, ¶126. Indeed, as discussed below, Bowen and Nagahama went to great lengths to provide a crystalline (001) bottom electrode that provided a template for growing an MgO(001) layer. *Id.* But the grounds *replace* Bowen's and Nagahama's carefully-formed crystalline (001) bottom electrode with a CoFeB layer that is indisputably amorphous (*i.e.*, *non-crystalline*) before annealing. Petition, 36-37 and 58-59; Ross, ¶126; EX1024, ¶156, ¶201; EX1062, 16:3-20; EX1057, 47-48; EX1030, ¶30.

Petitioner cites no evidence suggesting that a crystalline MgO(001) barrier layer in the ultrathin thickness used in MTJ devices like Bowen's and Nagahama's could have been achieved by forming it on a ferromagnetic layer that is not crystalline (001). To the extent Petitioner suggests that a POSA would have reasonably expected that annealing the entire MTJ would have converted the MgO layer into the claimed MgO(001) layer, Petitioner does not cite a single piece of evidence to support that. Dr. Ross is unequivocal that a POSA would have had no such reasonable expectation. *See infra* §IV.C.2.c; Ross, ¶¶127-128.

⁸Sunai never describes an MgO(001) barrier layer let alone teaches a POSA how to make one.

A POSA would not have had a reasonable expectation of success that annealing the entire MTJ in Petitioner's Ground 1 or Ground 2 combination would have yielded an MTJ device meeting Limitation 1[d] or 3[d]. *Id.*

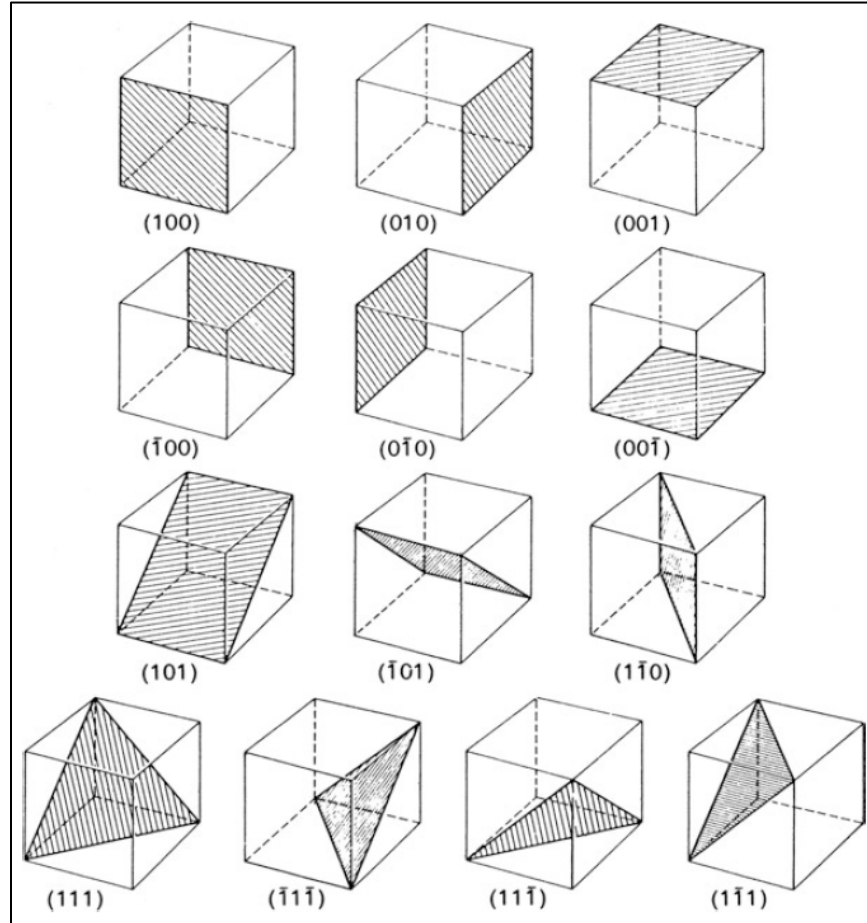
2. No Evidence Supports that a POSA Would Have Reasonably Expected that Annealing the CoFeB Electrode Before Forming the MgO Layer Would Have Yielded a Bowen-Sunai/Parkin or Nagahama-Sunai/Parkin MTJ Device with an MgO(001) Layer as Claimed

Petitioner cites no evidence that a POSA would have reasonably expected that annealing the CoFeB electrode would have produced a crystalline (001) layer on which to form the MgO layer in the combination in either ground.

a. Petitioner's Expert Had No Idea What Structure the CoFeB Layer Would Have Had

Petitioner proposes no changes to the manufacturing process of Bowen or Nagahama other than to (1) "replace either or both of Bowen's [or Nagahama's] electrodes with CoFeB" (Petition, 36 and 58); (2) anneal the CoFeB electrode to crystallize it (*id.*, 37 and 59) and (3) "anneal Bowen's [or Nagahama's] MTJ with CoFeB to obtain a crystalline ferromagnetic layer." (*id.*, 38 and 59). No evidence supports that annealing a CoFeB electrode in Bowen's or Nagahama's MTJ formation process would have yielded a CoFeB electrode that was even crystalline, let alone of (001) orientation. Ross, ¶¶129-130.

There are many crystal orientations that are not equivalent to (001) orientation. For example, in the cubic lattice, the (101), $(\bar{1}01)$, $(1\bar{1}0)$, (111), $(\bar{1}\bar{1}\bar{1})$, $(11\bar{1})$, $(1\bar{1}1)$ orientations shown below are not equivalent to (001). Ross, ¶131.



EX2069, 151.

It is undisputed that in the MTJ formation processes of Bowen and Nagahama, the bottom ferromagnetic layer is “uncapped” during annealing – meaning it has no layer above it during the annealing process. EX1026, 1655; EX1027, ¶62; Ross, ¶132; Bokor-Depo, 163:24-165:3. Petitioner’s expert Dr. Bokor *had no idea* what would have happened if a POSA had replaced an Fe

bottom electrode (as in Bowen and Nagahama) with CoFeB and (as taught in Bowen and Nagahama) annealed that bottom electrode before forming an MgO barrier layer atop it. Bokor-Depo, 169:16-171:19 (“*I’m unwilling to try to predict. An uncapped cobalt iron boron layer that would be annealed -- yeah, that -- I want to read through the references to see if anybody did that.* Off the top of my head, *I don’t recall such a situation.* ... [W]ithout having something to refer to, I – *I’m not willing to speculate.*”), 109:2-6. Petitioner’s expert admitted a POSA would have had “a natural reticence to anneal” an amorphous CoFeB layer “without a layer on top” (Bokor-Depo, 172:18-173:7) but that is precisely what Petitioner’s combinations propose. Bowen, 1655; Nagahama, ¶62.

Dr. Bokor’s inability to explain what structure the CoFeB electrode used in the Ground 1 and 2 combinations would have taken is understandable because there is no evidence in the record of anyone in the prior art having annealed a CoFeB electrode, like that in Sunai or Parkin, in an uncapped annealing process as used in Bowen and Nagahama. Ross, ¶¶132-136. As Dr. Bokor’s testimony lays bare, a POSA would have had *no reasonable expectation* about what structure the bottom CoFeB electrode might form upon annealing, let alone a reasonable expectation that it would have had a crystalline (001) structure of the type that the prior art taught was needed to form an MTJ’s ultrathin MgO(001) layer atop it. Ross, ¶136.

b. Petitioner’s Jimbo and Cardoso References Would Have Given a POSA an Expectation of Failure

Petitioner alleges it was known to anneal CoFeB electrodes “to crystallize them.” Petition, 37-38 (citing Jimbo (EX1060), Cardoso (EX1061) and Dr. Bokor’s ¶¶139-140 citing Jimbo and Cardoso).

