Filed on behalf of Patent Owner by:
Gerald B. Hrycyszyn, Reg. No. 50,474
Richard F. Giunta, Reg. No. 36,149
Adam R. Wichman, Reg. No. 43,988
Thomas A. Franklin, Reg. No. 63,456
Jie Xiang, Reg. No. 74,068
WOLF, GREENFIELD & SACKS, P.C.
600 Atlantic Avenue
Boston, MA 02210
(617) 646-8000 Phone
(617) 646-8646 Fax

Paper No. __

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. IPR2024-01385
Patent No. 8,319,263

PATENT OWNER'S PRELIMINARY RESPONSE

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LISTING OF EXHIBITS

Exhibit	Description
2001	Kittel, C., *Introduction to Solid State Physics*, 6th Edition, 1986, pgs. 13-15, 18, 23 ("Kittel")
2002	Duke, C.B., *Tunneling in Solids*, Solid State Physics: Advances in Research and Applications, 1969, pgs. 1, 6-7, 34-35, 78-79 ("Duke")
2003	Definition of "ferromagnetism," Oxford English Reference Dictionary, Second Edition, pg. 513 ("Oxford English Reference Dictionary")
2004	"Ferromagnetism," The New Encyclopaedia Britannica: Volume 4, 15th Edition, 2003, pgs. 748-749 ("Britannica")
2005	Zhu, J.G., et al., *Magnetic tunnel junctions*, Materials today, Volume 9, Number 11, November 2006, pgs. 36-45 ("Zhu")
2006	Wulfhekel, W., et al., *Single-crystal magnetotunnel junctions*, Applied Physics Letters, Volume 78, Number 4, January 2001, pgs. 509-511 ("Wulfhekel")
2007	Soukup, R.J., *Hot Electron Transport in Vacuum Deposited Thin Film Emission Diodes*, University of Minnesota, Ph.D., Physics, solid state, 1969, pgs. 1-209 ("Soukup-Dissertation")
2008	Declaration of James L. Mullins, Ph.D. ("Mullins Declaration")

I. INTRODUCTION

The challenged patent, Patent No. 8,319,293 (the "'263 Patent")[1] is directed to a ground-breaking advance to a special kind of solid-state electronics device known as a "magnetic tunnel junction" ("MTJ") device.

In simple terms, MTJ devices have two magnetic electrodes separated by an insulating layer. Under certain conditions, current can flow between the electrodes, through the insulator layer, via a quantum mechanical phenomenon known as "tunneling." One important parameter of an MTJ device is its "tunnel barrier height," which in simple terms relates to an energy potential, measured in electron volts ("eV"), that affects tunneling current flow through the insulating layer. The '263 Patent inventor developed an MTJ device with a lower barrier height than had been achieved previously.

An MTJ device has two different states (referred to as its parallel and antiparallel states) that correspond to different relative magnetizations between its

[1] Petitioner filed petitions challenging two related patents—Patent Nos. 7,884,403 (IPR2024-01384) and 9,123,463 (IPR2024-01449). POPRs responding to the other petitions were filed on the same day as this POPR. All failings identified herein for this Petition are shared by the petitions in IPR2024-01384 and IPR2024-01449. Thus, all three petitions fail for substantially the same reasons identified herein.

magnetic electrodes as illustrated below. MTJ's are referred to as "magnetoresistive" devices because the MTJ device resistance R_{ap} in its antiparallel state is higher than the resistance R_p in its parallel state. MTJs can be used in storage devices, with its parallel and antiparallel magnetic states being used to encode/decode binary data with one state corresponding to a "0" and the other corresponding to a "1."

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

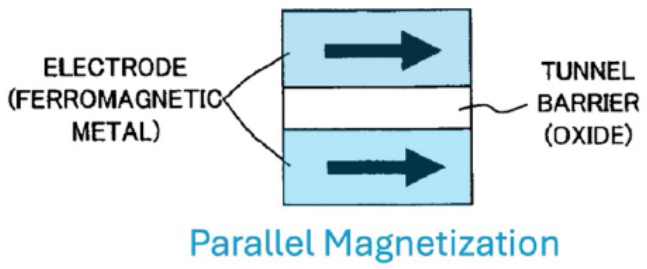
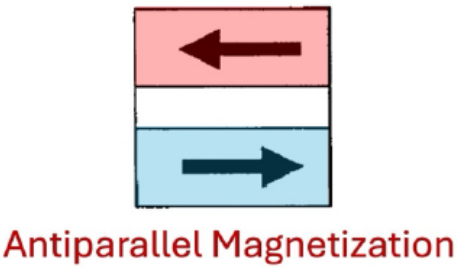


Fig. 8(B) (*High* Resistance)



A parameter of an MTJ device that Petitioner refers to as the "tunnel magnetoresistance ratio" ("TMR") represents the difference between the device's antiparallel resistance (R_{ap}) and its parallel resistance (R_p), normalized by the parallel resistance (R_p), as shown by the formula below reproduced from the Petition. A higher TMR desirably makes it easier to accurately determine whether the MTJ device is in its antiparallel or parallel state because a higher TMR reflects a larger difference between the antiparallel and parallel resistances than for a device with lower TMR.

$$\mathrm{TMR} = \frac{\Delta R}{R_{\mathrm{p}}} = \frac{R_{\mathrm{ap}} - R_{\mathrm{p}}}{R_{\mathrm{p}}}$$

The Petition presents two grounds (Grounds 1 and 2). Both share the same fatal flaws for every challenged claim. The challenged claims all recite a magnetoresistive device that has, *inter alia*, a tunnel barrier height of 0.2-0.5 eV. Petitioner identified no such device in the prior art.

Grounds 1 and 2 rely on different primary references. Both primary references disclose an MTJ device but neither has a tunnel barrier height that meets the claimed range. Grounds 1 and 2 rely on the same secondary reference "Soukup" to purportedly teach a tunnel barrier height of 0.33 eV within the claimed range, and each ground alleges that Soukup would have motivated a POSA to modify the primary reference to use this alleged barrier height. Petitioner's showing fails for a host of independent reasons.

A. Petitioner's Sole Alleged Motivation for Modifying the Primary References—to Allegedly Lower Their Barrier Heights—Is Unsupported

Grounds 1 and 2 offer the same single reason why a POSA allegedly would have been motivated by Soukup to lower the barrier height of the primary reference's MTJ device. Petitioner alleges that a POSA would have been motivated to do so because lowering the barrier height would have yielded a lower parallel

resistance (R_p) and thereby would have increased the device's tunnel magnetoresistance ratio ("TMR").

The fatal flaw in Petitioner's assertion is clear from simple mathematics. Petitioner ignores the impact that lowering the barrier height would have had on the device's ***other*** resistance—its antiparallel resistance R_{ap}. As seen from Petitioner's own TMR equation below, whether a change to an MTJ device that results in a lower parallel resistance R_p would increase the TMR depends entirely on the impact the change would have had on the antiparallel resistance R_{ap}. The TMR would only increase if lowering the barrier height of the MTJ caused the parallel resistance R_p to be reduced by a proportionally greater amount than that by which the antiparallel resistance R_{ap} is reduced. Petitioner does not even allege that this is true, let alone submit evidence to establish it. Thus, Petitioner fails to establish that lowering the barrier height of an MTJ device would increase its TMR.

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

As a result, Petitioner fails to support the ***only*** reason it alleged for why a POSA would have sought to lower the barrier height in either primary reference. Both grounds fail for this reason alone.

B. Petitioner Fails to Establish that Soukup Teaches a Tunnel Barrier Height Within the Claimed Range

Soukup's devices are not tunneling devices. But even if Soukup's reported barrier heights are considered to represent ***tunnel*** barrier heights, Petitioner fails to establish that the barrier height of any Soukup device falls within the claimed range. Soukup used two different methodologies for determining a barrier height of its devices and those methods produced vastly different values. While Petitioner seizes on the values from one of Soukup's methodologies (*e.g.*, 0.33 eV) because they are within the claimed range, the values produced by Soukup's other methodology are too high and fall outside the claimed range. Both values cannot be right. Petitioner did not even acknowledge that Soukup reports two inconsistent values, let alone provide the Board with any evidence to establish that the value falling within the claimed range was the correct value.

Worse yet, Soukup explicitly warned that the methodology Petitioner relies on for the 0.33 eV value might understate the actual barrier height. Indeed, Soukup's author also published his PhD dissertation describing the same work summarized in Soukup, and that dissertation publication conclusively stated that the number produced by the methodology Petitioner relies on is ***not*** correct and is ***smaller than the "real barrier height."*** Petitioner ignores this entirely.

The ***only*** evidence Petitioner relies on to purportedly teach a tunnel barrier height within the claimed range is Soukup's disclosure of a barrier height value

that is indisputably smaller than the device's ***real*** barrier height. Petitioner cites no credible evidence of any tunnel barrier height that falls within the claimed range. That is fatal to both grounds for a host of reasons. Soukup would not have motivated a POSA to modify either primary reference to achieve a tunnel barrier height within the claimed range because Soukup does not teach such a tunnel barrier height. And if a POSA were motivated to achieve Soukup's barrier height in the primary references, Petitioner submits no evidence that the "real barrier height" value would fall within the claimed range.

For these and other reasons detailed below, Petitioner fails to establish a reasonable likelihood of prevailing on either ground. Institution should be denied.

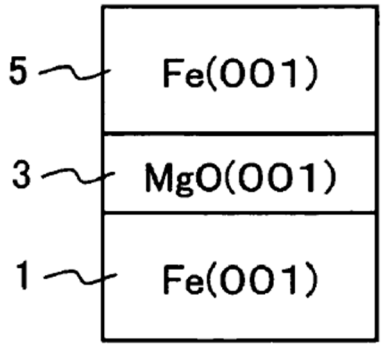
II. MAGNETIC TUNNEL JUNCTION DEVICES

A. Overview

A magnetic tunnel junction device is a special kind of solid-state electronics device. It has an insulator—called a tunnel barrier layer—sandwiched between two ferromagnetic electrodes. EX1003, 1:35-39. In '263 Patent Fig. 1(B) below, the ferromagnetic electrodes 1 and 5 are iron ("Fe") and the barrier layer 3 is magnesium oxide ("MgO"). The "(001)" in Fig. 1(B) is conventional notation indicating the orientation of crystalline Fe and MgO layers.[2] EX2001 ("Kittel"),

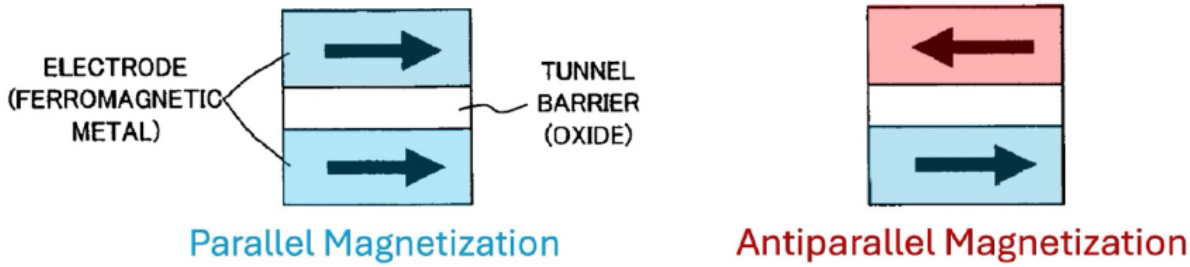
[2] "(001)" identifies a type of crystal plane orientation discussed *infra* §III.A.

14-15. Current flows through an MTJ device—*e.g.*, between electrodes—using a quantum mechanical phenomenon called "tunnelling" that is discussed further below. EX2002 ("Duke"), 1.



The ferromagnetic electrodes are highly susceptible to magnetization. EX2003 ("Oxford English Reference Dictionary"), 513 (definition of "ferromagnetism"). When an MTJ electrode is subjected to an applied magnetic field, the electrode magnetization may be aligned with the applied magnetic field. EX2004 ("Britannica"), 748-49. Arrows in '263 Patent Figures 8(A)-8(B), annotated below, show the magnetization direction in each electrode. An MTJ device is in a "parallel" state when its electrodes have the same magnetization (Fig. 8(A)) and in an "antiparallel" state when its electrode magnetizations point in different directions (Fig. 8(B)). EX1003, 1:41-51.

