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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
U.S. Patent No. 10,680,167

**PETITION FOR *INTER PARTES* REVIEW OF
U.S. PATENT NO. 10,680,167**

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Exhibit No.	Description
1001	U.S. Patent No. 7,884,403 (“’403 Patent”)
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1003	U.S. Patent No. 8,319,263 (“’263 Patent”)
1004	File History for U.S. Patent No. 8,319,263
1005	U.S. Patent No. 8,405,134 (“’134 Patent”)
1006	File History for U.S. Patent No. 8,405,134
1007	U.S. Patent No. 9,123,463 (“’463 Patent”)
1008	File History for U.S. Patent No. 9,123,463
1009	U.S. Patent No. 9,608,198 (“’198 Patent”)
1010	File History for U.S. Patent No. 9,608,198
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1012	File History for U.S. Patent No. 10,367,138
1013	U.S. Patent No. 10,680,167 (“’167 Patent”)
1014	File History for U.S. Patent No. 10,680,167
1015	U.S. Patent No. 11,737,372 (“’372 Patent”)
1016	File History for U.S. Patent No. 11,737,372
1017	U.S. Patent No. 11,968,909 (“’909 Patent”)
1018	File History for U.S. Patent No. 11,968,909
1019	Patent Family Tree
1020	Japanese Patent No. JP2004071186
1021	English Translation of Japanese Patent No. JP2004071186, from ’372 Patent File History (EX1016)
1022	Japanese Patent Application No. JP2004313350
1023	Certified English Translation (with Translator Declaration) of Japanese Patent Application No. JP2004313350
1024	Declaration of Jeffrey Bokor, Ph.D.

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1026	Bowen et al., <i>Large magnetoresistance in Fe/MgO/FeCo(001) epitaxial tunnel junctions on GaAs(001)</i> , 79 Appl. Phys. Letters 1655-1657 (2001) (“Bowen”)
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1063	Complaint, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. Mar. 15, 2024) (without exhibits)
1064	Claim Chart for ’403 Patent, Exhibit D to Complaint, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. Mar. 15, 2024)

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IPR Petition – U.S. Patent No. 10,680,167

Exhibit No.	Description
1065	Claim Chart for '263 Patent, Exhibit E to Complaint, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. Mar. 15, 2024)
1066	Claim Chart for '372 Patent, Exhibit F to Complaint, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. Mar. 15, 2024)
1067	First Amended Complaint, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. July 8, 2024)
1068	Amended Claim Chart for '403 Patent, Exhibit AA to First Amended Complaint, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. July 8, 2024)
1069	Amended Claim Chart for '263 Patent, Exhibit BB to First Amended Complaint, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. July 8, 2024)
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1076	Claim Chart for '134 Patent, Exhibit II to First Amended Complaint, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. July 8, 2024)
1077	Docket, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. Mar. 15, 2024)
1078	U.S. District Courts – Combined Civil and Criminal Federal Court Management Statistics (Dec. 31, 2023), https://www.uscourts.gov/statistics-reports/federal-court-management-statistics-december-2023 (excerpts)
1079	Microsoft Computer Dictionary (5th ed. 2002) (excerpts)
1080	Order Granting Motion to Transfer Venue to Northern District of California, <i>Godo Kaisha IP Bridge I v. Western Digital Corporation</i> , Case No. 24-cv-00342-RGA (D. Del. Sept. 4, 2024)
1081	U.S. Patent No. 7,751,156 ('156 Patent)
1082	U.S. Patent No. 8,427,791 ('791 Patent)
1083	U.S. Patent No. 8,914,970 ('970 Patent)
1084	Boubeta et al., <i>Epitaxial Fe/MgO heterostructures on GaAs(001)</i> , 226 J. of Crystal Growth 223-230 (2001)

LIST OF CHALLENGED CLAIMS

1[pre] A method of manufacturing a magnetic tunnel junction (MTJ) device, comprising:

1[a] forming a first CoFeB layer that is amorphous;

1[b] forming a magnesium oxide (MgO) layer over the first CoFeB layer;

1[c] forming a second CoFeB layer that is amorphous over the MgO layer; and

1[d] annealing the first and second CoFeB layers and the MgO layer, wherein the first and second CoFeB layers are crystallized by the annealing, and

1[e] wherein the MgO layer is poly-crystalline in which a (001) crystal plane is preferentially oriented.

2. The method of claim 1, wherein after the annealing, the first and second CoFeB layers are entirely crystallized.

3. The method of claim 1, wherein after the annealing, each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented.

4[pre] The method of claim 1, wherein

4[a] after the annealing, the first and second CoFeB layers are entirely crystallized, and

4[b] each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented.

5. The method of claim 1, wherein after the annealing, each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented and each of the first and second CoFeB layers includes a BCC (body-centered cubic) structure.

6[pre] The method of claim 1, wherein

6[a] after the annealing, the first and second CoFeB layers are entirely crystallized, and

6[b] each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented and each of the first and second CoFeB layers includes a BCC (body-centered cubic) structure.

7. The method of claim 1, wherein in the forming the MgO layer, the MgO layer is formed as a MgO_x ($0 < x < 1$) layer.

8. The method of claim 1, wherein in the forming the MgO layer, the value of x in MgO_x for the MgO layer is greater than 0 and less than 1.

9. The method of claim 1, wherein in the forming the MgO layer, the MgO layer is formed directly on the first CoFeB layer.

10[pre] The method of claim 1, wherein:

10[a] in the forming the MgO layer, the MgO layer is formed directly on the first CoFeB layer, and

10[b] in the forming the second CoFeB layer, the second CoFeB layer is formed directly on the MgO layer.

11[pre] A method of manufacturing a magnetic tunnel junction (MTJ) device, comprising:

11[a] forming a first ferromagnetic layer including a first CoFeB layer that is amorphous;

11[b] forming a barrier layer including a magnesium oxide (MgO) layer to have a poly-crystalline state in which a (001) crystal plane is preferentially oriented over the first ferromagnetic layer;

11[c] forming a second ferromagnetic layer including a second CoFeB layer that is amorphous over the barrier layer; and

11[d] annealing the first and second ferromagnetic layers and the barrier layer, to crystallize the first and second CoFeB layers.

12. The method of claim 11, wherein after the annealing, the first and second CoFeB layers are entirely crystallized.

13[pre] The method of claim 11, wherein

13[a] after the annealing, the first and second CoFeB layers are entirely crystallized, and

13[b] each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented and each of the first and second CoFeB layers includes a BCC (body-centered cubic) structure.

14. The method of claim 11, wherein in the forming the barrier layer, the MgO layer is formed as a MgO_x ($0 < x < 1$) layer.

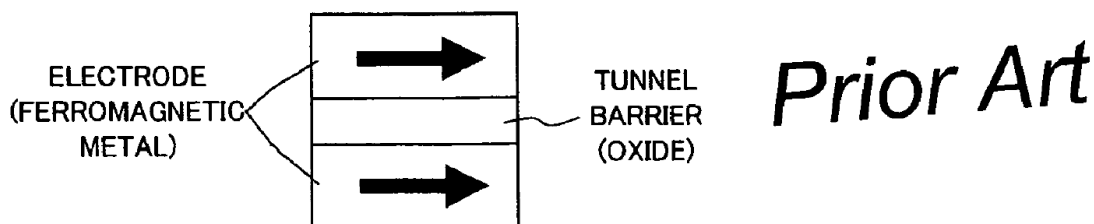
15[pre] The method of claim 11, wherein:

15[a] in the forming the barrier layer, the barrier layer is formed directly on the first ferromagnetic layer, and

15[b] in the forming the second ferromagnetic layer, the second ferromagnetic layer is formed directly on the barrier layer.

I. INTRODUCTION

This IPR concerns the storage elements underlying magnetoresistive random-access memory (MRAM). MRAM is a niche memory device: a non-volatile random-access memory that stores data in magnetic storage elements called magnetic tunnel junctions (MTJs, shown below), comprising two ferromagnetic electrodes separated by a thin insulating layer:



Patent Owner IP Bridge claims Shinji Yuasa invented magnesium oxide MTJs used in MRAM as claimed in the '167 Patent at issue here and the related asserted patents. But “[n]onvolatile MRAM is not really new.” EX1057 at xiv. Dr. Yuasa himself acknowledged that “[r]esearch and development of MRAM devices, which are fast and non-volatile memory devices, are being extensively carried out” before he filed his patent. EX1013 at 1:35-38. The '167 Patent instead purports to claim as its own decades of research by the brightest minds in quantum mechanics and device fabrication.

In the 1930s, researchers discovered a surprising phenomenon unexplained by classical physics: current flowing through a thin insulator sandwiched between two

electrodes. EX1031 at 1793 n.2. Simmons’ influential 1963 paper quantified the “tunnel effect” and provided a formula for quantifying the “barrier height,” or the energy required for electrons to tunnel across the insulating barrier. EX1031 at Abstract, 1797 (Eq. (25)).

During prosecution of the ’167 Patent, the Examiner incorrectly believed that crystallizing CoFeB electrodes by annealing was inventive. EX1014 at 220-21. Applicant did not inform him otherwise, EX1014 at 273, and indeed the prior art taught exactly that, *e.g.*, EX1062 at 18:49-19:26.

This Petition presents two grounds showing all claims of the ’167 Patent were obvious:

- Bowen (Ground 1): Bowen (EX1026) built high-quality FeCo/MgO/Fe MTJs to achieve a high TMR. Sunai (EX1030) or Parkin (EX1062) both taught the advantages of using CoFeB electrodes in MTJs, while Soukup (EX1028) taught the benefits of an MgO tunnel barrier layer with oxygen vacancy defects.
- Nagahama (Ground 2): Dr. Yuasa and collaborators (EX1027) disclosed nearly every aspect of an MgO MTJ he later sought to claim in the ’167 Patent, and is also combined with Sunai or Parkin and Soukup.

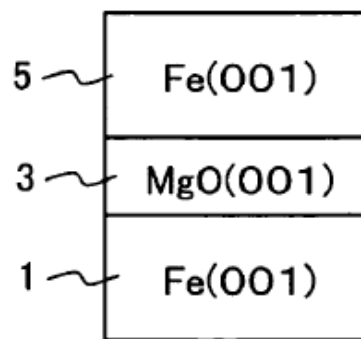
In short, Dr. Yuasa’s effort to individually stake a claim to the territory of MgO MTJs should be rejected, and his claims revoked.

II. BACKGROUND

A. The District Court Litigation

A few years ago, Patent Owner IP Bridge bought Dr. Yuasa’s patents on MgO-based MTJs, including the ’167 Patent challenged here. EX1063 ¶¶3, 10; EX1067 (same). In March, IP Bridge filed suit against Western Digital, asserting that essentially its entire hard drive product line infringed three patents. EX1063 ¶¶28-30, 33-35. It filed a similar suit against Seagate. *Infra* §XII.B.

IP Bridge touted Dr. Yuasa’s “pioneering contribution to the MgO-based MTJs” and explained that his patents “are directed to a MTJ structure comprising a thin insulating layer (a tunnel barrier layer) sandwiched between two ferromagnetic metal electrodes.” EX1063 ¶¶12, 14. The Complaint says Dr. Yuasa’s three-layer MTJ structure (right) obtained “the highest MR ratios.” *Id.* ¶18 (reproducing EX1001 at Fig. 1(B)).

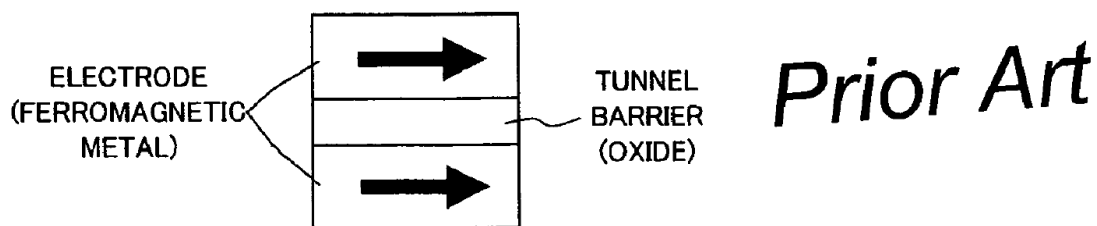


Almost nothing has happened in the pending litigation. Confronted with a motion to dismiss its original complaint, IP Bridge filed a First Amended Complaint asserting six more related patents, including the ’167 Patent. EX1067 ¶2; EX1019. Western Digital filed another motion to dismiss and requested a transfer of the case from Delaware to California federal court. EX1077. On September 4, 2024, the

district court ordered transfer to the Northern District of California. EX1080. As of the filing of this Petition, the motion to dismiss still remains pending.

B. Magnetic Memory Development

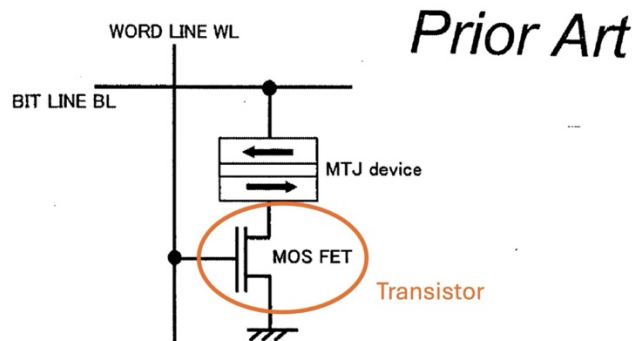
Conventional semiconductor-based memories like DRAM and EEPROM store data as electrical charges. EX1024 ¶30. Magnetic memory operates differently. As shown below, the simplest structure for magnetic memory conventionally is a magnetic tunnel junction (MTJ) with two ferromagnetic layers separated by a thin oxide layer:



EX1013 at Fig. 8(A); *see also id.* at Fig. 8(B), 1:39-64; EX1027 at Fig. 3; EX1030 at Fig. 1; EX1024 ¶¶31-35.

MRAM stores bits in MTJs, with a transistor typically controlling access to individual MTJs, as shown below.

FIG. 9 (B)



EX1013 at Fig. 9(B) (annotated); EX1030 ¶¶37-40, Figs. 4-5; EX1039 at 2816, 2818; EX1049 at Abstract, Fig. 2; EX1024 ¶30.

One MTJ electrode has a fixed polarity, while the other electrode's magnetization can be changed by an external electric field. EX1030 ¶19. To read the bit, typically the MRAM runs a small current through the electrodes and tunnel barrier and reads the resistance of

the MTJ. *Id.*; EX1013 at 1:48-64.

As shown at right, if the MTJ has

low resistance, this indicates the

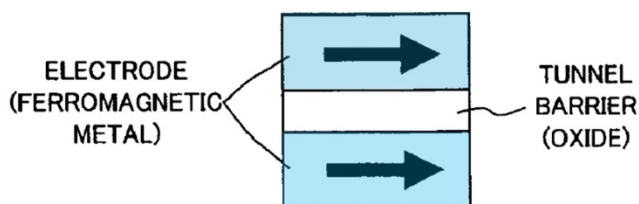
electrodes have **parallel**

magnetization; high resistance

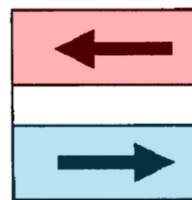
indicates **antiparallel**

magnetization. EX1013 at 1:48-

59, Figs. 8(A)-8(B) (excerpted, annotated). EX1024 ¶35.



Parallel Magnetization



Antiparallel Magnetization

Researchers were particularly interested in optimizing MTJs to improve MRAM performance. EX1026 at 1655; EX1045 at 1; EX1024 ¶31. An “important parameter” was the **tunnel magnetoresistance ratio (TMR)**, measuring the tunneling resistance across the MTJ. EX1055 at 2269. In 1973, the “pioneering work of Jullière” (EX1033), EX1057 at 9, discovered tunneling magnetoresistance in an MTJ at a low temperature (4.2 K, -452°F), EX1033 at 225. Mathematically, TMR for an MTJ is equal to the difference in the resistance between the antiparallel (R_{ap}) and parallel states (R_p), divided by the parallel state resistance:

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

EX1035 at 3273; EX1027 ¶2; EX1013 at 4:62-5:3; EX1024 ¶37. Thus, high anti-parallel resistance R_{ap} compared to lower parallel resistance R_p results in high TMR.

Id.

