

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. IPR2024-01493
Patent No. 10,680,167

PATENT OWNER'S RESPONSE

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37 C.F.R. §42.22	22
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EXHIBIT LIST

Exhibit	Description
2001	Kittel, C., <i>Introduction to Solid State Physics</i> , 6th Edition, 1986, pgs. 13-15, 18, 23 (“Kittel”)
2002	Duke, C.B., <i>Tunneling in Solids</i> , Solid State Physics: Advances in Research and Applications, 1969, pgs. 1, 6-7, 34-35, 78-79 (“Duke”)
2003	Definition of “ferromagnetism,” Oxford English Reference Dictionary, Second Edition, pg. 513 (“Oxford English Reference Dictionary”)
2004	“Ferromagnetism,” The New Encyclopedia Britannica: Volume 4, 15th Edition, 2003, pgs. 748-749 (“Britannica”)
2005	J-G Zhu and C. Park. “Review Feature: Magnetic tunnel junctions,” <i>Materials Today</i> , vol. 9, no. 11, 2006, pp. 36-45 (“Zhu”)
2006	Djayaprawira, D. et al. “230% room-temperature magnetoresistance in CoFeB/MgO/CoFeB magnetic tunnel junctions,” <i>Applied Physics Letters</i> , vol. 86, no. 9, 2005, pp. 092502-1 to -3
2007	Yuasa, S., et al. “High Tunnel Magnetoresistance at Room Temperature in Fully Epitaxial Fe/MgO/Fe Tunnel Junctions due to Coherent Spin-Polarized Tunneling,” <i>Japanese Journal of Applied Physics</i> , vol. 43, no. 4B, 2004, p. L588
2008	Yuasa, S., et al. “Giant room-temperature magnetoresistance in single crystal Fe/MgO/Fe magnetic tunnel junctions,” <i>Nature Materials</i> , vol. 3, no. 12, 2004, pp. 868-871
2009	Callister, W.D., <i>Fundamentals of Materials Science and Engineering, An Integrated Approach</i> , Department of Metallurgical Engineering, The University of Utah, Second Edition, 2005, pgs. 36-37, G1 (“Callister”)
2010	U.S. Patent No. 6,590,803 to Saito et al. (“the ’803 Patent”)
2011	U.S. Patent Application Publication No. 2002/0036877 to Sakakima et al. (“Sakakima”)

Exhibit	Description
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2013	S. Yuasa et al. “Characterization of growth and crystallization processes in CoFeB / MgO / CoFeB magnetic tunnel junction structure by reflective high-energy electron diffraction,” <i>Applied Physics Letters</i> , vol. 87, no. 24, p. 242503, 2005.
2014	Definitions of “crystalline” and “crystallize,” Webster’s Encyclopedic Unabridged Dictionary of the English Language (1989)
2015	Definitions of “anneal”, “crystalline” and “crystallized,” Webster’s Ninth New Collegiate Dictionary (1984)
2016	Gleiter, H. “Nanostructured Materials: Basic Concepts and Microstructure,” <i>Acta Materialia</i> , vol. 48, no. 1, pp. 1-29 (2000)
2017	Deposition of Jeffrey Bokor, Ph.D. (June 24, 2025)
2018	Deposition of Jeffrey Bokor, Ph.D. (June 25, 2025)
2019	Marrows, C.H. “Spin-polarised currents and magnetic domain walls,” <i>Advances in Physics</i> , vol. 52, no. 8, 2005, pp. 585-713
2020	Tsymbal, E., et al., <i>Handbook of Spin Transport and Magnetism</i> , 2012
2021	RESERVED
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
2024	The 23rd (FY2022) Japan Society of Applied Physics Achievement Award Recipients (with English translation), The Japan Society of Applied Physics, <i>available at</i> https://www.jsap.or.jp/outstanding-achievementaward/recipients/recipients23

Exhibit	Description
2025	RESERVED
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
2030	Yuasa, S., “IEEE Magnetics Society Distinguished Lecturers for 2012: Magnetoresistance and Spin-Transfer Torque in Magnetic Tunnel Junctions,” <i>IEEE Transactions on Magnetics</i> , vol. 48, no. 1, 2012, p.3
2031	Shinji Yuasa – IEEE Magnetics Society, <i>available at</i> https://ieemagnetics.org/contact/shinji-yuasa#biography
2032	AIST, “Winner of the 20th Tsukuba Award,” <i>available at</i> https://www.aist.go.jp/aist_j/news/prize/itemid025-000077.html
2033	Announcing the winners for “Tsukuba Prize,” “Esaki Leona Prize,” and “Tsukuba Encouragement Prize”: Ibaraki Prefectural Science and Technology Promotion Foundation (with English translation), <i>available at</i> https://www.tsukuba-sci.com/cms/?p=9853
2034	AIST: 34th Inoue Harunari Prize, <i>available at</i> https://www.aist.go.jp/aist_j/news/prize/itemid025-000082.html
2035	Technological seeds that overcome the valley of death (Shinji Yuasa/Head of the Spintronics Group, National Institute of Advanced Industrial Science and Technology), <i>available at</i> https://scienceportal.jst.go.jp/explore/highlight/20090717_01/

Exhibit	Description
2036-2037	RESERVED
2038	Maat, S., et al. “Physics and Design of Hard Disk Drive Magnetic Recording Read Heads,” <i>Handbook of Spintronics</i> , 2014
2039	Butler, et al. “Magnetic Memory: A signal boost is in order,” <i>Nature Materials</i> , vol. 3, no. 12, 2004, pp. 845-847
2040-2047	RESERVED
2048	M. Ohring, <i>The Materials Science of Thin Films</i> , Academic Press (1992).
2049-2051	RESERVED
2052	Google Scholar data page for Djayaprawira, D. et al. “230% room-temperature magnetoresistance in CoFeB/MgO/CoFeB magnetic tunnel junctions,” <i>Applied Physics Letters</i> , vol. 86, no. 9, 2005, pp. 092502-1 to -3
2053	Declaration of Caroline Ross, Ph.D.
2054	CV of Dr. Caroline Ross, Ph.D.
2055	Japanese Patent No. JP 5120680 B2 with certified English translation
2056	File History of U.S. Patent Application No. 10/824835 (EX1092 in <i>Western Digital v. IP Bridge</i> , IPR2025-00701)
2057	Google Scholar data page for Yuasa, S., et al. “Giant room-temperature magnetoresistance in single crystal Fe/MgO/Fe magnetic tunnel junctions,” <i>Nature Materials</i> , vol. 3, no. 12, 2004, pp. 868-871
2058	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> , vol. 39 (2000), pp. L 1035–L 1038.

Exhibit	Description
2059	Powder diffraction file for Au, from Joint Committee of Powder Diffraction Standards (JCPDS), The International Centre for Diffraction Data, icdd.com
2060	I. Petrov et al. “Microstructural evolution during film growth,” <i>Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films</i> , vol. 21, no.5, 2003, pp. S117-S128 (“Petrov”)
2061	E. Krikorian and R.J. Sneed. “Nucleation, Growth and Transformation of Amorphous and Crystalline Solids Condensing From the Gas Phase,” <i>Astrophysics and Space Science</i> , vol. 65, 1979, pp. 129-154 (“Krikorian”)
2062	M.O. Aboelfotoh. “Crystal Structure of Evaporated MgO Films on Amorphous and Polycrystalline Substrates,” <i>Journal of Vacuum Science and Technology</i> , vol. 10, no. 5, 1973, pp. 621-625
2063	Errata to EX2017 - Deposition of Jeffrey Bokor, Ph.D. (June 24, 2025)
2064	Errata to EX2018 - Deposition of Jeffrey Bokor, Ph.D. (June 25, 2025)

I. INTRODUCTION

The '167 patent concerns magnetic tunnel junctions (“MTJ”)— solid state devices that sandwich a tunnel barrier layer between two ferromagnetic electrodes. MTJs are key components in modern electronics including non-volatile magnetoresistive random access memory (MRAM) and hard disk drive magnetic heads.

The claims recite MTJ manufacturing methods that form a bottom and top ferromagnetic layer from amorphous cobalt iron boron (CoFeB), form a barrier layer from magnesium oxide (MgO), and anneal the three layers. The process results in each layer having certain properties: annealing “crystallize[s]” the two amorphous CoFeB layers, and the barrier comprises polycrystalline MgO with a preferentially-oriented (001) crystal plane.

The '167 Patent’s new manufacturing methods revolutionized the industry because they were highly manufacturable, allowed forming the MTJ trilayer on a wide variety of surfaces, and yielded MTJs that achieved high tunnel magnetoresistance ratio (“TMR”)—a desired characteristic for commercial MTJ device applications. Before Dr. Yuasa’s invention in the '167 Patent, nobody knew how to make MTJs with high TMR in a highly manufacturable process that annealed amorphous CoFeB layers sandwiching a MgO barrier, yielding a MTJ

with polycrystalline MgO having a particular microstructure (e.g., a preferentially-oriented (001) crystal plane).

Petitioner's two invalidity grounds each rely on a primary reference (Bowen in ground 1, Nagahama in ground 2) that discloses an MTJ with a *crystalline* (rather than polycrystalline) MgO(001) barrier layer and ferromagnetic electrodes that are *not CoFeB*. The grounds fail for several reasons.

A. No POSA Would Have Combined References in the Manner Alleged.

The primary references Bowen and Nagahama teach radically different manufacturing processes from the claimed invention, which requires forming *amorphous* CoFeB electrodes—a different material (CoFeB) and different material phase (amorphous) than used in Bowen or Nagahama's crystalline electrodes. Bowen and Nagahama went to heroic lengths to provide a *crystalline* (001) bottom electrode that provides a template for epitaxially growing a *crystalline* MgO(001) layer—processes yielding features that are incompatible with the claimed invention. Indeed, each reference *provided entirely new ways* to fabricate an underlayer that would template a crystalline (001) bottom electrode, which in turn would template epitaxial growth of a crystalline MgO(001) layer. The Petition's grounds fail because a POSA never would have modified *either* of Petitioner's

primary references to use an amorphous (*i.e.*, non-crystalline) structure which was *the exact opposite* of what Bowen and Nagahama were trying to achieve.¹

B. Secondary References Sunai and Parkin Are Incompatible with the Primary References Bowen and Nagahama.

Petitioner's obviousness grounds allege that two secondary references—"Sunai" and "Parkin"—would have motivated a POSA to modify Bowen's and Nagahama's fabrication processes to form *amorphous* CoFeB ferromagnetic electrodes. Petitioner alleges a POSA would have done this to increase TMR and reduce certain magnetic properties (coupling and coercivity) related to switching. Then Petitioner alleges the *very same reason* (increasing TMR) would have motivated a POSA to *crystallize* the amorphous layers—while ignoring that this would destroy the beneficial magnetic properties that Petitioner just alleged motivated using the amorphous layers in the first place, properties that Sunai and Parkin themselves explain were a consequence of that amorphous state. The scattershot combinations disregard that Sunai and Parkin each wanted the ferromagnetic layer to be amorphous (*i.e.*, non-crystalline), the opposite of the phase used in Bowen and Nagahama's processes.

¹ Patent Owner applies Petitioner's POSA definition herein. Pet., 20.

Petitioner's obvious combinations are an exercise in improper picking and choosing isolated teachings in the prior art in an attempt to reconstruct the claims in hindsight. Petitioner's references—Bowen, Nagahama, Sunai, and Parkin—each teach away from Petitioner's allegedly-obvious combinations because Sunai and Parkin used boron to *avoid* crystalline electrodes whereas Bowen and Nagahama tried to *achieve* perfect crystalline electrodes. Worse yet, after “picking” the teachings in Sunai and Parkin of an amorphous electrode, Petitioner ignores the reason why Sunai and Parkin wanted an amorphous electrode and “chooses” a crystalline electrode based on Bowen and Nagahama. Petitioner fails to establish that a POSA interested in retaining a crystalline electrode in Bowen or Nagahama had any reason to form an electrode comprising elements (boron) that would have inhibited the very crystallization that Bowen and Nagahama sought.

C. Petitioner Has Not Shown a Reasonable Expectation of Success.

But even if the Board were to find that a POSA had some reason to *attempt* modifying the process in Bowen or Nagahama, Petitioner fails to establish that a POSA would have had a reasonable expectation of success that either alleged process would achieve an MTJ device with a first and second “crystallized” CoFeB ferromagnetic layer and a polycrystalline MgO layer with the claimed microstructure. While the Petition offers two theories how a POSA would have

attempted to make such MTJs, no prior art supports that following either approach would have yielded a polycrystalline MgO layer with the claimed microstructure. Indeed, the Petition's *only* evidence that anyone actually achieved MgO as claimed from this trilayer combination is a 2017 treatise citing Dr. Yuasa's own papers published after the critical date (and describing the result as surprising).

Petitioner alleges that a POSA would have substituted CoFeB for the material used for the lower electrode in Bowen's or Nagahama's device, annealed the CoFeB layer, then formed the MgO layer on top of the annealed CoFeB layer. Petitioner's evidence does not support that a POSA would have reasonably expected this method to yield polycrystalline MgO with the claimed microstructure. Petitioner's expert admitted that *he had no idea* what would have happened if a POSA had actually used the processes alleged in the grounds.