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



The MTJ device's resistance to current flow through the device depends on the electrode magnetization, making the MTJ device a magnetoresistive device. EX1003, 1:41-51. The resistance R_{ap} in the antiparallel state is ***higher*** than the resistance R_p in the parallel state. *Id*. By applying appropriate magnetic fields, an MTJ device can be configured in its parallel or antiparallel state. EX1062, 1:40-56. An MTJ device is thus a form of programmable resistor because its resistance can be changed by changing the relative magnetization of its electrodes.

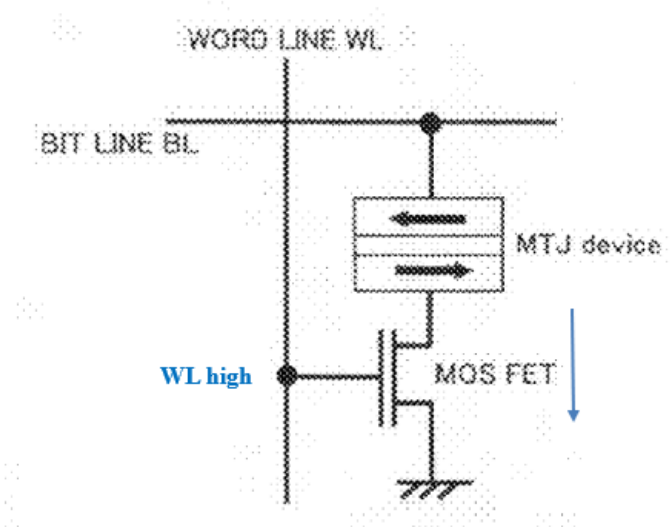
B. Use in Non-Volatile Storage Devices

While an MTJ device has many applications, one use is in persistent non-volatile storage devices (*i.e.*, storage that retains data when power is turned off) like a solid-state memory or hard drive.

A solid-state memory can be formed with an array of memory cells that each includes an MTJ device that can store a bit of data. EX1003, 1:20-2:16. The two resistive states of an MTJ device (the parallel low resistance state and the antiparallel high resistance state) can encode a stored bit value as a binary "0" or "1," respectively. EX1003, 1:51-54 ("information '1' or '0' can be stored

depending on whether the [MTJ] resistance value is high or not"), 1:66-2:2 ("[s]tored information can be read by reading the resistance value of the MTJ device"). The MTJ device in a memory cell can be a resistive load for a type of transistor referred to as a metal-oxide-semiconductor field effect transistor ("MOSFET"). EX1003, Figs. 9(B) (annotated below), 9(C); EX1003, 1:66-2:2.

antiparallel



A magnetoresistive random access memory ("MRAM") is a large-scale non-volatile memory device consisting of an array of WORD LINEs ("WLs") and BIT LINEs ("BLs") disposed in an intersecting manner, with an MRAM cell disposed at each intersection. EX1003, 1:25-31, 1:61-63, Fig. 9(A). When the WL in a MRAM cell is driven high ("WL high") the MOSFET turns on and current (blue arrow) flows through the MOSFET and the MTJ device on the BL, as illustrated above. This allows the resistance of the MTJ device to be read from the BL.

EX1003, 63-2:2. Because the MTJ device has a relatively high resistance R_{ap} in its ***antiparallel*** state compared to when the MTJ device is in its ***parallel*** state with relatively low resistance R_p, whether a "0" or "1" is stored in the MTJ memory cell can be determined by assessing whether the resistance value read on the BIT LINE is relatively high or low. *Id*.

An MTJ device can alternatively be used as a read-out sensor for a magnetic disk drive that stores data using different magnetization states on a disk to encode binary "0s" and "1s." EX1027 ("Nagahama"), [0082]; EX2005 ("Zhu"), 41, Fig. 12. In the read-out sensor, one of the MTJ's electrodes has fixed magnetization while the other electrode's magnetization is not fixed and therefore is sometimes called a "free layer". EX2005, 41, Fig. 12. When the read-out sensor is brought into proximity with a location on the disk that stores a data bit using magnetization, the read-out sensor's non-fixed MTJ electrode is impacted by the magnetic field of the stored data bit. *Id*. The read-out sensor's MTJ thus adopts its parallel magnetization state (*e.g.*, when the stored data is a "1") or its non-parallel magnetization state (*e.g.*, when the stored data is a "0") depending on the stored data bit's value. *Id*. When the read-out sensor pulls current through the MTJ to read the stored data bit value, the magnitude of the voltage across the MTJ's electrodes indicates whether the MTJ is in its low resistive parallel state or its high

resistive non-parallel state, and thereby indicates whether the stored data being read is a "1" or a "0." *Id*.

C. "Magnetoresistance Ratio" and "Tunneling Magnetoresistance Ratio" (TMR) Describe the Same Parameter

For both above-described exemplary use cases, it is desirable to increase the difference between the MTJ's parallel (R_p) and antiparallel (R_{ap}) resistances. EX1003, 2:22-47. For the same current passing through the MTJ device when a stored data value is read, a greater difference between R_p and R_{ap} provides a larger difference between the read-out voltages representing a "1" and "0," respectively. *Id.*, 4:51-58; 8:10-14. This reduces read-out errors by making it easier to distinguish between the voltages reflecting stored "1s" and stored "0s." *Id.*, 2:37-43.

A parameter the '263 Patent calls the "magnetoresistance ratio" ("MR ratio") quantifies the difference between the MTJ device's magnetoresistance in its antiparallel and parallel states. EX1003, 4:51-58. The '263 Patent represents this ratio as follows:

$$\text{MR ratio} = (R_{ap} - R_p) / R_p$$

Id.

The MR ratio is thus the difference between the MTJ device's magnetoresistance in its antiparallel and parallel states, normalized by the resistance in the parallel state. A relatively larger MR ratio corresponds to a larger

proportional difference between the antiparallel resistance R_{ap} and parallel resistance R_p.

The MTJ device parameter the ’263 Patent calls the MR ratio is called the “tunnel magnetoresistance ratio” (“TMR”) in the Petition and is represented using the same formula reproduced below. Petition, 6-7 (“Mathematically, the 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…. Thus, high antiparallel resistance R_{ap} compared to lower parallel resistance R_p results in high TMR”).

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

Id., 7.

Patent Owner primarily uses Petitioner’s TMR terminology herein, so the parties refer to the same parameter using the same terminology.

III. THE ’263 PATENT

A. Disclosed Embodiments

Dr. Shinji Yuasa, the ’263 Patent inventor, discovered how to make an MTJ device with an increased TMR. EX1003, 7:52-67 (an MTJ device produced using the inventive method achieved “the highest MR ratios that have so far been obtained at room temperature”).

Prior art MTJ devices used an amorphous material (aluminum oxide) as the tunnel barrier layer, meaning that the atoms in the tunnel barrier layer lacked an ordered arrangement. EX1003, 5:13-21. Dr. Yuasa determined that a barrier layer with a particular ordered arrangement would experience less scattering and that the "coherent states of electrons" would be conserved "during the tunneling process" through the barrier. *Id.*, 5:16-21. Dr. Yuasa determined that this could be achieved by using a barrier layer comprising single-crystal magnesium oxide (MgO) (001) or poly-crystalline (*i.e.*, made up of multiple crystals) MgO with the (001) crystal plane preferentially oriented. *Id.*, 5:16-59.

In a cubic crystal the sides of the cubic structure are in—or parallel to—planes, like the top face of the cube which is in the (001) plane as shown in the annotated figure below. In EX2001, 14-15, Fig. 16. The (001) notation means that a crystalline structure, *e.g.*, crystalline MgO(001), is oriented on the (001) plane.

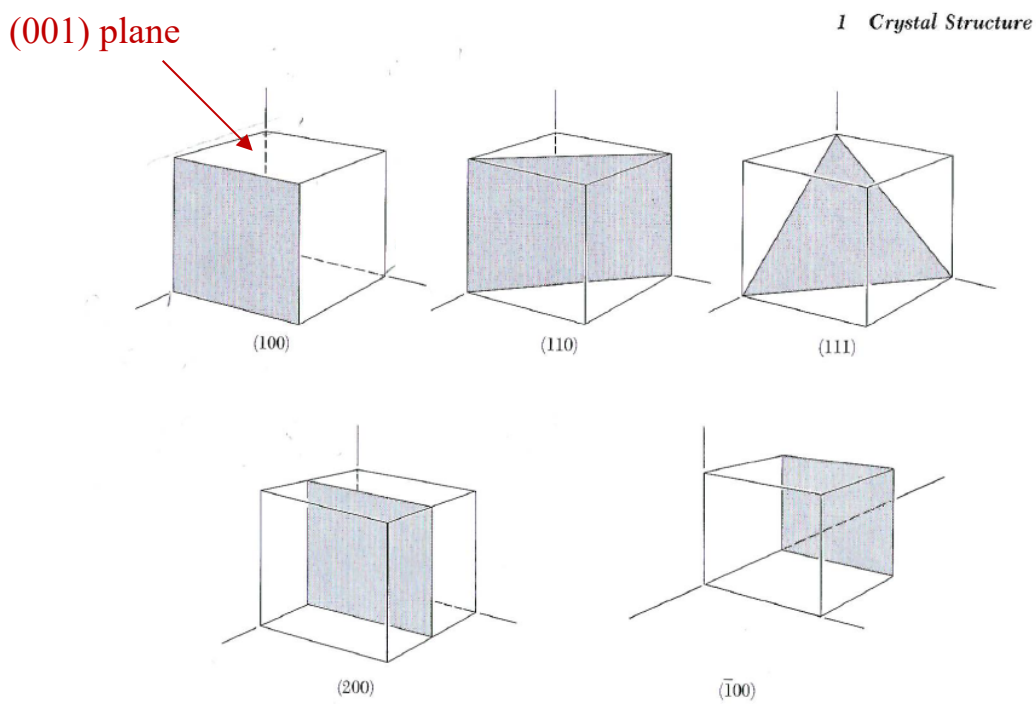


Figure 16 Indices of important planes in a cubic crystal. The plane (200) is parallel to (100) and to ($\bar{1}$00).

In one embodiment, Dr. Yuasa created an MTJ device with electrodes formed from Fe(001)—a crystalline iron layer with a (001) crystal plane orientation—sandwiching a single-crystalline MgO(001) layer. EX1003, 5:25-6:20. Oxygen vacancies were formed in the MgO barrier layer during the fabrication process. EX1003, 6:51-7:11. An oxygen vacancy refers to the absence of an oxygen atom where one is expected in a crystalline MgO structure. EX1037, 1, 3, Fig. 1. Because of the oxygen vacancies, the MgO crystal did not have a 1:1 ratio by atom of magnesium to oxygen. Instead, it was an MgO_x structure where "x" represents the number of oxygen atoms per magnesium atom, and where "x"

was a value less than 1. EX1003, 6:59-63, 7:5-7 ("The value of x in MgO_x ***due to oxygen vacancy defects*** is such that 0.98<x<1, and more preferably 0.99<x<1.").[3]

Dr. Yuasa noted that an MTJ device having an MgO_x crystalline or polycrystalline structure in which "x" was less than 1 had a lower barrier height than if a perfect single-crystal MgO barrier layer had been used.[4] *Id.*, 2:67-3:4 ("the ***height of the tunnel barrier*** … ***is smaller*** than an ideal value of a perfect single-crystal without defect"). The specification refers to work that had been done by Wulfhekel (EX2006). EX1003, 4:34-42. Wulfhekel used ultraviolet photoemission spectroscopy to identify an MgO crystal that was as perfect as could be made "with hardly any oxygen vacancy defect or lattice defect." *Id*. Wulfhekel determined that this perfect MgO layer had a barrier height of 3.6 eV. EX2006 ("Wulfhekel"), 509; *see also* EX1003, 6:65-67. The '263 Patent refers to this as the "ideal value" for the barrier height of an MgO barrier layer because Dr. Yuasa noted that any defects in an MgO barrier layer would reduce its barrier height, *e.g.*, Wulfhekel's ideal value of 3.6 eV represented an upper limit on the potential barrier height for an MgO barrier layer. EX1003, 4:41-49, 6:65-68.