Higher TMRs long promised improved performance for MRAM. EX1049 at 186 (“[L]arger MR ratio is the [sic] another important issue for the high speed MRAM operations.”); EX1013 at 2:36-53; EX1024 ¶¶36-44. High TMR allowed lower voltages (and smaller currents) to determine the MTJ’s resistance (i.e., read the memory cell) and lowered power consumption. EX1055 at 2269; EX1024 ¶¶41-43. High TMR also improved the signal-to-noise ratio; made sensing the

correct state more accurate; and paved the way for smaller, denser MRAMs. EX1055 at 2269; EX1049 at 194-95; EX1024 ¶¶41-44.

Two decades after Jullière, Miyazaki and Moodera separately measured TMR above 10%, demonstrating the tunneling effect at room temperature. EX1034 at Abstract (reporting TMR of “18% at 300 K”); EX1035 at Abstract (TMR of 11.8% at 295 K). “Since 1995, extensive experimental effort has been made on MTJs with amorphous AlO barriers and ferromagnetic electrode[s]....” EX1057 at 43. The patent itself acknowledges that then-current MTJ devices exhibited TMRs of “approximately 70%.” EX1013 at 5:18-21.

In 2001, separate research teams led by Butler and Mathon calculated that MTJs with a crystalline MgO barrier layer would achieve TMRs of over 1000%. EX1053 at 8041, 8043 nn.9-10 (citing EX1044, EX1046). Butler’s and Mathon’s publications spurred a scientific gold rush, with researchers publishing an explosion of research into MgO MTJs. As one researcher put it: “TMR[] in magnetic tunnel junctions (MTJs) is widely studied nowadays due to the large-scale potential applications of MTJs” in MRAM and data storage. EX1052 at 4507.

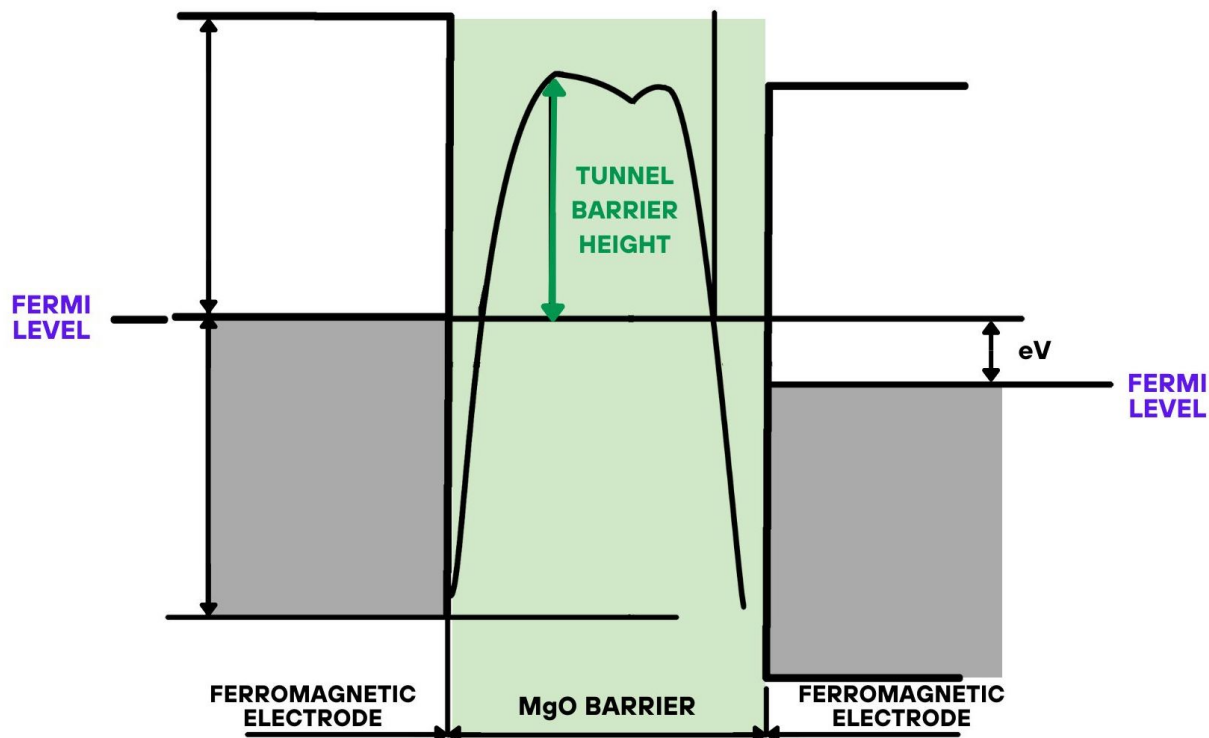
C. Quantum Tunneling In MTJs: Barrier Heights And Fermi Levels

MTJ behavior is explained by quantum mechanics. Current typically flows through conductors and is inhibited by insulators. EX1024 ¶¶45-49. But in the 1930s, researchers discovered that current (electrons) could flow between two

electrodes separated by a very thin insulating layer (or barrier). EX1031 at 1793 n.2 (citing Sommerfeld and Bethe (1933)).

Simmons published an influential 1963 paper describing the “tunnel effect” of electrons across the barrier using quantum mechanics and providing a mathematical formula to estimate the barrier height, which is explained below. EX1031 at Abstract, 1797 (Eq. (25)).

The **Fermi level** (E_F) corresponds to this highest energy level occupied by electrons at 0 K. EX1024 ¶46. Electrons that lie close to the Fermi level participate in tunneling. *Id.*; EX1052 at 4508; EX1031 at 1802.



As shown above, tunneling can occur across a barrier (green) separating two

ferromagnetic electrodes (**gray**). EX1031 at 1794, Fig. 1; EX1024 ¶46. At equilibrium, the Fermi levels (E_F) of the two electrodes align, so there is no net current flow (i.e., the same number of electrons tunnel in both directions across the barrier). EX1031 at 1796. If a bias voltage is applied to the junction, the Fermi level of the collector electrode (right) lowers by an amount (eV) compared to the injector electrode (left), allowing the electrons to tunnel across the barrier from the injector to empty states above the Fermi level in the collector. EX1031 at 1796, Figs. 1, 3.

In an MTJ, the **tunnel barrier height** represents the difference between the bottom of the conduction band of the tunnel barrier layer and the **Fermi level** of electrons in the conductor. EX1031 at Fig. 1; EX1047 at 509; EX1013 at 3:55-61; EX1024 ¶48. Simmons' 1963 paper provided a widely used formula for calculating the tunnel barrier height.¹ EX1031 at 1797 (Eq. (25)); EX1026 at 1656; EX1035 at 3274; EX1013 at 7:27-33; EX1024 ¶49.

¹ Simmons' formula for the low-voltage range is:

$$J = [3(2m\phi)^{\frac{1}{2}}/2s](e/h)^2 V \times \exp[-(4\pi s/h)(2m\phi_0)^{\frac{1}{2}}].$$

EX1031 at 1797 (Eq. (25)). Researchers later corrected Simmons' formula to remove an erroneous factor of 3/2:

$$J_c = \frac{(2m\phi_0)^{\frac{1}{2}}}{s} \left(\frac{e}{h}\right)^2 V \exp\left[-\frac{4\pi s}{h}(2m\phi_0)^{\frac{1}{2}}\right].$$

EX1059 at 1 (Eq. (1)).

D. Research Into Materials To Increase TMR

It was known that “the tunnel characteristics are an intrinsic function of the thermal properties of the *insulator*, as well as of the electrodes.” EX1031 at 1802 (emphasis in original); *see also* EX1050 at 2427. To improve tunneling and TMR, researchers studied different materials for the ferromagnetic electrodes and barrier layer. *E.g.*, EX1055 at 2269; EX1024 ¶¶50-72.

1. Ferromagnetic Materials

Well-known ferromagnetic materials such as Fe, Ni, Co, and their alloys typically have crystalline structures. EX1030 ¶33; EX1024 ¶54; *id.* ¶¶55-62. Alignment between the crystal of the electrodes and the barrier layer facilitates electron tunneling, reducing the barrier height and increasing TMR. EX1024 ¶56; EX1044 at 1; EX1046 at 1.

Researchers also found that alloys of iron (Fe) and cobalt (Co) improved TMR. EX1050 at 2428 (Yuasa 2002 study on FeCo electrodes); EX1026 at 1655 (depositing Fe₅₀Co₅₀ electrode layers); EX1052 at 4507 (using Fe and Co layers to try to achieve the calculated high TMRs); EX1024 ¶58.

By the early 2000s, researchers investigated using CoFeB alloys to increase TMR in magnetic memory. EX1030 ¶¶25-29; EX1055 at 2269-70 (“benefit of using CoFeB is multifold” including “a higher TMR value”); EX1056 ¶39. Introducing boron (B) to form a CoFeB electrode resulted in an initially “amorphous structure,”

EX1055 at Abstract, where “crystallization is inhibited,” EX1030 ¶¶24-25, 30; EX1024 ¶¶59-61. As a result, a “CoFeB/MgO/CoFeB MTJ can theoretically be grown on all kinds of underlayers.” EX1057 at 47. Without B, CoFe films had to be deposited as thicker or discontinuous films, decreasing TMR. EX1030 ¶27; EX1024 ¶¶60, 62.

2. Barrier Layers

Initially, there was significant interest in aluminum oxide (Al_2O_3) barrier layers. EX1024 ¶¶62-65; EX1052 at 4507; EX1044 at 1. But Al_2O_3 was amorphous and lacked an ordered crystalline lattice structure or symmetry with the electrodes. EX1044 at 1; EX1045 at 1; EX1013 at 5:25-33 (contrasting crystalline MgO and amorphous Al_2O_3 barriers). This “lattice disorder” resulted in incoherent tunneling with the electrons prone to scattering. EX1045 at 1. By the early 2000s, MTJs with Al_2O_3 barriers conventionally had TMRs “at approximately 70%.” EX1013 at 2:47-49, 5:18-21; EX1063 ¶18; EX1055 at 2270.

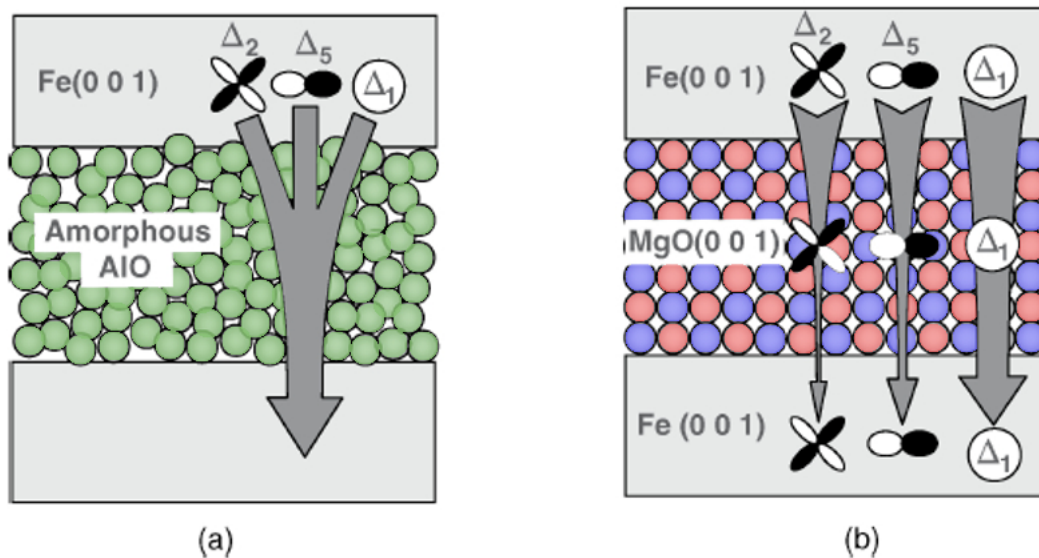
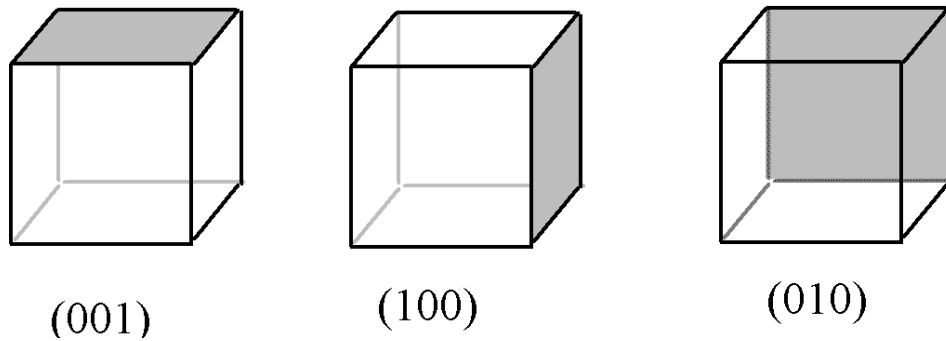


Figure 2.19 Schematic of electron tunneling through (a) an amorphous AlO barrier and (b) a crystalline MgO(0 0 1) barrier.

EX1057 at 44, Fig. 2.19 (annotated).

Thin-film magnesium oxide (MgO) barriers had been studied for years. EX1028 at 3229; EX1038 at Abstract; EX1024 ¶¶66-72. MgO was known to have a low barrier height because of its ordered crystalline structure. EX1028 at Abstract (0.33 eV barrier height of an MgO thin film); EX1024 ¶¶70-71.

Single-crystalline MgO barriers grew in a cubic crystalline lattice like table salt. EX1013 at 4:39-41; EX1040 at 2839. Its symmetric structure results in the (001), (100), and (010) crystalline planes being the same:



EX1013 at 4:39-41 (“[B]ecause MgO has a cubic crystal structure (NaCl structure), the (001) plane, the (100) plane, and the (010) plane are all equivalent.”); EX1024 ¶¶66-67.

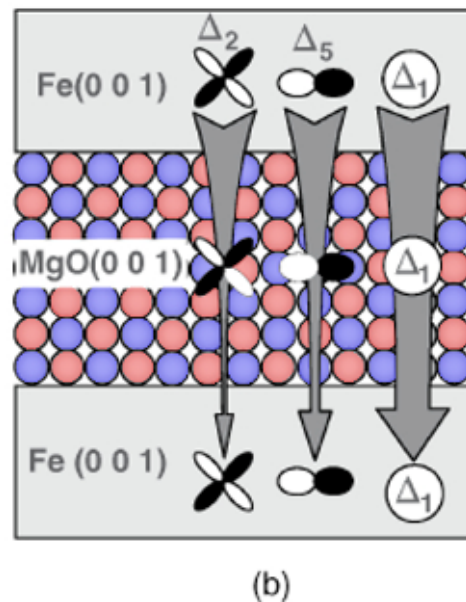
Butler and Mathon separately “calculated [the] optimistic TMR ratio is in excess of 1000% for an MgO barrier.” EX1046 at Abstract; *see also* EX1044 at Fig. 16; EX1024 ¶¶68. Butler pointed out that tunneling across an MgO barrier was facilitated by the “symmetry” between the electrodes and barrier material, which “are crucial to determining the tunneling conductance.” EX1044 at 1; EX1046 at 1. This symmetry permitted high TMRs because “[t]he tunneling resistance for the parallel” electrons was “estimated to be 100 times smaller than that for the antiparallel” electrons “due to the absence of scattering in the barrier.” EX1045 at 1; EX1044 at 1; EX1024 ¶¶69.

Butler’s and Mathon’s breakthroughs generated considerable excitement for MgO thin-film MTJs. EX1053 at 8041, 8043 nn.9-10 (citing Butler and Mathon); EX1045 at 1, 8 n.3 (citing Butler); EX1024 ¶¶72.