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.*

EX2018, 169:16-170:12.²

Section II demonstrates that Dr. Bokor's inability to explain what would have happened to the lower amorphous CoFeB electrode upon annealing *is fatal* to Petitioner's reasonable expectation of success that the modified process based on Bowen or Nagahama would have yielded a polycrystalline MgO layer with the claimed microstructure.

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 the invention any Challenged Claim.

The '167 Patent's invention received extensive praise in industry and academia and solved long-felt but unmet need. The work described in the '167 Patent has appeared in the field's pre-eminent journals, been cited thousands of times, and made a massive advance in making MTJ devices feasible for commercial applications. The assertion by Western Digital's attorneys and its paid

² Unless otherwise specified, in this Response all emphasis is added.

expert that Dr. Yuasa's contributions were "obvious" cannot be reconciled with the contemporaneous reaction of those in the field, including Western Digital's own employees, who praised Dr. Yuasa's invention as groundbreaking.

Petitioner's obviousness theories are baseless. Petitioner has not met its burden to prove any Challenged Claim obvious.

II. PETITIONER FAILS TO SHOW THAT A POSA HAD A REASONABLE EXPECTATION THAT THE ALLEGED COMBINATIONS WOULD PRODUCE AN MTJ AS CLAIMED.

Petitioner's expert testified that he *had no idea* what would have happened if a POSA had replaced Bowen's or Nagahama's iron bottom electrode with amorphous CoFeB and—as Bowen and Nagahama each teach—annealed the bottom electrode before forming an MgO barrier layer on top of it.

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.

EX2018, 169:16-170:12.

Dr. Bokor's bewilderment is *fatal* to both grounds because with no expectation what surface conditions that bottom CoFeB layer would have provided for the subsequent MgO deposition, a POSA had no reasonable expectation that the manufacturing process alleged in either ground would achieve a polycrystalline MgO with a preferentially-oriented (001) crystal plane (i.e., the claimed MgO microstructure) as the claims require (1[e], 11[b]). This brings Petitioner's entire house of cards crashing down.

A. Petitioner's Manufacturing Methods Expressly Rely on Annealing the Bottom Electrode Before Forming the MgO Barrier Layer.

First, the grounds expressly rely on Bowen's and Nagahama's manufacturing process when mapping the claims.

Bowen and Nagahama both describe annealing a bottom Fe electrode to provide a crystalline Fe(001) layer. EX2053 ("Ross"), ¶¶54, 62, 65, 106, 110. After depositing the bottom Fe electrode (at room temperature) Bowen anneals it at 400°C (a step that the Petition repeatedly cites in mapping the claim limitations), forming a high-quality crystalline Fe(001) layer that crucially provides a lattice match for Bowen to thereafter epitaxially grow its single-crystal MgO(001) barrier layer. Ross, ¶¶54-57, 61-63, 106-109; EX1026, 1655-1656; EX1084, 225; *infra*

§III.A.1. Nagahama also specifies depositing an Fe bottom layer 213 by sputtering (EX1027, [0062], step 6), then annealing it (EX1027, [0062], step 7), resulting in “high quality crystals... grown in the (001) direction,” e.g., Fe(001). Ross, ¶¶72-73, 99-100, 110-111; EX1027, [0065].

Petitioner alleges that Bowen and Nagahama separately taught a MTJ manufacturing method meeting the claims. Pet., 21 (Bowen), 49-50 (Nagahama); Ross, ¶¶101-105. Petitioner alleges that a POSA would have replaced Bowen’s and Nagahama’s Fe bottom electrode with an amorphous CoFeB layer. Pet., 22-28 (1[a], Bowen), 46 (11[pre]-11[a], Bowen); Pet., 50-54 (1[a], Nagahama), 66 (11[pre]-11[a], Nagahama). Petitioner expressly relies on Bowen’s *epitaxially growing* MgO(001)—which relies on having previously formed the Fe(001) crystalline electrode with Bowen’s 400°C annealing step—to meet 1[b] and 11[b]. Pet., 28, 33 (relying on 1[b] mapping to meet 1[e]), 47 (citing EX1026, 1655 and relying on 1[b] mapping to meet 11[b]); Ross, ¶¶106-109. Petitioner makes parallel allegations concerning Nagahama. Pet., 54 (1[b]), 57-58 (1[e], citing EX1027, [0073] and relying on 1[b] mapping), 67 (11[b], citing EX1027, [0073] and relying on 1[b] mapping); Ross, ¶¶110-111.

Second, Petitioner relies on Bowen and Nagahama annealing the Fe bottom electrode to meet 1[d] (and 11[d]).

In ground 1, Petitioner expressly relies on Bowen’s annealing the lower electrode to meet 1[d] “annealing the first... CoFeB layer.” Pet., 30 (1[d], “Bowen taught or suggesting [sic] annealing at 400°C its first ferromagnetic layer (‘Fe bottom electrode’)[.]”), quoting EX1026, 1655; *id.*, 31-32 (1[d], quoting EX1026, 1655, discussing EX1045), 47 (relying on 1[d] mapping to meet 11[d]); Ross, ¶¶112-114.

In ground 2 the Petition relies on Nagahama’s “annealing” the lower electrode in “preparing” its MTJ to include “the (001)-highly-oriented MgO barrier layer overlying the MgO double underlayer” (EX1027, [0074]), which describes the MgO(001) layer formed on top of the Fe(001) bottom electrode 213 (EX1027, [0073]), which was formed by Nagahama’s annealing (EX1027, [0062]-[0065]). Pet., 50 (citing EX1027, [0062]), 57; Ross, ¶116. Ground 2’s 1[d] analysis further relies on ground 1’s 1[d] analysis that relies, in turn, on *Bowen’s* epitaxial MgO(001) growth on Bowen’s Fe(001) crystalline bottom electrode to meet 1[b]. Pet., 56-57; Ross, ¶116.

Third, Petitioner never modified the process in Bowen or Nagahama to remove the step of annealing the lower electrode.

There is no credible argument that Petitioner modified Bowen or Nagahama to exclude annealing the bottom electrode before depositing the barrier layer. To

the contrary, as shown above, Petitioner expressly relied on Bowen/Nagahama as teaching annealing the bottom electrode before forming the MgO barrier layer.

Petitioner's expert admits that he never described modifying Bowen to skip Bowen's annealing step. EX2018, 172:18-24 ("Q: [W]here do you describe modifying Bowen to avoid the anneal step after the room temperature deposition of the bottom electrode? // A: So I don't have explicit discussion of that."), 180:24-181:8 (similar); *generally id.*, 172:18-182:11.

B. Petitioner's Expert Had No Idea What Would Have Happened If a POSA Annealed an Amorphous CoFeB Bottom Layer as Taught in Bowen And Nagahama.

Petitioner's expert *had no idea* what would have happened if a POSA had followed the process in the grounds and annealed an uncapped amorphous CoFeB layer. *Supra* §II; EX2018, 169:16-170:12. Petitioner's expert further testified:

Q And what would a person of ordinary skill in the art in 2004 have expected to have [happened] if in Bowen's process they deposited amorphous cobalt iron boron at room temperature on that magnesium oxide buffer layer and then annealed at 400 Celsius?

THE WITNESS: I don't recall anywhere right off the top of my head as I sit here any references that describe a process like that. And I think it's – I – *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*. I'm not saying it's not anywhere in the references. I just don't recall that. And without having something to refer to, I – *I'm not willing to speculate*.

EX2018, 170:13-171:19. And Petitioner's expert testified that a POSA would have had "a natural reticence to anneal" an amorphous CoFeB layer "without a layer on top"—i.e., to follow the alleged process. EX2018, 173:2-5.

In short, Petitioner's expert was *unable to explain* what would have happened if a POSA, having replaced Bowen's bottom Fe layer with amorphous CoFeB as ground 1 alleges, thereafter annealed it at 400°C.

Dr. Bokor's testimony concerning the result of ground 1's combination applies with equal force to the result of ground 2's Nakahama combination because just like Bowen, Nagahama describes annealing the bottom Fe electrode to form Fe(001) before growing MgO(001) on it. EX1027, [0062]; Ross, ¶¶95-97, 110-111, 122.

C. A POSA Had No Reasonable Expectation of Success That the Manufacturing Method in Either Ground Would Have Achieved the Claimed Invention.

Dr. Bokor's inability to explain what would have happened to the lower amorphous CoFeB electrode is *fatal* to a POSA's reasonable expectation of success that either ground would have yielded a polycrystalline MgO layer with the claimed microstructure.

1. Dr. Bokor’s testimony precludes a reasonable expectation of success.

Dr. Bokor’s testimony (*supra* §II.B) means that if the process in each ground were actually followed a POSA would have had ***no expectation*** concerning what surface the bottom CoFeB electrode would have provided as the basis for step 1[b] (and 11[b]) forming the MgO layer on top of it. In other words, a POSA could not have had a reasonable expectation that annealing the bottom CoFeB layer—as taught in Bowen and Nagahama—would have provided a surface on which forming an MgO layer would have been expected to achieve polycrystalline MgO with the claimed microstructure. Ross, ¶¶123-125. This is fatal to both grounds and should end the Board’s invalidity analysis.

2. Petitioner’s evidence contradicts any expectation of achieving a polycrystalline MgO layer as claimed.

There is no evidence that even the possible alternatives for what would have happened to the first CoFeB layer in each ground’s process would have supported forming the required MgO microstructure.

a. Jimbo and Cardoso gave the POSA an expectation of failure.

Petitioner relies on Jimbo (EX1060) and Cardoso (EX1061) as evidence that it was “known” to “crystallize” amorphous CoFeB by annealing. Pet., 30-31. But in both references annealing amorphous CoFeB allegedly resulted in a (111)-textured material. EX1060, 308-309 (describing a “fcc(111)” X-ray diffraction

peak); EX1061, 2273 (describing “some (111) texturing”). Petitioner’s own evidence makes clear that MgO(001) cannot be grown on a (111)-oriented surface. EX1057, 47 (“A fundamental problem with this structure is that an NaCl-type MgO(001) tunnel barrier... which [has] fourfold in-plane crystallographic symmetry, *cannot be grown on [a] fcc(111)-oriented... structure*, which has threefold in-plane crystallographic symmetry, *because of the lattice mismatch.*”), 127 (similar); EX2018, 76:12-78:3 (no epitaxy without lattice match). Thus, even if Petitioner’s reliance on Jimbo and Cardoso is credited, a POSA would have had no expectation of success in achieving the claimed MgO microstructure because the annealed first CoFeB layer would have had the wrong crystalline orientation, and MgO(001) would not grow on it. Ross, ¶¶126-127, 134.

b. Dr. Bokor distinguished Parkin’s embodiment.

Parkin provides no reasonable expectation of success that the process in either ground would yield a MgO layer meeting 1[b] (11[b]) because the only cited embodiment in Parkin formed a “highly (001) textured MgO layer” on layer 115—comprising layer 119—in Fig. 3A, which was a “bcc alloy formed from one or more of Co and Fe” and “textured in the (100) orientation.” EX1062, 13:10-25; Pet., 33, citing EX1062, 18:49-51, 18:63-19:10, discussing Fig. 3A embodiment; Ross, ¶128. Parkin’s layer 115 thus provided a template for the MgO layer 120’ to

form its “highly (001)” texture. EX1062, 19:16-19. The amorphous CoFeB lower layer in Petitioner’s grounds provides no such template.

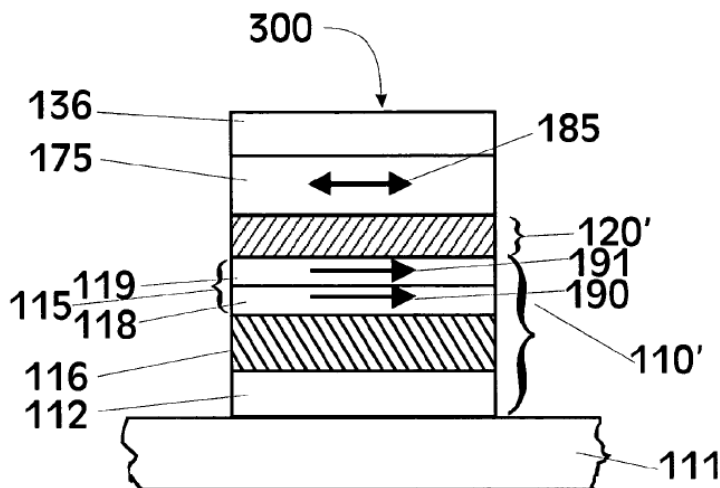


FIG. 3A

Moreover, Parkin annealed the *top* amorphous CoFeB layer 175 *after* it was covered with “capping layer 136... comprised of” 10 nm tantalum nitride (TaN) followed by 7.5 nm rubidium (Ru). EX1062, Fig. 3A, 17:54-59 (describing layer 136), 17:61-18:6 (describing annealing); Ross, ¶129. Unlike Parkin, both Bowen and Nagahama describe annealing the bottom ferromagnetic electrode *without* a capping layer, a point Dr. Bokor emphasized when refusing to “speculate” what would have happened to the amorphous CoFeB bottom electrode. EX2018, 170:13-171:19 (“*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.”). By Dr. Bokor’s own testimony, Parkin’s annealing—**with** capping layer 136—would not have given a POSA **any** expectation of what would have resulted from annealing the bottom CoFeB layer **without** a capping layer. Ross, ¶130.