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[3] Emphasis added unless otherwise noted.

[4] In conventional notation, "MgO" (*i.e.*, where no x appears) indicates a 1:1 ratio of magnesium and oxygen by atom. EX1003, 6:13-15.

Dr. Yuasa determined that making an MTJ device so that its electrodes had a crystalline structure, and its MgO barrier layer had oxygen defects so it was not a defect-free crystal, resulted in a tunnel barrier height of 0.10 to 0.85 eV—smaller than the 3.6 eV barrier height for an ideal MgO barrier layer..." *Id.*, 6:58-63.

Dr. Yuasa estimated the tunnel barrier height in his MTJ device by fitting electrical conductance characteristics (*i.e.*, current-voltage ("I-V") curves) of the MTJ device to the known Simmons' formula. *Id.*, 7:10-51. Simmons' formula was the accepted technique for determining the tunnel barrier height for a tunneling device, *e.g.*, where current flowed due to the quantum mechanical phenomenon known as tunneling, which is described *infra* §V.B.1.

Dr. Yuasa discovered that his MTJ devices with crystalline electrodes, and a crystalline MgO barrier layer with oxygen vacancies, had ***increased*** TMR as compared to conventional MTJ devices. EX1003, 3:4-6 ("[t]hese features ***increase the magnetoresistance***"). As discussed *supra* §§II.B-II.C, when the MTJ is used in a memory cell, increased TMR improves the read-out accuracy for a stored data bit by increasing the differentiation between the voltages that represent stored "0s" and "1s." EX1003, 3:4-8, Figs. 9(B), 9(C), 10 ("characteristics required for G bit-MRAM") .

B. Challenged Claims

The Petition challenges claims 1-4 ("Challenged Claims"). Claim 1 is independent. Claims 2-4 depend directly or indirectly from claim 1. Claim 1 requires a magnetoresistive device having, *inter alia*, first and second ferromagnetic layers of a crystalline structure (Limitations 1[a]-1[b]),[5] a tunnel barrier formed by single-crystalline or poly-crystalline MgO (Limitations 1[c]-1[d]), and a tunnel barrier height in a range of 0.2-0.5 eV (Limitation 1[e]).[6] EX1003, col. 9-10.

IV. PERSON OF ORDINARY SKILL IN THE ART ("POSA")

For purposes of this Preliminary Patent Owner Response only, Patent Owner does not challenge Petitioner's POSA definition (Petition, 29) because the Petition fails even if Petitioner's POSA definition is adopted.

V. GROUND 1 (BOWEN IN VIEW OF SOUKUP) FAILS

Bowen discloses a magnetoresistive MTJ device with a crystalline MgO, but Petitioner admits that Bowen's device has a tunnel barrier height that falls outside

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[5] The claims recite a "BCC structure" which means "body-centered cubic lattice structure" and refers to "the crystalline structure of ferromagnetic electrode layer." EX1003, 4:33-40.

[6] Patent Owner adopts Petitioner's claim limitation labelling. Petition, xiv ("List of Challenged Claims").

the range required by every Challenged Claim. Petition, 36-37. Petitioner could not identify a ***single*** reference that discloses a magnetoresistive device having an MgO barrier layer and a tunnel barrier height within the claimed range.

Petitioner alleges that Soukup teaches a barrier height (0.33 eV) within the claimed range and that Soukup would have motivated a POSA to modify Bowen's device to use a tunnel barrier height of 0.33 eV. Petitioner fails to substantiate either assertion for five independent reasons discussed in §§V.A-V.E below.

Petitioner also fails to prove that its Bowen-Soukup combination meets all the requirements of any Challenged Claim for the reasons discussed in §§V.A-V.F below.

A. Petitioner's Sole Alleged Reason Why a POSA Would Have Modified Bowen's Tunnel Barrier Height Based on Soukup Is Unsupported

1. Petitioner Needed to Establish Some Supportable Reason Why Soukup Would Have Motivated a POSA to Modify Bowen in the Manner Alleged to Meet the Claims

To demonstrate any Challenged Claim was obvious, Petitioner needed to establish some supportable non-hindsight ***reason why*** a POSA "would have selected and combined [the] prior art elements" in a manner that "yield[s] the claimed invention." *Unigene Labs. v. Apotex*, 655 F.3d 1352, 1360 (Fed. Cir. 2011); *see also KSR Int'l v. Teleflex*, 550 U.S. 398, 418 (2007) (establishing obviousness requires establishing some ***reason*** to combine the prior art in the

manner claimed); *TQ Delta v. CISCO Sys.*, 942 F.3d 1352, 1359 (Fed. Cir. 2019) (reversing the Board's obviousness determination because the Board "fails to identify any actual ***reason why*** a skilled artisan would have combined the elements in the manner claimed.'") (internal citation omitted)).

Petitioner offers a single reason why a POSA allegedly would have been motivated by Soukup to lower the barrier height of Bowen's MTJ device—because lowering the barrier height would have allegedly yielded a lower parallel resistance (R_p) and thereby would have allegedly increased the device's TMR. No credible evidence supports this assertion.

2. Petitioner's Sole Alleged Reason to Reduce Bowen's Barrier Height Was to Increase its TMR

Petitioner admits that Bowen's tunnel barrier height is outside of the claimed range of 0.2-0.5 eV. Petition, 37 (alleging Bowen "place[d] the barrier height at ϕ = 0.9 eV").[7] Instead, Petitioner alleges that Soukup teaches a "barrier height" of 0.33 eV and that a POSA had reason to use Soukup's "barrier height" of 0.33 eV in Bowen. Petition, 37-40.

Even if Soukup taught a tunnel barrier height of 0.33 eV (it does not as discussed *infra* §§V.B-V.D), to prove obviousness, Petitioner needed to establish

[7] Bowen teaches different ways of calculating the barrier height. Using Simmons' formula Bowen determined the barrier height was "ϕ ~1.1 eV." Bowen, 1656.

some ***reason why*** this teaching would have motivated a POSA to modify Bowen to adopt Soukup's alleged barrier height. *Supra* §V.A.1. Petitioner offers a single alleged reason why—because lowering the barrier height would have yielded a lower parallel resistance (R_p) and thereby ***increased its TMR***. Petition, 37-40.

More specifically, Petitioner asserts that a POSA "would have been motivated to apply Soukup's… 'barrier height' of 'about 0.33 eV' to Bowen's MgO barrier" because "lowering the resistance (barrier height)[8] for parallel electrons (R_p) would increase TMR" by "***increasing TMR*** to enable better performing MRAM [magnetoresitive random access memory]." Petition, 38; *see also* Petition, 38 (alleging that a POSA "looking to ***increase TMR*** of an MgO barrier would have been motivated to explore lower barrier heights") and 39-40

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[8] Barrier height is not the same thing as parallel resistance R_p as Petitioner itself acknowledges. *See e.g.*, Petition, 10 ("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"), 13 (tunnel barrier heights is measured in electron volts (eV)), 38 (alleging that Soukup teaches a barrier height despite Soukup's device having ***non-magnetic*** electrodes and not being MTJ devices that even have parallel (R_p) and antiparallel (R_{ap}) resistances as discussed *supra* §II.A).

(alleging that a POSA "would have been motivated to… ***increase TMR by lowering the barrier height*** as taught by Soukup.").

Petitioner says that the ***way*** a POSA would have lowered Bowen's barrier height was by increasing oxygen vacancy defects in the MgO barrier layer. Petition, 37 (alleging that in Soukup "a higher level of oxygen vacancy defects lowered the barrier height"). This offers no different reason why a POSA would have sought to lower the barrier height in the first place; the ***only*** reason Petitioner alleged to lower the barrier height was to allegedly increase the TMR. Petition, 39-40 ("one of skill would have been motivated to adjust oxygen vacancy defects ***to increase TMR <u>by</u> lowering the barrier height*** as taught by Soukup").

Petitioner's assertion that a POSA would have expected that lowering Bowen's barrier height would have increased the TMR is ***entirely unsupported***. Petition, 37. Thus, even if a POSA had motivation to increase Bowen's TMR, Petitioner's sole alleged motivation for making the Bowen-Soukup combination fails because nothing supports Petitioner's assertion that a POSA would have expected that lowering Bowen's barrier height would have increased the TMR.

3. Petitioner Admits TMR Depends on R_p <u>and</u> R_{ap}

Petitioner admits that the TMR is impacted by both the MTJ device's parallel (R_p) and antiparallel (R_{ap}) resistances. Petition, 6-7 ("high antiparallel

resistance $\boldsymbol{R_{ap}}$ ***compared to*** lower parallel resistance $\boldsymbol{R_p}$ results in high TMR"). Petitioner illustrates this using the below formula:

$$\mathrm{TMR} = \frac{\Delta R}{R_{\mathrm{p}}} = \frac{R_{\mathrm{ap}} - R_{\mathrm{p}}}{R_{\mathrm{p}}}$$

Petition, 7.

Petitioner asserts that lowering the barrier height would "lower[] the resistance… for parallel electrons (R_p) [and thereby] would increase TMR." Petition, 38. Petitioner's argument is premised on the implicit and entirely unsupported assumption that lowering Bowen's barrier height would not have also lowered its antiparallel resistance R_{ap} by proportionally the same (or greater) amount than it would have lowered the parallel resistance R_p.

As Petitioner's expert concedes, to increase the TMR by lowering the parallel resistance R_p, R_p must be lowered "***compared to*** [the] antiparallel" resistance R_{ap}. EX1024, ¶145. Indeed, as a matter of simple math, the parallel resistance R_p must be lowered by a ***proportionally greater amount*** than the antiparallel resistance R_{ap} to increase the TMR.[9] For example, an MTJ device with

[9] For completeness, lowering the parallel resistance Rp would increase TMR if: (1) R_{ap} remained unchanged; (2) R_{ap} increased; or (3) R_{ap} decreased, but by proportionally less than the amount by which Rp decreased. All three scenarios

an R_{ap} of 8 and an R_p of 4 would have a TMR of (8-4)/4=1. If R_{ap} and R_p were both reduced proportionally by half, that would not change the TMR: (4-2)/2=1. And if R_{ap} is reduced by a proportionally greater amount than R_p, that would have had the ***opposite*** effect and would have undesirably ***decreased*** Bowen's TMR.

4. Petitioner Fails to Show that Lowering Bowen's Barrier Height Would Have Increased its TMR

Petitioner alleges a POSA "would have been motivated to adjust oxygen vacancy defects to increase TMR by lowering the barrier height as taught by Soukup." Petition, 39-40. Petitioner alleges that "[a]ccording to the equation for TMR, ***lowering the resistance*** (barrier height) for ***parallel electrons*** (**R_p**) would increase TMR." Petition, 38.

But as the "equation for TMR" shows, Petitioner fatally ignores the impact that lowering the barrier height would have had on the ***antiparallel resistance R_{ap}***. As a result, Petitioner fails to substantiate its assertion that lowering Bowen's barrier height would have increased its TMR.

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fall under the umbrella of the parallel resistance R_p needing to be lowered by a proportionally greater amount than the anti-parallel resistance R_{ap}, and thus that is the language used herein.

$$\mathrm{TMR} = \frac{\Delta R}{R_{\mathrm{p}}} = \frac{R_{\mathrm{ap}} - R_{\mathrm{p}}}{R_{\mathrm{p}}}$$

Petition, 7.

As explained above, the formula for TMR is quite simple. As a matter of straightforward math, to support its assertion that a POSA would have been motivated to lower Bowen's barrier height because it would have lowered the parallel resistance R_p and thereby "increas[ed] TMR" (Petition, 38; *supra* §V.A.2), Petitioner needed to establish that lowering the barrier height would have either (1) had no impact on the antiparallel resistance R_{ap} despite lowering the parallel resistance R_p, (2) increased R_{ap} despite lowering R_p, or (3) reduced R_{ap} by a ***proportionally smaller*** amount than R_p is reduced. *Supra* §II.C. Yet, Petitioner did not even allege that any of these was true, let alone submit ***evidence*** to establish that any of these was true.