E. Oxygen Vacancy Defects In MgO Thin Films

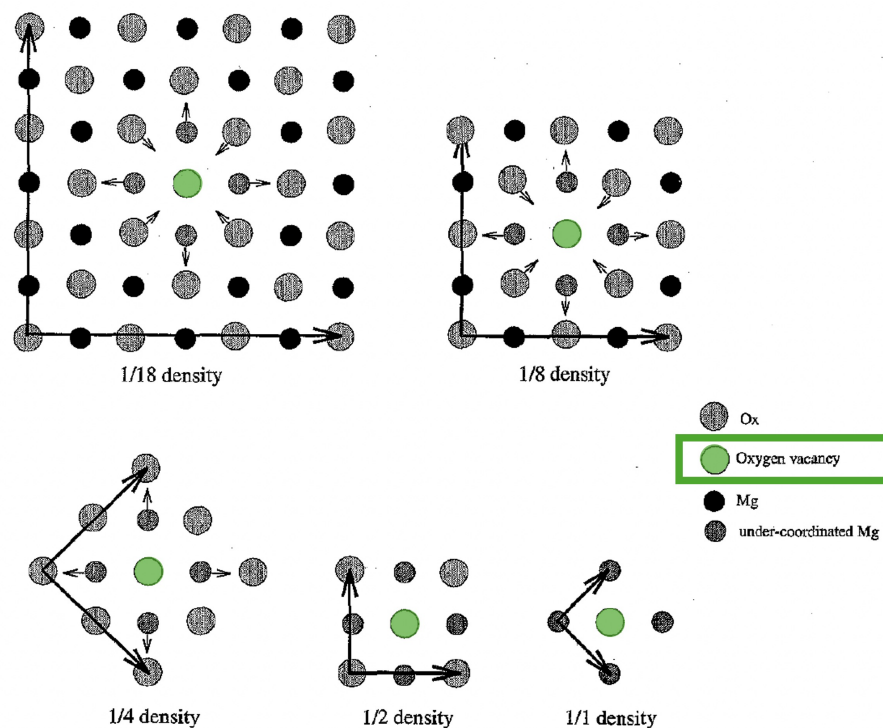
“One of the most important defects in oxides, if not the most important, is the oxygen vacancy.” EX1042 at 162; *id.* at Abstract; EX1024 ¶¶73-82. A metal oxide’s properties “are directly or indirectly connected to the presence of defects and in particular of point defects.” EX1042 at 161. “Oxygen vacancies are naturally present in every oxide....” EX1042 at 162; EX1008 at 198.

The idealized MgO structure is stoichiometric with a 1:1 ratio of Mg (blue) and O atoms (red) in its cubic crystalline structure. EX1042 at 162; EX1013 at 6:31-33; EX1057 at 44, Fig. 2.19 (excerpted, annotated); EX1024 ¶¶63, 74. One way to quantify the level of oxygen vacancies in MgO crystal is by describing a sub-



stoichiometric composition of MgO_x , where $x < 1$ ($x = 1$ in an idealized, perfectly stoichiometric crystal). EX1041 at 132 (“understoichiometric MgO_x ($x < 1$)”); EX1013 at 7:5-6, 7:22-24; EX1002 (’403 File History) at 168 (Applicant: “ MgO_x ($0 < x < 1$)” and “ x is $0 < x < 1$. (Namely, if this is represented as ‘MgO crystals,’ the crystals have oxygen vacancy defects.).”); EX1024 ¶¶74-75.

As shown below, oxygen vacancy defects (shown in **green**) result in a non-stoichiometric MgO crystalline structure:



EX1037 at 3, Fig. 1 (annotated); *see also* EX1013 at 6:31-33 (contrasting using “a source with oxygen vacancy defects” instead of “the MgO of the stoichiometric composition (the ratio of Mg to O is 1:1)”); EX1024 ¶76.

Researchers understood that oxygen vacancy defects lowered the barrier height of the MgO thin film. Soukup experimentally observed a 0.33 eV barrier height of an MgO thin film, noting that increased oxygen vacancy defects lowered the barrier height of MgO. EX1028 at Abstract, 3232; EX1024 ¶77. Bowen also observed a lower barrier height of his MgO thin film and hypothesized that it may

have resulted from “the presence of stoichiometric and/or thickness inhomogeneities in the insulating film.” EX1026 at 1656; *see also* EX1062 at 17:37-39; EX1024 ¶82.

F. The '167 Patent

The '167 Patent claims a method of manufacturing an MTJ with a polycrystalline MgO barrier layer sandwiched between two amorphous CoFeB electrodes. EX1013 at 9:55-67, 10:44-57 (Claims 1, 11), Fig. 1(B) (excerpted at right); EX1024 ¶¶83-86.

FIG. 1 (B)



G. The Prosecution Of The '167 Patent

The '167 Patent is in the same family as the '403 Patent and claims priority to JP 2004-071186 and 2004-313350. EX1013 at 1, [63], [30].

The '167 Patent claims were allowed after a single office action rejecting pending claim 1 for both double patenting and obviousness over U.S. Patent Publication No. 2008/0062581 (“Parkin581”) and Nashimoto. EX1014 at 216-22, 280. The Examiner found that Parkin disclosed a polycrystalline MgO MTJ with a first “amorphous ferromagnetic material layer 115 made of a COFEB alloy of a BCC structure” and a second “CoFeB alloy” electrode. *Id.* at 218. He stated the other claims were allowable, in part, because:

the prior art of record does not teach or suggest the combination of annealing the first and second CoFeB layers and the MgO layer, wherein the first and second CoFeB layers are crystallized by the annealing.

Id. at 220-21. Applicant acquiesced and cancelled Claim 1. *Id.* at 269, 273.

III. CLAIM CONSTRUCTION

Petitioner submits the claim terms should be given their plain and ordinary meaning and no claim construction is necessary to find the claims unpatentable, *see Vivid Techs. v. Am. Sci. & Eng'g*, 200 F.3d 795, 803 (Fed. Cir. 1999), and reserves the right to propose constructions in response to Patent Owner's arguments, EX1024 ¶¶87-88.

IV. STATEMENT OF PRECISE RELIEF REQUESTED FOR EACH CHALLENGED CLAIM (37 C.F.R. § 42.104(b)(1)-(2))

A. Grounds Presented

Petitioner requests review and cancellation of Claims 1-15 of the '167 Patent based on the following grounds.

Ground 1: Claims 1-6, 9-13, and 15 are obvious over Bowen in view of Sunai or Parkin. Claims 7-8 and 14 are obvious over Bowen in view of Sunai or Parkin and optionally Soukup.

Ground 2: Claims 1-6, 9-13, and 15 are obvious over Nagahama in view of Sunai or Parkin. Claims 7-8 and 14 are obvious over Nagahama in view of Sunai or Parkin and optionally Soukup.

B. The Prior Art

1. March 10, 2004 Critical Date For The '167 Patent

The '167 Patent is a pre-AIA patent. Under pre-AIA §102(b), a person is not entitled to a patent if

the invention was patented or described in a printed publication in this or a foreign country... more than one year prior to the date of the application for patent in the United States.

35 U.S.C. §102(b) (pre-AIA).

Under Section 102(b), the effective filing date is the international filing date, not the filing date of any foreign priority documents. *See, e.g.*, MPEP §2139.01.

“Under pre-AIA 35 U.S.C. 102(b), the one-year [bar] is measured from the filing date of the earliest application filed in the United States (directly or through the PCT) and not from the dates of earlier filed foreign patent applications.” MPEP §2151. The '167 Patent claims priority to the '403 Patent PCT application, PCT/JP2005/04720 filed on March 10, 2005. EX1013 at 2, [63]; *see also id.* at 1:6-22. Because the international filing date of the '403 Patent is the March 10, 2005 PCT filing date, EX1001 at [22], the critical date for the '167 Patent is also March 10, 2004, *Group One v. Hallmark Cards*, 254 F.3d 1041, 1044-45 (Fed. Cir. 2001).

2. Prior Art Status

Bowen, Nagahama, Soukup, and Sunai are all prior art under at least pre-AIA 35 U.S.C. §102(a) and (b) because they were each published before the March 10, 2004 critical date for the '167 Patent:

- Bowen is a printed publication published on September 10, 2001. EX1026 at 1655.
- Nagahama is a European patent application published on February 25, 2004. EX1027 at [43].
- Soukup is a printed publication published on July 1, 1970. EX1028 at cover, 3229.
- Sunai is a Japanese patent application published on July 19, 2002. EX1030 at [43].

U.S. Patent No. 7,270,896 to Parkin was filed on July 2, 2004. EX1062 at [22]. Parkin is prior art under pre-AIA 35 U.S.C. §102(a) and (e) because it was filed before the earliest possible filing date and before the purported invention of the subject matter of the '167 Patent. The '167 Patent claims a method of manufacturing MTJs by forming a “first” and “second CoFeB layer that is amorphous.” EX1013 at 9:55-67, 10:44-57. There is no disclosure of a CoFeB layer in the March 12, 2004 Japanese application (JP 2004-071186) to which the '167 Patent claims priority. EX1013 at [30]. The earliest disclosure of CoFeB is the October 28, 2004 Japanese

application (JP 2004-313350) to which the '167 Patent claims priority, rendering Parkin prior art under Section 102(a) and (e).

V. LEVEL OF ORDINARY SKILL IN THE ART

One of ordinary skill in the art as of 2004 would have had

- a Ph.D. in electrical engineering, physics, materials science, or a related field, and at least one year of experience in the research, design, and/or development of magnetic/spintronic devices, or the equivalent, or
- a Master's degree in electrical engineering, physics, materials science, or a related field, and four years of experience in the research, design, and/or development of magnetic/spintronic devices, or the equivalent.

EX1024 ¶25. Less work experience may be compensated by a higher level of relevant education, and vice versa. *Id.* This level of ordinary skill would be the same if the relevant time period were around the March 12, 2004 or October 28, 2004 Japanese priority applications, or the March 10, 2005 PCT filing date.

EX1024 ¶¶24-29.

VI. GROUND 1: CLAIMS 1-15 ARE OBVIOUS OVER BOWEN IN VIEW OF SUNAI OR PARKIN (AND SOUKUP)

A. Claim 1

Claim 1 would have been obvious over Bowen in view of Sunai or Parkin.

1. Claim 1[preamble]: “A method of manufacturing a magnetic tunnel junction (MTJ) device, comprising:”

To the extent limiting, Bowen taught or suggested a method of manufacturing a magnetic tunnel junction (MTJ) device as claimed. *E.g.*, EX1026 at Abstract, 1655-56 (discussing epitaxially growing FeCo/MgO/Fe MTJs), Fig. 1; EX1024 ¶¶109-19; *see also infra* §§VI.A.2-VI.A.6.

Bowen disclosed a manufacturing process for fabricating its MTJ device: “FeCo/MgO/Fe epitaxial structures were grown on GaAs(001) in a combined sputtering/laser ablation system....” EX1026 at 1655, 1657 n.8 (citing EX1084 for manufacturing the MTJ); EX1024 ¶¶111, 113. He explains that “in a subsequent step, the MgO barrier is grown at 400°C in order to obtain good crystallinity.” EX1026 at 1655. Bowen continues:

Fe₅₀Co₅₀ and Fe layers were deposited from individual Fe and Co targets by triode sputtering.... Optimal deposition temperatures were 400°C for the MgO, RT for FeCo top electrode, and RT plus annealing at 400°C for the Fe bottom electrode. This low-temperature deposition and subsequent annealing process leads to an optimal Fe electrode in terms of crystallinity, continuity, and interface sharpness.

EX1026 at 1655; EX1084 at 228-29; EX1024 ¶114; *id.* ¶¶112, 115-16. As shown below, Bowen analyzed the MTJ device he built:

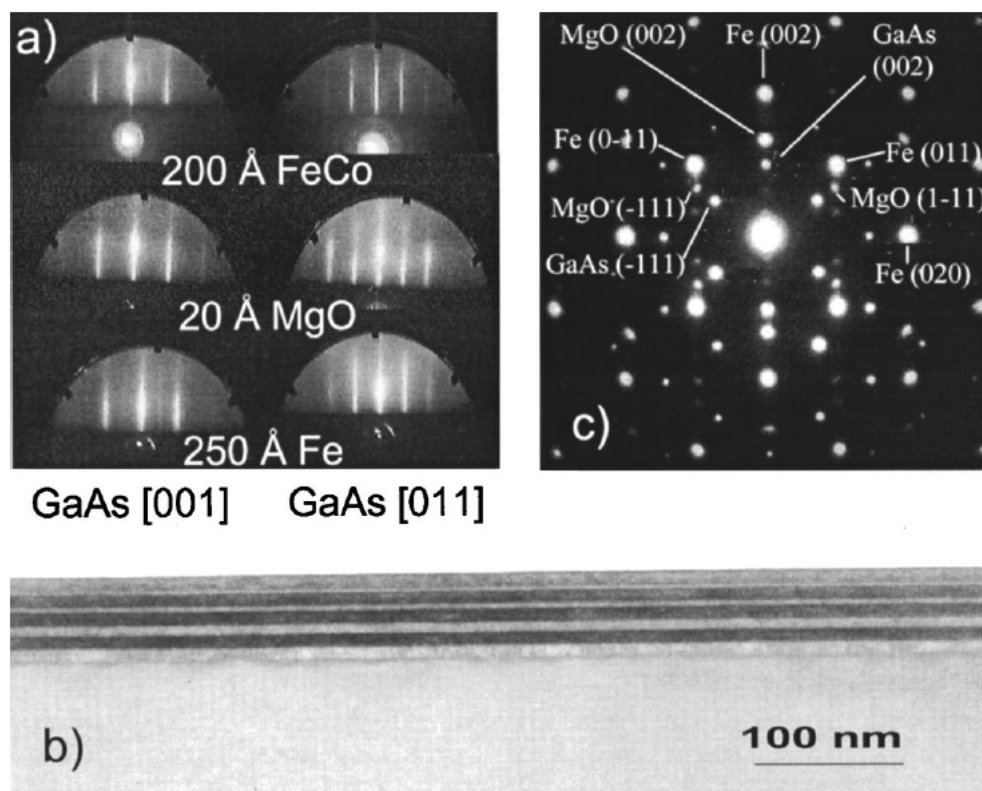


FIG. 1. (a) RHEED patterns along the GaAs [100] and [110] substrate azimuths of a typical FeCo/MgO/Fe epitaxial structure; (b) cross section TEM image of a Fe/MgO(001) multilayer with gradually decreasing MgO layer thickness; (c) TEM electron diffraction pattern.

E.g., EX1026 at 1655-57, Fig. 1; EX1024 ¶117.

Manufacturing magnetic tunnel junctions (MTJs) was known and conventional. EX1013 at Figs. 8(A)-8(B), 1:39-64, 9:35-38 (“deposition methods” for forming MgO layer “obvious”); EX1024 ¶¶118-19; *supra* §II.B.

2. Claim 1[a]: “forming a first CoFeB layer that is amorphous;”

This limitation was taught or suggested by Bowen in view of Sunai or Parkin.

EX1024 ¶¶120-36.

Claim 1[a] does not specify any molecular composition or stoichiometry of the claimed CoFeB layer, and thus any CoFeB alloy satisfies it. EX1013 at 9:57; EX1024 ¶121. CoFeB and FeCoB refer to the same alloy. EX1024 ¶121. For purposes of this Petition, “first” will refer to the “lower” ferromagnetic electrode that is closest to the substrate. EX1024 ¶122.

Bowen disclosed forming a first, Fe ferromagnetic layer: “FeCo/MgO/Fe epitaxial structures were grown on GaAs(001) in a combined sputtering/laser ablation system” that was “deposited from individual Fe and Co targets by triode sputtering.” EX1026 at 1655; *id.* at Abstract, 1656, Fig. 1; EX1024 ¶123. Bowen taught an “Fe bottom electrode” and explained that his MTJ was “grown epitaxially” and “processed by optical lithography.” EX1026 at 1655-56; EX1024 ¶123.

Manufacturing an MTJ by forming ferromagnetic layers was both known and conventional. EX1008 at 268 (Examiner in ’463 File History: “It is inherent the first ferromagnetic material layer would be deposited on a substrate.” (bold removed)); EX1013 at 1:42-46 (Description of Related Art), Figs. 8(A)-8(B); EX1045 at 1; EX1024 ¶124; *supra* §II.D.1.

One of skill would have found it obvious to replace Bowen’s Fe layer with an amorphous ferromagnetic CoFeB layer as taught by Sunai. EX1030 ¶28 (teaching CoFeB electrode by adding B to Co₉Fe), 24 (teaching “ferromagnetic layer 4 is represented by the general formula (CoFe)_{100-x}Y_x” and specifying Y is an “element

selected from the group consisting of B” or other elements), ¶25 (“crystallization is inhibited according to the above material containing element Y”); *id.* ¶¶25-29; EX1024 ¶125. Cobalt and iron were known ferromagnetic materials. EX1030 ¶33; EX1026 at 1655; EX1024 ¶125.