3. A POSA had no reasonable expectation of achieving the MgO barrier as claimed if it were deposited on an amorphous first CoFeB layer.

Although the Petition does not explain and Petitioner’s expert could not state what a POSA would have expected to happen after annealing the uncapped amorphous CoFeB lower ferromagnetic electrode, the lower electrode’s **top surface** would have crystallized, stayed amorphous—and/or reacted with any gases (like oxygen) in the chamber to form a new material.

Petitioner has no evidence that the bottom CoFeB layer’s **top surface**—providing an interface for the MgO buffer layer—would have crystallized with a (001) texture. Indeed, Petitioner’s expert **quotes** the very sentence in EX1057 that states “the stable structure of Co₆₀Fe₂₀B is not bcc but fcc [citing Yuasa’s EX2008].” EX1024, ¶61 (cited Pet., 11), quoting EX1057, 48 (but **omitting** the last half of the sentence stating that the stable structure is fcc); *accord* EX1061, 2273 (describing CoFeB with a “strong (111) texture” after annealing); *see also* EX2018, 93:3-97:16 (Petitioner’s expert admitting he had no evidence disputing that “the stable structure of Co₆₀Fe₂₀B” is fcc). Thus a POSA would have had a

reasonable expectation that if the lower CoFeB layer crystallized, it would have crystallized as fcc(111) (i.e., its stable structure). Ross, ¶¶131-133. Parkin provides no contrary evidence, because while its annealing step formed a thin CoFe crystalline layer at the interface with layer 120' the "bulk" of the CoFeB layer 175—including the top surface adjacent layer 136—"remain[ed] amorphous." EX1062, 18:51-60.

A POSA would never have used a process yielding a lower CoFeB electrode with fcc(111) because this was incompatible with subsequent steps of the alleged process yielding MgO (100) with the claimed microstructure. Ross, ¶¶126-127, 134-135. At worst, like Petitioner's expert, a POSA would have had no idea what would have resulted from annealing the lower electrode, and thus no reasonable expectation that the alleged processes would succeed, and thus no reason to combine the references in the manner alleged.

Even if it were assumed that Petitioner's process deposited MgO on an amorphous surface, there is no evidence that a POSA would have had a reasonable expectation that the alleged combinations would have resulted in an MTJ with the MgO layer having the claimed microstructure. Ross, ¶136.

a. Petitioner’s explicit reliance on epitaxial MgO growth to meet the claims fails with an amorphous CoFeB bottom layer.

First, ground 1 expressly relies on Bowen’s process of *epitaxially growing* MgO on the Fe(100) bottom electrode to meet 1[b], 1[e], and 11[b]. E.g., Pet., 28-29, 33, 47. This fails to meet the claims because—as Bowen demonstrates—epitaxially-grown MgO is *crystalline*, not polycrystalline. EX1026, 1655-1656; Ross, ¶¶47-48, 53-57, 63. But a POSA regardless had no expectation of success in epitaxially growing MgO on an amorphous surface. EX1057, 47; EX1055, 2270 (“amorphous CoFeB does not support any crystalline grain growth”); Ross, ¶137. Petitioner’s expert agreed. EX2018, 72:11-13 (“there’s no epitaxy from amorphous substrates[.]”). Therefore, a POSA had no reasonable expectation that the process that the Petition alleges a POSA would have used in ground 1 would have achieved MgO with microstructure meeting 1[e] or 11[b]. Ross, ¶138.

For ground 2 Petitioner relies on Nagahama’s description of an embodiment with a “(001)-highly-oriented MgO barrier layer” on a “(001)-highly-oriented lower ferromagnetic layer” (EX1027, [0073]) to meet 1[b] and 1[e]. Pet., 54-55, 57-58. While Nagahama is ambiguous on how it achieved the MgO(001) layer in [0073], that layer was unambiguously formed *only* in the presence of the Fe(001) lower ferromagnetic layer, which Nagahama formed by annealing the Fe deposited on the MgO(001) substrate specifically provided by its “double underlayer.”

EX1027, [0056], [0062], [0065]-[0074]; Pet., 50, citing EX1027, [0062]. Thus, just like with Bowen, replacing Nagahama's Fe(001) bottom electrode with amorphous CoFeB left a POSA with no reasonable expectation that the process alleged in ground 2 would have achieved MgO with a microstructure meeting 1[e] or 11[b]. Ross, ¶¶139-141.

b. Petitioner does not explain the “contemplated workings of the combination” required to show a reasonable expectation of success and does not even allege that MgO deposited on amorphous CoFeB would achieve the claimed microstructure.

Second, even if the grounds were read to encompass depositing (rather than epitaxially growing) MgO on an amorphous first CoFeB layer (they do not), the Petition *does not even allege* that forming MgO on an amorphous material (e.g., the assumed CoFeB surface) would have achieved polycrystalline MgO with a microstructure meeting 1[e] or 11[b]. There is *no* “clear, evidence-supported *account of the contemplated workings of the combination*” that the law makes “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.” *Personal Web Techs. v. Apple*, 848 F.3d 987, 994 (Fed. Cir. 2017).

In ground 1, Petitioner's 1[b] analysis recites *epitaxially growing* MgO(001) using Bowen's process, which Petitioner's expert testified was not possible on an

amorphous CoFeB layer. *Supra* §II.C.3.a; Ross, ¶¶137, 142-145. Petitioner’s 1[e] analysis make a conclusory assertion that it “would have been obvious to use” polycrystalline MgO with a preferentially-oriented (001) crystal plane without saying **how** a POSA would have expected to achieve it using the alleged process, let alone on an amorphous CoFeB layer, and without explaining how “us[ing]” polycrystalline MgO could be squared with Ground 1’s reciting Bowen’s epitaxial growth teachings to meet 1[b]. Pet., 33-35 (discussing 1[e]), 47 (discussing 11[b]).

In ground 2, Petitioner’s 1[b] analysis quotes Nagahama’s description of forming a “(001)-highly-oriented MgO barrier layer” over a “(001)-highly-oriented lower ferromagnetic electrode layer” without explaining how the modified process in ground 2 would achieve the claimed polycrystalline MgO, then cites its ground 1 analysis of 1[b] (relying on Bowen’s epitaxial MgO growth step). Pet., 54-55, citing Nagahama, [0073] and Petition “§VI.A.3” (i.e., ground 1, 1[b]). Petitioner’s 1[e] analysis simply asserts that Nagahama described achieving polycrystalline MgO with a preferentially-oriented (001) crystal plane, but never explains why a POSA would have expected this result after replacing Nagahama’s (001) textured lower ferromagnetic layer with amorphous CoFeB. Pet., 57-58 (Limitation 1[e]). Petitioner’s ground 2 analysis for Limitation 11[b] relies on the 1[b]/1[e] analysis. Pet., 67.

In short, nowhere does Petitioner explain how depositing MgO on amorphous CoFeB would have achieved MgO with the claimed microstructure (e.g., (001) texturing). And nowhere does Petitioner explain why a POSA would have had a reasonable expectation that the process in either ground would have achieved the claimed MgO microstructure. At most the Petition cites Yoon (EX1040), p. 2842, in ground 2 (but nowhere in ground 1) for the proposition that “MgO ‘polycrystalline structures’ have ‘preferred orientation.’” Pet., 57 (1[e]). But this discussion in Yoon concerned “MgO films *grown on GaAs (100)*” (EX1040, 2842), which is crystalline (100) rather than amorphous, and this teaching thus gave a POSA no expectation that MgO deposited on *amorphous* CoFeB would have formed the claimed microstructure. Ross, ¶¶149-151.

c. Petitioner cannot incorporate its expert discussion of Wulff or Yoon by reference.

Petitioner’s expert declaration cites Wulff (EX1036) p. 148 and Yoon (EX1040) p. 2840 for the proposition that MgO films achieved a (100) texture when deposited on an amorphous substrate. EX1024, ¶¶70, 175. But as explained *infra* §II.C.3.d this testimony fails to show a POSA’s reasonable expectation of success based on the thick-film studies reported in Wulff and Yoon. Moreover, Dr. Bokor’s admission that “the dynamics of crystallization are... complicated” (EX1028, 118:20-22) and “I’m no expert. I’m no crystal grower.” (EX1028, 77:19) makes clear that his testimony concerning a POSA’s expectations for

ultrathin MgO film texture formation on an amorphous substrate based on the thick-film results in Wulff and Yoon is entitled to little weight.

The Petition never cites EX1024, ¶¶70 or 175 for the proposition that MgO films achieved the claimed microstructure when deposited on an amorphous substrate. The Petition never cites or discusses EX1036 at all, and never cites or discusses EX1040, p. 2840 cited in EX1024, ¶¶70, 175. Petitioner cannot incorporate by reference arguments made only in the expert declaration. 37 C.F.R. §§42.22, 42.104(b)(3)-(4), 42.6(a)(3); *Instrumentation Lab. v. Hemosonics*, IPR2017-00855, Paper 55, 20 (Feb. 13, 2019) (“Arguments and information that are not presented and developed in the Petition, but instead are incorporated by reference, are not entitled to consideration[.]”).

d. Even if Wulff and Yoon are considered they do not support a reasonable expectation of success.

Even if the Board considers Wulff or Yoon, they would not have provided a reasonable expectation of success.

Neither Wulff nor Yoon investigated the microstructure of MgO films with ultrathin (2-10 nm thick) films that would be used in an MTJ. EX1013, 6:37-41; Ross, ¶¶152-153. Wulff described the behavior of MgO films with thicknesses exceeding 100 nm (i.e., 0.1 μm). EX1036, 150 (“MgO films of about 0.1, 0.5, and 1 μm thickness were deposited[.]”). Yoon does not report the thickness of films

formed on an amorphous substrate (although Yoon investigated 50 nm thick MgO films grown on *crystalline* Si(001)). EX1040, 2841, Fig. 3(a); Ross, ¶¶154-155.

Wulff and Yoon did not investigate the dependency of crystal structure on film thickness. Ross, ¶¶157. 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 useful for tunnel barrier layers (i.e., 2-10 nm thick). Ross, ¶¶158.

Contrary to Petitioner's suggestion that Wulff or Yoon's results were indicative of MgO microstructure in films under 10 nm thick, POSAs knew that MgO films formed on amorphous substrates "possessed a crystal orientation which varied with film thickness" and films thinner than 50 nm "showed a random orientation." EX2062, 621; Ross, ¶¶156, 159. EX2062 reported that when thickness increased above 50 nm MgO would form a (111) preferred orientation. *Id.* The conflicting results between EX2062, EX1036, and EX1040 meant that the POSA's expectations for even MgO thick-film orientation were uncertain.

POSAs knew that the initial crystal formation (e.g., nucleation stage) of film growth accounted for "the first few hundred angstroms of film thickness"—a range larger than ultrathin films (on the order of 20-100 angstroms) used in MTJs. EX2048, 195-197; Ross, ¶¶160-162. POSAs knew that nucleation on amorphous substrates resulted in *randomly oriented* or weakly textured islands of crystals that

could develop a preferred texture with increasing film thickness. EX2060 (Petrov), S118, S126; Ross, ¶163. A POSA would have expected this to result in “*randomly oriented* islands” of crystal grains for “low temperature deposition on amorphous substrates” as used in Bowen and Nagahama. EX2060, S117; EX1026, 1655 (room temperature Fe deposition); EX1027, [0062] (step 6 Fe 213 deposition by sputtering before step 7 annealing); Ross, ¶¶163-164. Petrov states “[n]ear the substrate, the microstructure consists of randomly oriented small grains” and that “[o]rientation selection during coarsening is incomplete, thus crystallites are nearly random or only weakly textured.” EX2060, S119-120; Ross, ¶163.

A POSA knew that lacking a lattice match providing epitaxy the MgO nucleation at the amorphous surface interface would have resulted in random grain orientation in the MgO. Ross, ¶¶156, 164. POSAs could not predict what crystal orientations would form on an amorphous CoFeB layer in the thicknesses typical for an MTJ barrier (i.e., less than 10 nm), or even within the first 30 nm of the film. Ross, ¶¶159-164; EX2018, 118:20-22 (“the dynamics of crystallization are... complicated”).

The process of MgO nucleation and grain growth depended crucially on multiple factors including the materials, surface morphology, deposition technique, deposition temperature, substrate temperature, deposition rate, and growth time. Ross, ¶164; EX2048, 203; *accord* EX1040, 2840 (“[T]he crystallinity of MgO

films depends sensitively on the deposition temperature[.]”). Different combinations of temperature and growth rate could produce amorphous, polycrystalline or single crystals. EX2061, 129, 150. Atoms impacting a nucleation site may stick to different extents across a temperature range, and the nucleation sites themselves can become mobile depending on, *inter alia*, substrate temperature. Ross, ¶164.

Yoon deposited the MgO films by a technique that a POSA would never use for forming MTJs, and Wulff and Yoon used at deposition rates that were inapplicable to MTJ fabrication, both of which made Wulff and Yoon’s thick-film results unrepresentative of an texture that might result by MgO ultrathin film deposition on amorphous CoFeB. EX1040, 2839 (deposition by aerosol-assisted chemical vapor deposition); EX2018, 79:19-80:4 (Petitioner’s expert could not say whether AACVD could be used to make an MTJ); Ross, ¶165. For example, Wulff uses a higher MgO deposition rate (1.6-2 nm/s, EX1036, 150) than would be used in making an MTJ (e.g. 0.02 nm/sec, EX1013, 6:23-26). Ross, ¶166. Yoon’s deposition rate of 5 nm/min (EX1040, 2840) was more than four times the rate that would be used in a method of making an MTJ as claimed. Ross, ¶166.