Petitioner's discussion of the TMR makes a single reference to "compar[ing]" the parallel and antiparallel states. Petition, 38. Petitioner alleges that "Butler and Mathon taught that MgO barriers would achieve higher TMRs due to improved symmetry matching between the MgO barrier and ferromagnetic electrodes, facilitating tunneling of parallel electrons across the barrier compared to antiparallel tunneling." Petition, 38 (*citing* EX1044 ("Butler") at 1, EX1046 ("Mathon") at 1, and EX1024 ¶146). But neither Butler nor Mathon teaches that

lowering the barrier height increases the TMR.[10] Indeed, as the Petition concedes, "Butler and Mathon taught that MgO barriers would achieve higher TMRs ***due to improved symmetry matching between the MgO barrier and ferromagnetic electrodes***"—not due to lowering barrier height. Petition, 38. Thus, Petitioner's only reference to teachings in the art about ***how*** to increase the TMR (Petition, 38) is obfuscation because those teachings never say that lowering the barrier height increases the TMR and thus do not support Petitioner's alleged motivation to modify Bowen based on Soukup.

Petitioner never even alleges that lowering Bowen's barrier height would have lowered its parallel resistance R_p by a ***proportionally greater amount relative to the antiparallel resistance*** $\boldsymbol{R_{ap}}$ as would have been required to increase the TMR. That should end the matter because the Petition was required to state its grounds "with particularity" (35 U.S.C. § 312(a)(3)) and to have "Content" that includes "a detailed explanation of the significance of the evidence" (37 C.F.R. § 42.22 (a)(2)). The Petition does not even allege facts sufficient to substantiate its assertion that lowering Bowen's barrier height would have increased its TMR.

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[10] Butler never mentions barrier height and Mathon reports a barrier height of about 3.6 eV (EX1046, 1), well above the claimed range.

Even if the Petition is somehow read as having alleged that lowering Bowen's barrier height would have lowered its parallel resistance R_p by a ***proportionally greater amount*** relative to the antiparallel resistance R_{ap} as would be required to increase the TMR (it did not), the Petition cites no ***evidence*** that would support such an assertion.

a. The Petition Cites No Teaching in the Art that Lowering the Barrier Height Increases the TMR

Petitioner does not cite a single reference that teaches that lowering the barrier height in an MTJ device like Bowen's would lower the parallel resistance R_p proportionally more than the antiparallel resistance R_{ap} and thereby increase the TMR. Petition, 37-40. There is good reason for this because there is no reason to believe that lowering Bowen's barrier height would have increased the TMR.

b. Petitioner's Expert Declaration Cannot and Does Not Cure the Petition's Failure

The Petition's section addressing Limitation 1[e] (reciting a barrier height of 0.2-0.5 eV) cites seventeen paragraphs of testimony from Dr. Bokor spanning over seven pages of his declaration. Petition, 37-40. Dr. Bokor, in turn, cites ***seven references*** that are ***never even cited***—let alone explained—***in the Petition's*** showing for Limitation 1[e]. EX1024, ¶¶139-155. None of that argument and evidence can save Petitioners because it cannot be incorporated by reference into the Petition. *Instrumentation Lab. v. Hemosonics*, IPR2017-00855, Paper 55, 20

(Feb. 13, 2019) (citing 37 C.F.R. § 42.6(a)(3)); *Cook Group v. Boston Scientific Scimed*, IPR2017-00131, Paper 13, 15 (May 15, 2017); 37 C.F.R. §42.104(b)(5).

But even if the Board were to wade into the Bokor Declaration, the Board would not find any evidence supporting Petitioner's assertion that lowering Bowen's tunnel barrier height would have increased Bowen's TMR. EX1024, ¶¶139-150. Dr. Bokor makes the same conclusory argument the Petition does—often in language that parrots the Petition ***verbatim***. Like the Petition does, Dr. Bokor fatally ignores the impact that lowering Bowen's barrier height would have had on its antiparallel resistance R_{ap}.

Dr. Bokor admits that increasing the TMR requires lowering the parallel resistance R_p "compared" to the antiparallel resistance R_{ap}. *Id.*, ¶¶145 ("lowering the resistance (barrier height) for parallel spin electrons ***compared to antiparallel*** [spin electrons] improved TMRs"), 146 (referring to a higher TMRs as "facilitating tunneling of parallel electrons across the barrier ***compared to antiparallel tunneling***."). Despite that, Dr. Bokor never addresses the impact that lowering Bowen's barrier height would have had on its antiparallel resistance R_{ap}.

Thus, Dr. Bokor ***never even alleges*** that a POSA would have believed that lowering Bowen's barrier layer would have lowered its parallel resistance R_p by proportionally more than it would have lowered its antiparallel resistance R_{ap} as

would be required to increase the TMR. Dr. Bokor's declaration shares the same fatal deficiency as the Petition.

Dr. Bokor simply states the naked conclusion that "[t]o increase TMR of an MgO barrier, skilled artisans would have been motivated to explore lower barrier heights to facilitate tunneling of ***parallel*** electrons." *Id.*, ¶147. This conclusory testimony offers no reasoning or explanation addressing the impact that lowering the barrier height would have on Bowen's ***antiparallel*** resistance R_{ap}, and cites no corroborating evidence to support its conclusory assertion that lowering the barrier height would have increased the TMR. This testimony warrants no weight under the Board's precedential *Xerox* case. *Xerox v. Bytemark*, IPR2022-00624, Paper 9, 15 (Aug. 24, 2022) (precedential) ("*Xerox*") ("the cited declaration ***testimony is conclusory and unsupported***, adds little to the conclusory assertion for which it is offered to support, and is ***entitled to little weight***") (citing 37 C.F.R. § 42.65(a) ("Expert testimony that does not disclose the underlying facts or data on which the opinion is based is entitled to little or no weight")).

The failure to address the impact that lowering Bowen's barrier height would have had on Bowen's antiparallel resistance R_{ap} is a glaring omission in Dr. Bokor's testimony. Likely Dr. Bokor offered no testimony that lowering Bowen's barrier layer would have lowered its R_p ***by proportionally more than its R_{ap}*** as

would be required to increase the TMR because there is no factual basis for such a position.

5. Petitioner Alleged No Reason to Adopt Soukup's Alleged Barrier Height in Bowen Other than to Allegedly Increase Bowen's TMR

Petitioner asserts that "[t]he claimed tunnel barrier height range of 0.2 to 0.5 eV would have been obvious." Petition, 39. If the Petition is read as suggesting that only this individual claim limitation needed to be proven obvious, that is legal error. It is a claim "as a whole" that must be proven obvious. 35 U.S.C. § 103; *Connell v. Sears, Roebuck*, 722 F.2d 1542, 1549 (Fed. Cir. 1983).

Petitioner admits that Bowen teaches a barrier height outside the claimed range and alleges that a POSA would have been motivated by Soukup to lower Bowen's barrier height to 0.33 eV. Petition, 37-40 ("Bowen 'place[d] the barrier height at $\phi = 0.9$ eV'"). To establish obviousness, Petitioner bears the burden to establish an evidence-based supportable ***reason why*** a POSA would have lowered Bowen's barrier height to 0.33 eV. *See supra* §V.A.1 (citing authority). The Petition offers no reason other than its failed unsupported assertion that a POSA would have believed that lowering Bowen's barrier height would have increased the TMR. Petition, 37-40.

6. Conclusion Regarding Petitioner's Failure to Establish any Supportable Reason Why a POSA Would Have Modified Bowen Based on Soukup

The sole reason Petitioner advances for why a POSA allegedly would have modified Bowen to adopt Soukup's alleged barrier height of 0.33 eV was to increase TMR "by lowering the barrier height." Petition, 40; *see also* Petition, 39 (POSA "would have been motivated to achieve Soukup's barrier height… to improve… TMR"), 38 (TMR is improved by increasing it). Yet, as detailed above, Petitioner fails to establish that a POSA would have believed that adopting Soukup's alleged lower barrier height in Bowen would have increased Bowen's TMR. *See supra* §V.A.4.

Thus, Ground 1's obviousness showing fails because Petitioner fails to establish any reason, ***supported by the evidence***, why a POSA would have modified Bowen to adopt Soukup's alleged barrier height. *See supra* §V.A.1 (citing authority establishing that a reason is required).

Ground 1 also fails for a host of additional independent reasons detailed in §§V.B-V.F below.

B. Petitioner Fails to Establish That Soukup Would Have Motivated a POSA to Pursue a Tunnel Barrier Height of 0.33 eV in Bowen Because Petitioner Fails to Establish that Soukup Discloses a Tunnel Barrier Height of 0.33 eV

1. Soukup Did Not Determine a Tunnel Barrier Height

The claimed "***tunnel*** barrier height" in a magnetoresistive device is

determined using something called "Simmons' formula." EX1003, 7:10-33; EX1026, 1656; *infra* §V.D.1 (describing Simmons' formula); Petition, 10 (admitting that "Simmons' 1963 paper provided a ***widely-used*** formula for calculating the tunnel barrier height.").

Soukup did not use Simmon's formula to determine a ***tunnel*** barrier height of its tested devices. Indeed, as discussed below, Soukup's tested emission diodes are not tunneling devices at all. Thus, as discussed in more detail below, Petitioner fails to establish that the "barrier height" values that Soukup reported are "***tunnel*** barrier heights" as claimed. Petitioner fails to support its assertion that Soukup would have motivated a POSA to lower Bowen's tunnel barrier height to 0.33 eV (Petition, 37-40) when Soukup does not disclose any value for a ***tunnel*** barrier height.

a. Soukup's Devices Are Neither Magnetic, Nor Tunneling Devices

Soukup's devices are neither magnetic nor tunneling devices, let alone magnetic tunnel junction devices.

i. Soukup's Devices are Not Magnetic

Soukup describes research into the carrier transport mechanism of emission diodes having gold ("Au") electrodes. EX1028 ("Soukup"), 3229 ("voltage-current characteristics of Au-MgO-Au thin-film emission diodes… are consistent with… Schottky field emission"). It was well-known that gold is not magnetic. EX1027,

[0011]-[0012] ("nonmagnetic" gold "interlayer"), [0043] ("nonmagnetic… layer is formed of Au").

Soukup characterized the behavior of sixty "thin-film ***emission diodes***" comprising MgO depositions between ***non-magnetic*** gold electrodes by measuring their currents at different voltages and temperatures. EX1028, 3229, 3230 ("Measurements of the *I-V* characteristics were made"), Fig. 3. Soukup's devices are thus not magnetic.

ii. Soukup is Not Directed to Tunneling Devices

Soukup's research was focused on ***identifying*** the current flow mechanism in the tested metal-insulator-metal emission diodes. And the tested devices were not "***tunnelling*** devices" as Petitioner erroneously alleges.

(1) Current flow mechanisms for metal-insulator-metal devices

Soukup recognized that several "possible current flow mechanisms from metal to metal have been proposed for metal-insulator-metal sandwich devices" like his emission diodes. EX1028, 3229. The insulator layer in these devices meant none of these mechanisms were typical current flow through a conductive wire, because the insulator was a barrier that blocked such conventional current. EX1031 ("Simmons"), 1794 ("[T]he insulating film… introduce[s] a potential barrier… which impedes the flow of electrons between the electrodes.").

(i) Schottky emission current

One way current flows between two electrodes separated by an insulator is when electrons in one electrode are sufficiently energized that they overcome the insulator's resistance to current flow—*i.e.*, the electrons have more energy than required to overcome the insulator's potential barrier (*e.g.*, the barrier height). EX1031, 1794 (describing current flow "if… electrons in the electrodes have enough thermal energy to ***surmount*** the potential barrier"); EX1028, 3229 ("***[I]f the barrier is low enough*** some electrons will have ***enough thermal energy to surmount the barrier*** and give rise to a Schottky current when a field is applied."); EX2002, 34-35 (comparing "tunneling current" with "thermionic emission current ***over*** the potential barrier"); EX2007 ("Soukup-Dissertation"), 2 ("electrons must either surmount the barrier, Richardson-Schottky current, or penetrate through it."). Soukup found that the current in his emission diodes was consistent with this mechanism, known as Schottky field emission. EX1028, 3229.

(ii) Tunneling current

Tunneling is a ***different*** type of current flow mechanism through an insulator. EX1031, 1793 (current flow by "tunnel effect"), 1794 (describing current flow through insulator "if… [t]he barrier is ***thin enough*** to permit its penetration by the electric tunnel effect"). In simple terms, tunneling—a purely quantum mechanical effect—occurs when certain conditions of the insulator, electrodes, and

electrons are met that result in current flow even though the electron's energy is ***not sufficient to overcome*** the insulator's potential barrier that opposes conventional current flow.