Jimbo and Cardoso teach that annealing amorphous CoFeB yielded a (111)-textured material. EX1060, 308-309 (describing a “fcc(111)” x-ray diffraction peak); EX1061, 2273 (describing “some (111) texturing”); Ross, ¶¶137-138. A POSA would have understood that a (111)-oriented structure is a dramatically different crystalline structure than one with a (001) orientation. Ross, ¶¶138-139. Petitioner’s own evidence teaches that MgO(001) cannot be formed on a (111)-oriented underlayer. EX1057, 47 (“an NaCl-type MgO(001) tunnel barrier... which [has] fourfold in-plane crystallographic symmetry, *cannot be grown on [an] fcc(111)-oriented... structure*, which has threefold in-plane crystallographic symmetry, *because of the lattice mismatch.*”); Ross, ¶138; *see also infra* §IV.C.2.c.

c. A POSA Would Have Had No Reasonable Expectation of Success in Achieving the Claimed MgO(001) Layer by Forming Bowen's or Nagahama's MgO on Anything Other Than a Crystalline (001) Underlayer

The only references Petitioner cites to teach annealing a CoFeB layer to crystallize it—Jimbo and Cardoso—teach that it would form a (111) orientation.⁹ Petitioner's own evidence (EX1057) teaches that the claimed MgO(001) layer could not be formed on such an underlayer with mismatched crystalline orientation. *See supra* §IV.C.1; Ross, ¶¶140-144.

While Petitioner ignored it, Parkin teaches that its annealed CoFeB layer had an *amorphous* top surface. EX1062, 18:51-60; 17:42-44.

Petitioner never explains how or why a POSA would have reasonably expected that MgO deposited on the surface of annealed CoFeB—whether that surface is amorphous as in Parkin or crystalline (111) orientation as in Jimbo and Cardoso—would have yielded the claimed MgO(001) layer, let alone cite evidence establishing this. Bokor-Depo, 103:22-104:13, 169:16-171:19; 19:10-17. Dr. Ross

⁹ Petitioner cited this evidence in connection with a different limitation that requires a ferromagnetic layer that is crystallized (and comprises CoFeB) but does not require a crystalline (001) orientation.

is unequivocal that a POSA would have had no such reasonable expectation. Ross, ¶¶167-171;

Buried in Dr. Bokor's ¶70 and ¶127 that the Petition cites only for *different* reasons,¹⁰ he advances an argument the Petition never makes—that Yoon (EX1040) and Wulff (EX1036) teach that MgO(001) could be grown on amorphous surfaces. EX1024, ¶70, ¶127. This argument should not be considered because it cannot be incorporated by reference into the Petition. 37 CFR §§ 42.6(a)(3), 42.22, and 42.104(b)(3)-(4).

Additionally, the Petition “must” identify “the supporting evidence relied upon to support the challenge and the relevance of the evidence to the challenge raised, including identifying specific portions of the evidence that support the challenge.” 37 CFR § 42.104(b)(5). The Petition never cites Wulff and only cites a different page of Yoon for a different proposition.

¹⁰ Petitioner cites ¶70 to establish that MgO had a low barrier height. Petition, 13. Petitioner cites ¶127 to establish that *unmodified* Bowen discloses the claimed MgO(001) limitation – which is irrelevant (*supra* §IV.C.1) – and that polycrystalline MgO(001) could be used instead of Bowen's single-crystal MgO(001). Petition, 32-33.

Even if the Board were to consider Wulff or Yoon, they do not establish that a POSA would have had a reasonable expectation of success in achieving the claimed MgO(001) layer. Wulff and Yoon discuss MgO films with thicknesses of at least 100 nm (0.1 μm) and 50 nm, respectively. EX1036, 150 (“MgO films of about 0.1, 0.5, and 1 μm thickness were deposited[.]”); EX1040, 2841, Fig. 3(a) (thinnest film was 50 nm and that was grown on crystalline Si(100)). Neither Wulff nor Yoon investigated the crystalline structure of MgO films on the order of 10 nm thick or less as used in MTJs. Ross, ¶¶145-152; *see supra* §IV.C.1.

When Wulff and Yoon did their work, it was not even possible to use X-ray diffraction to determine the crystal orientation of an MgO film of a thickness (on the order of 10 nm) useful in MTJ devices. Ross, ¶148. POSAs knew that film texture¹¹ evolves with thickness, and that crystal morphology is impacted by the grain zone. Ross, ¶¶149-150, (citing EX2048 (Ohring)). Well-developed grains that occur with thicker films are not necessarily of the same texture as grains near the substrate. Ross, ¶150; EX2067, 621, 623-625.

¹¹ Texture means “the preponderance of one (or more) crystallographic planes oriented parallel to the film surface compared with the case of randomly oriented planes.” EX2048, 565-566.

Wulff uses a higher MgO deposition rate (1.6-2 nm/s, see EX1036, 150) than would be used in making an MTJ (*e.g.*, 0.02 nm/sec, see EX1013, 6:12-13); Ross, ¶165. Yoon utilizes a deposition rate of 5 nm/min (EX1040, 2840), over four times the rate that would be used in a method of making an MTJ as claimed. Ross, ¶165. Yoon also deposited MgO films by techniques a POSA never would have used for forming MTJs. EX1040, 2839 (aerosol-assisted chemical vapor deposition (“AACVD”)); Bokor-Depo, 79:19-80:4 (Petitioner’s expert could not say whether AACVD could be used to make an MTJ); Ross, ¶¶164-166. Yoon’s technique also used a high temperature anneal which would have put the electronic components of an MTJ at risk. Ross, ¶164.

POSAs knew that without a lattice match providing epitaxy, MgO nucleation at an amorphous surface interface would have resulted in random grain orientation in the MgO. Ross, ¶¶153-163. MgO nucleation and grain growth depended on factors including the materials, surface morphology and surface effects, deposition technique, rate and temperature, substrate temperature, and growth time. Ross, ¶¶155-156; EX2066, 129-133, 144, 150; EX2065, S117, S120. For thin films of the type used in MTJ devices, if the MgO layer is formed on an amorphous surface the surface effects from that amorphous surface impact crystallization in ways that produce random crystal orientations. Ross, ¶¶157-158; EX2067, 621, 623-25. That is why all the prior art references that relate to MTJ devices—Wulff and Yoon do

not—taught that an MgO(001) layer be formed on a crystalline (001) underlayer to guide the formation of a thin film MgO(001) layer. Ross, ¶157; *supra* §IV.C.1.

It was known that initial crystal formation (called “nucleation”) on amorphous substrates results in randomly oriented islands of crystals which may evolve into a preferred texture as the film grows thicker. EX2065 (Petrov), S118, S126; EX2067, 621, 623-25; Ross, ¶¶158-159. In a study of the crystalline structure of thin films of MgO deposited on amorphous substrates, IBM found that “[f]ilms [of MgO] thinner than ~ 500 Å [50 nm] show a random orientation.” EX2067, 625; *see also* EX2065, S118 (“[R]andomly oriented islands” of crystals are expected for “deposition on amorphous substrates.”); Ross, ¶159.

“Near the substrate, the microstructure consists of randomly oriented small grains” and “[o]rientation selection during coarsening is incomplete, thus crystallites are nearly random or only weakly textured.” EX2065, S119-20; EX2067, 625 (“owing to the more or less random arrangement of the substrate atoms, no preferred orientation is induced” in the thin MgO films); Ross, ¶160. POSAs could thus not predict what crystal orientations would form (nucleate) on an amorphous surface in the thicknesses used for MTJ barriers (*i.e.*, less than 10 nm). Ross, ¶161-162. Thicker films where a preferred crystalline orientation eventually formed away from the substrate do not reflect the orientation within the first 50 nm of the film – let alone within the first 10 nm. Ross, ¶160; EX2067, 623

(IBM's study indicates that MgO growth on amorphous substrates is expected to develop a non-crystalline random orientation below 50 nm and a (111) crystalline orientation at thicknesses greater than 50 nm). Furthermore, it was known that many variables affect crystal growth.