These differences would have precluded a POSA from forming any expectation of success based on Wulff or Yoon’s thick-film results. Ross, ¶167. In short, Wulff and Yoon would not have given a POSA any reasonable

expectation that the processes alleged in grounds 1 or 2 would achieve the claimed MgO microstructure.

- e. **Petitioner’s only evidence that annealing a CoFeB/MgO/CoFeB trilayer would achieve the MgO microstructure as claimed is Dr. Yuasa’s post-dated work describing the claimed invention.**

Remarkably, Petitioner’s *only cited evidence* that annealing a CoFeB/MgO/CoFeB trilayer (with amorphous CoFeB) would *actually achieve* the claimed MgO microstructure is a 2017 “textbook”—*citing Dr. Yuasa’s famous post-filing publication from 2005*—that describes Dr. Yuasa’s result as surprising. EX1057, 47 (“[Yuasa] developed a new MTJ structure, CoFeB/MgO/CoFeB, by using a sputtering deposition technique [citing EX2006][.]... *Surprisingly*, the MgO layer grown on the amorphous CoFeB is (001)-oriented polycrystal (textured structure).”). Dr. Yuasa’s EX2006 paper has been cited at least 1268 times since its publication in 2005. EX2052. *See also* EX1057, 46-48 (citing EX2006 and EX2013); Pet., 10 (citing EX1024, ¶¶60-61), 11 (citing EX1024, ¶¶60-61 and EX1057, 47), 31 (citing EX1024, ¶60); EX1024, ¶¶60 (citing EX1057, 47), 61 (citing EX1057, 48), 283 (citing EX1057, 46).³ Petitioner’s expert described

³ At Institution the Board also relied on EX1057, 47—describing the *inventor’s post-dated publications*, describing the claimed invention—as evidence “that a MgO layer could be grown on a CoFeB layer.” Paper 9, 14.

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, 138:23-140:11.

In other words, Petitioner’s expert’s *own “very good comprehensive” treatise on MTJs* shows—at the portions Petitioner cites and relies upon—that *even in 2017 the field regarded* Dr. Yuasa’s achieving “(001)-oriented polycrystal (textured structure)” by annealing CoFeB/MgO/CoFeB—as described in a famous 2005 paper published after the critical date—*as a surprising result*. Ross, ¶¶171-172.

Thus, the Petitioner’s *only actual evidence* of anyone achieving MgO with the claimed structure by annealing a CoFeB/MgO/CoFeB trilayer sandwich *is a citation to a comprehensive treatise describing Dr. Yuasa’s invention in his famous post-dated publications*. Ross, ¶173.

D. There Was No Predictable Result for the Alleged Combinations.

Petitioner falsely alleges that modifying Bowen and Nagahama combined “familiar elements” with “predictable results.” Pet., 25 (replacing Bowen’s Fe electrode with amorphous CoFeB for 1[a], citing *KSR*), 26 (1[a], forming CoFeB electrode was “predictable”), 28 (same), 32 (1[d], “annealing MTJs and CoFeB layers was... predictable”), 33 (same), 34 (1[e], “substituting polycrystalline MgO

for single-crystal MgO would yield... entirely predictable results”, citing *KSR*), 36 (claim 2, “Crystallized CoFeB layers... were known to produce... entirely predictable results”), 38 (claim 2, “CoFeB layers that are entirely crystallized after annealing were known and predictable,” citing *KSR*), 52-53-54 (1[a], replacing Nagahama’s crystalline lower ferromagnetic electrode with amorphous CoFeB), 58 (claim 2, “CoFeB layers that are entirely crystallized after annealing was... predictable,” citing *KSR*).

The “familiar elements/predictable results” rationale is unsupported and inapplicable.

First, the rationale concerns an entire combination of familiar elements. *KSR Int’l v. Teleflex*, 550 U.S. 398, 415-416 (2007) (combination “unites old elements”). Petitioner’s hindsight reconstructions never discuss—or even identify—the alleged combinations as a whole, and never explain how the combinations as a whole use only familiar elements with predictable results. Indeed, Petitioner argues that using amorphous (1[a]) and crystallized (1[d]) CoFeB electrodes was a “familiar element”—and that a POSA had the same reason to use amorphous and crystalline electrodes. As explained *supra* §II.C.3.a, and further discussed *infra* §§III.D-III.F, Petitioner never explains how a POSA would have used Bowen’s or Nagahama’s process to epitaxially grow MgO on the amorphous lower CoFeB electrode, or how a POSA would have even achieved

polycrystalline MgO in the modified processes. And as explained *infra* §IV, Petitioner never identifies any evidence of an “entirely crystallized” CoFeB layer that would be a “familiar element.”

Second, the familiar elements rationale requires ***no change*** to the respective functions of the elements. *KSR*, 550 U.S. at 415-416 (describing as obvious “a combination which only unites old elements ***with no change in their respective functions***”). But Petitioner’s combinations change the “function” of the alleged elements by using “amorphous” CoFeB, whose amorphous structure provide the benefits that Petitioner alleges would have motivated their use, then change the known element by “crystallizing” those CoFeB layers, which Petitioner’s own references say would defeat the reasons to use amorphous CoFeB in the first place. *Infra* §III.F.2.

Third, as just explained (*supra* §II), Petitioner’s own expert ***could not explain*** what would have happened if Petitioner’s modified Bowen or Nagahama processes were actually followed. This confirms that there was ***nothing predictable*** about the process in either ground. The familiar elements rationale does not apply. This is another reason why the grounds fail.

III. A POSA WOULD NEVER HAVE COMBINED THE REFERENCES IN THE MANNER ALLEGED IN THE GROUNDS.

A. A POSA Would Never Have Combined Bowen with Sunai or Parkin in the Manner Alleged.

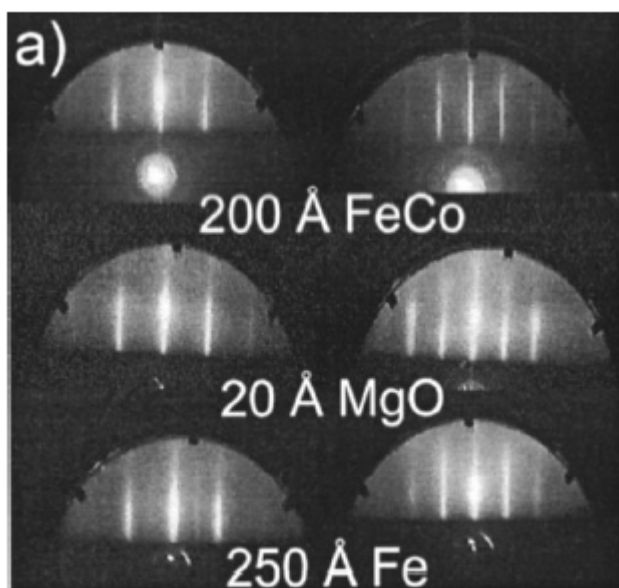
1. Bowen went to heroic efforts to achieve single-crystal epitaxial Fe(001)/MgO(001)/FeCo(001) MTJs.

Contrary to Petitioner's repeated mischaracterization of Bowen as seeking to "improve TMR" in an MTJ, Pet., 24, Bowen focused on experimentally testing Butler's "first-principles... calculations of the tunneling conductance and magnetoconductance of epitaxial Fe(100)/MgO(100)/Fe(100)" MTJ "sandwiches." EX1044 (Butler), 1 (Abstract); Ross, ¶174. Bowen explained that "numerical calculations of spin-dependent tunneling and TMR have been developed for *single crystal MTJs* such as... Fe/MgO(100)," citing Butler (EX1044) and Mathon (EX1046), and that Butler's model could be tested "on single-crystal epitaxially-grown structures." EX1026, 1655. That is precisely what Bowen did. Ross, ¶¶175-177, 186.

To test Butler's theory Bowen made an epitaxially-grown single-crystal MTJ under "optimized growth conditions" that resulted in "*entirely epitaxial* samples of *high crystalline quality* with flat, sharp interfaces." EX1026, 1657; Ross, ¶¶177-178. Bowen's MTJ comprised a crystalline iron (Fe) (001) bottom ferromagnetic electrode, single-crystal magnesium oxide (MgO) (001), and a crystalline iron-cobalt (FeCo) (001) top ferromagnetic electrode. EX1026, 1655-1656. Bowen's

layers and crystal orientation matched Butler's model, which Butler theorized would provide high TMR. EX1044, 1 (Abstract), 2 (describing DFT on "15 atom/supercell"); Ross, ¶¶177-178.

Bowen's Figure 1(a) shows a reflection high-energy electron diffraction (RHEED) pattern for "typical FeCo/MgO/Fe epitaxial structure" wherein the "Fe₅₀Co₅₀ and Fe layers are bcc structured with sharp diffraction lines[.]" EX1026, 1655-1656, Fig. 1(a) (detail below); Ross, ¶178; Pet., 22 (reproducing and citing Bowen Fig. 1(a)); EX2018, 167:10-15 (Petitioner's expert agreed that Bowen's process achieved "a near perfect" single-crystal MgO(001) barrier).



Bowen's process achieved an epitaxial MTJ wherein *the MTJ itself comprised a single crystal* and not just three separate crystalline layers stacked on top of each other. Bowen, 1655 ("[X]-ray diffraction symmetric and asymmetric

scans confirm that *the whole structure is epitaxial* with lattice parameters close to bulk values.”), 1657 (“optimized growth conditions result in *entirely epitaxial samples of high crystalline quality* with flat, sharp interfaces”); EX2018, 76:4-21 (Petitioner’s expert explaining epitaxy); Ross, ¶¶179-180.

To achieve this result, Bowen’s coauthors Boubeta et al. developed an *entirely new process* for epitaxially growing MgO(001) on a crystalline Fe(001) thin film. EX1084, 223-224, 228-229; EX2018, 144:3-148:14; Pet., 21 (citing EX1084, 228-229), EX1024, ¶¶115 (discussing EX1084); Ross, ¶181.

Each step in Bowen’s optimized process was crucial to the result. EX1026, 1655-1656, 1657 (“optimized growth conditions result in entirely epitaxial samples of high crystalline quality with flat, sharp interfaces”); Ross, ¶182. The single-crystal epitaxial device required achieving single-crystal MgO(001). EX1026, 1655-1656; Ross, ¶183. Achieving Bowen’s MgO(001) depended on providing the Fe(001) bottom layer. EX1026, 1655-1656; Ross, ¶¶55, 57-63, 106-109, 177-186. 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. EX2018, 74:6-9, 74:19-24; EX1026, 1655-1656; EX1084, 223-224; Ross, ¶184. Bowen’s process of depositing iron at room temperature then annealing it at 400°C—before growing MgO(001)—*was the reason* Bowen achieved “continuous and flat interfaces” between the bottom

Fe electrode and the MgO barrier. EX1026, 1655-1656; Ross, ¶185. Petitioner's expert agreed. EX2018, 160:8-161:16.

In short, Bowen went to heroic efforts to achieve single-crystal epitaxial MTJs precisely because this was the device that Butler's calculations modeled, whose predictions Bowen wanted to test. EX1026, 1655; EX1044, 2; EX2018, 74:6-9, 74:19-24, 144:3-148:14, 160:8-161:16; Ross, ¶186.

2. Bowen's teachings diverge from the path taken by Dr. Yuasa.

The carefully optimized process and heroic efforts that Bowen made to achieve MTJs with "*entirely epitaxial samples of high crystalline quality with flat, sharp interfaces*" (EX1026, 1657), to test Butler's theory of spin-dependent tunneling in *entirely crystalline* "epitaxial Fe(100)/MgO(100)/Fe(100) sandwiches" (EX1044, 1), diverge from the path Dr. Yuasa took in the claimed invention. *W.L. Gore & Assoc. v. Garlock*, 721 F.2d 1540, 1550-1551 (Fed. Cir. 1983) (totality of reference's teachings must be considered).

First, Bowen explained that "numerical calculations of spin-dependent tunneling and TMR" were developed for *single-crystal* Fe/MgO(001) MTJs, and that testing these models required "*single-crystal epitaxially grown structures*." EX1026, 1655 (citing Butler EX1044). This diverges from the path taken by Dr. Yuasa and teaches away from the invention, which *precludes* a single-crystal MgO barrier such as Butler modeled and requires a *polycrystalline* MgO barrier layer.

Ross, ¶¶48, 187-188. Replacing Bowen’s single-crystal epitaxial MgO(001) barrier layer with polycrystalline MgO would frustrate Bowen’s purpose of creating a single-crystal epitaxial Fe(001)/MgO(001)/FeCo(001) MTJ.