It was known that CoFeB would be formed as an amorphous layer. EX1030 ¶¶24-28; EX1055 at Abstract (“CoFeB has an amorphous structure”); EX1056 at Abstract (ferromagnetic layer of CoFeB alloy “has an amorphous structure”); EX1061 at Abstract, 2272 (“CoFeB films” known “for their soft properties”); EX1062 at 17:40-53, 18:49-19:27; EX1024 ¶130.

One of skill would have been motivated to substitute Sunai’s CoFeB electrode for either or both of Bowen’s electrodes to increase TMR, and lower H_f and H_c , of Bowen’s MTJ. EX1055 at 2270 (“[I]t is natural to replace both the free and pinned layers to CoFeB to further increase the TMR value.”); EX1056 ¶¶67-68 (“[B]oth the ferromagnetic layers 5, 7 are made of an FeCoB” to achieve “improvement of the TMR ratio.”); EX1035 at 3274 (Fe and “CoFe alloys were tried in this study as both bottom and top electrodes.”); EX1061 at Abstract; EX1024 ¶129.

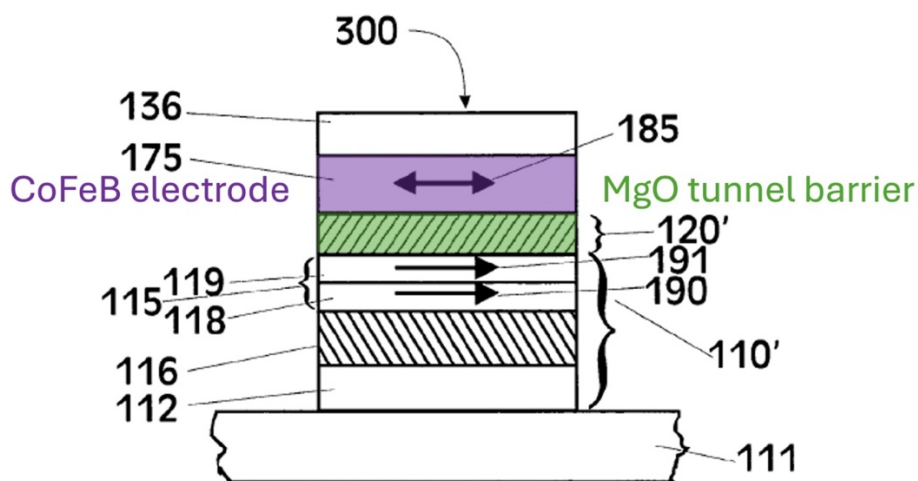
Bowen sought to increase TMR in its MgO MTJ, EX1026 at 1655, 1657, and understood that the properties of the MTJ’s electrodes contributed to improving the tunneling and hence TMR of its device, EX1026 at 1657; EX1024 ¶128. A skilled artisan knew that using CoFeB electrodes improved TMR and lowered H_f and H_c .

EX1024 ¶¶127-29. CoFeB was known to increase TMR compared to CoFe, EX1030 ¶¶27-28 (describing improvements to TMR by adding B to CoFe), and CoFe was known to obtain better results than Fe, EX1035 at 3274; *see also* EX1061 at Abstract (“CoFe-based junctions ($R \times A \sim 500 \Omega \cdot \mu\text{m}^2$) have lower TMR ($\sim 35\%$) and larger H_f ($\sim 5\text{-}6$ Oe) and H_c ($\sim 12\text{-}14$ Oe) [compared to CoFeB-based junctions].”); EX1024 ¶127. Other researchers obtained similar results. *E.g.*, EX1055 at 2269-70 (The “benefit of using CoFeB is multifold,” including “a higher TMR value.”); EX1056 ¶¶39 (When the “ferromagnetic layer” is “comprised of a CoFeB alloy,” it “exhibits a larger TMR ratio.”), 78, 103-04, Fig. 7; EX1024 ¶¶127, 129. Such a “combination of familiar elements according to known methods is likely to be obvious when it does no more than yield predictable results.” *KSR Int’l v. Teleflex*, 550 U.S. 398, 416 (2007).

One of skill would have looked to Sunai’s teachings to improve Bowen’s method of manufacturing its MTJ because both Bowen and Sunai focused on fabricating thin-film structures to improve TMR of magnetoresistive devices, a problem to which the ’167 Patent was directed. EX1026 at Abstract, 1655; EX1030 at Abstract, ¶¶1, 10; EX1013 at Abstract, 1:27-2:26. Both were directed to improving MRAM memory performance, as was the ’167 Patent. EX1026 at 1655; EX1030 at Figs. 4-5, ¶¶1, 4, 37-40; EX1013 at 2:54-57; EX1024 ¶126. Both formed ferromagnetic alloy electrodes. EX1026 at Abstract, 1655; EX1030 ¶¶24, 35;

EX1024 ¶126. Because forming electrodes with CoFeB alloys in MTJs was known and had been successfully done, one of skill would have found it to be a straightforward, predictable, and desirable improvement to Bowen's TMR. EX1024 ¶135; EX1030 ¶¶24-29; EX1055 at 2269-70; EX1056 ¶¶39, 78.

Alternatively, this limitation is also obvious over Bowen in view of Parkin. EX1024 ¶¶131-36. Parkin taught forming an “amorphous ferromagnetic layer 175” that “may be comprised of 75 Å thick $(\text{Co}_{73}\text{Fe}_{27})_{74}\text{B}_{26}$ ” as shown in Fig. 3A below:



EX1062 at Fig. 3A (annotated), 17:42-44; *see also id.* at 19:16-17; EX1024 ¶131. Parkin taught that this “layer is formed by magnetron sputtering in a pure argon plasma where a target of composition $(\text{Co}_{70}\text{Fe}_{30})_{80}\text{B}_{20}$ is used.” EX1062 at 17:44-46. One of skill knew that CoFeB would be deposited as an amorphous layer. EX1062

at 17:40-50 (deposition of “amorphous ferromagnetic layer 175”); EX1030 ¶¶24-28; EX1055 at Abstract; EX1056 at Abstract; EX1024 ¶¶130-31.

As explained for Bowen and Sunai, one of skill would have been motivated to replace either or both of Bowen’s electrodes with CoFeB to increase TMR and lower H_f and H_c . EX1055 at 2270; EX1056 ¶¶67-68; EX1035 at 3274; EX1024 ¶132; *KSR*, 550 U.S. at 416. Parkin itself teaches that the top and bottom electrodes in Figure 3A may be “inverted.” EX1062 at 17:7-10.

One of skill would have found it obvious to use Parkin’s CoFeB layer in place of Bowen’s electrodes to increase TMR. EX1062 at 18:49-51 (“[V]ery high TMR values are unexpectedly found for MTJs with highly textured (100) MgO tunnel barriers but with nominally amorphous storage layers.”), 18:63-19:10 (“The TMR of the device of FIG. 3A is nearly two times higher than the highest TMR ever reported in prior art devices using conventional alumina tunnel barriers... [which] is likely due to the formation of a very thin crystalline ferromagnetic interface layer” at “the boundary between the MgO tunnel barrier 120’ and the [CoFeB] layer 175.”); EX1024 ¶133.

One of skill would have also looked to Parkin’s teachings to improve Bowen’s MTJ because both Bowen and Parkin focused on fabricating MTJs with improved TMR, a problem to which the ’167 Patent was directed. EX1026 at Abstract, 1655; EX1062 at 1:18-21 (“[T]his invention relates to an improved MTJ exhibiting high

tunneling magnetoresistance...”); EX1013 at Abstract, 1:27-2:26; EX1024 ¶134. Both were directed to improving MRAM memory performance, as was the ’167 Patent. EX1026 at 1655; EX1062 at 2:65-3:1 (“[F]or non-volatile magnetic memory storage cells, high TMR values are needed for improving the performance of these devices.”); EX1013 at 2:54-57; EX1024 ¶134. Both formed ferromagnetic-alloy electrodes. EX1026 at Abstract, 1655; EX1062 at 1:18-21 (“[T]his invention relates to an improved MTJ... with one or more electrodes formed from amorphous ferromagnetic materials.”); EX1024 ¶134. Because forming electrodes with CoFeB alloys in MTJs was known and had been successfully done, one of skill would have found it to be a straightforward, predictable, and desirable improvement to TMR, H_f , and H_c in Bowen’s MTJ. EX1024 ¶135; EX1062 at 18:49-51, 18:63-19:10; EX1055 at 2269-70; EX1056 ¶¶39, 78; EX1060 at Abstract.

3. Claim 1[b]: “forming a magnesium oxide (MgO) layer over the first CoFeB layer;”

This limitation was taught or suggested by Bowen in view of Sunai or Parkin. EX1024 ¶¶137-40.

Bowen disclosed forming an MgO layer epitaxially over a lower ferromagnetic layer: “the *MgO barrier* is grown at 400 °C in order to obtain good crystallinity” above the “Fe bottom electrode.” EX1026 at 1655²; *see also id.* at

² All emphasis added unless otherwise noted.

1655-56, Fig. 1, Abstract (describing “Fe(001)/MgO(20 Å)/FeCo(001) single-crystal epitaxial junctions”); EX1024 ¶139. As explained for Claim 1[a], one of skill would have been motivated to replace Bowen’s lower, Fe electrode with a CoFeB layer. *Supra* Claim 1[a], §VI.A.2; EX1024 ¶139.

Forming an MgO layer over a ferromagnetic layer in an MTJ was conventional. EX1013 at 1:42-46; *id.* at Figs. 8(A)-8(B); EX1045 at 8 (describing “high quality... MgO tunnel barrier”); EX1024 ¶140; *supra* §II.B.

4. Claim 1[c]: “forming a second CoFeB layer that is amorphous over the MgO layer; and”

Bowen in view of Sunai or Parkin also taught or suggested this limitation. EX1024 ¶¶141-48. “[S]econd” refers to the “upper” ferromagnetic electrode formed “over the MgO layer.” EX1013 at 9:60-61; EX1024 ¶142.

Bowen disclosed forming a second, FeCo ferromagnetic layer over its MgO barrier: “FeCo/MgO/Fe epitaxial structures were grown on GaAs(001) in a combined sputtering/laser ablation system...” EX1026 at 1655; *id.* at Abstract, 1656, Fig. 1; EX1024 ¶143. Bowen described its FeCo layer as an “FeCo top electrode” in its “trilayer” MTJ structure, meaning the FeCo layer is formed on top of the MgO barrier layer. EX1026 at 1655-56; EX1024 ¶143.

One of skill would have been motivated to replace Bowen's top FeCo electrode layer with an amorphous CoFeB layer from Sunai or Parkin for the same reasons as explained for Claim 1[a]. *Supra* §VI.A.2; EX1024 ¶¶145-48.

5. Claim 1[d]: “annealing the first and second CoFeB layers and the MgO layer, wherein the first and second CoFeB layers are crystallized by the annealing, and”

This limitation was taught or suggested by Bowen in view of Sunai or Parkin. EX1024 ¶¶149-70. As explained, replacing Bowen's upper and lower ferromagnetic electrode layers with Sunai's or Parkin's CoFeB layers was obvious. *Supra* §§VI.A.2, VI.A.4 (Claims 1[a]/1[c]); EX1024 ¶¶150, 159.

Annealing ferromagnetic electrodes and MgO barrier layers was known. *E.g.*, EX1026 at 1655; EX1062 at 7:53-59; EX1041 at Abstract, 131-34; EX1045 at 1; EX1047 at 509-10; EX1052 at 4507; EX1060 at 1; EX1024 ¶¶151-57. Bowen taught or suggesting annealing at 400°C its first ferromagnetic layer (“Fe bottom electrode”) and MgO barrier layer. EX1026 at 1655 (“Optimal deposition temperatures were “400°C for the MgO, RT for FeCo top electrode, and RT plus annealing at 400°C for the Fe bottom electrode.”); *id.* (“[I]n a subsequent step, the MgO barrier is grown at 400°C in order to obtain good crystallinity.”); EX1024 ¶151.

Annealing CoFeB electrodes to crystallize them was also known. EX1024 ¶¶161-66. “[T]he CoFeB layer is confirmed to be amorphous in the as-deposited

state and begin[s] to crystallize after annealing at 250°C,” and found the magnetoresistive effect was “enhanced by the annealing” even “above 300°C.” EX1060 at 311; *see also* EX1061 at 2272-73 (“After deposition, the structures were annealed 10 min at 280 °C.... X-ray measurements... confirmed that the CoFeB films are not amorphous.”); *id.* at Abstract; EX1062 at 7:53-59; EX1024 ¶163. Researchers further found that CoFeB had a crystalline structure “[a]fter annealing at 400°C.” EX1060 at 309. It was known that TMR was “enhanced by the annealing” performed “above 300°C,” which was likely attributed to “structural change of the interface” between the CoFeB and adjoining layers. EX1060 at 311; EX1024 ¶164.

One of skill reading Bowen and Sunai would have been motivated to anneal the CoFeB layers and MgO barrier layer to increase TMR and crystallize the CoFeB layers. EX1024 ¶¶155, 162, 164-66. Bowen touted crystalline layers for optimizing the interface between the barrier and metal electrode. EX1026 at 1655-56. He attributed the “[l]arge magnetoresistance” values to his “low-temperature deposition and subsequent annealing process lead[ing] to an optimal Fe electrode in terms of crystallinity, continuity, and interface sharpness.” EX1026 at 1655. Bowen taught his annealing “optimized growth conditions result[ing] in entirely epitaxial samples of high crystalline quality with flat, sharp interfaces” with “27% TMR at 300 K which increases to 60% at 30 K.” EX1026 at 1657; EX1024 ¶156. Other researchers

agreed, finding that “nearly perfect crystalline MgO(001) films on high-quality single crystals of Fe” were effective in improving TMR. EX1045 at 1. Crystallizing improves tunneling and hence TMR, as researchers observed for crystallized Fe electrodes. EX1045 at 6 (“[T]he entire Fe layer has crystalline structure.... This indicates that the thin Fe film is basically transparent for electrons that tunnel and that diffuse transport in the Fe film does not play an important role.”).

The same phenomena, and lower H_f and H_c , has been observed for crystallized CoFeB electrodes. EX1061 at Abstract (“CoFe-based junctions ($R \times A \sim 500 \Omega \cdot \mu m^2$) have lower TMR ($\sim 35\%$) and larger H_f ($\sim 5-6$ Oe) and H_c ($\sim 12-14$ Oe) [compared to CoFeB-based junctions].”); EX1062 at 18:49-59, 19:10-17; EX1024 ¶166. Because annealing MTJs and CoFeB layers was known, predictable, and expected to increase TMR and device performance, one of skill in the art would have had a reasonable expectation of success in undertaking it. EX1024 ¶¶157, 170.

Alternatively, this limitation is also obvious over Bowen in view of Parkin. EX1024 ¶¶167-170. Parkin disclosed that annealing its MTJ increases TMR and results in its CoFeB layer containing a “very thin crystalline interface layer” of CoFeB. EX1062 at 18:49-19:26; *see also id.* at 7:53-59, 8:50-67, 17:60-18:48, Figs. 4-5; EX1024 ¶168. According to Parkin, “[t]he highly (100) textured MgO layer is likely to form an excellent template layer for the formation of a thin crystalline layer of CoFeB,” which Parkin explains is “lower in B content” because “the B diffuses

away from the interface with the MgO layer, during the thermal anneal treatments.”

EX1062 at 19:16-22; *id.* at 18:51-55; EX1024 ¶168.

One of skill would have been motivated to anneal the MTJ layers and crystallize the CoFeB electrodes by annealing because Parkin taught it improved TMR. EX1062 at 18:49-51, 18:63-19:10 (“The TMR of the device of FIG. 3A is nearly two times higher than the highest TMR ever reported in prior art devices using conventional alumina tunnel barriers... [which] is likely due to the formation of a very thin crystalline ferromagnetic interface layer” at “the boundary between the MgO tunnel barrier 120’ and the [CoFeB] layer 175.”); EX1024 ¶169; *id.* ¶¶164-66. Because annealing MTJs was routine, predictable, and expected to improve TMR, one of skill would have had a reasonable expectation of success in applying Parkin’s annealing. EX1024 ¶¶157, 170; *e.g.*, EX1062 at 7:53-59; EX1026 at 1655.