(iii) Magnetic-dependent tunneling current

Magnetic tunnel junctions use a special type of tunneling that depends on a combination of factors including at least the materials that form the barrier layer, the structure of the barrier layer, the thickness of the barrier layer, the materials forming ferromagnetic electrodes, and the symmetry between the materials that form the electrodes and the barrier layer. EX1026, 1655 ("[A] correct depiction of the spin-dependent tunneling properties of epitaxial MTJs must transcend the simple potential barrier image and take into account the interplay of electronic structure between metal and insulator.").

(2) Soukup's diode current measurements were consistent with Schottky emission

Soukup studied emission diodes, not MTJ devices. The diodes had non-magnetic (gold) electrodes and an MgO insulator between them. EX1028, 3230, 3233, Fig. 1. In simple terms, emission diodes allow current flow in only one direction, when the diode's anode is positively biased relative to the opposing electrode. EX1028, 3230, Fig. 2 (illustrating "anode"), 3233 ("[t]he only way in which an emission current was observed was with both the overlayer and anode biased positively with respect to the underlayer."). It was known before Soukup's

research ***that*** current flows through emission diodes. EX1028, 3229. The purpose of Soukup's research was to determine ***how*** and ***why*** current flowed in those devices, *i.e.*, what is the "current flow mechanism[]." EX1028, 3235 ("SUMMARY").

Soukup characterized the diodes by measuring their voltage-current characteristics, and determined that his measured results were consistent with field emission from a Schottky barrier (*i.e.*, "Schottky emission") as explained *supra* §V.B.1.b.i(1). EX1028, 3229 ("The voltage-current characteristics of Au-MgO-Au thin-film emission diodes[11]… are consistent with an expression derived for Schottky field emission into the conduction band of the oxide."), 3230 (*I-V* "functional dependence… is the same as for Schottky emission."), 3232 ("the functional dependence of *I* upon *V* indicates a Schottky mechanism"), 3235-3236 (discussing evidence of Schottky emission).

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[11] Soukup's emission diodes had barrier thicknesses from 6-68 nm, many times thicker than the 2 nm crystalline MgO barrier layers in the MTJ's described in Bowen and the '263 Patent. EX1028, 3230-31, Fig. 3, 3233 Table I (column 2, S^a oxide thickness); *cf.* EX1026, 1656-1657, Fig. 2 (2 nm barrier); EX1003, Abstract (2 nm barrier). Petitioner cites no evidence suggesting that tunnelling could even occur through barrier layers as thick as Soukup's.

Soukup found that tunneling was ***not*** the current flow mechanism in the diodes he tested because tunnelling was inconsistent with the observed *I-V* (*i.e.*, current-voltage) measurements in several sample diodes. EX1028, 3230 ("the Fowler-Nordheim [tunneling] equation ***does not hold*** for these devices"), 3235 ("[a] number of current flow mechanisms were ruled out"); *cf.* EX2002, 7 ("calculation [] made by Fowler and Nordheim" is one "application of the idea of tunneling.").

b. Conclusion

Soukup's emission diodes are neither magnetic devices nor tunneling devices, let alone ***magnetic tunnel*** junction devices. Thus, the operation of Soukup's diodes is not impacted by a **magnetic** polarization state of its (non-magnetic) electrodes, which is a fundamental operating principle of an MTJ device. *See supra* §II.A. Soukup's emission diodes have non-magnetic (gold) electrodes. EX1028, 3229. Soukup's devices do not have parallel (R_p) and antiparallel (R_{ap}) resistances, let alone a TMR that quantifies a difference between those magnetic-state-dependent resistances. *See supra* §II.C.

2. Petitioner Fails to Reconcile Soukup's Inconsistent Teachings About What its Barrier Heights Were

Even if Soukup is considered to teach that its reported barrier height values represent ***tunnel*** barrier heights, Petitioner fails to support its assertion that Soukup teaches a tunnel barrier height within the claimed range. Soukup reported two

different barrier height results for the emission diodes Petitioner relies upon. One value is within the claimed range but the other is not. Both barrier height values cannot be correct. Petitioner never establishes that a POSA would have accepted the value that Petitioner relies upon as the correct value for the device's barrier height.

Soukup used two different methods to calculate a "barrier height[]" for each emission diode: (1) the "zero-field intercept" method and (2) "an Arrhenius plot" method. EX1028, 3229. The two methods yielded different and ***inconsistent*** results for every diode for which both methods yielded a result.[12] EX1028, 3233, Table I (below). While the "barrier height" calculations arrived at using the Arrhenius plot method (highlighted blue in Soukup's Table I below) provided values—like the 0.33 eV Petitioner seizes upon—within the claimed range, the values produced using the zero-field intercept method (highlighted yellow below) all fell outside the claimed range of 0.2-0.5 eV. EX1028, 3233, Table I.

[12] The Arrhenius plot method failed to produce a barrier height value for four diodes whose value is noted as "****" in Table I. EX1028, 3233.

TABLE I. Summary of device data.

Device No.	S^a	S_0^b	φ_1^c	φ_2^d	$P_{O_2}^e$
PY-G-11(1)	80	200	0.714	0.33	
PY-G-16(3)	105	···	0.721	···	···
PY-G-17(1)	200	194	0.721	0.33	···
PY-G-18(1)	105	···	0.694	0.34	···
PY-G-18(2)	105	222	0.700	0.35	···
PY-G-19(2)	70	133	0.710	0.33	···
PY-G-20(1)	680	···	0.695	···	···
PY-G-20(3)	680	···	0.695	···	···
PY-G-21(3)	90	···	0.732	0.34	···
PY-G-22(2)	90	209	0.780	0.21	10^{-8}
PY-G-25(3)	60	200	0.823	0.11	10^{-7}
PY-G-38(1)	120	···	1.9, 1.74[f]	···	10^{-5}, ···

[a] S = oxide thickness, in Å.
[b] S_0 = overlayer thickness, in Å.
[c] φ_1 = barrier obtained by zero intercept method, in eV.
[d] φ_2 = barrier obtained from slope of Arrhenius plot, in eV.
[e] P_{O_2} = pressure of admitted O_2 during MgO deposition, in Torr.
[f] The barrier was obtained from the slope of the Fowler-Nordheim plot.

The difference in Soukup's reported barrier heights could not be more material because ***none*** of the barrier height values determined using the zero-field intercept method (yellow above) fall within the range required by every Challenged Claim. Viewing Soukup's disclosure in a light most favorable to Petitioner, Soukup is at best ambiguous about whether the barrier height of any of its diodes fell within the claimed range. The Federal Circuit has made clear that "it has long been understood that ambiguous references do not, as a matter of law, anticipate a claim." *Wasica Fin. GmbH v. Cont'l Auto. Sys., Inc.*, 853 F.3d 1272, 1284 (Fed. Cir. 2017). While Ground 1 is based on obviousness rather than anticipation, the same principle applies. Petitioner cannot meet its burden to show that Soukup discloses a barrier height within the claimed range when Soukup

discloses two inconsistent values and is, at best, ambiguous about whether any of its diodes had a barrier height within the claimed range.

Worse yet, Petitioner entirely ignores the values Soukup obtained using the zero-field intercept method. Petitioner does not even attempt to reconcile the different barrier height values that Soukup reports.

Petitioner does not even allege, let alone establish with ***evidence***, that a POSA would have accepted Soukup's values calculated using the Arrhenius plot method (blue above) rather than those calculated using the zero-field intercept method (yellow above). That is reason enough why Ground 1 fails.

Petitioner cannot carry its burden by cherry-picking disclosure in Soukup that Petitioner alleges supports unpatentability of the Challenged Claims while ignoring other disclosure that supports patentability. "It is impermissible… to pick and choose from any one reference only so much of it as will support a given position, to the exclusion of other parts necessary to the full appreciation of what such reference fairly suggests to [POSA]." *In re Wesslau*, 353 F.2d 238, 241 (C.C.P.A. 1965); *see also In re Hedges*, 783 F.2d 1038, 1041 (Fed. Cir. 1986) ("the prior art as a whole must be considered" to determine whether "the totality of the prior art disclosures leads substantially away from the claimed invention."); *Google v. AGIS Software Dev.*, IPR2018-01083, Paper 10, 25 (Jan. 10, 2019) (denying institution because petitioner's expert "improperly picks and chooses

teachings from [the prior art] and fails to represent accurately what [the prior art] fairly suggests to a skilled artisan."), citing *In re Hedges*; *Mylan Pharms v. Gilead Scis*, IPR2014-00885, Paper 15, 9 (Dec. 9, 2014) ("[W]hen evaluating claims for obviousness, 'the prior art as a whole must be considered.'"), citing *In re Hedges*.

3. Soukup Teaches that the Methodology Used to Calculate a Barrier Height of 0.33 eV Was Wrong and Underestimated the "Actual Barrier Height"

Compounding the problem for Petitioner, Soukup itself explains that the Arrhenius plot method that provided the results highlighted blue in Soukup's Table I above—including the 0.33 eV value Petitioner seizes upon—"will give a number ***which is smaller than the actual barrier [height]"*** if "the barrier [height] increases with increasing temperature." EX1028, 3234.

Petitioner ignores this teaching entirely. Petitioner presents no evidence establishing that a POSA would have believed that the barrier height in Soukup's tested devices did ***not*** in fact increase with temperature. Thus, Petitioner presents no evidence establishing that a POSA would have accepted Soukup's barrier height values arrived at using the Arrhenius plot method, despite Soukup warning that this method might "give a number which is ***smaller than the actual barrier [height]***." *Id*., 3234.

Despite Petitioner ignoring it, the question of whether the barrier height in Soukup's tested devices increased with temperature was readily answerable, and

the answer is fatal to Ground 1. R.J. Soukup himself provided the answer before the ’263 Patent’s critical date. Soukup reports research by R.J. Soukup with D.E. Speliotis that is described in greater detail by R.J. Soukup’s PhD dissertation (EX2007, “Soukup-Dissertation”), which was published no later than November 9, 1987 and is prior art to the ’263 Patent. EX2008 (“Mullins Decl.”), ¶¶63, 34-62 (the Soukup-Dissertation was cataloged and could be searched for by author, title, and subject, and accessed from the University of Minnesota library at least as early as November 9, 1987, and through ProQuest as early as January 1969). A POSA would have understood that the dissertation provides a more in-depth explanation of the research summarized in the Soukup article Petitioner relies on. Even a cursory review of Soukup (EX1028) and the Soukup-Dissertation (EX2007) reveals that they describe the same research work:

- Soukup was received for publication in October 1969, shortly after R.J. Soukup submitted his dissertation in June 1969 at the University of Minnesota (*compare* EX1028, 3229 *with* EX2007, Title);
- Soukup lists correspondence addresses at the University of Minnesota where R.J. Soukup performed the research that is the subject of his dissertation (*compare* EX1028, 3229 *with* EX2007, Title);

- Soukup has the same Air Force funding acknowledgment as the dissertation (*compare* EX1028, 3236 *with* EX2007, Acknowledgements);
- Soukup reports on the same named emission diode samples as the dissertation (*compare* EX1028, 3233 (Table I) *with* EX2007, 70 (Table IV)); and
- Soukup and the dissertation use the same figures, as follows:

Soukup Figure	Soukup-Dissertation Figure
1	8a
3	17
4	20
5	21
6	22
7	25
8	28
9	29
10	31
11	37
12	23

The Soukup-Dissertation explains that in the devices Soukup tested, "barrier heights ***do*** increase with increasing temperature. Thus, ***the slope of the Arrhenius plot will give a value for the barrier height which is actually less than the real barrier height***, as seen in these experiments." EX2007, 89, Fig. 40.

Ground 1 alleges that the claimed tunnel barrier height limitation is met because a POSA "would have been motivated to apply Soukup's teachings about…

a ‘barrier height’ of ‘about 0.33 eV.” Petition, 38. But a POSA would have understood from R.J. Soukup himself that the 0.33 eV value reported in Soukup “is actually less than the ***real*** barrier height.” EX2007, 89, Fig. 40.