Second, Petitioner’s expert agrees 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. EX2018, 74:6-9, 74:19-24; EX1026, 1655-1656; EX1084, 223-224; Ross, ¶189. This diverges from the path taken by Dr. Yuasa and teaches away from the invention, which required forming “a first CoFeB layer that is *amorphous*” (1[a], 11[a]) and—contrary to Bowen’s detailed and carefully optimized process for epitaxial growth—forming a MgO layer over the *amorphous* first CoFeB layer (1[b], 11[b]). Replacing Bowen’s Fe(001) ferromagnetic electrode with amorphous CoFeB would frustrate Bowen’s purpose of creating a single-crystal epitaxial Fe(001)/MgO(001)/FeCo(001) MTJ.

While Bowen’s epitaxial growth was critical to achieving its MTJs, a POSA would not have expected that MgO could be epitaxially grown on the amorphous “first CoFeB” layer in the claims. Ross, ¶190. Petitioner’s expert admits that “there’s no epitaxy from amorphous substrates.[.]” EX2018, 72:12-13, 77:4-7 (“if you have an amorphous layer and you try to grow a crystalline on it, there is no epitaxy, there is no templating”), 76:4-21 (explaining epitaxy). No POSA reading Bowen would have replaced Bowen’s Fe(001) bottom electrode with amorphous

CoFeB, and no POSA seeking to make CoFe electrodes amorphous would have looked to Bowen’s teachings about making perfect single-crystal epitaxial devices. Ross, ¶¶191-192.

Third, Bowen demonstrates that “the spin polarization of tunneling electrodes... depends on the actual electronic structure of *the entire electrode/barrier system*”—including the crystal Fe(001) ferromagnetic layer and the near-perfect MgO(001) barrier. EX1026, 1655; EX1044, 1-2; Ross, ¶¶193-194. This diverges from the path taken by Dr. Yuasa and teaches away from the invention, which required forming amorphous CoFeB layers and polycrystalline MgO, with a *different* electrode/barrier system from Bowen.

Replacing Bowen’s Fe(001) ferromagnetic electrode with amorphous CoFeB (a different material and phase), and replacing Bowen’s MgO(001) with polycrystalline MgO (a different microstructure), would have changed Bowen’s process so far as to make it unrecognizable, changed the properties of the resulting MTJ, and frustrated Bowen’s purpose of creating a single-crystal epitaxial Fe(001)/MgO(001)/FeCo(001) MTJ to test Butler’s theory. Ross, ¶195.

Bowen’s coauthors included Albert Fert, who later received a Nobel Prize in physics for spintronics. EX1057, 7; EX2018, 187:20-190:24. Bowen’s collaborators had exceptional skill in the art. If the Petition’s alleged reasons to modify Bowen’s process were meritorious, Bowen would have tried it. EX2018,

216:20-217:9; Ross, ¶¶196-197. The fact that they did not speak volumes, confirms that Bowen led in a path divergent from the claimed invention, and refutes Petitioner's alleged reasons to combine.

3. Petitioner's own evidence disparaging Bowen's process confirms that a POSA would not have used Bowen to make MTJs with "improved TMR."

Petitioner ignores the teachings in its own references that explain Bowen was not suitable for "fabricating MTJs with improved TMR" for "improving MRAM"—the very reason that Petitioner alleges a POSA would have combined Bowen with Sunai (Pet., 25) or Parkin (Pet., 27). Petitioner's expert admits that MTJ design required POSAs to make tradeoffs, and that a POSA would have regarded MTJ *manufacturability* as an important consideration in identifying a process for making an MTJ. EX2017, 77:10-79:14.

Parkin explicitly states that "[e]xotic techniques, such as... epitaxy and deposition at elevated temperatures on single crystalline substrates, are *not useful* for the mass-manufacturing of cheap devices for MRAM and other applications[.]" EX1062, 15:35-41. Bowen anneals the bottom Fe ferromagnetic electrode and epitaxially grows MgO(001) at 400°C (EX1026, 1655-1656)—which Petitioner's expert admits is an "elevated temperature." EX2018, 79:15-18. Bowen grows MgO on a single-crystalline substrate provided by the annealed Fe(001) layer. EX1026, 1655-1656. Bowen's requirement for a single-crystal substrate to support

an epitaxial film on top is a significant manufacturing burden, particularly for a semiconductor industry that is built around processing silicon rather than exotic single crystalline substrates to support single-crystal MgO growth. Ross, ¶201.

In short, Bowen uses precisely the “exotic techniques” that Parkin describes as “*not useful*” for MTJ fabrication. Ross, ¶¶198-202. Parkin’s disparagement provides yet another reason that a POSA would not have combined Bowen with Sunai or Parkin in the manner alleged in ground 1. Ross, ¶¶202, 207.

Nagahama similarly disparages Bowen’s process. *Citing Bowen*, Nagahama states “[i]n this instance, a single-crystal substrate is necessary to form an element [e.g., MTJ]. *This however makes it difficult to form the element on a silicon LSI, and thus a challenge for realizing a magnetic random access memory has not yet overcome.*” EX1027, [0014]. A POSA reading Nagahama would have been discouraged from using Bowen’s process to fabricate an MTJ. Ross, ¶¶203-204.

Several other references likewise explain the problems with Bowen’s manufacturing process that would have discouraged a POSA from using Bowen as alleged. EX2038, 7 (“MgO barriers [that are] fully epitaxial grown on single-crystal substrates [are] incompatible with read-head manufacturing where junctions are grown by sputtering on plated magnetic shields.”); EX2005, 39 (“[I]t has proven difficult to grow bcc Co or bcc Fe with (001) texture directly by any

practical physical vapor deposition technique without a single crystal substrate (the use of which would vastly limit commercial applications).”); Ross, ¶¶205-206.

Indeed, the ’167 Patent’s invention was praised as having “significant technology importance for the magnetic recording head industry” *specifically because* its manufacturing method used “a conventional sputtering method instead of an MBE system” and achieved “a giant TMR ratio with simple amorphous CoFeB ferromagnetic electrodes, instead of strenuously high temperature deposition with single crystal structures” like Bowen. EX2023, 2; EX2024, 2-3 (Yuasa “developed a process that enabled device fabrication on arbitrary underlying layers. This structure and process enabled mass production on large-diameter wafers by room-temperature sputter deposition, which opened the door to industrial applications of MgO MTJ devices.”); *infra* §V.A. POSAs knew that Bowen did not teach a manufacturable solution, and thus diverged from the claimed invention. Ross, ¶207.

B. A POSA Would Never Have Combined Nagahama with Sunai Or Parkin in the Manner Alleged.

Nagahama invented detailed steps to form a “MgO double underlayer.” E.g., EX1027, [0055]-[0059], [0067] (describing MgO double underlayer 212), Fig. 12 (layer 204 comprising amorphous MgO 202 and crystalline MgO 203), Fig. 13 (layer 212). The double underlayer comprised an amorphous MgO (202, 212-1) covered by a “(001)-oriented highly oriented” crystal MgO layer (203, 212-2).

EX1027, [0058], [0067]. This double underlayer provided a way to form MTJs with crystalline ferromagnetic layers “on an amorphous substrate, such as SiO₂, and polycrystalline wires.” EX1027, [0059]; Ross, ¶¶208-210. Nagahama’s MgO double underlayer thus served a similar purpose as Bowen’s MgO buffer layer, and provided a template for forming (001) ferromagnetic lower electrodes for an MTJ.

Nagahama’s process forming a crystalline (001) ferromagnetic lower electrode on a double underlayer diverges from the path taken by Dr. Yuasa and teaches away from the invention, which forms an amorphous first CoFeB layer. Limitations 1[a], 11[a]; Ross, ¶211. A POSA would never have modified Nagahama to form an amorphous electrode because the purpose of the double underlayer that Nagahama went to heroic lengths to fabricate was to provide a (001) crystalline surface that would encourage lattice-matched crystalline (001) growth of a lower ferromagnetic electrode. Ross, ¶212.

C. Petitioner’s Combinations Fail Because They Would So Fundamentally Change the Basic Principles Under Which Bowen and Nagahama Were Designed to Operate as to Render Those References Unrecognizable.

A combination that so modifies a reference as to change its “basic principles” of operation fails to support obviousness. *In re Ratti*, 270 F.2d 810, 813 (C.C.P.A. 1959) (combination that “would require a substantial reconstruction and redesign” of a reference’s elements “as well as a change in the basic principles under which” the reference “was designed to operate” is “not a proper ground for

rejection”); *Samsung Elecs. v. Mojo Mobility*, IPR2023-01096, Paper 11, 26 (Feb. 6, 2024) (applying *Ratti*). By replacing the crystalline lower electrode with amorphous CoFeB in Bowen and Nagahama, Petitioner’s combinations would discard the very feature and process steps—forming a crystalline lower electrode to template the epitaxial growth of an MgO barrier layer—that Bowen and Nagahama went to heroic efforts to accomplish by inventing their entirely new processes of forming a MgO(001) buffer layer on GaAs(001) (in Bowen) and a MgO double underlayer (in Nagahama). Ross, ¶213. Petitioner’s combinations fail because they would so alter the processes in Bowen and Nagahama, contrary to their principle of operation, as to make them unrecognizable. *Ratti*, 270 F.2d at 813.

D. A POSA Would Never Have Combined Sunai in the Manner Alleged.

Petitioner alleges that a POSA would have modified Bowen’s Fe(001) ferromagnetic bottom layer with Sunai’s teachings to replace Bowen’s Fe(001) bottom ferromagnetic electrode with an amorphous CoFeB ferromagnetic bottom layer to “increase TMR, and lower H_f and H_c , of Bowen’s MTJ.” Pet., 24.

Petitioner alleges that a POSA would have replaced Nagahama’s lower Fe(001) layer 213 with amorphous CoFeB based on Sunai for the same reasons. Pet., 51.

This reasoning fails on multiple levels.

First, Petitioner argues that “CoFeB was known to increase TMR compared to CoFe,” citing Sunai ¶¶27-28. Pet., 24-25. But Bowen and Nagahama used

Fe(001) for the bottom electrode, not CoFe; as Petitioner's expert recognized, nothing in Sunai makes a relevant comparison of TMR achieved with amorphous CoFeB to TMR achieved with Fe(001). EX2018, 184:10-15 ("Q: Where does Sunai describe [CoFeB] as superior to [Fe]? A:... Okay. I'm having trouble finding that."); EX1027, [0060]-[0062], Fig. 13 (layer 213 on MgO "double underlayer" 212), [0064], [0066] ("By using the MgO double underlayer of the present invention, the plane orientation of the ferromagnetic electrode layer can be aligned at angles of $\pm 1^\circ$ from (001) planes."); Ross, ¶¶214-215.

Second, a POSA would not have looked to Sunai to improve Bowen's TMR because Sunai's TMR of less than 25% with an amorphous CoFeB bottom electrode was *inferior* to the TMR that Bowen achieved. EX2018, 182:23-183, 11; EX1030, [0026], Fig. 3; Ross, ¶216. Nagahama achieved TMR exceeding 90% and a POSA had even less reason to look to Sunai, with its inferior TMR, to improve Nagahama. Ross, ¶216; EX1027, [0074].

At Institution the Board credited Petitioner's reliance on EX1055 and EX1056 as supporting the alleged reason to replace Bowen or Nagahama's Fe(001) with amorphous CoFeB. Paper 9, 12-13. Petitioner's reliance is unsupported because those references each used an amorphous Al_2O_3 barrier, not Bowen's single-crystal MgO(001), Nagahama's "(001)-highly-oriented MgO," or the invention's polycrystalline MgO. EX1055, 2269 ("Al₂O₃ tunnel barrier."), 2270;

EX1056, [0112] (barrier is Al₂O₃); Ross, ¶217. Petitioner’s expert emphatically *rejected* the suggestion that a POSA would have considered TMR data from MTJs with an Al₂O₃ barrier—like EX1055 and EX1056—as indicative of what would have happened to TMR in an MTJ with an MgO barrier. EX2017, 200:16-19 (“Bowen uses MgO. *The whole point about using MgO for a tunnel barrier is because it has special properties, unique properties about how the – what happens to the TMR.*”), 203:12-19 (“What makes Bowen special... is the single crystal electrodes and the single crystal MgO barrier.... [I]t made a significant jump in the field by going to the MgO—single crystal MgO barrier.”), 201:3-17 (“I reject the hypothetical that... a POSA would look at [EX2058] and have... *I don’t see how a POSA has a reasonable expectation to accept any of this for the Bowen MTJ... [b]ecause it’s for—it’s for an aluminum oxide barrier.*”), 199:23-203:24; Ross, ¶218.

Third, Petitioner disregards that Sunai specifically teaches the importance that the bottom CoFeB layer be *amorphous*. Sunai describes the amorphous CoFeB alloy as having a “smaller saturated magnetization M_s ” than alloys that form crystalline films. EX1030, [0025]. Using the amorphous CoFeB alloy facilitates maintaining “the reversal magnetic field of the ferromagnetic layer 4... at a sufficiently small value[.]” EX1030, [0025]; *see also* EX2018, 204:21-206:7 (citing Sunai and explaining benefit of lower power consumption using a smaller

reversal magnetic field); Ross, ¶219. Petitioner’s corroborating references EX1055 and EX1056 likewise each used MTJ with an *amorphous* CoFeB electrode, not the “crystallized” CoFeB of the invention (e.g., 1[d], 11[d]). EX1055, 2269 (“[T]he CoFeB has an amorphous structure[.]”), 2270; EX1056, [0036] (“information recording layer”—i.e., the “free” or storage layer—is amorphous CoFeB alloy), [0038] (same); Ross, ¶220.

