

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.

IPR2024-01449
Patent 9,123,463 B2

Before JUSTIN T. ARBES, SHEILA F. McSHANE, and
JOHN D. HAMANN, *Administrative Patent Judges*.

ARBES, *Administrative Patent Judge*.

DECISION
Denying Institution of *Inter Partes* Review
35 U.S.C. § 314

I. INTRODUCTION

A. *Background and Summary*

Petitioner Western Digital Technologies, Inc. filed a Petition (Paper 1, “Pet.”) requesting *inter partes* review of claims 1 and 2 of U.S. Patent No. 9,123,463 B2 (Ex. 1007, “the ’463 patent”) pursuant to 35 U.S.C. § 311(a). Patent Owner Godo Kaisha IP Bridge 1 filed a Preliminary Response (Paper 8, “Prelim. Resp.”) pursuant to 35 U.S.C. § 313.

Pursuant to 35 U.S.C. § 314(a), the Director may not authorize an *inter partes* review unless the information in the petition and preliminary response “shows that there is a reasonable likelihood that the petitioner would prevail with respect to at least 1 of the claims challenged in the petition.” *See* 37 C.F.R. § 42.4(a) (“The Board institutes the trial on behalf of the Director.”). For the reasons that follow, we do not institute an *inter partes* review.

B. Related Matters

The parties indicate that the ’463 patent is the subject of *Godo Kaisha IP Bridge 1 v. Western Digital Technologies, Inc.*, No. 24-cv-06555 (N.D. Cal.) (transferred from D. Del.), and *Godo Kaisha IP Bridge 1 v. Seagate Technology LLC*, No. 24-cv-03691 (D. Minn.) (transferred from D. Del.). *See* Paper 5, 1; Paper 9, 2. Petitioner filed petitions challenging patents related to the ’463 patent in IPR2024-01384, IPR2024-01385, IPR2024-01386, IPR2024-01447, IPR2024-01448, IPR2024-01493, IPR2024-01494, and IPR2025-00701.

C. The ’463 Patent

The ’463 patent discloses a “magnetic tunnel junction” (MTJ) device with a “high magnetoresistance.” Ex. 1007, col. 1, ll. 26–29. The ’463 patent describes that “[m]agnetoresistive random access memories (MRAMs) refer to a large-scale integrated memory circuit that is expected to replace the currently widely used [dynamic random-access memory (DRAM)] memories.” *Id.* at col. 1, ll. 31–34. The patent further explains that “a MTJ device comprises a tunnelling junction structure in which a

tunnel barrier (to be hereafter also referred to as a ‘barrier layer’) made of an oxide is sandwiched between a first and a second electrode made of a ferromagnetic metal.” *Id.* at col. 1, ll. 41–45, Figs. 8(A), 8(B). Objectives of the patent are to “increase the output voltage of a MTJ device” and “provide a memory device with a high magnetoresistance for stable operation.” *Id.* at col. 2, ll. 51–54.

Figure 1(B) of the ’463 patent is reproduced below:

FIG. 1 (B)

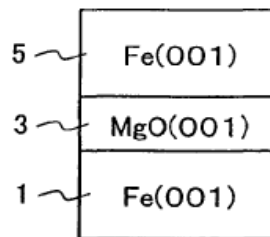


Figure 1(B) depicts the MTJ device comprising “a first Fe (001) layer 1, a second Fe (001) layer 5, and a single-crystalline MgO_x (001) layer 3 or a poly-crystalline MgO_x ($0 < x < 1$) layer 3 sandwiched therebetween, the polycrystalline layer having the (001) crystal plane preferentially oriented therein.” *Id.* at col. 5, ll. 32–34, 36–42. Further, the patent explains, “[w]hen there are oxygen vacancy defects, the potential barrier height of the MgO tunnel barrier is thought to decrease (such as in the range of 0.10 to 0.85 eV; more specifically, 0.2 to 0.5 eV), which is thought to result in an increase in the tunneling current.” *Id.* at col. 7, ll. 3–7. “Using the method according to the present embodiment of the invention, a tunnel barrier height of approximately 0.3 eV is expected, indicating that the resistance of the tunnel barrier can be lowered.”¹ *Id.* at col. 7, ll. 11–14. The ’463 patent