Because of the above differences, most notably the substantial differences in MgO thickness, a POSA would have not reasonably expected success in making a crystalline MgO layer for an MTJ (of less than 10 nm) on an amorphous surface based on Wulff or Yoon's thick-film results. Ross, ¶162. Thus, a POSA would not have had a reasonable expectation that depositing MgO on amorphous CoFeB would have yielded a MgO(001) layer in Bowen's or Nagahama's MTJ. *Id.*

As explained *supra* §IV.C.1, Petitioner's references (Bowen, Nagahama, and Parkin) disclosing an MTJ with an MgO(001) layer achieved it by depositing the MgO layer on a crystalline (001) ferromagnetic layer and Petitioner cites no evidence establishing that a POSA would have reasonably expected success in forming an MgO(001) layer in an MTJ device in any other way. Ross, ¶163. Petitioner's failure to establish that annealing the CoFeB layer in the uncapped process of Bowen or Nagahama would have yielded a crystalline upper surface of (001) orientation – which Petitioner nowhere even alleges – is fatal to any suggestion that a POSA would have reasonably expected that annealing the CoFeB

electrode would have resulted in the an MgO(001) layer, as required by every Challenged Claim, forming atop it. *Id.*

3. No Evidence Supports that a POSA Would Have Reasonably Expected that Annealing the CoFeB Electrode Before Depositing the MgO Layer or Annealing the Entire MTJ Would Have Yielded the Claimed MgO(001) Layer

Petitioner cites no evidence that annealing the CoFeB electrode before forming the MgO layer would have yielded the claimed MgO(001) layer (*supra* §IV.C.2) or that annealing the entire MTJ would have done so (*supra* §IV.C.1). Petitioner cites no evidence establishing a reasonable expectation of success that performing both annealing steps together would have, for some unexplained reason, achieved the claimed MgO(001) layer. Every reference Petitioner cites that discloses an MTJ with an MgO(001) layer achieved that MgO(001) layer by depositing the MgO layer on a crystalline (001) ferromagnetic layer and Petitioner cites no evidence suggesting that a POSA would have reasonably expected success in forming an MgO(001) layer in an MTJ device in *any other way*. Ross, ¶¶167-172; *See supra* §IV.C.1.

* * *

Dr. Ross is unequivocal that a POSA would not have had a reasonable expectation that the formation processes proposed in the Petition's grounds would have yielded an MTJ with the claimed MgO(001) layer. Ross, ¶¶167-171. Dr. Ross's testimony is corroborated by extensive citation to the prior art and by the

objective evidence demonstrating that those in the field were surprised by the results that Dr. Yuasa achieved. *See supra* §VII; Bokor-Depo, 73:24-77:8; EX1057, 47.

Establishing a reasonable expectation of success is a prerequisite to establishing obviousness. *Eli Lilly v. Teva*, 8 F.4th 1331, 1348 (Fed. Cir. 2021). Petitioner’s failure to carry its burden to show that a POSA would have reasonably expected either of Petitioner’s combinations to meet the claimed MgO(001) layer is an additional reason why both grounds fail.

V. A POSA WOULD NOT HAVE COMBINED THE REFERENCES IN THE MANNER PETITIONER ALLEGES

Both grounds rely on a primary reference (Bowen or Nagahama) that describes the importance of using perfectly crystalline ferromagnetic electrodes with a crystalline MgO layer. It is undisputed that boron “resulted in an amorphous [] layer with ‘inhibited’ crystallization.” Petition, 37. Indeed, Petitioner’s secondary references (Sunai and Parkin) used CoFeB electrodes because they wanted amorphous (*i.e.*, non-crystalline) electrodes.¹² A POSA never would have

¹² At institution, the Board found that Sunai and other prior art references taught benefits of CoFeB unrelated to forming amorphous electrodes. DI, 19-21. Dr. Ross explains that the Board misunderstood those prior art teachings. *See infra* § V.C; Ross, ¶¶74-84.

modified either of Petitioner's primary references (Bowen and Nagahama) to use a ferromagnetic layer with boron because boron was known to yield a non-crystalline ferromagnetic structure that was the opposite of what Bowen and Nagahama were trying to achieve. Ross, ¶173.

Moreover, after having modified the primary references to use amorphous CoFeB electrodes, Petitioner alleges a POSA would have sought to crystallize them. A POSA would not have done that either because the entire purpose of using boron in the secondary references was to avoid crystallization. *W.L. Gore v. Garlock*, 721 F.2d 1540, 1550-1551 (Fed. Cir. 1983) (totality of reference's teachings must be considered).

Petitioner fails to establish that a POSA would have combined the references in the manner claimed. Ross, ¶174.

A. Bowen Went to Heroic Efforts to Achieve Single-Crystal Epitaxial Fe(001)/MgO(001)/FeCo(001) MTJs

Bowen was focused on experimentally testing Butler's "calculations of the tunneling conductance and magnetoconductance of epitaxial Fe(100)/MgO(100)/Fe(100)" MTJ "sandwiches." EX1044 (Butler), 1 (Abstract); Ross, ¶¶175-181. Bowen tested Butler's model "on *single-crystal* epitaxially grown structures." EX1026, 1655; Ross, ¶175.

Bowen's coauthors Boubeta *et al.* developed an *entirely new process* for epitaxially growing MgO(001) on a crystalline Fe(001) thin film. EX2061, 223,

224, 228-229; Bokor-Depo, 144:3-148:14; Ross, ¶¶182-184. Bowen's fabrication process achieved an epitaxial MTJ. Bowen, 1655, 1657; Bokor-Depo, 76:4-21 (Petitioner's expert explaining epitaxy); Ross, ¶¶182-184.

The structure of Bowen's MgO(001) depended on the Fe(001) underlayer. EX1026, 1655-1656; Ross, ¶¶184-185. Petitioner's expert agreed that the lattice match between Bowen's crystalline Fe(001) bottom electrode and the single-crystal MgO(001) was crucial to Bowen achieving its epitaxial single-crystal device. Bokor-Depo, 74:6-75:24, 76:4-77:8; EX1024, ¶56, EX1026, 1655-1656; EX2061, 224, 228-229; Ross, ¶¶184-187.

Petitioner's expert conceded that achieving Bowen's near-perfect single-crystal MgO(001) barrier required the lattice match provided by the high-quality crystalline Fe(001) bottom electrode. Bokor-Depo, 74:6-75:24; EX1026, 1655-1656; EX2061, 224, 228-229; Ross, ¶¶184-187.

B. Nagahama Teaches a Special Process to Achieve Crystalline Ferromagnetic Electrodes

Nagahama formed a "MgO double underlayer" to ensure formation of a crystalline (001) ferromagnetic bottom electrode on which an MgO(001) barrier layer was formed. EX1027, ¶¶55-59, ¶67 (describing MgO double underlayer 212), ¶73, Fig. 12 (layer 204), Fig. 13 (layer 212); Ross, ¶¶188-189. The double underlayer comprised an amorphous MgO (202, 212-1) covered by a "(001)-oriented highly oriented" crystal MgO layer (203, 212-2). EX1027, ¶58, ¶61, ¶67.

This double underlayer provided a way to form MTJs with crystalline ferromagnetic layers “on an amorphous substrate.” EX1027, ¶59. Nagahama’s MgO underlayer provided a template for forming *crystalline (001) ferromagnetic lower electrodes*. EX1027, ¶¶62-65; Ross, ¶¶188-89.

C. Sunai Teaches That Increased TMR and Low H_c Derive From Amorphous Electrodes

Petitioner alleges a POSA would have replaced Bowen’s Fe(001) ferromagnetic bottom electrode and Nagahama’s lower Fe(001) layer 213¹³ with a CoFeB electrode as taught by Sunai and Parkin to “increase TMR and lower H_f and H_c .” Petition, 36, 39, 51-52, 57-58. Sunai does not explicitly mention H_f ; it discusses TMR and H_c (which relates to an MTJ’s switching speed between its parallel and antiparallel states) and is explicit that the benefits the Petition touts from a CoFeB electrode derive from the fact that it is *amorphous*. EX1030, ¶30; Ross, ¶¶ 82-83 (explaining that the Board’s reading (DI, 21) was inconsistent with a POSA’s), 190-202 (explaining why Sunai teaches away from crystallizing the CoFeB electrode).