Moreover, to the extent Petitioner contends that Cardoso (EX1061) motivated using CoFeB electrodes because it teaches that the fcc(111)-texture of its CoFeB may have been the reason for lowering H_f (coupling between electrodes) and H_c (coercivity affecting magnetic switching speeds) (e.g., Pet., 24-25, 32, 52, citing EX1061, Abstract), no POSA would have been motivated to use CoFeB based on Cardoso because (1) a fcc(111) textured CoFeB is not “amorphous” and thus not relevant to meeting 1[a] or 1[c], and (2) an fcc(111) lower electrode would have precluded achieving MgO with a preferential (001) crystal plane orientation (as Petitioner alleges the combinations would achieve to meet 1[e], 11[b]). EX1057, 48; Ross, ¶¶126-127, 134.

Moreover, Sunai explained that crystallizing the electrode resulted in unstable magnetization and *reduced* TMR. 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 the TMR to “drop significantly.” EX1030, [0027]; *id.*, [0030] (crystalline ferromagnetic thin films formed “island structures” that “exhibit superparamagnetism, in which magnetization direction fluctuates, resulting in a significantly low magnetoresistance change rate.”); Ross, ¶¶221-222.

In short, Sunai’s emphasis on the importance of keeping the lower CoFeB layer amorphous diverges from the path taken by Dr. Yuasa and teaches away from the invention, which requires that the CoFeB layers be “crystallized” (1[d], 11[d]) or “entirely crystallized” (claims 2, 4 (4[a]), 6 (6[a]), 12, 13 (13[a])). Even apart from Bowen’s teaching away, Sunai’s divergent teachings alone would have prevented a POSA from relying on Sunai to achieve the claimed invention. Ross, ¶223.

E. A POSA Would Never Have Combined Parkin in the Manner Alleged.

Parkin’s disparagement of Bowen’s techniques, as explained above, would have discouraged a POSA from combining Parkin with Bowen or Nagahama. Ross, ¶¶198-202, 224.

Furthermore, Petitioner alleges that a POSA would have replaced Bowen’s lower Fe(001) layer with Parkin’s amorphous CoFeB to “lower H_f and H_c ” (Pet., 27) and replaced Nagahama’s lower Fe(001) layer 213 with Parkin’s amorphous

CoFeB for the same reasons—to provide “desirable improvement to TMR, H_c , and H_f ” (Pet., 53-54). Ross, ¶¶225-226.

Parkin teaches that “reducing the variation in [MTJ] magnetic switching fields” would have been a benefit of using *amorphous* CoFeB (“*amorphous magnetic materials*”) for MTJ storage layer 175 (EX1062, 5:48-51) because “the use of *amorphous* [ferromagnetic] layers... would 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” between MTJ devices that is “mitigated” by using ferromagnetic storage layers “*formed from materials that have no preferred crystallographic orientation*” such as “*amorphous magnetic materials*” (e.g., amorphous CoFeB). EX1062, 15:62-16:4; Ross, ¶¶226-228. Thus, adding “glass forming elements” like boron to CoFe “*causes the crystalline structure to be eliminated*” such that “*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, 16:30-40, *see also id.*, 18:49-62; Ross, ¶229. In short, Parkin explains that the CoFeB layer’s *amorphous* nature is *critical* to improving the MTJ magnetic switching properties, which the Petition calls “lowering H_f and H_c .” Ross, ¶230.

Parkin's teaching on the importance of the CoFeB layer being amorphous *diverges* from the path taken by Dr. Yuasa and *teaches away* from the invention, which requires that the CoFeB layers be "crystallized" (1[d], 11[d]) or "entirely crystallized" (claims 2, 4 (4[a]), 6 (6[a]), 12, 13 (13[a])), depriving the combination of the very benefit that Parkin attributes to the amorphous state of the CoFeB and that Petitioner alleges was a reason to replace Bowen's Fe(001) or Nagahama's Fe(001) lower electrode with amorphous CoFeB in 1[a] and 11[a]. Parkin's divergent teachings alone would have prevented a POSA from relying on Parkin in the manner alleged. Ross, ¶¶231-232.

F. Petitioner Provides No Credible Reason That a POSA Would Have Replaced Bowen/Nagahama's Crystalline Electrodes with Amorphous CoFeB Only to Then Crystallize Them Based on Bowen/Nagahama's Teachings.

Petitioner alleges that after modifying Bowen/Nagahama to use an *amorphous* CoFeB bottom (Pet., 22-28 (1[a], Bowen), 50-54 (1[a], Nagahama)) and top layer (Pet., 29-30 (1[c], Bowen), 55-56 (1[c], Nagahama)), a POSA—motivated by Bowen or Nagahama's use of crystalline electrodes that the POSA just modified—would have *crystallized* each amorphous layer (Pet., 30-33 (1[d], Bowen), 56-57 (1[d], Nagahama)). But Petitioner never identifies a coherent reason *why* a POSA would have modified Bowen/Nagahama to use *amorphous* electrodes then crystallized the electrodes based on same Bowen/Nagahama teachings that the POSA just altered.

1. Petitioner’s inconsistent reasons to combine are incoherent.

Petitioner argues a POSA would have replaced Bowen’s Fe(001) bottom electrode with *amorphous* CoFeB in order to “increase TMR and lower H_f and H_c .” Pet., 23-24, 26-27. Petitioner relies on the same 1[a] arguments to meet 1[c] and 11[c]. Pet., 29-30, 46-47; Ross, ¶¶235-236. To meet 1[d] (and 11[d], Pet., 47) Petitioner alleges a POSA—based on Bowen/Nagahama’s crystalline electrodes, which Petitioner just argued a POSA would have altered/ignored for 1[a] and 1[c]—would have annealed the amorphous CoFeB layers to crystallize them. Pet., 31, (“[A POSA] reading Bowen and Sunai would have been motivated to anneal the CoFeB layers... *to increase TMR and crystallize the CoFeB layers.*”), 33 (“[A POSA] would have been motivated to anneal the CoFeB layers and crystallize the CoFeB layers by annealing because Parkin taught it improved TMR.”); Ross, ¶237. The Petition thus argues that a POSA would have picked CoFeB electrodes that were *simultaneously amorphous* (to meet 1[a] and 1[c]) and *crystalline* (to meet 1[d]). Ross, ¶238

At Institution the Board relied on differentiation from the “*entirely* crystallized” limitation in claim 2 to conclude that “we view claim 1 as not requiring that *the entirety* of the first and second CoFeB layers be crystallized.” Paper 9, 20. The Board thus agreed that “entirely crystallized” means that “the entirety of the first and second CoFeB layers be crystallized.” *Id.* Petitioner relies

on the *same combinations* (Bowen/Nagahama in view of Sunai or Parkin) to meet claim 2—requiring CoFeB layers to be “entirely crystallized”—as it does to meet 1[d] (and 11[d]). Pet., 35-38.

An “entirely crystallized” CoFeB layer has *no* amorphous portion, and *forming such a layer would have deprived the combination of the very benefit*—“lower H_c and H_f ” that improved magnetic switching—*that Petitioner argues would have motivated* replacing Bowen’s Fe(001) with *amorphous* CoFeB for 1[a] (and 11[a]). *Supra* §III.E (Parkin explaining benefit of amorphous material); Ross, ¶241.

For this reason alone the combinations fail. “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, Inc. v. Medtronic Sofamor Danek, Inc.*, 567 F.3d 1314, 1326 (Fed. Cir. 2009). Petitioner’s Nagahama ground has the same defects and fails for the same reasons. Ross, ¶242.

2. The Petition never identifies a reason to “crystallize” the CoFeB layers.

The Petition contends that a POSA “would have been motivated to ... crystallize the CoFeB layers” (Pet., 31, citing EX1060, 311; EX1061, 2273-2273; and EX1062, 7:53-5) but never gives a reason *why* a POSA would have done this other than “it was known.” But whether it “was known” that annealing amorphous

CoFeB would “crystallize” it *does not provide a POSA with a reason to have done it*, particularly where Petitioner specifically argues that a POSA would had reasons *to do the exact opposite* and *replace Bowen’s crystalline Fe(001) electrode with amorphous CoFeB* to, among other things, *reduce the magnetic coupling and switching fields* (e.g., lower H_f , H_c) for a ferromagnetic storage layer *by destroying any crystalline order* in the electrode. Ross, ¶¶243-244; *supra* §III.E (Parkin explaining benefit of amorphous material). The same defects apply to the Nagahama arguments in ground 2. Ross, ¶245.

a. EX1060 does not support Petitioner’s alleged reasons to combine.

Petitioner cites EX1060 as showing “[i]t was known that TMR was ‘enhanced by... annealing’ [] which was likely attributed to ‘structural change of the interface’ between the CoFeB and adjoining layers. Pet., 31, citing EX1060, 311. This argument fails for many reasons.

First, Petitioner’s argument relies on a false premise. *There was no TMR* in the EX1060 devices. EX1060 studied *spin valves*, not MTJs. EX1060’s spin valves disposed a copper (Cu) film between CoFeB electrodes. EX1060, 308, 310. Copper is a conductor, i.e., the “barrier height” is zero and electrons move by ordinary conduction. Ross, ¶¶246-247. There is *no tunneling* through copper, let alone spin-dependent tunneling that Butler describes as the basis for TMR in MTJs (like Bowen’s) using crystalline MgO(001). Ross, ¶247; EX1024, ¶¶49 (tunnel

current density (J or J_c) is directly proportional to barrier height $(\varphi_0)^{\frac{1}{2}}$, so that tunneling current density is zero for $\varphi_0=0$), 45-49 (describing tunneling); EX1031, 1797. In other words, the spin valves in EX1060 *had no tunneling magnetoresistance* but operated using a completely different physical mechanism. Ross, ¶248. Petitioner's suggestion that EX1060 shows "TMR was enhanced by annealing" is baseless.

Second, even if EX1060's devices provided TMR (they did not), the Petition does not identify any reason that EX1060's suggestion of "structural change of the interface" between CoFeB (with unspecified Co and Fe content) and Cu would have had any bearing on the "structural changes" of an interface between an amorphous CoFeB alloy and an adjoining MgO deposition with unspecified microstructure. Ross, ¶249. The CoFeB/Cu interfaces in the EX1060 devices, in short, were fundamentally different from interfaces in MTJs allegedly made using the Bowen combination, and EX1060 would not have motivated a POSA to do anything to modify Bowen's MTJ fabrication process. Ross, ¶249.

Third, contrary to Petitioner's suggestion (Pet., 30-31), EX1060 does *not* teach that CoFeB crystallizes when annealed. EX1060 provided X-ray diffraction patterns for devices with a gold (Au) layer. EX1060, 309. Gold has a (200) diffraction peak at 44 degrees, precisely where EX1060 labels a "CoFe fcc(111)" peak in Fig. 1. EX2059; Ross, ¶¶250-251. Thus Fig. 1 in EX1060 would have

contained a peak at 44 degrees *regardless* of whether the SiN/CoFeB/Au trilayer contained CoFe fcc(111). Ross, ¶251. A POSA could not have concluded that annealing yielded CoFe fcc(111), because Jimbo’s Fig. 1 simply showed the expected diffraction from Au(200). Ross, ¶¶251-253.

Finally, if Petitioner’s reason to “crystallize” CoFeB was to “enhance” TMR, then as explained below this is inconsistent with relying on “increasing TMR” as a reason to replace Bowen’s crystalline Fe(001) and FeCo(001) with amorphous CoFeB as alleged for 1[a]. Ross, ¶254.

b. EX1061 does not support Petitioner’s alleged reasons to combine.

EX1061 does not show “crystallized CoFeB” as the Petition alleges. Petition, 37. The Petition’s quoted language (*id.*, citing EX1061, 2273) shows *only* that post-annealing films were “not amorphous.” Ross, ¶255. EX1061 provides no explanation of what happened to the CoFeB film, or any explanation of the material content of any grain or microstructure that might have nucleated in the CoFeB layer whose description the Petition quotes. Ross, ¶256.

EX1061 also does not support any assertion that annealing CoFeB would increase TMR in Bowen’s modified MTJ because EX1061’s MTJs used an amorphous Al₂O₃ barrier. Petitioner’s own expert testified that MgO’s “special properties” governed Bowen’s TMR. “[I]t was understood that *MgO was a special – had special properties with regard to MR that depended on the detailed*

band structure of the MgO.” EX2017, 62:20-23; *see also id.*, 124:7-8, 200:16-19, 203:12-14; *supra* §III.D. By Dr. Bokor’s testimony, a POSA would not have considered EX1061’s results as a reason to modify Bowen’s fabrication process. Ross, ¶257.

Moreover, to the extent Petitioner contends that Cardoso (EX1061) motivated “crystallizing” CoFeB electrodes because it teaches that the fcc(111)-texture of its CoFeB may have been the reason for lowering H_f (coupling between electrodes) and H_c (coercivity affecting magnetic switching speeds) (e.g., Pet., 24-25, 32, 52, citing EX1061, Abstract), no POSA would have been motivated to “crystallize” CoFeB based on Cardoso because a fcc(111) textured CoFeB would have precluded achieving MgO with a preferential (001) crystal plane orientation (as Petitioner alleges the combinations would achieve to meet 1[e], 11[b]). *Supra* §II.C.2.a; EX1057, 47; Ross, ¶¶126-127, 134.

c. Bowen does not support Petitioner’s alleged reasons to combine.