6. Claim 1[e]: “wherein the MgO layer is poly-crystalline in which a (001) crystal plane is preferentially oriented.”

Bowen taught or suggested this limitation. EX1024 ¶¶171-78. As explained for Claim 1[b], Bowen taught or suggested a single-crystal MgO barrier layer. *Supra* §VI.A.3; EX1026 at Abstract, 1655; EX1024 ¶172.

It would have been obvious to use a polycrystalline MgO with the (001) crystal plane preferentially oriented in place of Bowen’s single-crystal MgO barrier. EX1024 ¶¶173-77. Bowen explained that Moodera’s 1996 study used

“polycrystalline MgO” to obtain the same barrier height of 0.9 eV that Bowen obtained. EX1026 at 1656 (citing EX1038); EX1047 at 509, 511 nn. 5-7 (Moodera 1996 and other “[s]tudies using polycrystalline MgO indicated a low tunneling barrier of ≈ 0.9 eV (Refs. 5–7)”); KSR, 550 U.S. at 416 (“combination of familiar elements” obvious); EX1008 at 289, 299-303 (’463 File History: applicant acquiesced to Examiner rejection that Bowen taught “a poly-crystalline magnesium oxide layer in which a (001) crystal plane is preferentially oriented.”).

Like Bowen, one of skill would have understood that substituting polycrystalline MgO for single-crystal MgO would yield desirable and entirely predictable results, such as improved flexibility in substrate selection. EX1026 at 1656; EX1024 ¶175. As Bowen disclosed, a skilled artisan readily understood that polycrystalline MgO(001) could be used in place of single-crystal MgO(001) with similar results. EX1024 ¶¶174, 176, 178; EX1026 at 1656 (same barrier height with single-crystalline or polycrystalline MgO barrier); EX1062 at 9:58-10:2 (describing use of polycrystalline MgO methods to prepare “epitaxial single crystalline film structures”), 13:3-10 (describing high TMR derived from crystalline ferromagnetic electrodes above and below “the (100) textured MgO tunnel barrier”), 14:35-41 (describing preferred MgO layers, which are (100) oriented [(001) oriented] bcc), 15:15-18 (“[T]he TMR will be increased to the extent that the film structure is textured [i.e., poly-crystalline].”), 18:49-51 (“highly textured (100) MgO tunnel

barriers”). MgO(100) is the same as MgO(001) because the cubic structure is symmetrical. EX1013 at 4:39-41 (MgO (001), (100), (010) planes are the same); EX1024 ¶¶53, 181.

B. Claim 2: “The method of claim 1, wherein after the annealing, the first and second CoFeB layers are entirely crystallized.”

Claim 2 was obvious over Bowen in view of Sunai or Parkin.

As explained for Claim 1[d], these references taught or suggested that both CoFeB layers are crystallized by the annealing. *Supra* §§VI.A.5. According to IP Bridge, having the CoFeB be “entirely crystallized” after the annealing, as required by Claim 2, was also obvious over Bowen in view of Sunai or Parkin. For example, IP Bridge asserts that annealed CoFeB ferromagnetic layers, and those in which only the CoFeB immediately adjacent to the MgO barrier layer is crystallized, are “entirely crystallized”:

[E]ach of the first and second ferromagnetic material layers in the WD Accused Products is entirely crystallized after anneal.

...

Another WD patent (U.S. Patent No. 8,427,791...) describes that ... “In order to obtain a high MR ratio in amorphous CoFeB/crystalline MgO/amorphous CoFeB MTJs, an annealing step is necessary in order to produce *crystallized bcc CoFeB* (100)/MgO(100)/*crystallized bcc CoFeB* (100).” ...

As another example, in another WD patent (U.S. Patent No. 7,751,156...), it is described that ... “[d]uring anneal, ***the CoFeB immediately contacting the MgO barrier layer 717 crystallizes*** thus forming the desired CoFeX/MgO/CoFeX structure....”

EX1072 at 6-7 (quoting U.S. Patent Nos. 8,427,791 (EX1082), 7,751,156 (EX1081) (emphases in original)); *id.* (citing U.S. Patent No. 8,914,970 (EX1083)); EX1012 at 200 (Examiner in ’138 File History: prior art annealing “would allow the first and second ferromagnetic layers to be entirely crystallized based on the annealing process”).

The prior art disclosed annealed CoFeB layers with at least as much detail regarding crystallization as IP Bridge contends meets its asserted claims. For the reasons explained for Claims 1[a] and 1[c]-1[d], it would have been obvious to use CoFeB for either or both ferromagnetic layers and anneal to crystallize the CoFeB. *Supra* §§VI.A.2, VI.A.4-VI.A.5. Crystallized CoFeB layers were known in the art and were known to produce desirable and entirely predictable results. *Id.*

For example, a skilled artisan knew and understood the benefits of crystallized CoFeB layers for MTJs. EX1061 at 2272 (“Amorphous ***or nanocrystalline*** CoFeB films have been previously used in spin valves and tunnel junctions for their soft properties.”), 2274 (“Higher TMR values were obtained using thicker CoFeB bottom electrodes (50 or 60 Å, instead of the standard 40 Å).”); *see also id.* at Abstract (“The

CoFeB layer has a strong (111) texture that can be the origin of lower H_f and coercivity when compared with CoFe.”). The layers tested in Cardoso were crystallized CoFeB. EX1061 at 2273 (“X-ray measurements of bulk CoFe and CoFeB 200 Å thick films (Fig. 3) confirmed that the CoFeB films *are not amorphous*. In fact, the spectra show clearly the existence of a peak around 45.3° corresponding to a *strong texture enhancement upon annealing*.”).

Similarly, Parkin disclosed that “[t]he simple cubic crystalline MgO layer thus provides a template for the formation of a thin crystalline ferromagnetic layer which has the bcc structure of CoFe and is oriented in the same (100) direction as the MgO layer.” EX1062 at 18:55-59. Just like Western Digital’s ’156 Patent relied upon by IP Bridge to assert infringement, EX1072 at 6-7 (citing EX1081), Parkin disclosed that “[c]ross-section transmission electron microscopy reveals that a portion of the storage layer 175 adjacent to the MgO tunnel barrier 120’ has crystallized and is, moreover, textured in the same orientation as the crystalline MgO tunnel barrier.” EX1062 at 18:51-55. Indeed, Parkin disclosed that “[t]he TMR of these devices was found to increase substantially on *annealing* as shown in FIG. 5.” *Id.* at 18:47-48, Fig. 5. Thus, according to IP Bridge’s contention that annealing produces “entirely crystallized” CoFeB layers and that crystallized layers of CoFeB immediately adjacent to an MgO barrier layer produces “entirely crystallized” CoFeB layers, EX1072 at 6-7, “entirely crystallized” CoFeB layers were known to be successfully

used with MgO tunnel barriers such that their use with Bowen in view of Sunai or Parkin would have been obvious.

Thus, according to IP Bridge, CoFeB layers that are entirely crystallized after annealing were known and predictable. *E.g.*, EX1061 at 2272-74; EX1062 at 18:47-59, Fig. 5; *KSR*, 550 U.S. at 416 (“combination of familiar elements” is obvious).

C. Claim 3: “The method of claim 1, wherein after the annealing, each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented.”

Claim 3 was obvious over Bowen in view of Sunai or Parkin. *Supra* §VI.A (Claim 1); EX1024 ¶179-82.

Bowen disclosed an “MgO(001)” tunnel barrier layer. EX1026 at 1655; EX1024 ¶180. One of skill would have understood that in annealing Bowen’s MgO(001) MTJ with CoFeB layers from Sunai or Parkin, the “MgO layer... provides a template for the formation of a thin crystalline ferromagnetic layer which... is oriented in the *same (100) direction* as the MgO layer.” EX1062 at 18:55-59; *id.* at 19:17-22; EX1024 ¶181. MgO(100) is the same as MgO(001) because the cubic structure is symmetrical. EX1024 ¶181. Thus, it was understood that annealing produced CoFeB layers having a (001) crystal plane that is preferentially oriented. EX1024 ¶181

Further, annealing Bowen’s MTJ with CoFeB layers would have resulted in polycrystalline CoFeB layers. EX1024 ¶182. Annealing CoFeB electrodes was

known to produce polycrystalline CoFeB, as evidenced by Cardoso. EX1061 at 2273 (“X-ray measurements of bulk CoFe and CoFeB 200 Å thick films (Fig. 3) confirmed that the CoFeB films *are not amorphous*. In fact, the spectra show clearly the existence of a peak around 45.3 ° corresponding to a *strong texture enhancement upon annealing*.”). One of skill understood that Cardoso’s “strong texture enhancement upon annealing” meant that the CoFeB was “polycrystalline.” EX1062 at 14:46-50, 15:47-49; EX1024 ¶182.

D. Claim 4

Claim 4 was obvious over Bowen in view of Sunai or Parkin.

1. Claim 4[preamble]: “The method of claim 1, wherein,”

Supra Claim 1, §VI.A.

2. Claim 4[a]: “after the annealing the first and second CoFeB layers are entirely crystallized, and”

Supra Claim 2, §VI.B.

3. Claim 4[b]: “each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented.”

Supra Claim 3, §VI.C.

- E. Claim 5: “The method of claim 1, wherein after the annealing, each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented and each of the first and second CoFeB layers includes a BCC (body-centered cubic) structure.”**

Claim 5 was obvious over Bowen in view of Sunai or Parkin. *Supra* §VI.A (Claim 1); EX1024 ¶¶183-85.

As explained, Bowen in view of Sunai or Parkin taught or suggested both CoFeB layers are polycrystalline and (001)-preferentially-oriented after annealing. *Supra* §VI.C (Claim 3); EX1024 ¶184. Additionally, both CoFeB layers would have a BCC structure. EX1024 ¶185. One of skill would have understood that in annealing Bowen’s MgO(001) MTJ with CoFeB layers, the “MgO layer... provides a template for the formation of a thin crystalline ferromagnetic layer which has the *bcc structure* of CoFe...” EX1062 at 18:55-59; *id.* at 19:17-22; EX1026 at 1655; EX1024 ¶185.

F. Claim 6

Claim 6 was obvious over Bowen in view of Sunai or Parkin.

- 1. Claim 6[preamble]: “The method of claim 1, wherein”**

Supra Claim 1, §VI.A.

- 2. Claim 6[a]: “after the annealing, the first and second CoFeB layers are entirely crystallized, and”**

Supra Claim 2, §VI.B.

3. **Claim 6[b]: “each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented and each of the first and second CoFeB layers includes a BCC (body-centered cubic) structure.”**

Supra Claim 5, §VI.E.

- G. **Claim 7: “The method of claim 1, wherein in the forming the MgO layer, the MgO layer is formed as a MgO_x ($0 < x < 1$) layer.”**

Claim 7 was obvious over Bowen in view of Sunai or Parkin and optionally Soukup. EX1024 ¶¶186-207.

Bowen taught or suggested forming an MgO layer. *Supra* §VI.A.3 (Claim 1[b]); EX1024 ¶¶139, 187. Bowen’s layer was MgO_x ($0 < x < 1$), a mathematical notation indicating less than a one-to-one stoichiometric ratio of oxygen to magnesium (i.e., oxygen vacancy defects) in the MgO layer. EX1026 at 1656; EX1024 ¶¶187-89; EX1013 at 6:31-33, 7:5-6; EX1002 at 168 (Applicant: “ MgO_x ($0 < x < 1$)” means the MgO “crystals have oxygen vacancy defects.”); EX1008 (’463 File History) at 198 (Examiner: “It is inherent that the magnesium oxide layer has some level of oxygen vacancy defects.” (bold removed)); *supra* §II.E.

MgO with oxygen vacancy defects was inherently MgO_x where $0 < x < 1$ because x has to be greater than 0 to constitute MgO and less than 1 to constitute nonstoichiometric MgO with oxygen vacancies. EX1024 ¶¶187-89; EX1008 at 198; EX1037 at 3, Fig. 1 (oxygen vacancy defects $0 < x < 1$ were known); EX1041 at 132 (“understoichiometric MgO_x ($x < 1$)”). Bowen observed a lower MgO tunnel

“barrier height at $\phi = 0.9$ eV,” and attributed it to oxygen vacancy defects, or “stoichiometric” inhomogeneities, in the MgO barrier layer. EX1026 at 1656; EX1024 ¶190.

A skilled artisan would have expected the same lower barrier height and higher TMR to result from oxygen vacancy defects in polycrystalline MgO barriers because there is no reason they would be different in this respect. Indeed, Bowen recognized that the 0.9 eV barrier height for his single-crystal MgO barrier layer had also been observed by other researchers using “poly-crystalline MgO” barriers. EX1026 at 1656; EX1024 ¶¶174, 176.

Alternatively, Bowen in view of Soukup also taught or suggested an MgO barrier layer with oxygen vacancy defects. EX1024 ¶¶191-206. Soukup studied “the effect of nonstoichiometry on the device characteristics,” EX1028 at 3232, and experimented with fabricating devices with different levels of nonstoichiometry, EX1028 at Abstract, 3232-33, Table I; EX1024 ¶191. Soukup varied the level of oxygen vacancy defects, adjusting the amount of oxygen present when depositing the MgO. EX1028 at Abstract, 3229, 3232, 3236; EX1024 ¶192. One of skill would have understood that Bowen’s and/or Soukup’s stoichiometric inhomogeneities in the MgO barrier referred to oxygen vacancy defects in the MgO crystal. EX1013 at 6:31-33, 7:5-13; EX1042 at 162; EX1024 ¶¶190-91; *supra* §II.E.

One of skill would also have been motivated to apply Soukup's teachings about varying the level of oxygen vacancy defects to Bowen's MgO MTJ to improve tunneling current and TMR. EX1031 at Fig. 1; EX1024 ¶193; *supra* §II.C.

While not a claim requirement, the '167 Patent disclosed that "[w]hen there are oxygen vacancy defects, the potential barrier height of the MgO tunnel barrier is thought to decrease" to a range of "0.2 to 0.5 eV." EX1013 at 7:6-9. Bowen in view of Soukup taught or suggested a tunnel barrier height in this range. EX1026 at 1656; EX1028 at Abstract, 3231-32, Fig. 5, Table I; EX1024 ¶¶194-205. Soukup taught that oxygen vacancy defects had an impact on the barrier height for MgO, suggesting a higher level of oxygen vacancy defects lowered the barrier height. EX1028 at 3232; EX1024 ¶196.

One of skill would have been motivated to apply Soukup's teachings of a low barrier height for an MgO thin-film barrier to improve TMR, which was an "important parameter" for improving MRAM performance. EX1055 at 2269; *see also* EX1026 at Abstract, 1655; EX1055 at 2271; *supra* §II.B; EX1024 ¶¶197-98. The TMR equation shows lowering the resistance (barrier height) for parallel electrons (R_p) would improve TMR. EX1035 at 3273; EX1027 ¶2; EX1013 at 4:62-5:3; EX1024 ¶197. Following Butler's and Mathon's teachings that MgO barriers would achieve higher TMRs due to improved symmetry matching and facilitate parallel electron tunneling, EX1044 at 1; EX1046 at 1, one of skill in the art looking

to increase TMR of an MgO barrier would have been motivated to explore lower barrier heights to facilitate tunneling of parallel electrons, EX1024 ¶199. A skilled artisan would have looked to Soukup to improve Bowen’s MgO MTJ by introducing defects to lower the barrier height. EX1024 ¶¶199-205. Indeed, Bowen and Soukup both studied properties of MgO barriers and were focused on fabricating thin-film structures to improve tunneling devices, the problem to which the ’167 Patent was directed. EX1026 at Abstract, 1655-57; EX1028 at 3229-30; EX1013 at Abstract, 1:27-2:26; EX1024 ¶199.