Sunai describes the amorphous CoFeB alloy as having a “smaller saturated magnetization M_s ” than alloys (like CoFe) that form crystalline films. EX1030, ¶25. The amorphous CoFeB alloy maintains “the reversal magnetic field,” (H_c) “of

¹³ See *supra* note 7.

the ferromagnetic layer 4... at a sufficiently small value[.]” EX1030, ¶25, ¶58; *see also* Bokor-Depo, 204:21-206:7 (citing Sunai and explaining benefit of lower power consumption using a smaller reversal magnetic field); Ross, ¶¶190-192.

Sunai also teaches that *crystallized electrodes* result in unstable magnetization and *reduce TMR*. EX1030, ¶27, ¶30; *see also* Petition, 36 (alleging a POSA would have used Sunai’s CoFeB electrode to *increase* TMR). Sunai explains that crystalline CoFe forms a “discontinuous film composed of aggregate fine particles” that each “loses its ferromagnetism at room temperature, and the magnetization direction becomes unstable, becoming so-called superparamagnetic,” causing TMR to “drop significantly.” EX1030, ¶27; *id.*, ¶30 (crystalline ferromagnetic thin films formed “island structures” that “exhibit superparamagnetism resulting in a significantly low magnetoresistance change rate.”); Ross, ¶¶193-197 (low “magnetoresistance change rate” means low TMR).

Thus, Sunai says the TMR and H_c properties Petitioner touts from CoFeB derive from an amorphous electrode. Ross, ¶¶198-202.

D. Parkin Teaches that Increased Switching Speed Derives from Amorphous Electrodes

Parkin “reduc[es] the variation in magnetic switching fields” by using “*amorphous magnetic*” CoFeB for electrode 175 (EX1062, 5:48-51) because “*amorphous ferromagnetic* layers... likely give rise to smaller variations in magnetic switching fields” (EX1062, 6:9-13). Parkin teaches that the “strong (100)

crystallographic texture of the MgO layer will likely lead to significant variations in the orientation and strength of the magnetocrystalline anisotropy field” that is “mitigated” by using a ferromagnetic electrode “*formed from materials that have no preferred crystallographic orientation*” such as “*amorphous*” CoFeB.

EX1062, 15:62-16:11; Ross, ¶¶203-206. Adding boron to CoFe “*causes the crystalline structure to be eliminated* or results in the crystalline grains being very small” so “*there is no longer any crystallographic orientation along which the magnetic moments prefer to align, so the magnetic switching characteristics of such devices are much more uniform than crystalline devices.*” EX1062, 16:35-40; *see also id.*, 18:49-62; Bokor-Depo, 130:8-19; Ross, ¶207.

Thus, Parkin says the improved switching properties – what Petitioner calls lowering H_f and H_c – Petitioner touts from CoFeB derive from an amorphous electrode. Ross, ¶¶208-210.

E. Other Cited References Teach Benefits of CoFeB Not Applicable in Either Ground’s Combination

Petitioner’s assertion that CoFeB had known benefits also cites EX1055 (Wang), EX1056 (Hosomi) and EX1061 (Cardoso). Petition, 35-36.

Wang and Hosomi disclose MTJ devices with an *amorphous* CoFeB electrode and *aluminum oxide* barrier layers. EX1055, 2269-2270; EX1056, ¶36, ¶38, ¶111; Ross, ¶211. At institution, the Board suggested that Petitioner cited Wang and Hosomi to teach that the CoFeB alloy enhances TMR. DI, 19. But

Petitioner’s expert testified that teachings related to improving TMR for AlO MTJs are irrelevant to MTJs with MgO barrier layers like Bowen and Nagahama.

Bokor-Depo2, 148:10-18, 193:5-195:12, 197:22-198:4, 199:23-203:24.

Cardoso teaches that the fcc(*111*)-texture of its CoFeB electrode *may* have been the reason for lowering H_f (electrode coupling) and H_c (coercivity affecting switching speeds). EX1061, Abstract; Ross, ¶212. No POSA would have used a crystalline (111) CoFeB lower electrode in Petitioner’s combinations because that would have precluded achieving the claimed MgO(001) layer atop it. *See supra* §IV.C.2.b; Ross, ¶212; Petition, 34-41 and 56-61 (substituting a CoFeB electrode for the lower “first” electrode in Bowen and Nagahama).

F. Petitioner Provides No Credible Reason Why a POSA Would Have Modified Bowen or Nagahama by Replacing the Bottom Fe Electrode with Amorphous CoFeB and Attempting to Crystallize That Amorphous CoFeB

To demonstrate any claim obvious, Petitioner needed to establish some supportable non-hindsight *reason why* a POSA “would have selected and combined [the] prior art elements” *in a manner “yield[ing] the claimed invention.”* *Unigene Labs. v. Apotex*, 655 F.3d 1352, 1360 (Fed. Cir. 2011); *see also KSR v. Teleflex*, 550 U.S. 398, 418 (2007) (establishing obviousness requires establishing some *reason* to combine the prior art *in the manner claimed*); *TQ Delta v. Cisco*, 942 F.3d 1352, 1359 (Fed. Cir. 2019) (reversing the Board’s obviousness determination because the Board “fails to identify any actual *reason*

why a skilled artisan would have combined the elements *in the manner claimed.*”) (internal citations omitted)).

As detailed above, Petitioner’s primary references (Bowen and Nagahama) go to great lengths to ensure that the lower ferromagnetic electrode is crystalline (001) to facilitate growth of an MgO(001) layer well-matched to the (001) ferromagnetic layer. *Supra* §IV.C.1. A POSA never would have modified Bowen or Nagahama to use a ferromagnetic layer with boron because boron was known to yield an amorphous (*i.e.*, non-crystalline) ferromagnetic structure which was the opposite of what Bowen and Nagahama sought to achieve.

Petitioner’s secondary references (Sunai and Parkin) took a different approach. They introduced boron into a ferromagnetic electrode to make that electrode amorphous. *Supra* §§V.C-D. If a POSA were motivated by those teachings to modify Bowen or Nagahama to use a CoFeB electrode, a POSA would have made the CoFeB electrode amorphous because Sunai and Parkin teach that it is the *amorphous* structure of the electrode that achieved the benefits Petitioner cites as motivating the combination. *Supra* §§V.C-D; Ross, ¶¶213-215.

Petitioner’s allegation that a POSA would have then attempted to *crystallize* the CoFeB electrode (Petition, 37-41, 59-61) goes against the teachings in the art of why boron was used in the electrode in the first place. “An inference of nonobviousness is especially strong where the prior art’s teachings undermine the

very reason being proffered as to why a [POSA] would have combined the known elements.” *DePuy Spine v. Medtronic*, 567 F.3d 1314, 1326 (Fed. Cir. 2009).

Petitioner’s assertion that a POSA would have attempted to *crystallize a CoFeB layer* in the modified Bowen-Sunai/Parkin and Nagahama-Sunai/Parkin devices is unsupported by any evidence establishing a reason *why* a POSA would have done so. Petition, 37-41, 59-61 (discussing 1[e])).

1. Petitioner’s Alleged Reasons to Combine Are Internally Inconsistent

To meet Limitation 1[e]’s requirement that “said first ferromagnetic material layer ... comprises CoFeB alloy” Petitioner alleges a POSA would have replaced the Fe(001) bottom electrode in Bowen and Nagahama with CoFeB as taught in Sunai or Parkin to “increase TMR and lower H_f and H_c .” Petition, 36, 39, 57 and 61. As detailed supra §§V.C-E, to the extent Sunai and Parkin teach that CoFeB provides any of those benefits (increased TMR and lower H_f and H_c) they teach that they are achieved because the CoFeB electrode is *amorphous*.