Petitioner’s contention that Bowen motivated “crystallizing” the amorphous CoFeB electrodes ignores that Petitioner just finished arguing that a POSA would have modified Bowen to use amorphous (not crystalline) electrodes. Petitioner states that “Bowen touted crystalline layers” and describes Bowen’s process step of annealing the bottom Fe electrode in order to provide a template for epitaxially growing MgO(001) (Pet., 31-32), but the Petition ignores that Bowen never used

any amorphous material, let alone amorphous CoFeB, in its MTJ. Nor does the Petition explain how **Bowen** could motivate crystallizing the amorphous CoFeB while at the same time arguing that a POSA was motivated to **replace** Bowen's crystalline Fe with **amorphous** CoFeB. Ross, ¶¶258-259. Petitioner's incoherent motivation arguments fail.

**d. EX1045 does not support and contradicts
Petitioner's alleged reasons to combine.**

The Petition's reliance on EX1045 for the proposition that "'nearly perfect crystalline MgO(001) films on high-quality single crystals of Fe' were effective in **improving TMR**" and touting the benefits of an MTJ wherein an "entire Fe layer has crystalline structure" (Pet., 32, quoting EX1045, 1, 6) is likewise misplaced. EX1045 provides **no reason** for a POSA to anneal and "crystallize" **amorphous** CoFeB because (1) EX1045 (and the quoted language) describes **precisely** the structure in Bowen **that the Petition contends a POSA would have modified with amorphous CoFeB**, (2) EX1045 started with crystalline Fe electrodes; and (3) EX1045 has nothing to say about the effect of annealing an MTJ with amorphous CoFeB electrodes. EX1045, 1 ("**Single-crystal** epitaxial MgO thin films **were grown directly onto high-quality Fe single crystal**[.]"); Ross, ¶¶260-262. To the extent that EX1045 gave a POSA a reason to do anything, it would have been to leave Bowen's fabrication process **unchanged**. Ross, ¶262.

e. Parkin does not support Petitioner’s alleged reasons to combine.

Petitioner’s reliance on EX1062, 7:53-59 for annealing increasing TMR (Pet., 30-31) is likewise misplaced because unlike the three MTJ layers that the Petitioner purports to “anneal,” the cited passage in EX1062 describes an MTJ in which one ferromagnetic electrode was already crystalline—not amorphous—and “has a [bcc] structure... preferably oriented in the (100) direction” and “in proximity with the tunnel barrier[.]” EX1062, 7:15-22, 7:51-53; Ross, ¶263.

The Petition’s contention that “Parkin taught” that “anneal[ing] the MTJ layers and crystal[lizing] the CoFeB electrodes” would have “improved TMR” likewise misrepresents the cited teachings in Parkin’s Fig. 3A embodiment that the Petition relies upon. Pet., 32-33; Ross, ¶264. In Parkin’s Fig. 3A embodiment, a single amorphous CoFeB storage layer was deposited on a “highly textured (100) MgO tunnel barrier[.]” 120’ that itself was formed on a *crystalline* “ferromagnetic layer 115” that was “preferably formed *from a bcc alloy* formed from one or more of Co and Fe” and was “textured in the (100) orientation.” EX1062, 13:10-25; Ross, ¶265. The Petition relies upon an embodiment that had a bcc (001) crystalline ferromagnetic electrode, which templated a “highly textured” MgO (001) barrier layer, which was already textured when it was covered with an amorphous CoFeB storage layer 175. Ross, ¶265. The cited Parkin embodiment did not teach annealing an amorphous lower reference electrode 115 (as required

for 1[d] and 11[d]); that layer was already bcc CoFe(001) when the MgO was deposited on it. Ross, ¶266. Parkin would not have motivated a POSA to anneal the top and bottom amorphous CoFeB electrodes in either ground. Ross, ¶266.

IV. THE PETITION FAILS TO ESTABLISH THAT CLAIMS 2, 4, 6, 12, AND 13 ARE OBVIOUS.

No evidence supports that the manufacturing methods in either ground results in “first and second CoFeB layers [that] are *entirely* crystallized” after annealing as recited in claim 2, 4[a], 6[a], claim 12, and 13[a]. Petitioner’s showing for claims 2, 4, 6, and 12-13 is so facially deficient that it warrants little of the Board’s attention.

At Institution the Board relied on differentiation from the “entirely crystallized” limitation in claim 2 to conclude that “we view claim 1 as not requiring that the entirety of the first and second CoFeB layers be crystallized.” Paper 9, 20. The Board thus agreed that “entirely crystallized” means that “the entirety of the first and second CoFeB layers be crystallized.” *Petitioner’s expert offered no opinion that either ground would yield a ferromagnetic layer that comprise a CoFeB alloy and is “entirely crystallized.”* EX2018, 140:2-141:16 (admitting he was not asked to provide an opinion on “entirely crystallized” CoFeB layers). That should end the matter for claims 2, 4, 6, and 12-13.

It is undisputed that the technology in this case is extremely complex. Pet., 20 (Petitioner’s POSA definition requires a high level of skill). Petitioner cannot

carry its burden to show that claims 2, 4, 6, and 12-13 are rendered obvious where no expert testimony (indeed, no evidence of any kind) supports Petitioner's showing for a critical limitation in these claims. At best Petitioner's cited prior art for "entirely crystallized" indicates there might be some portion of a CoFeB layer that might be crystallized, but Petitioner has not cited any prior art disclosing an "entirely crystallized" CoFeB layer (Ross, ¶¶269-279) or shown that either combination would achieve an "entirely crystallized" CoFeB layer (Ross, ¶¶280-282)

Petitioner's showing for claims 2, 4, 6, and 12-13 also inherit all the failings discussed above that apply to all the Challenged Claims. Ross, ¶¶283-284.

V. SECONDARY CONSIDERATIONS DEMONSTRATE NON-OBVIOUSNESS OF EACH CHALLENGED CLAIM.

The law makes secondary considerations highly relevant to nonobviousness to guard against *precisely* the hindsight reconstruction animating Petitioner's grounds, i.e., using the claim language as a guide to cherry-pick prior art disclosures as a substitute for evaluating a POSA's actual knowledge or motivations at the time of invention. *Graham v. John Deere*, 383 U.S. 1, 17-18 (1966). Even if Petitioner had articulated a competent obviousness theory—which it did not—secondary considerations including industry praise, the recognition of contemporaries, unexpected results, failure of others, and solving a long-felt but

unmet need, would still compel a conclusion that the claims are non-obvious.

Ross, ¶285

Objective indicia have nexus when they are “reasonably commensurate with the scope of the claims” for some aspect of the claim not already in the prior art.

Institut Pasteur & Universite Pierre et Marie Curie v. Focarino, 738 F.3d 1337,

1347 (Fed. Cir. 2013) (citation omitted); *In re Kao*, 639 F.3d 1057, 1068–1069

(Fed. Cir. 2011). The objective indicia discussed below are reasonably

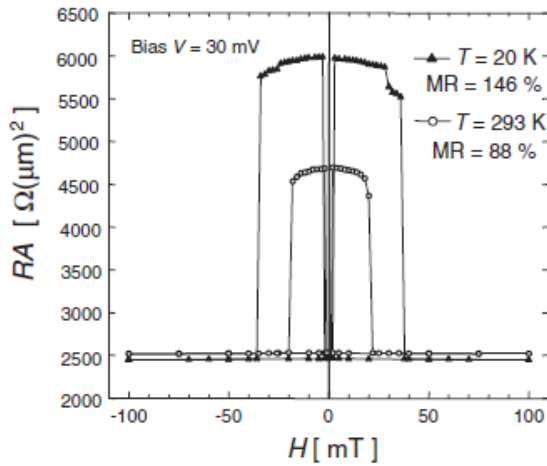
commensurate with the claims for aspects that were not in the prior art, and plainly

show the invention in each Challenged Claim was non-obvious. Ross, ¶287.

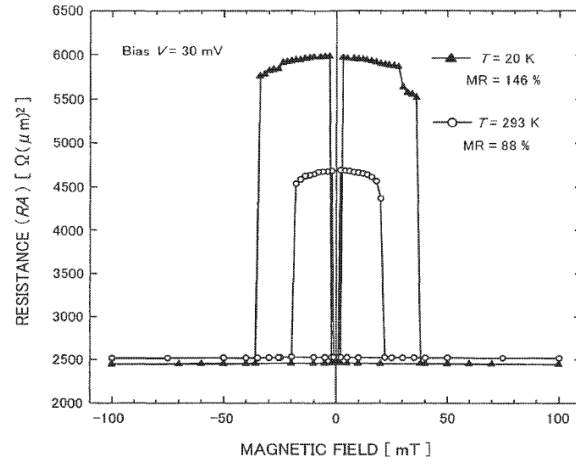
A. The Claimed Technology Received Widespread Praise from Industry And Academia.

Shortly after filing the two Japanese patent applications to which the '167 Patent claims priority, Dr. Yuasa publicly disclosed the '167 Patent's embodiments that use Fe electrodes through articles in the Japanese Journal of Applied Physics ("JJAP," EX2007) and Nature Materials ("Nature," EX2008), which each include versions of the '167 Patent's figures.

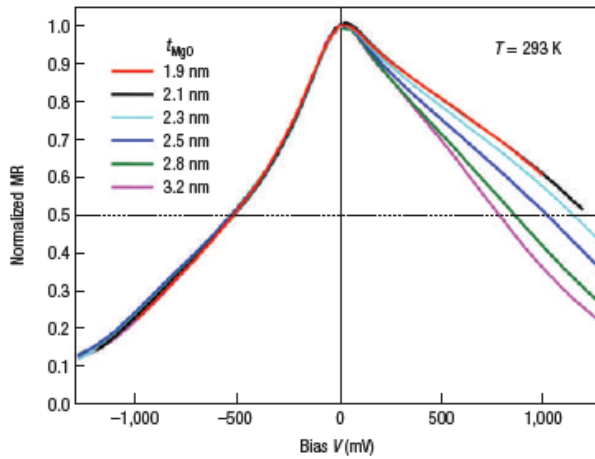
JJAP Fig. 3



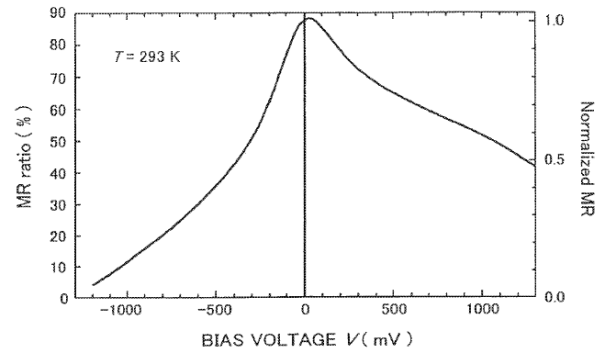
'167 Patent Fig. 6



Nature Fig. 3a



'167 Patent Fig. 7(A)



Ross, ¶288, citing EX2007, 589; EX2008, 870; EX1013, Figs. 6 and 7(A).

Albert Fert—a Nobel laureate in physics for his work in spintronics, and notably a co-author on Petitioner’s primary reference Bowen—when providing a historical overview of spintronics in a 2012 textbook, specifically described Dr. Yuasa’s work in his famous 2004 Nature Materials paper (EX2008) as an “important breakthrough” in “the most important step [of] the transition from MTJ

with amorphous tunnel barrier (alumina) to single-crystal MTJ and especially MTJ with MgO barrier.” EX2020, 8; EX1026, 1655; EX1057, 7; EX2018, 187:20-190:24; Ross, ¶289. EX2008 has been cited at least 4,216 times. EX2057.

Dr. Yuasa also disclosed the results achieved by the '167 Patent's claimed methods in Applied Physics Letters (EX2006, “Yuasa-APL2005”). Ross, ¶290. For example, Yuasa-APL2005 discloses a method of manufacturing an MTJ (1[pre]) by disclosing “[t]hin films for MTJs were deposited onto thermally oxidized Si wafer (100) using magnetron sputtering system.” EX2006, 1; Ross, ¶290. Yuasa-APL2005 disclosed that “CoFeB was deposited” for both the “reference and free layers (each 3 nm),” and that the CoFeB was “amorphous,” thus meeting 1[a] and 1[c]. EX2006, 1; Ross, ¶291. Yuasa-APL2005 disclosed “grow[ing]” an “MgO layer” “sandwiched” in-between the “amorphous CoFeB ferromagnetic electrodes,” thus meeting 1[b]. EX2006, 1; Ross, ¶292. Yuasa-APL2005 disclosed “annealing” that “caused” at least “partial crystallization” of the “CoFeB layers,” thus meeting 1[d]. EX2006, 2; Ross, ¶293. Yuasa-APL2005 disclosed that “the MgO layer [had] (001) fiber texture” that was “polycrystalline,” thus meeting 1[e] and 11[b]. Ross, ¶294. Yuasa-APL2005 also disclosed “a possibility of local crystallization of a few monolayers of CoFeB at the electrode/barrier interfaces.” EX2006, 2; Ross, ¶295. A POSA would have recognized that the crystalized “monolayers” of CoFeB met the claimed first and

second CoFeB layers that “are entirely crystallized” “after the annealing,” thus meeting, e.g., independent claims 1 and 11 and the “entirely crystallized” limitations in claims 2, 4, 6, and 12-13. Ross, ¶296. In sum, Yuasa-APL2005 disclosed the claimed methods of the ’167 Patent. Ross, ¶296.