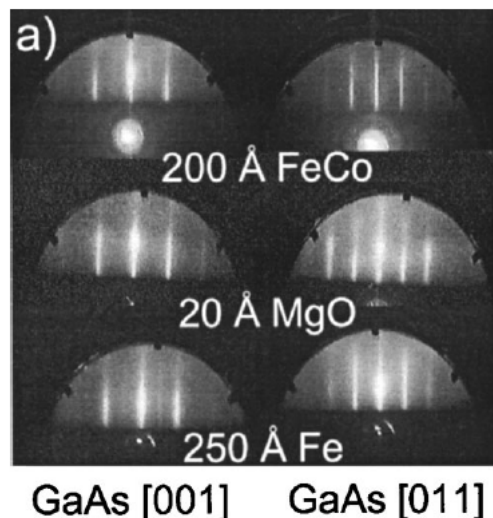
One of skill would have had a reasonable expectation of success in achieving oxygen vacancy defects in Bowen’s MTJ. EX1024 ¶199. Soukup had already demonstrated forming an MgO barrier achieving a height of 0.33 eV, EX1028 at Abstract, and that the barrier height was varied by adjusting the oxygen vacancy defects in the MgO barrier layer, EX1028 at Abstract, 3232, 3236; EX1024 ¶199. One of skill would have predictably followed this trail. *Id.*

H. Claim 8: “The method of claim 1, wherein in the forming the MgO layer, the value of x in MgO_x for the MgO layer is greater than 0 and less than 1.”

The mathematical notation “ $0 < x < 1$ ” is equivalent to “the value of x ... is greater than 0 and less than 1.” EX1024 ¶207. Claim 8 was obvious for the same reasons as Claim 7. *Supra* §VI.G; EX1024 ¶207.

I. Claim 9: “The method of claim 1, wherein in the forming the MgO layer, the MgO layer is formed directly on the first CoFeB layer.”

Claim 9 was obvious over Bowen in view of Sunai or Parkin. EX1024 ¶¶208-10. As explained and shown at right, Bowen taught that growing an MgO(001) tunnel barrier layer directly on the “Fe bottom electrode,” that one of skill would have replaced with a CoFeB layer. EX1026 at 1655; *id.* at 1655-56, Fig. 1



(excerpted); *supra* §§VI.A.2-VI.A.3 (Claims 1[a]-1[b]); EX1024 ¶¶209-10.

J. Claim 10

Claim 10 was obvious over Bowen in view of Sunai or Parkin.

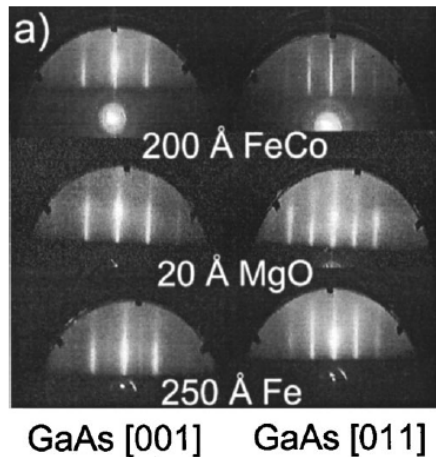
1. Claim 10[preamble]: “The method of claim 1, wherein:”

Supra Claim 1, §VI.A; EX1024 ¶211.

2. Claim 10[a]: “in the forming the MgO layer, the MgO layer is formed directly on the first CoFeB layer, and”

Supra Claim 9, §VI.I; EX1024 ¶212.

3. **Claim 10[b]: “in the forming the second CoFeB layer, the second CoFeB layer is formed directly on the MgO layer.”**



As explained and shown at left, this limitation was obvious. *Supra* §VI.A.4 (Claim 1[c]); EX1024 ¶¶213-14. Bowen’s “FeCo top electrode”—that would have been replaced with a CoFeB layer—is formed directly on the MgO barrier layer. EX1026 at 1655-56, Fig. 1 (excerpted); EX1024 ¶¶213-14.

K. Claim 11

Claim 11 was obvious over Bowen in view of Sunai or Parkin.

1. **Claim 11[preamble]: “A method of manufacturing a magnetic tunnel junction (MTJ) device, comprising:”**

Supra Claim 1[preamble], §VI.A.1; EX1024 ¶215.

2. **Claim 11[a]: “forming a first ferromagnetic layer including a first CoFeB layer that is amorphous;”**

As explained for Claim 1[a], this limitation is obvious, and a CoFeB layer is a ferromagnetic layer. *Supra* §§VI.A.2, II.D.1; EX1030 ¶33; EX1013 at 9:16 (“ferromagnetic alloy, such as CoFeB layers”); EX1024 ¶216.

3. **Claim 11[b]: “forming a barrier layer including a magnesium oxide (MgO) layer to have a poly-crystalline state in which a (001) crystal plane is preferentially oriented over the first ferromagnetic layer;”**

Bowen teaches an “MgO barrier” layer. EX1026 at 1655, Fig. 1; *supra* Claims 1[b]/1[e], §§VI.A.3, VI.A.6; EX1024 ¶217.

4. **Claim 11[c]: “forming a second ferromagnetic layer including a second CoFeB layer that is amorphous over the barrier layer; and”**

Supra Claim 1[c], §VI.A.4; EX1024 ¶218. CoFeB is a ferromagnetic layer.
Supra Claim 11[a], §VI.K.2.

5. **Claim 11[d]: “annealing the first and second ferromagnetic layers and the barrier layer, to crystallize the first and second CoFeB layers.”**

Supra Claim 1[d], §VI.A.5; EX1024 ¶219.

- L. **Claim 12: “The method of claim 11, wherein after the annealing, the first and second CoFeB layers are entirely crystallized.”**

Claim 12 was obvious over Bowen in view of Sunai or Parkin. *Supra* Claims 2, 11, §§VI.B, VI.K.

M. Claim 13

Claim 13 was obvious over Bowen in view of Sunai or Parkin.

1. **Claim 13[preamble]: “The method of claim 11, wherein”**

Supra Claim 11, §VI.K.

2. **Claim 13[a]: “after the annealing, the first and second CoFeB layers are entirely crystallized, and”**

Supra Claim 2, §VI.B.

3. **Claim 13[b]: “each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented and each of the first and second CoFeB layers includes a BCC (body-centered cubic) structure.”**

Supra Claim 5, §VI.E.

- N. **Claim 14: “The method of claim 11, wherein in the forming the barrier layer, the MgO layer is formed as a MgO_x ($0 < x < 1$) layer.”**

Claim 14 was obvious Bowen in view of Sunai or Parkin and optionally Soukup. *Supra* Claims 7, 11, §§VI.G, VI.K; EX1024 ¶220.

O. Claim 15

Claim 15 was obvious over Bowen in view of Sunai or Parkin.

1. **Claim 15[preamble]: “The method of claim 11, wherein:”**

Supra Claim 11, §VI.K; EX1024 ¶221.

2. **Claim 15[a]: “in the forming the barrier layer, the barrier layer is formed directly on the first ferromagnetic layer, and”**

Bowen teaches an “MgO barrier” layer. EX1026 at 1655, Fig. 1; *supra* Claim 9, §VI.I; EX1024 ¶222.

3. **Claim 15[b]: “in the forming the second ferromagnetic layer, the second ferromagnetic layer is formed directly on the barrier layer.”**

Supra Claim 10[b], §VI.J.3; EX1024 ¶223.

VII. GROUND 2: CLAIMS 1-15 ARE OBVIOUS OVER NAGAHAMA IN VIEW SUNAI OR PARKIN (AND SOUKUP)

Nagahama disclosed a series of MTJ embodiments focused on forming a basic structure of a ferromagnetic layer on top of an insulating layer on top of an ultrathin ferromagnetic layer on top of an underlayer. *E.g.*, EX1027 at 10 (claim 1), ¶¶73-74 (describing same arrangement with an MgO barrier layer); EX1024 ¶¶232, 240. Additionally, Nagahama disclosed that “[t]he present invention relates to... a tunnel magnetoresistive element whose crystal orientation is set to the (001) direction of a body-centered cubic lattice, a face-centered cubic lattice, or a tetragonal lattice.” EX1027 ¶1; EX1024 ¶291. Manufacturing an MTJ according to the methods described in the claims would have been obvious to a skilled artisan in view of Nagahama’s teachings, as discussed below.

A. Claim 1

Claim 1 would have been obvious over Nagahama in view of Sunai or Parkin.

1. Claim 1[preamble]: “A method of manufacturing a magnetic tunnel junction (MTJ) device, comprising:”

To the extent limiting, Nagahama taught or suggested a method of manufacturing a magnetic tunnel junction (MTJ) device as claimed. EX1027 ¶73 (“magnetoresistive element was prepared”); *id.* ¶¶74-76, Abstract, Claim 1, Figs. 3, 17; EX1024 ¶¶225-36; *see also infra* §§VII.A.2-VII.A.6.

Nagahama taught a manufacturing method for its MTJ, explaining:

A magnetoresistive element was prepared which includes a (001)-highly-oriented lower ferromagnetic electrode layer, a (001)-highly-oriented MgO barrier layer, and a (001)-highly-oriented upper ferromagnetic electrode layer on the MgO double underlayer of the present invention.

EX1027 ¶73; EX1024 ¶¶227, 232; *id.* ¶¶228-34. A “larger tunnel magnetoresistive effect of more than 90% was produced” by annealing (“heat treatment”) the MTJ. EX1027 ¶74; EX1024 ¶232. Nagahama provided further details on a “procedure” and “method of manufacturing” the MTJs in Figures 12-13. EX1027 ¶¶57, 62; *see also id.* ¶¶28, 78; EX1024 ¶¶228-30. To the extent IP Bridge asserts the Figures 12-13 disclosures do not apply to Nagahama’s paragraphs 73-74 embodiment, it would have been obvious to one of skill to use these deposition techniques with a reasonable expectation of success because they were conventional and all applied to Nagahama’s “third group” of MTJs. EX1027 ¶55; EX1024 ¶¶229-30.

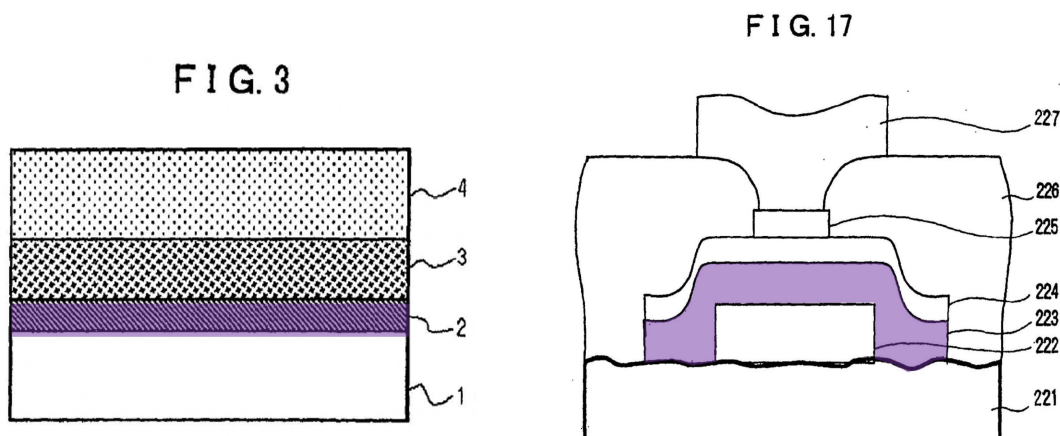
As explained, manufacturing MTJs was known. *Supra* §VI.A.1.

2. Claim 1[a]: “forming a first CoFeB layer that is amorphous;”

This limitation was taught or suggested by Nagahama in view of Sunai or Parkin. EX1024 ¶¶237-54. As explained in Ground 1, “first” refers to the lower electrode, and any CoFeB alloy satisfies this limitation. *Supra* §VI.A.2.

Nagahama “prepared” a “**lower ferromagnetic electrode**” of its “high-quality tunnel magnetoresistive element,” as shown by items 2 and 223 in Figures 3

and 17 below. EX1027 ¶¶73, 75-76, Fig. 17; *see also id.* ¶22, Fig. 3, ¶62 (“Deposit the Fe 213 (20 nm) by sputtering.”); EX1024 ¶¶242-43. Nagahama disclosed various examples of this “lower ferromagnetic electrode” material, including Fe, Co, Ni, or an alloy of these metals. *E.g.*, EX1027 ¶¶28, 31, 61, 68, Fig. 17 (reference numeral 223).



EX1027 at Figs. 3 (excerpted), 17 (both annotated).

As explained, forming ferromagnetic layers was known and conventional. *Supra* §VI.A.2; EX1024 ¶244.

One of skill would have found it obvious to replace Nagahama’s lower ferromagnetic electrode material with amorphous CoFeB as taught by Sunai increase the TMR and lower the H_f and H_c . EX1030 ¶¶24-29; EX1024 ¶¶245-50. Cobalt and iron were known ferromagnetic materials. EX1030 ¶33; EX1026 at 1655; EX1024 ¶246. As explained in Ground 1, it was known that CoFeB would be formed as an amorphous layer. *Supra* §VI.A.2 (Claim 1[a]); EX1024 ¶250.

One of skill would have been motivated to replace either or both of Nagahama's upper and lower electrodes with CoFeB to increase TMR and lower H_f and H_c . EX1030 ¶¶24-29; EX1055 at 2270 (“[I]t is natural to replace both the free and pinned layers to CoFeB to further increase the TMR value.”); EX1056 ¶¶67-68; EX1035 at 3274; EX1061 at Abstract; EX1024 ¶¶245, 247. Such a “combination of familiar elements” is obvious. *KSR*, 550 U.S. at 416. Nagahama sought to “obtain a high magnetoresistive effect” in forming its MgO MTJ, EX1027 ¶6, and understood that the properties of the ferromagnetic electrodes impacted TMR, EX1027 ¶23; EX1024 ¶247. As explained in Ground 1, a skilled artisan knew that using CoFeB electrodes both improved TMR while lowering H_f and H_c . *Supra* §VI.A.2 (Claim 1[a]); EX1024 ¶¶247, 249.

One of skill would have looked to Sunai's teachings to improve Nagahama's method of manufacturing its MTJ because both Nagahama and Sunai focused on fabricating thin-film structures to improve TMR, a problem to which the '167 Patent was directed. EX1027 ¶¶6, 15; EX1030 at Abstract, ¶¶1, 10; EX1013 at Abstract, 1:27-2:26; EX1024 ¶248. Both were directed to improving MRAM memory performance, as was the '167 Patent. EX1027 ¶¶3, 49; EX1030 at Figs. 4-5, ¶¶1, 4, 37-40; EX1013 at 2:54-57; EX1024 ¶248. Both formed the same MgO barrier layer and similar ferromagnetic alloy electrodes. EX1027 ¶¶6, 73; EX1030 ¶¶24, 35; EX1024 ¶248. Because forming electrodes with CoFeB alloys in MTJs was known

and had successfully been done, one of skill would have found it to be a straightforward, predictable, and desirable improvement to Nagahama's MTJ to increase TMR. EX1024 ¶249; EX1030 ¶¶24-29; EX1055 at 2269-70; EX1056 ¶¶39, 78.

Alternatively, this limitation is also obvious over Nagahama in view of Parkin. EX1024 ¶¶251-54. As explained in Ground 1, Parkin taught forming an “amorphous ferromagnetic layer 175” that “may be comprised of 75 Å thick (Co₇₃Fe₂₇)₇₄B₂₆.” EX1062 at 17:42-46, 19:16-17, Fig. 3A; *supra* §VI.A.2 (Claim 1[a]). It was known that CoFeB would be deposited as an amorphous layer. EX1062 at 17:40-50 (deposition of “amorphous ferromagnetic layer 175”); EX1030 ¶¶24-28; EX1055 at Abstract; EX1056 at Abstract; EX1024 ¶251.

As explained, one of skill would have been motivated to replace either or both of Nagahama's electrodes with CoFeB to increase TMR. *Supra* §VI.A.2 (Claim 1[a]); EX1062 at 17:7-10 (Parkin: Fig. 3A top and bottom electrodes may be “inverted.”).

One of skill would have also looked to Parkin's teachings to improve Nagahama's MTJ because both Nagahama and Parkin focused on fabricating MTJs with improved TMR, a problem to which the '167 Patent was directed. EX1027 ¶¶6, 15; EX1062 at 1:18-21; EX1013 at Abstract, 1:27-2:26; EX1024 ¶253. Both were directed to improving MRAM memory performance, as was the '167 Patent.