Petitioner fails to carry its burden to show that Soukup disclosed a barrier height within the claimed range because Petitioner relied on a value (0.33 eV) that is “less than the real barrier height.” *Id*. Petitioner presents no evidence that Soukup’s “actual barrier height” (EX1028, 3234)—its “real barrier height” (EX2007, 89)—fell within the range required by any Challenged Claim. Ground 1 fails for this additional independent reason.

C. Petitioner Conflates Disparate Teachings in Soukup in Alleging that Soukup Discloses that Adding Oxygen Vacancy Defects Would Have Lowered Bowen’s Barrier Height to 0.33 eV

Soukup made some samples in which oxygen pressure was introduced during the deposition of the MgO film and Petitioner asserts that the samples made in the absence of oxygen gas pressure had more oxygen vacancy defects. Petition, 37-38. Specifically, Soukup fabricated samples PY-G-22(2), PY-G-25(3), and PY-G-38(1)—shown in the last three rows of Table I below—with increasing oxygen gas pressure so the resulting devices had “more stochiometric oxygen films,” which Petitioner asserts means ***fewer*** oxygen vacancy defects. EX1028, 3232-33; Petition, 37-38.

Soukup reported that "[t]he apparent barrier height determined from the zero-intercept ***went up*** for increasing oxygen pressure and the barrier height determined from the Arrhenius plot ***went down***." EX1028, 3229, *see also* Abstract (same).

This is shown in Soukup's Table I in which "P_{02} = pressure of admitted O_2 during MgO deposition." Id., 3233. Oxygen pressure was admitted for the samples in the bottom three rows, with the pressure increasing from PY-G-22(2) to PY-G-25(3) to PY-G-38(1) as shown in Table I. Accepting Petitioner's assertion that increased oxygen pressure results in fewer oxygen vacancy defects, Table I is annotated below to show that oxygen vacancy defects increase while ascending through Table I's bottom four samples/rows. The barrier height determined using the Arrhenius plot method (blue below) ***increases*** with ***more oxygen vacancies*** while the barrier height determined using the zero intercept method (yellow below) ***decreases***. *Id*.

TABLE I. Summary of device data.

Device No.	S^a	S_0^b	φ_1^c	φ_2^d	$P_{O_2}^e$
PY-G-11(1)	80	200	0.714	0.33	
PY-G-16(3)	105	...	0.721	...	...
PY-G-17(1)	200	194	0.721	0.33	...
PY-G-18(1)	105	...	0.694	0.34	...
PY-G-18(2)	105	222	0.700	0.35	...
PY-G-19(2)	70	133	0.710	0.33	...
PY-G-20(1)	680	...	0.695	...	...
PY-G-20(3)	680	...	0.695	...	...
PY-G-21(3)	90	...	0.732	0.34	...
PY-G-22(2)	90	209	0.780	0.21	10^{-8}
PY-G-25(3)	60	200	0.823	0.11	10^{-7}
PY-G-38(1)	120	...	1.9, 1.74[f]	...	10^{-5}, ...

[a] S = oxide thickness, in Å.
[b] S_0 = overlayer thickness, in Å.
[c] φ_1 = barrier obtained by zero intercept method, in eV.
[d] φ_2 = barrier obtained from slope of Arrhenius plot, in eV.
[e] P_{O_2} = pressure of admitted O_2 during MgO deposition, in Torr.
[f] The barrier was obtained from the slope of the Fowler-Nordheim plot.

zero intercept
MgO barrier height ***decreases*** as oxygen vacancies increase

Arrhenius plot
MgO barrier height ***increases*** as oxygen vacancies increase

The barrier height cannot both increase and decrease with more oxygen vacancy defects. Petitioner entirely ignores Soukup's irreconcilably inconsistent teaching and does not even attempt to establish which teaching a POSA would have believed to be correct.

Petitioner simply alleges that Soukup teaches that its samples made with fewer oxygen vacancy defects (due to admitted oxygen gas pressure) had higher barrier heights, so "Soukup suggested a higher level of oxygen vacancy defects lowered the barrier height." Petition, 37. But that is clearly wrong when the barrier height was measured using Soukup's Arrhenius plot method (blue above) that determined the 0.33 eV barrier height value that Petitioner relies upon. EX1028, 3233, Table I; Petition, 38-40. Soukup teaches that the barrier height measured

using the Arrhenius plot method (blue) ***increased*** for the samples Petitioner alleges had more oxygen vacancy defects. *Id*. That is the exact opposite of what Petitioner alleges. Petition, 37 ("a higher level of oxygen vacancy defects ***lowered*** the barrier height").

A POSA would have only understood Soukup to teach that the barrier height decreased for the samples Petitioner alleges had more oxygen vacancy defects if the POSA believed that the barrier height should be determined using the zero-intercept method (yellow above). EX1028, 3233 and Table I. But ***none*** of Soukup's samples had barrier heights measured using the zero-intercept method (yellow) that were within the claimed range of 0.2-0.5 eV.

Petitioner improperly cherry-picks from disparate disclosures in Soukup. *In re Wesslau*, 353 F.2d at 241 ("It is impermissible… to pick and choose from any one reference only so much of it as will support a given position, to the exclusion of other parts necessary to the ***full appreciation of what such reference fairly suggests to [POSA]***."). Petitioner cannot have it both ways.

1. Soukup Teaches that Barrier Heights Determined Using the Arrhenius Plot Method Increased with Oxygen Vacancy Defects—Exactly the Opposite of What Petitioner Alleges

If a POSA would have believed that Soukup's Arrhenius plot method was the way to accurately determine the barrier height—as Petitioner argues in asserting that Soukup teaches a barrier height of 0.33 eV (Petition, 37-38)—then

the POSA would have understood that according to this methodology the barrier height ***increases*** as oxygen vacancies increase as shown in Table I (blue above). That ***contradicts*** Petitioner's assertion that a POSA would have added oxygen vacancies to lower Bowen's barrier height "as taught by Soukup." Petition, 40.

Soukup teaches that adding oxygen vacancy defects would have had the exact ***opposite*** effect from the one Petitioner alleges and would have increased the barrier height determined using the Arrhenius plot method (blue) that Petitioner relies upon to establish an alleged barrier height (0.33 eV) within the claimed range. EX1028, 3233, Table I, 3229 ("for increasing oxygen pressure [which Petitioner says means ***fewer*** oxygen defects]… the barrier height determined from the Arrhenius plot ***went down***.").

Thus, a POSA that accepted Soukup's Arrhenius plot method as the way to determine the barrier height never would have added oxygen vacancy defects to "***lower***[] the barrier height" as Petitioner erroneously alleges (Petition, 39-40), because Soukup teaches that this would have had the exact opposite effect and would have ***increased*** the barrier height determined by the Arrhenius plot method.

2. Soukup Teaches That Adding Oxygen Vacancy Reduces the Barrier Height Determined by a Methodology Under Which None of Soukup's Devices Had a Barrier Height Within the Claimed Range

Petitioner's assertion that Soukup teaches that "a higher level of oxygen vacancy defects lowered the barrier height" (Petition, 37) is only supported by Soukup's test results that measured the barrier height using the zero-intercept method (yellow above). EX1028, 3232, Table I.

But if a POSA would have accepted Soukup's zero-intercept method (yellow) as the way to determine the barrier height – rather than the Arrhenius plot method (blue) – then the POSA would have understood that ***all*** of Soukup's tested samples, including those that Petitioner alleges have oxygen vacancy defects, had barrier heights above the claimed range of 0.2-0.5 eV. EX1028, 3233, and Table I.

Petitioner's assertion that Soukup teaches that introducing oxygen vacancy defects would have lowered Bowen's barrier height to 0.33 eV (Petition, 37-40) is entirely unsupported. Petitioner's cherry picking of a barrier height value (0.33 eV) determined using one Soukup methodology, while alleging that a POSA would have increased oxygen vacancy defects to achieve this alleged lower barrier height despite Soukup teaching that increasing oxygen vacancy defects would have had the exact ***opposite*** effect on the barrier height determined according to that methodology, is legally improper because that is not remotely what Soukup "fairly suggests." *In re Wesslau*, 353 F.2d at 241 ("It is impermissible… to pick and

choose from any one reference only so much of it as will support a given position, to the exclusion of other parts necessary to the ***full appreciation of what such reference fairly suggests to [POSA]***."); *Panduit Corp. v. Dennison Mfg. Co.*, 810 F.2d 1561, 1568 (Fed. Cir. 1987) (prior art "must be considered… as a whole, including portions that would lead away from the invention in suit"). Ground 1 fails for this additional independent reason.

D. Even if a POSA Would Have Made Petitioner's Hypothetical Bowen-Soukup Combination Petitioner Fails to Establish that it Would Have Met Limitation 1[e]

Limitation 1[e] requires "the tunnel barrier layer has a tunnel barrier height ϕ in a range of 0.2 to 0.5 eV." The antecedent for "the tunnel barrier layer" is in Limitation 1[c] ("a tunnel barrier layer"). And Limitation 1[d] requires that the tunnel barrier layer is single-crystalline MgO(001) or poly-crystalline MgO "in which a (001) crystal plane is preferentially oriented."

1. "Tunnel Barrier Height" Is an Energy Difference in a Tunnel Barrier Junction Structure

The claimed "***tunnel*** barrier height" is the energy difference between "a Fermi energy" of at least one MTJ electrode and "a bottom of a conduction band" in the "tunnel barrier layer" in the claimed "magnetoresistive device." EX1003, 2:67-3:5, 3:46-49; EX1031 ("Simmons"), 1795 ("mean barrier height above Fermi level"), Fig. 2 (annotated below).

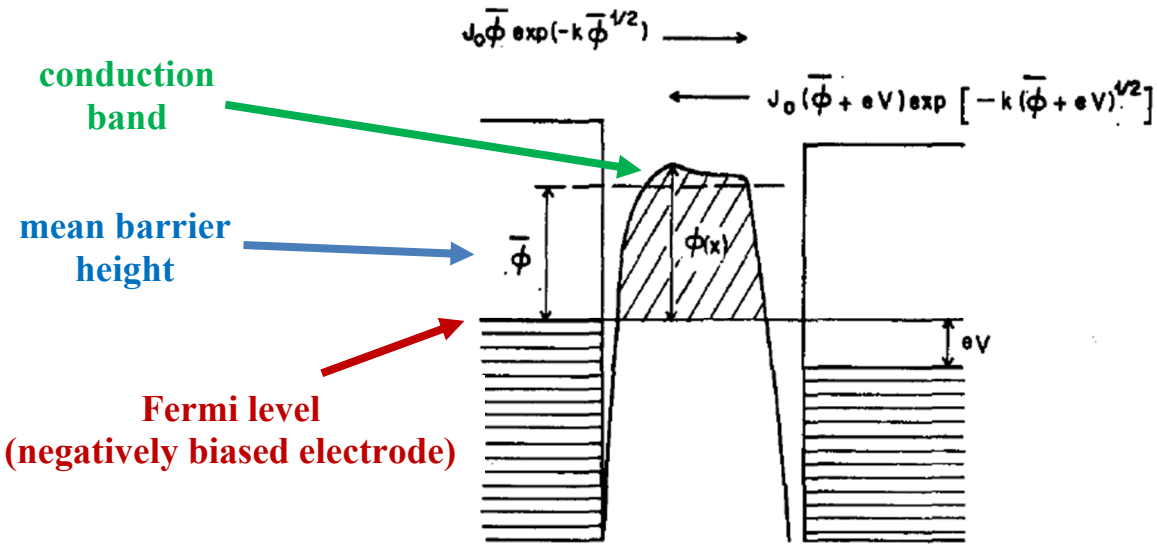

FIG. 2. Pictorial illustration of Eq. (20), showing current flow between the electrodes.

Simmons, 1795, (Fig. 2).

As discussed *supra* §§I, II.A, tunneling is a quantum mechanical phenomenon. The '263 Patent specification explains that the "***tunnel*** barrier height" is determined by fitting current and voltage measurements of an MTJ device to a mathematical description—called "Simmons' formula"—for a ***tunnelling*** junction. EX1003, 7:10-23 (Simmon's formula is "Equation (20))" in Simmons' 1963 paper)[13]; EX1031 ("Simmons"), 1793 (the Simmons' formula in

[13] The specification says that if the thickness of the tunnel barrier layer MgO "can be accurately determined" by cross-sectional TEM image then the tunnel barrier height can be determined by a simplified version of Simmon's formula. EX1003, 7:34-51.

equation (20) is a "formula… for the electric ***tunnel*** effect through a potential barrier of arbitrary shape existing in a thin insulating film.").