¹ Petitioner explains that “MTJ behavior is explained by quantum mechanics” and, for a MTJ device, “the tunnel barrier height represents the

notes that the “aforementioned tunnel barrier height ϕ was determined by fitting the electric conductance characteristics of the MTJ device (the relationship between tunnel current density J and bias voltage V) onto the Simmons’ formula . . . based on the WKB approximation, using the least squares method.” *Id.* at col. 7, ll. 21–27. Simmons’ formula, as listed in the ’463 patent and claim 1, is:

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

Id. at col. 7, ll. 45–59, col. 10, l. 19.

D. Challenged Claims

Claims 1 and 2 recite (with letter designations used in the Petition to refer to the various limitations):

1. [preamble] A tunnel barrier layer disposed on a ferromagnetic material layer that is disposed on a substrate,

[a] wherein the tunnel barrier layer comprises a poly-crystalline magnesium oxide layer in which a (001) crystal plane is preferentially oriented,

[b] wherein the tunnel barrier layer has a barrier height ϕ in a range of 0.2 to 0.5 e V, [c] where the barrier height ϕ is obtained by fitting J-V characteristics of a tunnel barrier junction structure to an equation (1):

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

[d] 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 the free electron mass, e is the elementary electric charge, h is the Plank’s constant, Δs is an effective thickness of the tunnel barrier layer that is approximately equivalent to

difference between the bottom of the conduction band of the tunnel barrier layer and the Fermi level of electrons in the conductor,” where “[e]lectrons that lie close to the Fermi level participate in tunneling.” Pet. 8–10 (citing Ex. 1024 ¶¶ 45–49).

($t_{\text{MgO}} - 0.5 \text{ nm}$), and t_{MgO} is an actual thickness of the tunnel barrier layer determined using a cross-sectional transmission electron microscope image, and

[e] wherein the ferromagnetic material layer comprises CoFeB alloy that is at least partially crystallized.

2. The tunnel barrier layer according to claim 1, wherein the ferromagnetic material layer is entirely crystallized.

E. Evidence

Petitioner relies on the following prior art:

U.S. Patent No. 7,270,896 B2, filed July 2, 2004, issued Sept. 18, 2007 (Ex. 1062, “Parkin”);

European Patent Application Publication No. EP1391942A1, published Feb. 25, 2004 (Ex. 1027, “Nagahama”);

Japanese Patent Application Publication No. JP2002-204004A, published July 19, 2002 (Ex. 1029) (Ex. 1030, English translation, “Sunai”);

M. Bowen *et al.*, *Large Magnetoresistance in Fe/MgO/FeCo(001) Epitaxial Tunnel Junctions on GaAs(001)*, 79 Appl. Phys. Letters 1655–1657 (2001) (Ex. 1026, “Bowen”); and

R. J. Soukup & D. E. Speliotis, *Voltage-Current Characteristics for Electrical Conduction Through Thin MgO Films*, 41 J. Appl. Phys. 3229–3236 (1970) (Ex. 1028, “Soukup”).