But to meet Limitation 1[e]’s *other* requirement that “said first ferromagnetic material layer is crystallized,” Petitioner alleges a POSA would have crystallized the CoFeB electrode. Petition, 37. Petitioner offers no reason *why* a POSA would have sought to crystallize the CoFeB electrode in Bowen-Sunai/Parkin or Nagahama-Sunai/Parkin and simply alleges this was “known.” *Id.* (citing EX1060-EX1061). As detailed below, neither EX1060 nor EX1061

provides any reason why a POSA would have sought a crystallized CoFeB electrode in an MTJ device with an MgO(001) layer because EX1060 is not directed to an MTJ, EX1061 used boron to achieve an *amorphous* CoFeB electrode and was surprised to see some evidence of crystallinity, and both references teach that annealed CoFeB had a (111) crystalline orientation that was incompatible with growing an MgO(001) layer on top as in Bowen and Nagahama. Ross, ¶¶216-217.

Recognizing that no reference disclosing a CoFeB layer teaches a reason to crystallize it, Petitioner incredibly returns to the primary references (Bowen and Nagahama) to teach the desirability of a crystalline electrode. Petition, 38 (“Bowen touted crystalline layers for optimizing the interface between the barrier and metal electrode.”) and 59 (“Nagahama recognized that using a crystallized first ferromagnetic electrode increases TMR.”). A POSA motivated by those teachings in Bowen and Nagahama of the benefits of a crystalline electrode never would have added boron to their electrodes in the first place. Ross, ¶¶218-219.

Petitioner’s internally inconsistent and contradictory modifications to Bowen and Nagahama ignore the teachings of the references as a whole and “pick and choose” selected teachings in an attempt to reconstruct the claims in hindsight. Because no evidence supports a reason to have combined the prior art teachings in the manner claimed, both grounds fail.

2. Petitioner Never Identifies a Reason to “Crystallize” the CoFeB Layers

a. Crystallized CoFeB Layers Being “Known” Provides No Reason to Use Them in Either Combination

Petitioner contends that “[a]nnealing CoFeB electrodes to crystallize them was... *known*.” Petition, 37 and 59 (citing EX1060 at 311, EX1061 at 2273-2273). That provides no *reason why* a POSA would have done so in Petitioner’s combinations, particularly where Petitioner’s secondary references (Sunai and Parkin) teach that the benefits Petitioner cites as motivating the use of CoFeB derives from the electrode being *non*-crystalline. *Supra* §§VC-D; Ross, ¶220.

b. EX1060 (Jimbo) Provided No Reason to Crystallize the CoFeB Electrodes in Petitioner’s Combinations

Petitioner cites Jimbo as teaching “TMR ratios were ‘enhanced by... annealing’ [] which was likely attributed to ‘structural change of the interface’ between the CoFeB and adjoining layers.” Petition, 37-38. This provides no support for crystallizing the CoFeB electrodes in Petitioner’s combinations for several reasons.

First, Jimbo’s devices have *no TMR*. Jimbo studied spin valves – not MTJs – with a copper (Cu) film between CoFeB electrodes. EX1060, 308, 310. Copper is a conductor. Ross, ¶¶221-223. There is *no tunneling* through copper, let alone the spin-dependent tunneling present in devices having a TMR. Ross, ¶222; EX1024, ¶¶45-49 (tunneling requires an “*insulating* layer” between electrodes, not a

conductor); EX1031, 1793-1794. Thus, Jimbo's spin valves *had no tunneling magnetoresistance*. Ross, ¶223. Jimbo does not teach that "TMR was enhanced by annealing" because Jimbo's devices have no TMR. Ross, ¶223.

Second, Petitioner identifies no reason why Jimbo's suggestion of "structural change of the interface" between CoFeB and Cu had any relevance to an interface between CoFeB and MgO in the Bowen-Sunai/Parkin or Nagahama-Sunai/Parkin MTJs which were fundamentally different. Ross, ¶224. Jimbo would have given a POSA no reason to modify either combination. *Id.*

Third, contrary to Petitioner's suggestion (Petition, 37-38), a POSA would have understood that Jimbo does *not* teach that CoFeB crystallizes when annealed. Jimbo provided X-ray diffraction patterns for devices where a layer of gold (Au) was added to cap the CoFeB before annealing and to conduct current. EX1060, 309. Gold—including fcc(111) gold—has a (200) diffraction peak at 44 degrees (indicating crystals of the (200) orientation), precisely where Jimbo labels a "CoFe fcc(111)" peak. EX2058 [powder file]; Ross, ¶¶225-228. Because Jimbo's devices had a peak at 44 degrees from the Au(200) (*i.e.*, gold), Jimbo's data would not have allowed a POSA to conclude that crystallized CoFeB fcc(111) was even present. Ross, ¶¶225-228.

Fourth, even if Jimbo taught that annealing CoFeB caused it to crystallize into (111) orientation, that provides no reason to anneal the CoFeB lower layer in

Bowen-Sunai/Parkin or Nagahama-Suna/Parkin because MgO(001) could not be grown on a (111) underlayer. *See supra* §IV.C.2.b; Ross, ¶229.

c. EX1061 (Cardoso) Provided No Reason to Crystallize the CoFeB Electrode in Petitioner’s Combinations

Petitioner quotes Cardoso’s teaching that post-annealing CoFeB films were “not amorphous.” Petition, 37 (quoting EX1061, 2273). Cardoso saw “some (111) texturing” which “was unexpected for CoFeB films.” EX1061, 2273. Cardoso provides no reason to anneal the CoFeB lower layer in Bowen-Sunai/Parkin or Nagahama-Suna/Parkin because MgO(001) could not be grown on a (111) underlayer. *See supra* §IV.C.2.b; Ross, ¶¶230-233.

d. Bowen and Nagahama Provide No Reason to Crystallize a CoFeB Electrode

Petitioner’s assertion that the primary references (Bowen and Nagahama) would have motivated a POSA to crystallize the amorphous CoFeB electrode(s) (Petition, 38 and 59) fails because the Petition just finished arguing that Sunai and Parkin would have motivated a POSA to modify the primary references to achieve the benefits of a CoFeB electrode, and Sunai and Parkin teach that those benefits derive from the electrode being *non*-crystalline. *Supra* §V.C-D.

Bowen’s and Nagahama’s *only* annealing was to anneal the lower Fe electrode that Petitioner argues a POSA would have replaced with CoFeB. EX1026, 1655; EX1027, ¶62; Ross, ¶¶234-235.

Petitioner argues that “Bowen touted crystalline layers” (Petition, 38) and “Nagahama recognized that using a crystallized first ferromagnetic layer increases TMR” (Petition, 59). Petitioner ignores that Bowen and Nagahama teach that the benefits Petitioner touts were achieved not from any and all types of crystalline electrode, but instead derived from using *crystalline (001) electrodes that matched the crystalline MgO(001) layer*. EX1026, 1655-1656; EX1027, ¶14, ¶¶73-74; Ross, ¶236.

Neither Bowen, Nagahama nor any other prior art reference of record taught that CoFeB could take on a crystalline (001)¹⁴ structure that would match the MgO(001) layer. Ross, ¶237. Thus, Bowen and Nagahama provide no reason to crystallize a CoFeB electrode, and instead teach the use of an electrode formed from a material (*e.g.*, Fe or CoFe) that had no boron so that it had the lattice structure and crystalline (001) orientation conducive to forming MgO(001) atop it. *Supra* §IV.C.2.c; Ross, ¶237.

e. EX1045 Provides No Reason to Crystallize a CoFeB Electrode

Petitioner’s citation to EX1045’s teachings that “‘nearly perfect crystalline MgO(001) films on high-quality *single crystals of Fe*’ were effective in improving

¹⁴ Petitioner’s references that teach any crystallinity of CoFeB teach a (111) orientation on which MgO(001) could not be formed. *Supra* §IV.C.2.b.

TMR” (Petition, 38, 59, quoting EX1045, 1) is baffling. This teaches away – not towards – Petitioner’s combinations because EX1045 describes *precisely* the structure in Bowen and Nagama *that the Petition contends a POSA would have replaced with CoFeB*. Ross, ¶238.