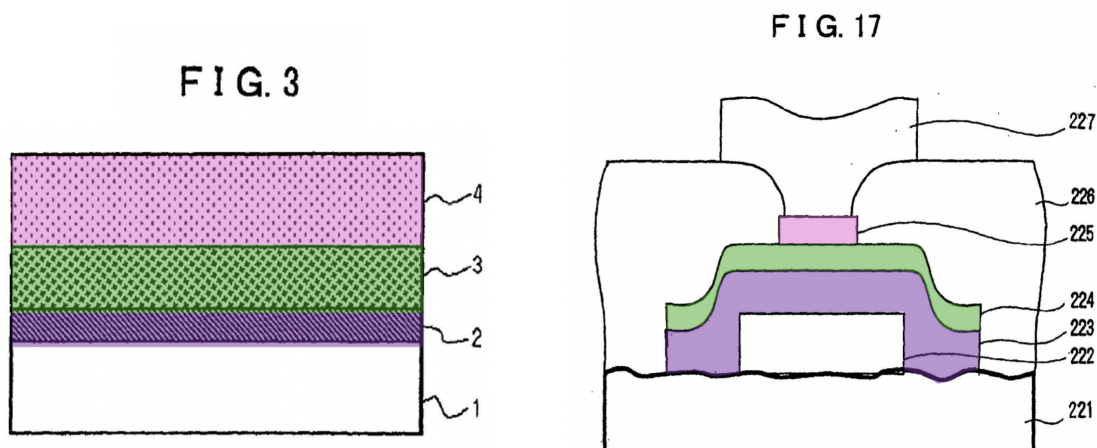
EX1027 ¶¶3, 49; EX1062 at 2:65-3:1; EX1013 at 2:54-57; EX1024 ¶253. Both formed the same MgO barrier layer and similar ferromagnetic-alloy electrodes. EX1027 ¶¶6, 73; EX1062 at 1:18-21; EX1024 ¶253. Because forming electrodes with CoFeB alloys in MTJs was known and had successfully been done, one of skill would have found it to be a straightforward, predictable, and desirable improvement to TMR, H_f , and H_c in Nagahama's MTJ. EX1024 ¶254; EX1062 at 18:49-51, 18:63-19:10; EX1055 at 2269-70; EX1056 ¶¶39, 78; EX1060 at Abstract.

3. Claim 1[b]: “forming a magnesium oxide (MgO) layer over the first CoFeB layer;”

This limitation was taught or suggested by Nagahama in view of Sunai or Parkin. EX1024 ¶¶255-61.

In its paragraphs 73-74 embodiment, Nagahama described forming an MTJ with an MgO layer over a lower ferromagnetic layer: “magnetoresistive element was prepared which includes... a (001)-highly-oriented MgO barrier layer.” EX1027 ¶¶73-74; *id.* ¶¶75-76, Fig. 17; *see also id.* ¶¶21-22, Fig. 3 (describing same arrangement for Fig. 3), ¶28 (An “insulating [barrier] layer” is “deposited on the Fe layer.”); EX1024 ¶¶257-58.

Figures 3 and 17 depict this arrangement: 2 and 223 represent a **lower ferromagnetic layer**; 3 and 224 represent a **barrier layer**; and 4 and 225 represent an **upper ferromagnetic layer**. EX1027 ¶¶21-22, 75-76; EX1024 ¶260.



EX1027 at Figs. 3 (excerpted), 17 (both annotated). As explained for Claim 1[a], one of skill would have been motivated to replace Nagahama’s lower ferromagnetic layer with a CoFeB layer. *Supra* §VII.A.2; EX1024 ¶259.

Forming an MgO layer over a ferromagnetic layer in an MTJ was conventional. *Supra* §VI.A.3 (Ground 1); EX1024 ¶261.

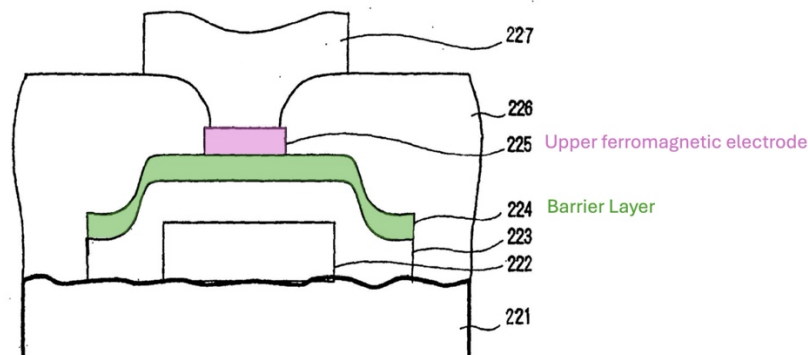
4. Claim 1[c]: “forming a second CoFeB layer that is amorphous over the MgO layer; and”

Nagahama in view of Sunai or Parkin also taught or suggested this limitation. EX1024 ¶¶262-69. Again, “second” refers to the “upper” ferromagnetic electrode. *Supra* §VI.A.4.

Nagahama taught or suggested forming an “**upper ferromagnetic electrode**” over its MgO barrier layer. EX1027 ¶¶73, 75-76; *see also id.* ¶22, Fig. 3, ¶62 (“Form the upper electrode”); EX1024 ¶¶264-65. This is shown in Figures 3 and 17, where

3 and 224 represent a **barrier layer** and 4 and 225 represent an **upper ferromagnetic layer**. EX1027 ¶¶21-22, 75-76; EX1024 ¶266.

FIG. 17



EX1027 at Fig. 17 (annotated). Nagahama disclosed various examples of this “upper ferromagnetic electrode” material, including Fe, Co, Ni, or an alloy of these metals. *E.g.*, EX1027 ¶¶28, 31, 61, 68, Fig. 17 (reference numeral 225).

One of skill would have been motivated to replace Nagahama’s upper ferromagnetic electrode layer with an amorphous CoFeB layer from Sunai or Parkin for the same reasons as explained for Claim 1[a]. *Supra* §VII.A.2; EX1024 ¶¶268-69.

5. Claim 1[d]: “annealing the first and second CoFeB layers and the MgO layer, wherein the first and second CoFeB layers are crystallized by the annealing, and”

This limitation was taught or suggested by Nagahama in view of Sunai or Parkin. EX1024 ¶¶270-80. As explained, it would have been obvious to replace

Nagahama’s upper and lower ferromagnetic electrode layers with Sunai’s or Parkin’s CoFeB layers. *Supra* §§VII.A.2, VII.A.4 (Claims 1[a]/1[c]); EX1024 ¶¶271, 276.

As explained in Ground 1, annealing ferromagnetic electrodes and MgO barrier layers, and crystallizing CoFeB electrodes by annealing, were known. *Supra* §VI.A.5 (Claim 1[d]); EX1024 ¶¶273, 278-80. Indeed, Nagahama taught that annealing (“heat treatment”) netted “a larger tunnel magnetoresistive effect of more than 90%.” EX1027 ¶74; EX1024 ¶274. For the reasons explained in Ground 1, one of skill would have been motivated to anneal the combination of Nagahama and Sunai or Parkin to crystallize the CoFeB layers, improve TMR, and lower H_f and H_c . *Id.*; *supra* §VI.A.5 (Claim 1[d]).

6. Claim 1[e]: “wherein the MgO layer is poly-crystalline in which a (001) crystal plane is preferentially oriented.”

Nagahama taught or suggested this limitation. *Supra* §VII.A.3 (Claim 1[b]); EX1024 ¶¶281-83.

Nagahama taught a polycrystalline “(001)-highly-oriented MgO barrier layer” in his MTJ. EX1027 ¶73; EX1024 ¶¶282-83. Because single-crystal layers have the same orientation throughout the crystalline lattice, “highly-oriented” is a term that describes the predominant orientation of a polycrystalline layer containing many crystals. EX1024 ¶283; EX1040 at 2842 (MgO “polycrystalline structures” have “preferred orientation”). Nagahama’s description, EX1027 ¶73, confirms the MgO

barrier was polycrystalline and preferentially oriented in the (001) plane, EX1024 ¶¶282-83.

B. Claim 2: “The method of claim 1, wherein after the annealing, the first and second CoFeB layers are entirely crystallized.”

Claim 2 was obvious over Nagahama in view of Sunai or Parkin.

As explained for Claim 1[d], these references taught or suggested the first and second CoFeB layers are crystallized by the annealing. *Supra* §VII.A.5. Having CoFeB layers be “entirely crystallized” after annealing was also obvious over these references, according to IP Bridge and as explained in Ground 1. *Supra* §VI.B (Claim 2). Nagahama taught annealing (“heat treatment”) of the MTJ. EX1027 ¶74. As explained, the prior art disclosed annealed CoFeB layers with at least as much detail regarding crystallization as IP Bridge contends meets its claims. *Supra* §VI.B (Claim 2 in Ground 1). Because CoFeB layers that are entirely crystallized after annealing was known and predictable according to IP Bridge, this claim is obvious. *Id.*; *KSR*, 550 U.S. at 416.

C. Claim 3: “The method of claim 1, wherein after the annealing, each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented.”

Claim 3 was obvious over Nagahama in view of Sunai or Parkin. *Supra* §VII.A (Claim 1); EX1024 ¶¶284-87.

Nagahama disclosed “a (001)-highly-oriented MgO barrier layer.” EX1027 ¶¶73-74; EX1024 ¶285. As explained in Ground 1, it was understood that annealing

an MgO(001) MTJ with CoFeB layers resulted in CoFeB layers having a (001) crystal plane that is preferentially oriented. *Supra* §VI.C (Claim 3); EX1062 at 18:55-59, 19:17-22; EX1024 ¶285-86. As also explained, annealing CoFeB electrodes was known to produce polycrystalline CoFeB. *Supra* §VI.C; EX1061 at 2273; EX1062 at 14:46-50, 15:47-49; EX1024 ¶287. Thus, one of skill would have known that annealing Nagahama's MgO(001) MTJ with CoFeB layers would predictably result in forming polycrystalline CoFeB(001) layers. EX1024 ¶287.

D. Claim 4

Claim 4 was obvious over Nagahama in view of Sunai or Parkin.

1. Claim 4[preamble]: “The method of claim 1, wherein”

Supra Claim 1, §VII.A.

2. Claim 4[a]: “after the annealing, the first and second CoFeB layers are entirely crystallized, and”

Supra Claim 2, §VII.B.

3. Claim 4[b]: “each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented.”

Supra Claim 3, §VII.C.

- E. Claim 5: “The method of claim 1, wherein after the annealing, each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented and each of the first and second CoFeB layers includes a BCC (body-centered cubic) structure.”**

Claim 5 was obvious over Nagahama in view of Sunai or Parkin. *Supra* §VII.A (Claim 1); EX1024 ¶¶288-91.

As explained, Nagahama in view of Sunai or Parkin taught or suggested both the first and second CoFeB layers are poly-crystalline and (001) preferentially oriented after annealing. *Supra* Claim 3, §VII.C; EX1024 ¶289. Additionally, both layers would be BCC structured. EX1024 ¶¶290-91. Nagahama taught that its MTJ included “a ferromagnetic electrode layer... oriented in the (001) direction of a body-centered cubic lattice....” EX1027 ¶18 (item [20]); EX1024 ¶291. To the extent that IP Bridge asserts this disclosure is inapplicable to the paragraphs 73-74 embodiment, it would have been obvious to generate Nagahama’s bcc-structured ferromagnetic layers because Nagahama himself taught that bcc layers were desirable to achieve “a large magnetoresistive effect.” EX1027 ¶¶18 (item [20]), 81 (item [F]); *id.* at 11 (claim 20); EX1024 ¶291. Further, annealing would have predictably resulted in CoFeB layers having a BCC structure. *Supra* §VI.E (Claim 5); EX1027 ¶¶73-74; EX1024 ¶290.

- F. Claim 6**

Claim 6 was obvious over Nagahama in view of Sunai or Parkin.

1. Claim 6[preamble]: “The method of claim 1, wherein”

Supra Claim 1, §VII.A.

2. Claim 6[a]: “after the annealing, the first and second CoFeB layers are entirely crystallized, and”

Supra Claim 2, §VII.B.

3. Claim 6[b]: “each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented and each of the first and second CoFeB layers includes a BCC (body-centered cubic) structure.”

Supra Claim 5, §VII.E.

G. Claim 7: “The method of claim 1, wherein in the forming the MgO layer, the MgO layer is formed as a MgO_x ($0 < x < 1$) layer.”

Claim 7 was obvious over Nagahama in view of Sunai or Parkin and optionally Soukup. EX1024 ¶¶292-310.

Nagahama taught or suggested forming an MgO layer. *Supra* §VII.A.3 (Claim 1[b]); EX1024 ¶¶257-58, 293. Nagahama’s MgO layer inherently satisfied MgO_x ($0 < x < 1$), a mathematical notation indicating MgO oxygen vacancy defects. EX1024 ¶293; EX1013 at 6:31-33, 7:5-6; EX1002 at 168; EX1008 at 198; *supra* §II.E. One of skill would have understood that Nagahama’s MgO layer inherently included oxygen vacancy defects (MgO_x where $0 < x < 1$) because these defects occur in all MgO layers. EX1042 at 162 (“Oxygen vacancies are naturally present in every oxide,” including MgO.); EX1008 at 198; EX1024 ¶294; *supra* §II.E.

Alternatively, Nagahama in view of Soukup also taught or suggested an MgO barrier layer with oxygen vacancy defects. EX1024 ¶¶295-310. As explained in Ground 1, Soukup determined that increasing oxygen vacancy defects reduced tunnel barrier height, which predictably raises TMR, and did so by varying O₂ during deposition. *Supra* §VI.G (Claim 7); EX1028 at Abstract, 3229, 3232, 3236; EX1024 ¶¶295-97, 299-301. One of skill thus would have been motivated to add oxygen vacancy defects to Nagahama’s MgO MTJ to improve tunneling current and TMR. EX1024 ¶¶297, 301.

While not a claim requirement, Nagahama in view of Soukup taught or suggested forming an MgO barrier with an MgO tunnel barrier height in the disclosed range of 0.2 to 0.5 eV. EX1013 at 7:6-9; EX1024 ¶¶298-305. Nagahama taught forming an MgO MTJ. EX1027 ¶¶73-74, Abstract, Figs. 3, 17. Soukup observed a “barrier height” of “*about 0.33 eV*” for its MgO barrier. EX1028 at Abstract; *id.* at 3231-32, Fig. 5, Table I; EX1024 ¶302. As explained for Claim 7 in Ground 1, one of skill reading Soukup understood there was a relationship between oxygen vacancy defects and barrier height. *Supra* §VI.G; EX1024 ¶¶299, 308.

Soukup taught that oxygen vacancy defects had an impact on the barrier height for MgO. EX1024 ¶308. Soukup suggested a “higher barrier?[] present for the devices fabricated with more oxygen present during MgO deposition, which could mean more stoichiometric oxide films” (i.e., fewer oxygen vacancy defects).

EX1028 at 3232; EX1024 ¶308. In other words, Soukup suggested a higher level of oxygen vacancy defects lowered the barrier height. *See id.* One of skill reading Soukup would understand there was an inverse relationship between oxygen vacancy defects and barrier height. EX1024 ¶299.

One of skill would have been motivated to apply Soukup’s teachings about forming an MgO thin-film barrier with a “barrier height” of “about 0.33 eV” to Nagahama’s MgO barrier. EX1028 at Abstract, 3232, 3236; EX1024 ¶305. As explained in Ground 1, TMR was an “important parameter” and of high interest for improving MRAM performance, and lowering the resistance (barrier height) for parallel electrons would improve TMR. EX1055 at 2269, 2271; EX1035 at 3273; EX1027 ¶2; EX1024 ¶300; *supra* §VI.G (Claim 7). Nagahama’s stated goal was to improve TMR in its MTJ. EX1027 ¶¶6, 15; *see also id.* ¶¶3-8; EX1024 ¶301. Nagahama sought to increase TMR by modifying properties of the MgO barrier layer. EX1027 ¶¶15-17. Indeed, Nagahama discussed prior research on increasing TMR in MgO MTJs by Mathon, Bowen, and others. EX1027 ¶¶2-14; EX1024 ¶305.