The '263 Patent's explanation that the tunnel barrier height in an MTJ is determined using Simmons' formula is consistent with the understanding in the art. *See e.g.*, EX1026, 1656 (estimating an MTJ's tunnel barrier height using "Simmons' equations"); Petition, 10 (admitting that "Simmons' 1963 paper provided a ***widely-used*** formula for calculating the tunnel barrier height.").

2. Petitioner Fails to Establish that Soukup Discloses a Tunnel Barrier Height of 0.2-0.5 eV as Required by Limitation 1[e]

Petitioner alleges that Limitation 1[e]'s requirement of a tunnel barrier height of 0.2-0.5 eV is met by the Bowen-Soukup combination because a POSA would have "appl[ied] ***Soukup's teaching*** about an MgO thin film barrier with a '***barrier height' of 'about 0.33 eV***' to Bowen's MgO barrier." Petition, 38; *see also id*., 39 (a POSA "would have been motivated to achieve ***Soukup's barrier height*** in an MgO MTJ"). But Petitioner fails to establish that "Soukup's barrier height" is a tunnel barrier height of 0.2-0.5 eV as claimed for several independent reasons detailed below.

a. Soukup Does Not Teach Any Value for a *Tunnel* Barrier Height as Claimed

As discussed *supra* §III.B, every Challenged Claim requires a "***tunnel*** barrier height" of 0.2-0.5 eV in a "magnetoresistive device."

Petitioner alleges that its Bowen-Soukup combination meets the claimed "magnetoresistive device having a tunnel barrier junction" because ***Bowen*** teaches such a device. Petition, 30 ("Bowen disclosed a magnetoresistive device having a tunnel barrier structure as claimed"), 34 ("Bowen disclosed an MgO tunnel barrier layer"). Bowen teaches that the way to determine the ***tunnel*** barrier height of its magnetoresistive device is by using Simmons' formula. EX1026, 1656. That is consistent with the '263 Patent's explanation and with Petitioner's admission that Simmons' formula was the "widely-used" technique in the art for determining a tunnel barrier height. EX1003, 7:10-23; Petition, 10. Yet, Petitioner does not allege that its Bowen-Soukup combination would have a tunnel barrier height falling within the claimed range if the tunnel barrier height were determined using Simmons' formula.

Petitioner merely alleges that Soukup "observed" a barrier height of "***about 0.33 eV***." Petition, 37 (emphasis in original). Petitioner does not even acknowledge that Soukup used the Arrhenius plot method to determine this alleged "barrier height." Soukup used the Arrhenius plot method—and the zero field intercept method—to determine a barrier height by trying to fit the Richardson-Schottky equation that describes Schottky emission current which is a ***different*** kind of current flow mechanism than tunneling. EX1028, 3231, Equation 5, and 3229

(explaining that Schottky emission and tunneling are different current flow mechanisms), 3233, Table I; *supra* §§V.B.1.a.i(1)-V.B.1.a.i(2).

The Board need look no further than Soukup to see that the technique chosen to determine a "barrier height" can have a profound impact on the determined value. As discussed *supra* §V.B.2, Soukup's two techniques for determining "barrier height" produced very different results. For the same emission diode for which the Arrhenius plot technique (blue below) produced the 0.33 eV value Petitioner relies upon, the zero intercept method (yellow below) produced a value that was more than twice as high and falls well above the upper end (0.5 eV) of the claimed range. *See supra* §V.B.2.

TABLE I. Summary of device data.

Device No.	S[a]	S_0[b]	φ_1[c]	φ_2[d]	P_{O_2}[e]
PY-G-11(1)	80	200	0.714	0.33	
PY-G-16(3)	105	···	0.721	···	···
PY-G-17(1)	200	194	0.721	0.33	···
PY-G-18(1)	105	···	0.694	0.34	···
PY-G-18(2)	105	222	0.700	0.35	···
PY-G-19(2)	70	133	0.710	0.32	···
PY-G-20(1)	680	···	0.695	···	···
PY-G-20(3)	680	···	0.695	···	···
PY-G-21(3)	90	···	0.732	0.34	···
PY-G-22(2)	90	209	0.780	0.21	10^{-8}
PY-G-25(3)	60	200	0.823	0.11	10^{-7}
PY-G-38(1)	120	···	1.9, 1.74[f]	···	10^{-5}, ···

[a] S = oxide thickness, in Å.
[b] S_0 = overlayer thickness, in Å.
[c] φ_1 = barrier obtained by zero intercept method, in eV.
[d] φ_2 = barrier obtained from slope of Arrhenius plot, in eV.
[e] P_{O_2} = pressure of admitted O_2 during MgO deposition, in Torr.
[f] The barrier was obtained from the slope of the Fowler-Nordheim plot.

zero intercept
MgO barrier height ***decreases*** as oxygen vacancies increase

Arrhenius plot
MgO barrier height ***increases*** as oxygen vacancies increase

The Petition was required to state its grounds "with particularity" (35 U.S.C. § 312) and to have "Content" that includes "a detailed explanation of the significance of the evidence" (37 C.F.R. § 42.22 (a)(2)). Despite this, Petitioner never explains what method a POSA purportedly would have used to determine the ***tunnel*** barrier height of Petitioner's Bowen-Soukup device. That is reason enough why Petitioner fails to prove that its Bowen-Soukup combination meets the Challenged Claims.

To the extent Ground 1 is based on the (unstated) assertion that a POSA would have used Soukup's Arrhenius plot method (blue above) to determine the barrier height of the Bowen-Soukup device—instead of using Simmons' formula as taught by Bowen—nothing supports that. Petitioner offers no reason why a POSA would have done so, let alone substantiate any (unstated) reason. There is not a single piece of evidence in the record of anyone in the art using the Arrhenius plot technique to determine the ***tunnel*** barrier height in a "magnetoresistive device having a tunnel barrier junction" like the Bowen-Soukup device. Petition, 30.

Bowen is the primary reference in the Bowen-Soukup combination. It is Bowen that Petitioner relies on to teach a "magnetoresistive device having a tunnel barrier junction structure as claimed" (Petition, 30), and Bowen used the Simmons' formula to determine the tunnel barrier height for such a device. Bowen, 1656. Indeed, Petitioner admits that Simmons' formula is "widely-used … for calculating

the ***tunnel*** barrier height" (Petition, 10) and was the technique the '263 Patent used (EX1003, 7:10-23). Petitioner does not allege that a POSA had any reason to use the Arrhenius plot method, instead of Simmons' formula, to determine the ***tunnel*** barrier height of Bowen-Soukup's "magnetoresistive device having a tunnel barrier junction," and Petitioner cites no ***evidence*** establishing that a POSA would have done so.

Petitioner does not even allege, let alone submit ***evidence*** to establish, that a "barrier height" of 0.33 eV determined using the Arrhenius plot method would have corresponded to a "***tunnel*** barrier height" for a magnetoresistive device in the range required by every Challenged Claim. Thus, even if a POSA would have been motivated by Soukup to modify Bowen's device so that the resulting device would have had a "barrier height" of 0.33 eV ***as determined using the Arrhenius plot method***,[14] Petitioner fails to establish that the resulting device would have had a "***tunnel*** barrier height" within the range required by every Challenged Claim when determined using Simmons' formula as taught by Bowen (EX1026, 1656) or when determined using ***any*** technique recognized in the art for determining a ***tunnel***

[14] A POSA would have done no such thing for the reasons discussed *supra* §§V.A-V.B

barrier height in a tunneling device like Petitioner's Bowen-Soukup device. Ground 1 fails for this additional reason.

b. Petitioner Fails to Show that Soukup's Devices Had a Barrier Height of 0.33 eV

Even if the Board were to accept Petitioner's assertion that a POSA "would have been motivated to achieve ***Soukup's*** barrier height in an MgO MTJ" (Petition, 39), Petitioner fails to establish that the actual barrier height of the Bowen-Soukup device would have met Limitation 1[e]'s requirement of a tunnel barrier height of 0.2-0.5 eV.

As discussed *supra* §V.B.2 for every diode Petitioner relies on as having an alleged barrier height of 0.33 eV, Soukup's Table I also provides a different barrier height value (measured a different way) that falls outside the claimed range. *Supra* §V.B.2. Petitioner provides no evidence establishing that the 0.33 eV value Petitioner relies on—rather than the other value Soukup reports that is outside the claimed range—accurately reflects the device's barrier height.

Worse yet, as discussed *supra* §V.B.3, Soukup warned that the Arrhenius plot method which produced the 0.33 eV value Petitioner relies on "will give a number which is ***smaller than the actual barrier [height]"*** if "the barrier [height] increases with increasing temperature" (Ex1028, 3234), and R.J. Soukup's dissertation confirmed that the barrier height of the tested diodes did in fact increase with temperature so the Arrhenius plot method "give[s] a value for the

barrier height which is ***actually less than the real barrier height***" (EX2007, 89, Fig. 40). Petitioner cannot meet its burden by relying on Soukup's reported barrier height value when a POSA understood that that reported value is wrong because it is too low and "smaller than the ***actual*** barrier [height]" (EX1028, 3234) and "actually less than the ***real*** barrier height" (EX2007, 89).

Petitioner fails to establish that the "actual barrier [height]" (EX1028, 3234) of Soukup's devices fell within the range required by any Challenged Claim. Ground 1 fails for this additional reason.

E. Petitioner Fails to Establish that the Claimed Tunnel Barrier Height Is Inherent

Recognizing that neither Bowen nor Soukup teaches a tunnel barrier height within the range required by every Challenged Claim, Petitioner desperately alleges that "the tunnel barrier height limitation is inherent when there are oxygen vacancy defects as disclosed by both Bowen and Soukup." Petition, 40. This assertion fails.

To establish that the claimed barrier height is "inherent when there are oxygen vacancy defects" (Petition, 40), Petitioner would need to prove that a tunnel barrier height within the claimed range is "necessarily present" when there are oxygen vacancy defects. *Guangdong Alison Hi-Tech Co. v. Int'l Trade Comm'n*, 936 F.3d 1353, 1364 (Fed. Cir. 2019) ("An element may be inherently disclosed only if it is ***necessarily present***, not merely probably or possibly present,

in the prior art.") (cleaned up); *PAR Pharm., Inc. v. TWI Pharms., Inc*., 773 F.3d 1186, 1195 (Fed. Cir. 2014) ("inherency must be limited when applied to obviousness, and is present only when the limitation at issue is the 'natural result' of the combination of prior art elements"). Petitioner does not remotely carry that burden.

A tunnel barrier height of 0.2-0.5 eV is ***not*** "inherent when there are oxygen vacancy defects" because the claimed tunnel barrier height range is clearly not a necessary result for every MgO barrier having "oxygen vacancy defects." Petition, 40. The Board need look no further than Bowen to see that. Petitioner argues that "there are oxygen vacancy defects [] disclosed by both Bowen and Soukup." Petition, 40. It is undisputed that Bowen reports barrier heights for its MTJ devices with an MgO barrier layer that are above the claimed ranged of 0.2-0.5 eV. EX1026, 1656 ("Simmons' equations yield ~1.1 eV for a barrier thickness d ~15Å"); Petition, 37 ("Bowen 'place[d] the barrier height at ϕ = 0.9 eV").[15]

[15] The assertion that Bowen inherently teaches the claimed tunnel barrier height is also irrelevant because Ground 1 relies on Soukup—***not Bowen***—to meet the claimed tunnel barrier height. Petition, 37-40.

Petitioner asserts that "according to the '263 Patent, the tunnel barrier height limitation is inherent when there are oxygen vacancy defects." Petition, 40. The '263 Patent says no such thing. The '263 Patent says that the MgO tunnel barrier height "is thought to decrease [] ***such as in the range of 0.10 to 0.85 eV***; more specifically, 0.2 to 0.5 eV []." EX1003, 6:59-63. Petitioner misleadingly used an ellipsis in the Petition in order to leave out the bolded language when quoting the '263 Patent (EX1003, 6:59-63). Petition, 40. The '263 Patent's broader range includes values ***outside*** the claimed range. This directly ***contradicts*** Petitioner's assertion that the '263 Patent says that a barrier height within the claimed range is "inherent" or necessarily achieved when there are oxygen vacancy defects.