EX1045 also provides *no reason* for a POSA to anneal or “crystallize” amorphous CoFeB because EX1045 annealed already-crystalline Fe electrodes and says nothing about the effect of annealing an MTJ with amorphous CoFeB electrodes. Ross, ¶239.

To the extent EX1045 gave a POSA a reason to do anything, it would have been to leave Bowen’s and Nagahama’s devices *unchanged*. *Id.*

3. KSR’s Familiar Elements/Predictable Results Rationale is Inapplicable

Petitioner alleges that replacing Bowen’s or Nagahama’s electrodes with a CoFeB electrode would have been an obvious combination of familiar elements yielding predictable results. Petition, 36 and 58 (citing *KSR*). Petitioner makes this assertion for an *interim* “combination” before alleging that it “also would have been obvious to crystallize” the CoFeB electrode. *Id.*, 37 and 59.

Petitioner badly misapplies the law. It is the “claim as a whole” that must be proven obvious. 35 U.S.C. § 103. Petitioner never even alleges that *KSR*’s familiar elements/predictable results rationale applies to any Challenged Claim as a whole and for good reason. That *KSR* rationale only applies when the elements are

combined without “change in their respective functions” and where the results were “predictable.” *KSR*, 550 U.S. 398 at 415-16 (describing as obvious “a combination which only unites old elements *with no change in their respective functions*”).

Petitioner’s grounds do not use Sunai’s or Parkin’s amorphous CoFeB electrode without changing its function. Petitioner’s grounds seek to crystallize the CoFeB electrode that Sunai and Parkin teach should be amorphous. Petition, 37, 59; *Supra* §V.C-D. That change to the function of the allegedly “familiar” CoFeB electrode precludes application of this *KSR* rationale.

Moreover, the result of attempting to crystallize the amorphous CoFeB electrode and grow MgO(001) atop it was the furthest thing from “predictable.” Ross, ¶¶240-242; Bokor-Depo, 76:4-78:3, 109:2-6, 118:11-24; 201:16-202:12. Petitioner never even attempts to explain what crystalline structure the CoFeB electrode allegedly would have taken on, let alone explain how it would have interacted with the MgO layer. Ross, ¶241. MTJs using MgO barrier layers were highly complex. The technology was in its infancy, poorly understood and the results Dr. Yuasa achieved surprised those in the field. *See infra* §VII; Ross, ¶242. Even at his deposition, Dr. Bokor could not explain what would have happened if the CoFeB electrode were annealed uncapped as in Bowen’s and Nagahama’s processes. *Supra* §IV.C.2.a. *KSR*’s “predictable results” rationale does not apply.

VI. BOTH GROUNDS FAIL FOR CLAIMS 3-4 FOR AN ADDITIONAL REASON

Claims 3-4 require an “*entirely* crystallized” first ferromagnetic layer that “comprises CoFeB alloy” whereas claims 1-2 only require the first ferromagnetic layer “is crystallized.” Both grounds fail for claims 3-4 for the same reasons they fail for claims 1-2 (*supra* §§IV-V) and for an additional reason.

No evidence supports that Petitioner’s Bowen-Sunai/Parkin (Ground 1) or Nagahama-Sunai/Parkin (Ground 2) MTJ has a “first ferromagnetic material layer [that] is *entirely* crystallized and comprises CoFeB alloy.” Ross, ¶¶243-244. Petitioner does not allege any prior art reference discloses an entirely crystallized layer comprising CoFeB. *Id.*

Petitioner also cites no expert testimony alleging either ground’s combination has an “*entirely* crystallized” first ferromagnetic layer (Petition, 45-49 and 63-65) because *Petitioner’s expert declaration includes no such opinion*. The technology is indisputably complex. Petition, 27-28 (Petitioner’s POSA definition requires a high level of skill); Ross, ¶¶245-254. Petitioner cannot carry its burden to prove claims 3-4 obvious where no expert testimony supports a limitation in claims 3-4 is met. *Wyers v. Master Lock*, 616 F.3d 1231, 1240 n.5 (Fed. Cir. 2010) (“expert testimony regarding matters beyond the comprehension of laypersons is sometimes essential, particularly in cases involving complex technology”).

Petitioner’s nonsensical assertion that PO’s infringement contentions somehow demonstrate obviousness fails. Petition, 45-49, 63-65. PO will carry its burden to prove infringement in the litigation. Petitioner bears the burden to demonstrate obviousness here and fails to do so for claims 3-4.

VII. OBJECTIVE EVIDENCE DEMONSTRATES NON-OBVIOUSNESS

Secondary considerations of non-obviousness must be considered prior to reaching a conclusion on obviousness. *Nike v. Adidas*, 812 F.3d 1326, 1339-40 (Fed. Cir. 2016) (remanding to the Board to consider objective indicia of non-obviousness); *Intri-Plex Techs. v. Saint-Gobain*, IPR2014-00309, Paper 83 at 35 (Mar. 23, 2014) (“Evidence of secondary considerations of non-obviousness, when present, must always be considered.”). “Evidence of secondary considerations ‘may often be the most probative and cogent evidence of non-obviousness in the record.’” *Id.* (quoting *Ortho-McNeil v. Mylan*, 520 F.3d 1358, 1365 (Fed. Cir. 2008)).

PO is not required to “produce objective evidence of non-obviousness for every potential embodiment of the claim.” *Rambus v. Rea*, 731 F.3d 1248, 1257 (Fed. Cir. 2013). There need only “be a nexus to some aspect of the claim not already in the prior art.” *In re Kao*, 639 F.3d 1057, 1068–69 (Fed. Cir. 2011). As detailed below, that is true here.

The law makes secondary considerations highly relevant to non-obviousness to guard against precisely the type of impermissible hindsight reconstruction Petitioner employs by using the claims as a guide to cherry-pick prior art disclosures as a substitute for evaluating a POSA's actual knowledge and motivations at the time of invention. *Graham v. John Deere*, 383 U.S. 1, 17-18 (1966).

Secondary considerations of non-obviousness here – including industry praise, the recognition of contemporaries, failure of others, and solving a long-felt but unmet need – leave no doubt that the claims are non-obvious. Ross, ¶¶255-277.

A. The Claimed Technology Received Industry-Wide Praise

Shortly after filing patent applications to which the '134 Patent claims priority, Dr. Yuasa disclosed the '134 Patent's embodiments using Fe electrodes in articles in the Japanese Journal of Applied Physics ("JJAP," EX2007) and Nature Materials ("Nature," EX2008). Ross, ¶258, citing EX2007, L589; EX2008, 870; EX1005, Figs. 6 and 7(A).

Dr. Yuasa disclosed the '134 Patent's *claimed* device in Applied Physics Letters ("APL," EX2006). Ross, ¶259. APL disclosed:

- Limitation 1[pre] by disclosing "MTJs" (EX2006, 092502-1);

- Limitations 1[a]-1[b] by disclosing a first “reference” ferromagnetic layer on a “substrate,” a second “free” ferromagnetic layer and “CoFeB” for the “reference and free layers” (EX2006, 092502-1);
- Limitation 1[c] by disclosing an “MgO layer” “sandwiched” between the “CoFeB ferromagnetic electrodes” (EX2006, 092502-1);
- Limitation 1[d] by disclosing “the MgO layer [had] a good crystalline structure with a (001) fiber texture” (EX2006, 092502-1-092502-2); and
- Limitation 1[e] and claim 2 by disclosing at least “partial crystallization” of the “CoFeB layers” and “local crystallization of a few monolayers of CoFeB at the electrode/barrier interfaces” (EX2006, 092502-2); Ross, ¶259.