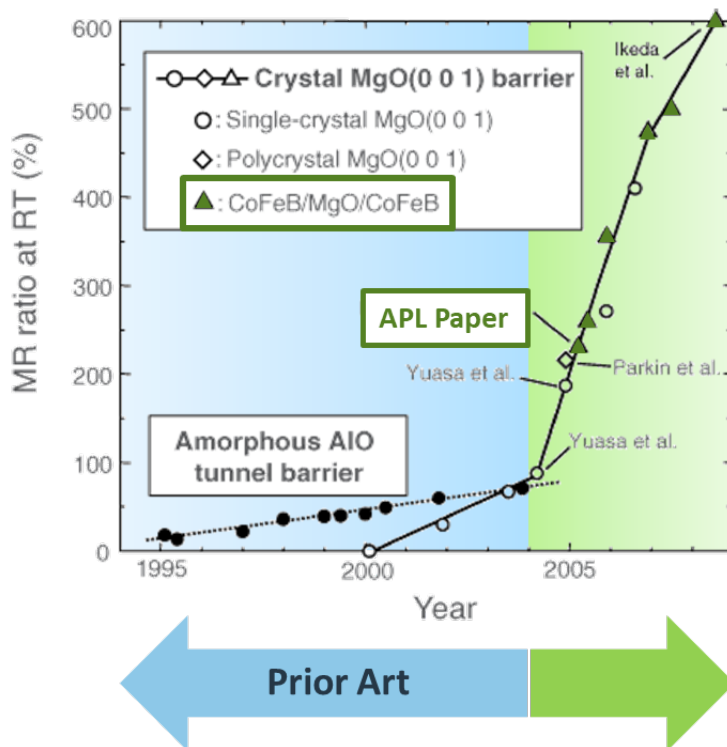
Dr. Yuasa’s public disclosure of the claimed methods drew immediate and sustained attention and praise from across the industry and research community, including from Petitioner’s own employees. Indeed, according to Google Scholar, Dr. Yuasa’s Yuasa-APL2005 paper has been cited more than 1,200 times. EX2052.

As one example, a 2005 review cited Dr. Yuasa’s Yuasa-APL2005 paper as one of the “most recent developments at the time of writing.” EX2019, 592 (citing [43]), 694 ([43] is EX2006); Ross, ¶298. EX2019 praised the claimed methods that achieved a “230% room temperature magnetoresistance,” characterizing the results as “*unprecedentedly large TMR ratios*”. EX2019, 591-592. Because Yuasa-APL2005 disclosed the claimed methods that directly resulted in the “unprecedentedly large” 230% TMR, the praise is directly connected to the claimed invention (Ross, ¶299), providing the necessary nexus.

Petitioner cites a 2017 book chapter, Petition, 6-7, 11-12, 14, citing EX1057, that discusses Yuasa-APL2005 disclosing the claimed invention and how its methods solved a long-felt but unmet need for forming MgO(001) on (111) underlayers. EX1057, 46-47 (citing [33]), 52 ([33] is EX2006); Ross, ¶¶300-303.

Figure 2.21 shows graphically how the claimed methods disclosed in Yuasa-APL2005 unleashed a new era of skyrocketing TMRs. EX1057, 46; Ross, ¶304.

Figure 2.21 (Annotated)



EX1057 explains that a “fundamental problem” with the prior art was “a problem concerning crystal growth.” EX1057, 46-47. It credits the claimed method disclosed by Yuasa-APL2005 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. EX1057 explains that “[s]urprisingly” the MgO barrier became “a (001)-oriented polycrystal” despite being grown on an “amorphous CoFeB” underlayer. *Id.*; Ross, ¶¶300-303. As Figure 2.21’s triangle icons show, others then applied the claimed

methods, “known as solid-phase epitaxy,” to achieve increasingly higher TMRs of “up to 600%.” *Id.*, 48; Ross, ¶304.

Significant industry praise came from Petitioner itself. For example, Chando Park co-authored a 2006 review on MTJs. EX2005, 36. The review article lists Mr. Park as working for “Western Digital Corporation.” *Id.* It asserts, “[t]he development of CoFeB/MgO/CoFeB tunnel junctions” disclosed by the Yuasa-APL2005 paper “provides a practical solution to overcome this difficulty [of crystal growth]” that Dr. Yuasa’s amorphous CoFeB layers solved. EX2005, 39 (citing [21]), 45 ([21] is EX2006 Yuasa-APL2005); Ross, ¶305.

Another Western Digital employee, Zheng Gao, “Recording Head Development Group, Western Digital Corporation” co-authored a 2018 paper that credited the “even higher TMR ratio of 230%” disclosed by Yuasa-APL2005 and recognized the “significance” of Yuasa’s MTJ manufacturing method’s using “a fully integrated film directly produced from sensor deposition sputtering” 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. EX2022, 107 (citing [10]), 110 ([10] is EX2006); Ross, ¶306.

Employees of TDK, a competitor to Petitioner, authored a 2023 paper that recognized the importance of the ’167 Patent’s claimed methods in the development of MTJs. EX2023, 1. The TDK paper states the claimed method was

significant because it “used a conventional sputtering system instead of an MBE system... [to] achieve a giant TMR ratio with simple amorphous CoFeB ferromagnetic electrodes, instead of strenuously high temperature deposition with single crystal structures.” EX2023, 2 (citing reference [20], i.e., EX2006). The magnetic recording and MRAM industries widely use “conventional sputtering systems,” so Dr. Yuasa’s invention provided significant advantages over methods requiring rarely-used MBE, and achieving a 230% TMR at room temperature this way in 2004 was extraordinary. Ross, ¶308.

Dr. Yuasa has received many prizes recognizing his groundbreaking work in the ’167 Patent’s invention. In 2022, Dr. Yuasa received the “Japan Society of Applied Physics Achievement Award,” for his “invent[ion] of MTJs combining MgO and cobalt iron boron (CoFeB) alloys,” including his “*process* that enabled [MTJ] device fabrication on arbitrary underlying layers,” which “enabled mass production on large-diameter wafers by room-temperature sputter deposition, which opened the door to industrial applications of MgO MTJ devices.” EX2024, 2-3. In 2021, he was made an IEEE Fellow for his “contributions to MgO-based magnetic tunnel junctions.” EX2026, 1. Also in 2021, Dr. Yuasa received the “Future Creative Invention Prize” for his “invention... of [JP] patent no. 5120680” (EX2055), which is a foreign counterpart of the ’167 Patent. EX2027. Ross, ¶309.

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.*; Ross, ¶310.

IEEE named Dr. Yuasa a Magnetics Society Distinguished Lecturer in 2012, noting his work with “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 Magnetics society profile notes that “[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; Ross, ¶311.

In 2009, Dr. Yuasa received the Tsukuba Prize, 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. In the same year, he received 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; Ross, ¶312.

Dr. Yuasa has received numerous other awards for his work on MTJs, including the JSPS Prize in 2010 for the “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 the “Study on tunnel magnetoresistance effect,” and the Ichimura Science Prize in 2005. EX2028, 4; Ross, ¶313.

In sum, Dr. Yuasa’s development of the method for making MTJs disclosed and claimed the ’167 Patent has been widely and repeatedly praised. Ross, ¶314.

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

The claimed methods also satisfied a long-felt but unmet need for commercially manufacturable processes for mass MRAM production providing MTJs with high room-temperature TMR (Ross, ¶315), further confirming their nonobviousness. An MTJ with a 10% TMR was achieved in 1995. EX2039, 846. By the late 1990s, MTJ devices were considered the “most viable” MRAM technology (EX1039, 2819) but commercialization was not feasible because TMR

was too low and manufacturing techniques were incompatible with large scale manufacturing (EX2038, 6-7). Ross, ¶316. There was a need to achieve TMRs with manufacturing methods for making MTJs in mass quantities rather than one single crystal at a time. EX2056, 8; Ross, ¶¶316-317.

Researchers undertook extensive experimental effort from 1995 to 2000 to make MTJs using an amorphous alumina tunnel barrier layer, but the resulting 10-70% TMRs were still “lower than those needed for many applications of spintronic devices.” EX1057, 9; EX2056, 6, 7; EX1011, 2:42-56; Ross, ¶318. In 2001, Butler and Mathon speculated that higher TMRs could be obtained using crystalline MgO tunnel barriers with epitaxially grown crystalline 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”—i.e., MTJs with purely crystalline layers. EX2056, 11; Ross, ¶319.

Early attempts at making MTJs using crystalline MgO tunnel barriers failed to achieve the theoretical predictions and such epitaxially-grown single-crystal structures were unsuited to mass production. Ross, ¶320. One well-known example was Bowen, which was the “first report of significant tunneling magnetoresistance through epitaxially grown MgO tunnel barriers,” but whose 27% TMR was inferior to conventional amorphous alumina tunnel barriers.

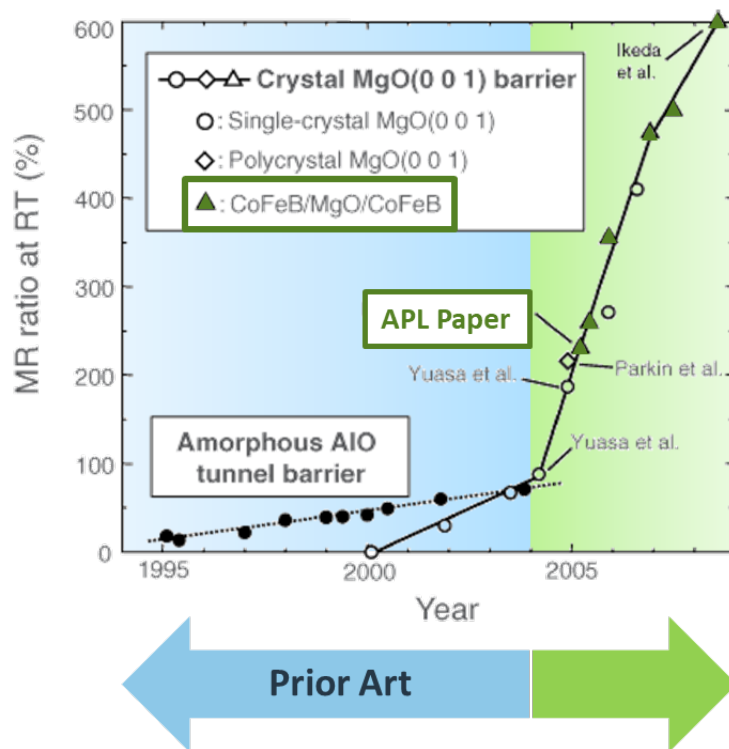
EX2056, 10, EX1057, 45; Ross, ¶321. Early attempts also failed to address the problem of manufacturability, as the MgO barriers “were either very thick resulting in high resistance-area (RA) values or fully epitaxial grown on single-crystal substrates, which is incompatible with read-head manufacturing.” EX2038, 7. Even Petitioner’s employees recognized that such single-crystal approaches “vastly limit commercial applications.” EX2005, 39; Ross, ¶321.

The ’167 Patent’s claimed invention solved these long-felt but unmet needs. Ross, ¶322. The ’167 Patent provided a breakthrough for commercially manufacturing MTJs by avoiding “strenuously high temperature deposition with single crystal structures.” EX2023, 2. Because the claimed method used amorphous CoFeB, it allowed for the use of “conventional sputtering system instead of an MBE system.” *Id.*, 1; Ross, ¶323. Indeed, this ease of manufacturing formed the basis of many of the awards that the ’167 Patent’s inventor, Dr. Yuasa, received in recognition of his achievements. *Supra* §V.B; EX2024, 2-3; Ross, ¶¶300-303, 323.

The ’167 Patent’s claimed methods using CoFeB electrodes achieved even higher 230% room temperature TMR. EX2006, 1-2; *see also supra* §V.A (comparing the claimed method published by EX2006 with the claimed method and finding them identical); EX1013, 8:4-20, 9:6-27; Ross, ¶324. This immediately shifted the focus of industrial and academic MTJ research and

development efforts. Ross, ¶325. As Figure 2.21 shows, after the pioneering Yuasa-APL2005 published—describing the '167 Patent's invention—skyrocketing TMR improvements focused almost entirely on CoFeB/MgO/CoFeB MTJs as claimed. EX1057, 46; Ross, ¶325.

Figure 2.21 (Annotated)



Secondary considerations compel a conclusion that the Challenged Claims are non-obvious over the alleged combinations. Ross, ¶326.

VI. CONCLUSION

Petitioner fails to meet its burden to show that any Challenged Claim is unpatentable. The Board should deny the Petition in its entirety.

Respectfully submitted,
GODO KAISHA IP BRIDGE I

Date: July 16, 2025

By: /Adam R. Wichman/

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CERTIFICATE OF WORD COUNT

Pursuant to 37 C.F.R. § 42.24, the undersigned certifies that the foregoing **PATENT OWNER'S RESPONSE** contains 13,991 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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