As explained, Butler and Mathon taught that MgO barriers improved TMRs due to improved symmetry facilitating tunneling of parallel electrons, and one of skill would have been motivated to explore lower barrier heights to accomplish that. EX1044 at 1; EX1046 at 1; EX1024 ¶198; *supra* §VI.G. One of skill seeking to improve Nagahama’s MTJ would have looked to Soukup’s teachings about how

defects lowered MgO barrier height. EX1024 ¶305. Indeed, both Nagahama and Soukup studied tunneling and other properties of MgO barriers and were focused on fabricating thin-film structures to improve tunneling devices, the problem to which the '167 Patent was directed. EX1027 ¶¶2-4, 13-15; EX1028 at 3229-30; EX1013 at Abstract, 1:27-2:26; EX1024 ¶305.

One of skill would have had a reasonable expectation of success in achieving oxygen vacancy defects in Nagahama's MTJ. EX1024 ¶307. Soukup had already demonstrated forming an MgO barrier achieving a height of 0.33 eV, EX1028 at Abstract, and that the barrier height was varied by adjusting the oxygen vacancy defects in the MgO barrier layer, EX1028 at Abstract, 3232, 3236; EX1024 ¶307. One of skill would have predictably followed this trail. *Id.*

This limitation was taught or suggested by Nagahama in view of Sunai or Parkin and optionally Soukup.

H. Claim 8: “The method of claim 1, wherein in the forming the MgO layer, the value of x in MgO_x for the MgO layer is greater than 0 and less than 1.”

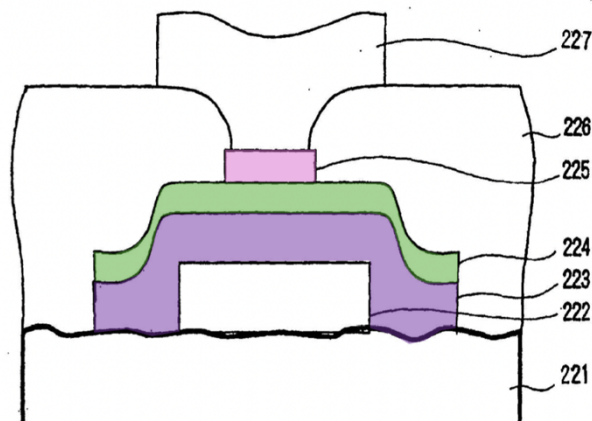
As explained in Ground 1, Claims 7-8 have equivalent requirements and Claim 8 is obvious for the same reasons as Claim 7. *Supra* §VII.G; EX1024 ¶311.

I. Claim 9: “The method of claim 1, wherein in the forming the MgO layer, the MgO layer is formed directly on the first CoFeB layer.”

Claim 9 was obvious over Nagahama in view of Sunai or Parkin. EX1024

¶¶312-13. As explained and shown at right, Nagahama taught forming its MgO **barrier layer** directly on the **lower ferromagnetic layer** that one of skill would have been motivated to replace with a CoFeB layer. EX1027 ¶¶21-22, 73-74

FIG. 17



(“(001)-highly-oriented MgO barrier layer”), 75-76, Figs. 3, 17 (annotated); *supra* §§VII.A.2-VII.A.3 (Claims 1[a]-1[b]); EX1024 ¶313.

J. Claim 10

Claim 10 was obvious over Nagahama in view of Sunai or Parkin.

1. Claim 10[preamble]: “The method of claim 1, wherein:”

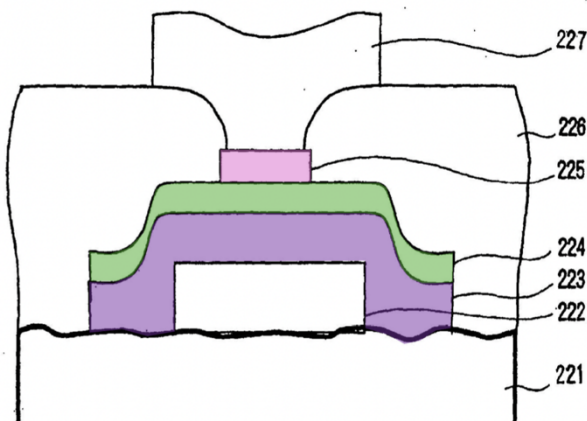
Supra Claim 1, §VII.A; EX1024 ¶314.

2. Claim 10[a]: “in the forming the MgO layer, the MgO layer is formed directly on the first CoFeB layer, and”

Supra Claim 9, §VII.I; EX1024 ¶315.

3. **Claim 10[b]: “in the forming the second CoFeB layer, the second CoFeB layer is formed directly on the MgO layer.”**

FIG. 17



As explained and shown at left, this limitation was obvious. *Supra* §VII.A.4 (Claim 1[c]). Nagahama’s **upper ferromagnetic layer**—that would have been replaced with CoFeB—is formed directly on the MgO **barrier layer**. EX1027 ¶¶21-

22, 73-76, Figs. 3, 17; EX1024 ¶316.

K. Claim 11

Claim 11 was obvious over Nagahama in view of Sunai or Parkin.

1. **Claim 11[preamble]: “A method of manufacturing a magnetic tunnel junction (MTJ) device, comprising:”**

Supra Claim 1[preamble], §VII.A.1; EX1024 ¶317

2. **Claim 11[a]: “forming a first ferromagnetic layer including a first CoFeB layer that is amorphous;”**

As explained for Claim 1[a], this limitation is obvious, and a CoFeB layer is a “ferromagnetic layer.” *Supra* §VII.A.2; II.D.1; EX1030 ¶33; EX1013 at 9:16 (“ferromagnetic alloy, such as CoFeB layers”); EX1024 ¶318.

3. **Claim 11[b]: “forming a barrier layer including a magnesium oxide (MgO) layer to have a poly-crystalline state in which a (001) crystal plane is preferentially oriented over the first ferromagnetic layer;”**

Nagahama taught a polycrystalline MgO(001) barrier layer. EX1027 ¶¶73-74;
supra Claims 1[b]/1[e], §§VII.A.3, VII.A.6; EX1024 ¶319.

4. **Claim 11[c]: “forming a second ferromagnetic layer including a second CoFeB layer that is amorphous over the barrier layer; and”**

Supra Claim 1[c], §VII.A.4; EX1024 ¶320. CoFeB is a ferromagnetic layer.
Supra Claim 11[a], §VII.K.2.

5. **Claim 11[d]: “annealing the first and second ferromagnetic layers and the barrier layer, to crystallize the first and second CoFeB layers.”**

Supra Claim 1[d], §VII.A.5; EX1024 ¶321.

- L. **Claim 12: “The method of claim 11, wherein after the annealing, the first and second CoFeB layers are entirely crystallized.”**

Claim 12 was obvious over Nagahama in view of Sunai or Parkin. *Supra*
Claims 2, 11, §§VII.B, VII.K.

M. Claim 13

Claim 13 was obvious over Nagahama in view of Sunai or Parkin.

1. **Claim 13[preamble]: “The method of claim 11, wherein”**

Supra Claim 11, §VII.K.

2. **Claim 13[a]: “after the annealing, the first and second CoFeB layers are entirely crystallized, and”**

Supra Claim 2, §VII.B.

3. **Claim 13[b]: “each of the first and second CoFeB layers is poly-crystalline in which a (001) crystal plane is preferentially oriented and each of the first and second CoFeB layers includes a BCC (body-centered cubic) structure.”**

Supra Claim 5, §VII.E.

- N. **Claim 14: “The method of claim 11, wherein in the forming the barrier layer, the MgO layer is formed as a MgO_x ($0 < x < 1$) layer.”**

Claim 14 was obvious over Nagahama in view of Sunai or Parkin and optionally Soukup. *Supra* Claims 7, 11, §§VII.G, VII.K; EX1024 ¶322.

O. Claim 15

Claim 15 was obvious over Nagahama in view of Sunai or Parkin.

1. **Claim 15[preamble]: “The method of claim 11, wherein:”**

Supra Claim 11, §VII.K; EX1024 ¶323.

2. **Claim 15[a]: “in the forming the barrier layer, the barrier layer is formed directly on the first ferromagnetic layer, and”**

Nagahama taught a polycrystalline $\text{MgO}(001)$ barrier layer. EX1027 ¶¶73-74; *supra* Claim 9, §VII.I; EX1024 ¶324.

3. **Claim 15[b]: “in the forming the second ferromagnetic layer, the second ferromagnetic layer is formed directly on the barrier layer.”**

Supra Claim 10[b], §VII.J.3; EX1024 ¶325.

VIII. SECONDARY CONSIDERATIONS

Western Digital is unaware of any relevant secondary considerations of non-obviousness for the '167 Patent. EX1024 ¶326.

IX. DISCRETIONARY DENIAL IS UNWARRANTED HERE

Discretionary denial under either Section 314(a) or 325(d) is inappropriate.

A. *Fintiv* Is No Roadblock To Institution

The *Fintiv* factors do not support denying institution under Section 314(a) here. *See Apple v. Fintiv*, IPR2020-00019, 2020 WL 2126495, at *2 (P.T.A.B. Mar. 20, 2020) (precedential); Director's Interim Procedure for Discretionary Denials (June 21, 2022) ("Guidance Memo").

IP Bridge filed its initial complaint in March 2024 in the District of Delaware, EX1063, which transferred the case to the Northern District of California, EX1080. The 48.9-month median time to trial in the Northern District of California puts any trial long after the final written decision here. *F5 v. Sunstone Info.*, IPR2022-00483, Paper 13 at 12 (P.T.A.B. Aug. 12, 2022); EX1078 at 3; Guidance Memo at 8-9 (median time-to-trial statistics must be considered).

The district court litigation is still in its infancy and progressing slowly. Western Digital's renewed motion to dismiss the First Amended Complaint is pending. No trial date has been set.

To date, IP Bridge has asserted only a single claim of the '167 Patent in the

litigation, EX1067 ¶201, while this Petition challenges all claims, leading to little risk of duplication, *see Precision Planting v. Maschio Gaspardo*, IPR2024-00008, 2024 WL 1283507, at *7 (P.T.A.B. Mar. 26, 2024). This Petition presents a compelling challenge showing all aspects of the claims existed in the prior art, including the aspects of the claims the Examiner found allegedly novel. *Supra* §§VI-VII; Guidance Memo at 4-5. *Fintiv* presents no bar to instituting trial here.

B. Discretionary Denial Under 35 U.S.C. §325(d) Is Unwarranted

Section 325(d) does not support discretionary denial. The Examiner did not consider the prior art combinations presented in this Petition showing that the claims of the '167 Patent were unpatentable. *See generally* EX1014. The Board has ample reason to conclude that neither part one nor two of the *Advanced Bionics* framework apply.

The Board applies a two-part framework under *Advanced Bionics v. MED-EL Elektromedizinische Geräte*, IPR2019-01469, 2020 WL 740292, at *3 (P.T.A.B. Feb. 13, 2020) (precedential).

Part 1 supports ordering trial here. The Board considers “the similarities and material differences between the asserted art and the prior art involved during examination, the cumulative nature of the art, and the overlap of the arguments presented.” *BMW of N. Am. v. Stragent*, IPR2021-00419, 2021 WL 3039219, at *5 (P.T.A.B. July 19, 2021) (citing *Advanced Bionics*).

During prosecution, the Examiner did not have the benefit of the combinations of prior art presented in this Petition which render the claims obvious. *Supra* §§VI-VII. Bowen, Nagahama, Sunai, and Parkin were listed in an IDS, but never discussed or meaningfully addressed during prosecution. *See* EX1014 at 110-12. Applicant acquiesced to the Examiner’s rejection of Parkin581 by cancelling Claim 1. EX1014 at 269, 273. The Examiner found the remaining claims allowable on the mistaken belief that crystallizing CoFeB electrodes after annealing was inventive, EX1014 at 220-21, apparently unaware that another Parkin patent taught exactly that, *e.g.*, EX1062 at 18:49-59. That disclosure was absent from Parkin581 that the Examiner relied on to reject Claim 1. *Compare* EX1062 at Fig. 3A, 18:49-19:27, *with* US2008/0062581 at Fig. 3, ¶¶69-70. The Examiner was also apparently unaware of other prior art teaching the benefits of crystallized CoFeB electrodes. *E.g.*, EX1060 at 309-11; EX1061 at 2272-74.

Thus, this Petition presents new information that the Examiner did not have the opportunity to consider during his initial examination. Because the grounds in this Petition were not “previously presented” to the Patent Office, trial is warranted here. *See, e.g., Lifecore Fitness v. Woodway USA*, IPR2024-00083, Paper 13 at 22 (P.T.A.B. May 17, 2024); *JUUL Labs. v. NJOY*, IPR2024-00160, 2024 WL 2697567, at *5 (P.T.A.B. May 24, 2024).

If the Board deems consideration of *Advanced Bionics* step two necessary, it also supports instituting trial here. Material error by the Office “may include misapprehending or overlooking specific teachings of the relevant prior art where those teachings impact patentability of the challenged claims.” *Advanced Bionics*, 2020 WL 740292, at *3 n.9. Indeed, the Examiner erred in a way that was material to patentability.

Allowing Claims 1-15 was material error. These claims were never rejected over the prior art. *See* EX1014 at 220 (“Claims 2-16 are allowed.”); *ChemtronicsUSA v. Flatfrog Labs.*, IPR2024-00015, 2024 WL 1719468, at *9 (P.T.A.B. Apr. 22, 2024) (ordering trial because “the Examiner did not issue a rejection based on” the Petition’s prior art).

The Examiner materially erred in allowing Claims 1-15 based on his finding that the prior art did not teach or suggest “annealing the first and second CoFeB layers” so they “are crystallized by the annealing.” EX1014 at 220-21; *supra* §II.G. As explained, the Examiner was unaware that another Parkin (EX1062) taught exactly that, *id.*; EX1062 at 18:49-19:26, and Applicant never informed him, EX1014 at 273. The Examiner also was not informed of Patent Owner’s position that annealed CoFeB ferromagnetic layers are “entirely crystallized.” EX1072 at 6-7.

Trial is warranted here.

X. CONCLUSION

For the reasons set forth above, Western Digital requests judgment cancelling claims 1-15 of U.S. Patent No. 10,680,167.

XI. GROUNDS FOR STANDING

Western Digital hereby certifies that the '167 Patent is available for IPR and meets the requirements of 37 C.F.R. §42.101.

XII. MANDATORY NOTICES

Pursuant to 37 C.F.R. §42.8(a)(1), the mandatory notices identified in 37 C.F.R. §42.8(b) are provided below as part of this Petition.

A. Real Party-In-Interest (37 C.F.R. §42.8(b)(1))

Petitioner Western Digital Technologies, Inc., and related entity Western Digital Corporation, are the real parties-in-interest.

B. Related Matters (37 C.F.R. §42.8(b)(2))

Petitioner is currently aware of the following matters related to the '167 Patent: *Godo Kaisha IP Bridge 1 v. Western Digital Technologies, Inc.*, No. 24-cv-06555 (N.D. Cal.) (transferred from the District of Delaware); *Godo Kaisha IP Bridge 1 v. Seagate Technology LLC*, No. 24-cv-03691 (D. Minn.) (transferred from the District of Delaware).

C. Lead and Backup Counsel (37 C.F.R. §42.8(b)(3))

Petitioner provides the following designation of counsel:

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Pursuant to 37 C.F.R. §42.10(b), a Power of Attorney accompanies this Petition.

D. Service Information (37 C.F.R. §42.8(b)(4))

Service information for lead and backup counsel is above. Petitioner hereby consents to service by email at the following email address:
ipr@armondwilson.com.

Western Digital v. Godo Kaisha IP Bridge
IPR Petition – U.S. Patent No. 10,680,167

ARMOND WILSON LLP

Dated: September 27, 2024

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Attorneys for Western Digital Technologies, Inc.

CERTIFICATE OF COMPLIANCE

Pursuant to 37 C.F.R. §42.24(d), the undersigned certifies that foregoing
PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 10,680,167
exclusive of the parts exempted as provided in 37 C.F.R. §42.24, contains 13,886
words and therefore complies with the type-volume limitations of 37 C.F.R. §42.24.

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CERTIFICATE OF SERVICE

I hereby certify that a true and correct copy of the foregoing **PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 10,680,167** and **EXHIBITS 1001-1084**, are being served on September 27, 2024, via overnight mail on the patent owner at the correspondence address of record for U.S. Patent No. 10,680,167, as addressed below:

Xsensus
100 Daingerfield Road, Ste. 402
Alexandria, VA 22314

A courtesy copy is also being served by electronic mail on counsel for the patent holder in the pending litigation:

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