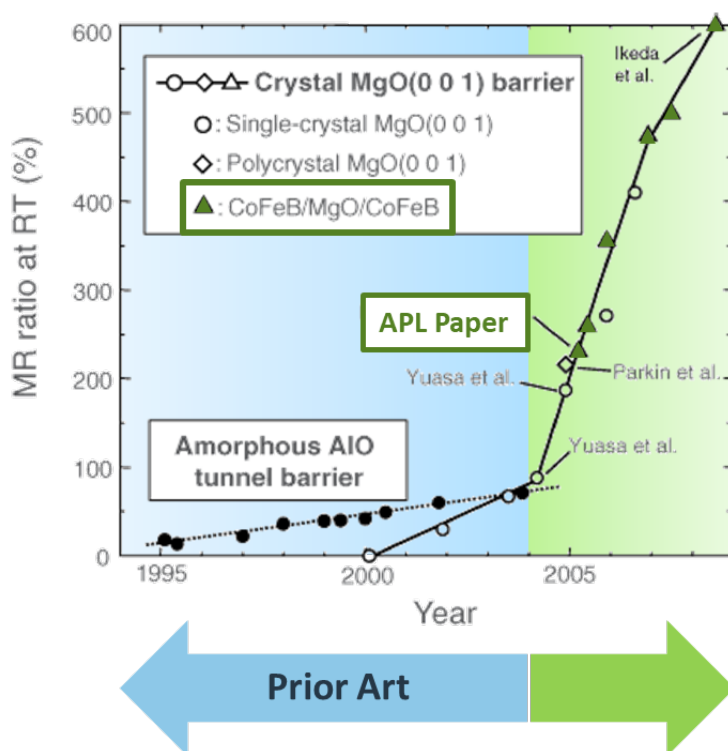
Dr. Yuasa’s disclosure of the claimed invention drew attention and praise across the industry and research community, including from Petitioner’s own employees. Dr. Yuasa’s APL paper has been cited more than **1,200** times. EX2052; Ross, ¶260.

As one example, a 2005 review article cited Dr. Yuasa’s APL paper as reference 43. EX2019, 592, 694; Ross, ¶261. The article praised the claimed invention that achieved a “230% room temperature magnetoresistance,” characterizing the results as “unprecedentedly large TMR ratios.” EX2019, 591-

592. Because APL disclosed the claimed invention that achieved the “unprecedentedly large” 230% TMR, there is a direct nexus between this praise and the claimed invention. Ross, ¶261.

Another example is a chapter Dr. Yuasa authored for a 2017 textbook. Petitioner cites this chapter repeatedly. Petition, 7, 11, 13, 15 (citing EX1057). That chapter cites as reference 33 the APL paper disclosing the claimed invention. EX1057, 52; Ross, ¶262. Figure 2.21 shows that the claimed invention disclosed in APL unleashed a new era of skyrocketing TMRs. EX1057, 46; Ross, ¶262.

Figure 2.21 (Annotated)



The chapter explains that a “fundamental problem” with the prior art was “a problem concerning crystal growth.” EX1057, 46-47. The chapter credits the

claimed method disclosed in APL as “solv[ing] this problem” “by using a sputtering deposition technique” to make a “CoFeB/MgO/CoFeB” “MTJ structure,” where the “as-grown state” of the CoFeB was “amorphous.” *Id.*, 47. The chapter explains that, “[s]urprisingly,” the MgO barrier became “a (001)-oriented polycrystal” despite being grown on an “amorphous CoFeB” underlayer. *Id.*; Ross, ¶263. As can be seen in Figure 2.21, others then applied the claimed device structure, “(001)-textured CoFeB/MgO/CoFeB,” to achieve increasingly higher TMRs of “up to 600%.” *Id.*, 48; Ross, ¶264.

Significant industry praise came from Petitioner itself. Ross, ¶265. Chando Park co-authored a 2006 review on MTJs that identified Mr. Park as working for “Western Digital Corporation.” EX2005, 36. The article cites APL as reference 21. *Id.*, 45. The article recognizes the “CoFeB/MgO/CoFeB tunnel junctions” disclosed in the APL paper “provides a practical solution to overcome this difficulty [of crystal growth]” and characterizes the solution as epitaxially induced crystallization of CoFeB layers with well-matched lattice to MgO with (001) texture. EX2005, 39-40. As another example, “Zheng Gao, Recording Head Development Group, Western Digital Corporation” co-authored a 2018 paper that cited APL as reference 10. EX2022, 106, 110. The paper credited the “even higher TMR ratio of 230%” disclosed by APL and the “significance” of making that MTJ using “amorphous (*a*)-CoFeB ... to promote strong (001) MgO texture in the as-

deposited state” where “post annealing transforms” the CoFeB layer to a polycrystalline layer. *Id.*, 107-108.

Others praised Dr. Yuasa’s invention too. Ross, ¶¶266-267. Employees of TDK, a competitor to Petitioner, authored a 2023 paper recognizing the importance of the ’134 Patent’s claimed invention in MTJ development. EX2023, 1. The TDK paper cites APL as reference 20 (*id.*, 7) and lauded the claimed device as having “made the technology transition from Al₂O₃ to MgO barrier much easier thanks to the use of simple CoFeB amorphous magnetic electrodes ... Upon annealing CoFeB and MgO can be crystallized.” *Id.*, 2. “After demonstrating superior performance ... MgO TMR became the state-of-art technology for all future spintronic devices including HDD recording read heads.” *Id.*

Even Nobel laureate, Albert Fert, when providing a historical overview of spintronics in a 2012 textbook, characterized Dr. Yuasa’s work disclosed in Nature (EX2008) as an “important breakthrough” and “the most important step [of] the transition from MTJ with amorphous tunnel barrier (alumina) to ... MTJ with MgO barrier.” EX2020, 8, 15, f.n. 30. This is among the more than **4,100 times** that Dr. Yuasa’s Nature paper has been cited. EX2057.

In recognition of his groundbreaking work related to the invention of the ’134 patent, Dr. Yuasa has been awarded or co-awarded many prizes. Ross, ¶¶268-272. In 2022, Dr. Yuasa was awarded the “Japan Society of Applied Physics

Achievement Award,” for his “invent[ion] of MTJs combining MgO and cobalt iron boron (CoFeB) alloys.” EX2024, 2-3. In 2021, he was made an “IEEE Fellow” for his “contributions to MgO-based magnetic tunnel junctions” (EX2026, 1) and awarded the “Future Creative Invention Prize” for his “invention ... of [JP] patent no. 5120680,” a foreign counterpart of the ’134 Patent (EX2027; EX2055).

In 2016, Dr. Yuasa won the “Science and Technology Prize” for his “new type of tunnel magnetoresistance element ... using crystalline magnesium oxide (MgO) as the tunnel insulating film,” for which “*a giant tunnel magnetoresistance effect of approximately 200% at room temperature was realized for the first time in the world.*” EX2029, 2. The award noted that “mass production technology was developed that combines MgO and the magnetic alloy CoFeB, making industrial applications of MgO tunnel magnetoresistance elements possible.” *Id.*

IEEE honored Dr. Yuasa as a Magnetism Society Distinguished Lecturer in 2021, noting that his “MTJs with a CoFeB/MgO/CoFeB structure were developed for practical application and found to have MR ratios of above 200% and other practical properties.” EX2030, 3. The IEEE Magnetism society profile notes “[Dr. Yuasa’s] most important scientific achievements are the development of MgO-based MTJs including CoFeB/MgO/CoFeB-type MTJs and their applications to read heads of hard disk drives and STT-MRAM.” EX2031, 1.

Dr. Yuasa was awarded the Tsukuba Prize in 2009, including a monetary award of 5 million yen, for his development of an MTJ using a crystalline MgO tunnel barrier that “achieved a huge MR ratio of 180% at room temperature” and for his work “developing mass production technology for crystalline MgO-MTJ elements.” EX2032, 1; *see also* EX2033, 2. In the same year, he was awarded the “Inoue Harushige Prize” for his invention of “an original method of growing a crystalline layer [MgO] on an amorphous layer [CoFeB].” EX2034, 1; *see also* EX2035, 1.