Lastly, Petitioner alleges that Patent Owner's assertion in district court litigation that certain accused products meet the claimed barrier height limitation means that "[t]his limitation is satisfied" by the Bowen-Soukup combination and rendered "obvious." Petition, 40. This misapprehends Petitioner's burden. Petitioner cites Patent Owner's infringement mapping, attached to the Complaint. Petition, 40. At the ***pleading*** stage, Patent Owner argued that the accused products meet Limitation 1[e] "[o]n information and belief," and cited, *inter alia*, statements from defendant Seagate concerning its process for making the accused products. Petition, 40 (citing EX1065, 20, 22). Ultimately, Patent Owner will carry the

burden in the litigation to prove that the accused products infringe, and Patent Owner stands ready to meet that burden.

Nothing in Patent Owner's litigation pleadings absolve Petitioner of the need to carry ***its burden in this proceeding*** to prove that the Bowen-Soukup combination meets the claimed tunnel barrier height limitations. Petitioner's reliance on *Spectrum Sols. v. Longhorn Vaccines*, IPR2021-00847, Paper 13 (Nov. 12, 2021) is misplaced. In that non-precedential decision, the Board panel expressly stated that "we find Petitioner has met its burden in showing" that the prior art met all the claim limitations, including certain functional limitations. *Id*., 22. The panel ***then*** found that "[m]oreover, Patent Owner's position in the parallel district court case undercuts its various arguments on [why the petitioner allegedly failed to meet its burden on] the functional limitations of claim 1." *Id*. The panel did not find that any litigation arguments somehow absolved the petitioner of its burden to prove that the prior art met the challenged claims. The *Spectrum Sols.* decision cannot save Petitioner from its failure to carry its burden.

Petitioner bears the burden to prove the claims unpatentable. To meet that burden for Ground 1, Petitioner needs to show that its Bowen-Soukup combination has a tunnel barrier height within the range required by every Challenged Claim. Petitioner's assertion that the '263 Patent and Patent Owner's litigation pleadings somehow demonstrate that Petitioner only needed to prove that its hypothetical

Bowen-Soukup device has oxygen vacancy defects because this inherently meets the claimed tunnel barrier height is plainly wrong. Indeed, it is refuted by Petitioner's own evidence and admissions.

Petitioner says that "there are oxygen vacancy defects [] disclosed by both Bowen and Soukup." Petition, 40. Petitioner admits that Bowen teaches an "MgO barrier device" with a tunnel barrier height outside the claimed range. Petition, 37 ("Bowen 'place[d] the barrier height at $\phi = 0.9$ eV.'"). Thus, by the Petition's own admission, Bowen teaches an MgO barrier device with oxygen vacancy defects and a tunnel barrier height that does not meet the claimed range. That is fatal to Petitioner's inherency argument. Nothing in the '263 Patent or in Patent Owner's litigation pleadings can excuse Petitioner's failure to show that its Bowen-Soukup combination meets the tunnel barrier height required by every Challenged Claim.

F. Ground 1 Fails for *All* Challenged Claims for the Same Reasons It Fails for Claim 1

Claims 2-4 depend directly or indirectly from claim 1. Ground 1 thus fails for dependent claims 2-4 for the same reasons it fails for claim 1.

VI. GROUND 2 (NAGAHAMA AND SOUKUP) FAILS FOR ALL THE SAME REASONS GROUND 1 FAILS

Ground 2 uses a different primary reference—Nagahama instead of Bowen—than Ground 1 to purportedly disclose a magnetoresistive device (an MTJ) that has an MgO barrier layer and meets all the limitations of the

independent claims other than the tunnel barrier height. Petition, 46-58 (citing EX1027, ¶¶[0073]-[0075]).

Nagahama does not disclose the device's tunnel barrier height. Petitioner relies on the same Soukup reference used in Ground 1 to meet the tunnel barrier height limitation required by every Challenged Claim.

For Limitation 1[e]'s tunnel barrier of 0.2-0.5 eV, Ground 2's arguments closely track Ground 1's arguments, often word-for-word. *Compare* Petition, 55-58 *with* Petition, 37-40.

Petitioner again relies on Soukup's alleged disclosure of a "'barrier height' of 'about 0.33 eV.'" Petition, 56. As shown below, Ground 2 alleges that a POSA "would have been motivated to apply Soukup's teachings about an MgO thin film barrier with a 'barrier height' of 'about 0.33 eV' to Nagahama's MgO barrier" in the same way Ground 1 alleges that Soukup would have motivated a POSA to adopt this alleged barrier height in Bowen. Petition, 56.

Ground 2 states that "TMR was an 'important parameter'" and that a POSA was motivated to "increase TMR." Petition, 56; *compare with* Petition, 38. Like Ground 1, Ground 2 cites to Butler and Mathon to purportedly teach a desire to improve TMR. *Compare* Petition, 57 *with* 38.

Ground 2 alleges that "lowering the resistance (barrier height) for parallel electrons would increase TMR." Petition, 56; *compare with* Petition, 38 (Ground 1:

"lowering the resistance (barrier height) for parallel electrons (R_p) would increase TMR"). This assertion fails for the same reasons discussed *supra* §V.A in connection with Ground 1, because Petitioner again fatally ignores the impact that lowering the barrier height would have had on the antiparallel resistance R_{ap} which is critical to determining whether a change to barrier height would increase, decrease, or have no effect on the TMR.

Ground 2 further states that "[a]s explained for Claim 1[e] in Ground 1, one of skill reading Soukup understood there was a relationship between oxygen vacancy defects and barrier height." Petition, 56. Like Ground 1, Ground 2 alleges that a POSA would have "followed" Soukup's alleged teaching "that the barrier height was varied by adjusting the oxygen vacancy defects in the MgO barrier layer." *Compare* Petition, 57-58 *with* 39. As with Ground 1, Ground 2 alleges that "Soukup had already shown that an MgO barrier achieved a height of 0.33 eV… and that the barrier height was varied by adjusting the oxygen vacancy defects in the MgO barrier layer." *Compare* Petition, 63 *with* 38-40.

Thus, Ground 2 (like Ground 1) alleges that Soukup would have motivated a POSA to add oxygen vacancy defects to an a MgO barrier layer and that this would have achieved the alleged 0.33 eV barrier layer taught by Soukup and would have increased the TMR. This assertion fails for all the same reasons discussed *supra* §§V.A-E in connection with Ground 1, because:

- Petitioner's assertion that a POSA would have expected that lowering Nagahama's barrier height would have increased the TMR is ***entirely*** unsupported because Petitioner fails to address the impact of lowering the tunnel barrier height on R_{ap} and thus on TMR (*supra* §V.A.1-6);
- Petitioner fails to prove that Soukup teaches a ***tunnel*** barrier height at all because Soukup is not a tunneling device and Soukup did not use Simmon's equation or any other technique taught in the art for determining a ***tunnel*** barrier height in a tunneling device (*supra* §§V.B.1-V.B.3, V.D.1-V.D.2);
- Petitioner fails to prove that Soukup's barrier height is 0.33 eV because Soukup teaches that a different methodology determined a different barrier height outside the claimed range (*supra* §V.B.2, V.C, V.D) and a POSA would have been aware of R.J. Soukup's teaching that the technique used in determining the 0.33 eV value produced values that are "actually less than the real barrier height" (EX2007, 89; *supra* §V.B.3);
- Petitioner impermissibly cherry-picks disparate disclosures from Soukup in alleging that increasing oxygen vacancy defects would have lowered the barrier height to within the claimed range because:

- when the barrier height is determined using Soukup's method that produced the 0.33 eV value the barrier height increases (rather than decreases) when oxygen vacancy defects are increased; and
- Soukup only reported a decreased barrier height in response to increased oxygen vacancy defects when using a methodology for determining barrier height under which none of Soukup's devices had a barrier height within the claimed range (*supra* §V.C).

Ground 2 states that "[f]or the same reasons explained in Ground 1, the claimed tunnel barrier height range of 0.2 to 0.5 eV also would have been obvious" and that this is shown by Patent Owner's litigation pleadings. *Compare* Petition, 58 *with* 40 (Ground 1). These arguments fail for the same reasons discussed in connection with Ground 1. It is a claim "as a whole" that must be proven obvious, not an individual limitation. *Supra* §V.B.2.

Finally, Ground 2 repeats Petitioner's erroneous assertion that the claimed tunnel barrier height range of 0.2-0.5 eV is "inherent when there are oxygen vacancy defects" based on the '263 Patent and Patent Owner's litigation pleadings. *Compare* Petition, 58 *with* 40 (Ground 1). This argument fails for the same reasons discussed in connection with Ground 1. *Supra* §V.E.

As demonstrated above, Ground 2 shares every flaw identified above for Ground 1 and thus fails for the same reasons that Ground 1 fails.

VII. CONCLUSION

Petitioner fails to meet its burden to demonstrate a likelihood of showing that any Challenged Claim is unpatentable. The Board should deny institution.

Respectfully submitted,
GODO KAISHA IP BRIDGE 1

Date: December 18, 2024

/Gerald B. Hrycyszyn/

Gerald B. Hrycyszyn, Reg. No. 50,474
Richard F. Giunta, Reg. No. 36,149
WOLF, GREENFIELD & SACKS, P.C.

VIII. APPENDIX A: U.S. PATENT NO. 8,319,263 CLAIM LIST

1[pre] A magnetoresistive device having a tunnel barrier junction structure, the magnetoresistive device comprising:

1[a] a first ferromagnetic material layer of BCC structure;

1[b] a second ferromagnetic material layer of a BCC structure; and

1[c] a tunnel barrier layer located between the first and second ferromagnetic material layers, and wherein the tunnel barrier layer comprises:

1[d] a single-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented or a poly-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented, and

1[e] wherein the tunnel barrier layer has a tunnel barrier height ω in a range of 0.2 to 0.5 eV.

2. The magnetoresistive device according to claim 1, wherein at least one of the first and second ferromagnetic material layers comprises CoFeB alloy.

3[pre] The magnetoresistive device according to claim 1,

3[a] wherein said tunnel barrier height ψ is obtained by fitting J-V characteristics of the tunnel barrier junction structure to an equation (1)

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

3[b] where J is a tunnel current density flowing through the tunnel barrier layer, V is an applied bias voltage that is 100 mV or smaller, m is a mass of the free electron, e is the elementary electric charge, h is the Planck's constant, Δs is an effective thickness of the tunnel barrier layer that is approximately equivalent to (T_{MgO}−0.5 nm), and t_{MgO} is an actual thickness of the tunnel barrier layer determined using a cross-sectional transmission electron microscope image.

4. The magnetoresistive device according to claim 3, wherein at least one of the first and second ferromagnetic material layers comprises CoFeB alloy.

CERTIFICATE OF WORD COUNT

Pursuant to 37 C.F.R. § 42.24, the undersigned certifies that the foregoing **PATENT OWNER'S PRELIMINARY RESPONSE** contains 12,990 words excluding; a table of contents, a table of authorities, a certificate of service or word count, or appendix of exhibits or claim listing. Patent Owner has relied on the word count feature of the word processing system used to create this paper in making this certification.

Date: December 18, 2024

/Dara Del Rosario/
Dara Del Rosario
Paralegal
WOLF, GREENFIELD & SACKS, P.C.

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

I certify that on December 18, 2024, I will cause a copy of the foregoing document, including any exhibits filed therewith, to be served via electronic mail, as previously consented to by Petitioner, upon the following:

Michelle E. Armond	michelle.armond@armondwilson.com
Douglas R. Wilson	doug.wilson@armondwilson.com
Josepher Li	josepher.li@armondwilson.com
Monica Arnold	monica.arnold@armondwilson.com
Yue Han	amy.han@armondwilson.com
	ipr@armondwilson.com

Date: December 18, 2024

/Dara Del Rosario/
Dara Del Rosario
Paralegal
WOLF, GREENFIELD & SACKS, P.C.