Dr. Yuasa has been awarded numerous other awards for his MTJ work, including the JSPS Prize in 2010 for “Development of High Performance Magnetic Tunnel Junction Devices,” the Asahi Award in 2008 for his “Studies on development and application of tunnel magnetoresistive effect,” the IBM Japan Science Prize in 2007 for “Studies on tunnel magnetoresistive effects and their application,” the Tokyo Techno Forum 21 Gold Medal Prize in 2006 for “Study on spintronics technology for MRAM,” the Marubun Science Prize in 2006 for “Study on tunnel magnetoresistance effect,” and the Ichimura Science Prize in 2005. EX2028, 4.

B. The Claimed Technology Solved a Long-Felt Unmet Need

Nobel laureates Albert Fert and Peter Grunberg first discovered the giant magnetoresistance (GMR) effect in metallic structures in 1988, spawning MTJ

devices. EX2020, vii, 3. GMR principles were used in magnetoresistive heads in disk drives beginning in 1998 (EX1057, 8-9), and the industry thought the technology could be adapted for use in MRAM (EX1039, 2814; EX1005, 1:28-38). Ross, ¶273X. The industry was only able to achieve an MTJ with a 10% TMR by 1995. EX2039, 846. By the late 1990s, MTJ devices were considered the “most viable” MRAM technology (EX1039, 2819) but commercialization was not feasible because TMRs were too low and manufacturing techniques were incompatible with large scale manufacturing (EX2038, 6-7). Ross, ¶273. Higher TMRs were needed, as was a method to make MTJs in mass quantities rather than one single crystal at a time. EX2056, 8; Ross, ¶273.

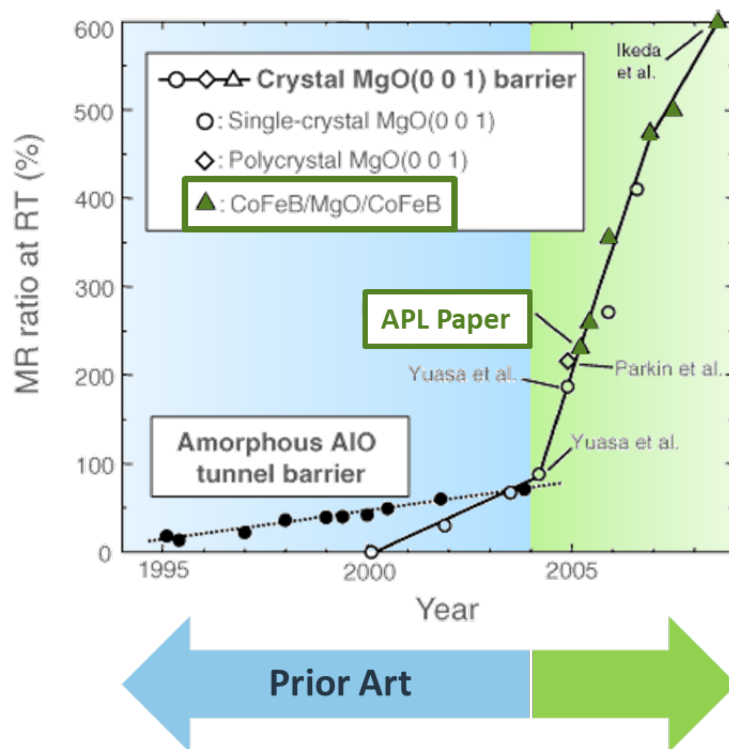
Researchers engaged in extensive experimental effort from 1995-2000 making MTJs using amorphous alumina tunnel barrier layers, but the resulting TMRs were only 10-70%—“lower than those needed for many applications of spintronic devices.” EX1057, 9; EX2056, 6:47:9; EX1005, 2:32-46. In 2001, theorists Butler and Mathon speculated that higher TMRs could be obtained using crystalline MgO tunnel barriers with epitaxially-grown Co or Fe electrodes. EX1057, 16. These theoretical predictions “led to numerous experimental studies to explore the possibility of high TMR in epitaxial (100) oriented Fe/MgO/Fe tunnel junctions.” EX2056, 11:8-11.

Early attempts at making MTJs using crystalline MgO tunnel barriers failed to achieve the theoretical high TMR predictions. *Id.*, 11:8-12:12; Ross, ¶273. One well-known failure was Bowen, which was the “first report of significant tunneling magnetoresistance through epitaxially grown MgO tunnel barriers,” but produced TMR values of only 27% — lower than had been achieved with conventional amorphous alumina tunnel barriers. EX2056, 12, EX1057, 45; Ross, ¶273. Early attempts also failed to address the problem of manufacturability, as the MgO barriers “were either very thick resulting in high resistance-area (RA) values or fully epitaxial grown on single-crystal substrates, which is incompatible with read-head manufacturing.” EX2038, 7. Petitioner’s employees recognized that single-crystal approaches “vastly limit commercial applications.” EX2005, 39; Ross, ¶273.

The ’134 Patent’s claimed invention solved these long-felt but unmet needs by achieving a TMR of 88% at a room temperature which “represent[ed] the highest MR ratios that have so far been obtained at room temperature.” EX1005, 7:55-8:3, 8:56-9:10; Ross, ¶273. The MTJs claimed by the ’134 Patent using CoFeB electrodes achieved even higher 230% room temperature TMR. EX2006, 092502-1-092502-2; *see also supra* §VII.A (showing the nexus between the claimed invention and the device disclosed in the APL paper (EX2006)). The significant increase in TMR spawned by the ’134 Patent’s claimed invention—first

published in the APL paper—is seen in the below chart. EX1057, 46-47, fig. 2.21; Ross, ¶273. TMRs skyrocketed after the world learned of, and built upon, Dr. Yuasa’s invention claimed in the ’134 Patent. EX1057, 46-48; Ross, ¶273

Figure 2.21 (Annotated)



The ’134 Patent’s claimed invention also represented a breakthrough for commercial manufacturing of MTJs. Gone were the days of “strenuously high temperature deposition with single crystal structures.” EX2023, 2. Because the devices were formed using an amorphous CoFeB electrode layer later crystallized through annealing, it allowed for use of a “conventional sputtering method instead of an MBE system.” *Id.*; Ross, ¶274; *See supra* §VII.A (e.g. Dr. Yuasa was

recognized for his “invent[ion] of MTJs combining MgO and cobalt iron boron (CoFeB) alloys,” which “*enabled mass production on large-diameter wafers by room-temperature sputter deposition, which opened the door to industrial applications of MgO MTJ devices*,” citing EX2024, 4); Ross, ¶274.

C. Conclusion: Secondary Considerations Strongly Support Non-obviousness

The ‘134 Patent’s invention solved long felt needs to increase TMR and make MTJs commercially feasible for mass production. Ross, ¶276. Dr. Yuasa received contemporaneous and continuing praise for his groundbreaking achievements. Ross, ¶276. These *objective* indicia are hallmarks of a non-obvious invention and refute Petitioner’s assertion now, decades later, that what Dr. Yuasa did would have been obvious to a POSA.

Respectfully submitted,
GODO KAISHA IP BRIDGE I

Date: July 16, 2025

/Gerald B. Hrycyszyn/

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WOLF, GREENFIELD & SACKS, P.C.

CERTIFICATE OF WORD COUNT

Pursuant to 37 C.F.R. § 42.24, the undersigned certifies that the foregoing **PATENT OWNER'S RESPONSE** contains 13,993 words excluding; a table of contents, a table of authorities, a certificate of service or word count, or appendix of exhibits or claim listing. Patent Owner has relied on the word count feature of the word processing system used to create this paper in making this certification.

Date: July 16, 2025

/Dara Del Rosario/

Dara Del Rosario

Paralegal

WOLF, GREENFIELD & SACKS, P.C.

CERTIFICATE OF SERVICE UNDER 37 C.F.R. § 42.6 (e)(4)

I certify that on July 16, 2025, a copy of the foregoing document, including any exhibits filed therewith, is being served via electronic mail, as previously consented to by Petitioner, upon the following:

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