F. Prior Art and Asserted Grounds

Petitioner asserts that claims 1 and 2 of the '463 patent are unpatentable on the following grounds:

Claims Challenged	35 U.S.C. §	References/Basis
1, 2	103(a) ²	Bowen, Soukup, Sunai
1, 2	103(a)	Bowen, Soukup, Parkin
1, 2	103(a)	Nagahama, Soukup, Sunai
1, 2	103(a)	Nagahama, Soukup, Parkin

II. ANALYSIS

A. Legal Standards

A claim is unpatentable for obviousness if, to one of ordinary skill in the pertinent art, “the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made.” *KSR Int’l Co. v. Teleflex Inc.*, 550 U.S. 398, 406 (2007). The question of obviousness is

² The Leahy-Smith America Invents Act, Pub. L. No. 112-29, 125 Stat. 284 (2011) (“AIA”), amended 35 U.S.C. § 103. Because the challenged claims of the '463 patent have an effective filing date before the effective date of the applicable AIA amendment, we refer to the pre-AIA version of 35 U.S.C. § 103. *See* Pet. 26; Ex. 1007, codes (22), (63). Petitioner asserts that claims 1 and 2 would have been obvious “over Bowen in view of Soukup and Sunai *or* Parkin,” and makes alternative arguments for limitation 1[e] based on Sunai and Parkin. Pet. 26 (emphasis added), 43–49. Similarly, Petitioner asserts that claims 1 and 2 would have been obvious “over Nagahama in view of Soukup and Sunai *or* Parkin,” and makes alternative arguments for limitation 1[e] based on Sunai and Parkin. *Id.* at 26 (emphasis added), 62–66. We view each assertion as stating two separate grounds of unpatentability. *See* 37 C.F.R. § 42.104(b)(2).

resolved on the basis of underlying factual determinations, including “the scope and content of the prior art”; “differences between the prior art and the claims at issue”; and “the level of ordinary skill in the pertinent art.”

Graham v. John Deere Co., 383 U.S. 1, 17–18 (1966). Additionally, secondary considerations, such as “commercial success, long felt but unsolved needs, failure of others, etc., might be utilized to give light to the circumstances surrounding the origin of the subject matter sought to be patented. As indicia of obviousness or nonobviousness, these inquiries may have relevancy.” *Id.* When conducting an obviousness analysis, we consider a prior art reference “not only for what it expressly teaches, but also for what it fairly suggests.” *Bradium Techs. LLC v. Iancu*, 923 F.3d 1032, 1049 (Fed. Cir. 2019).

A patent claim “is not proved obvious merely by demonstrating that each of its elements was, independently, known in the prior art.” *KSR*, 550 U.S. at 418. An obviousness determination based on a combination of references requires finding “both ‘that a skilled artisan would have been motivated to combine the teachings of the prior art references to achieve the claimed invention, and that the skilled artisan would have had a reasonable expectation of success in doing so.’” *Intelligent Bio-Sys., Inc. v. Illumina Cambridge Ltd.*, 821 F.3d 1359, 1367–68 (Fed. Cir. 2016); *see KSR*, 550 U.S. at 418 (for an obviousness analysis, “it can be important to identify a reason that would have prompted a person of ordinary skill in the relevant field to combine the elements in the way the claimed new invention does”).

“Although the *KSR* test is flexible, the Board ‘must still be careful not to allow hindsight reconstruction of references . . . without any explanation as to *how* or *why* the references would be combined to produce the claimed

invention.” *TriVascular, Inc. v. Samuels*, 812 F.3d 1056, 1066 (Fed. Cir. 2016). Further, an assertion of obviousness “cannot be sustained by mere conclusory statements; instead, there must be some articulated reasoning with some rational underpinning to support the legal conclusion of obviousness.” *KSR*, 550 U.S. at 418 (quoting *In re Kahn*, 441 F.3d 977, 988 (Fed. Cir. 2006)); accord *In re NuVasive, Inc.*, 842 F.3d 1376, 1383 (Fed. Cir. 2016) (stating that “conclusory statements” amount to an “insufficient articulation[] of motivation to combine”; “instead, the finding must be supported by a ‘reasoned explanation’”); *In re Magnum Oil Tools Int’l, Ltd.*, 829 F.3d 1364, 1380 (Fed. Cir. 2016) (“To satisfy its burden of proving obviousness, a petitioner cannot employ mere conclusory statements. The petitioner must instead articulate specific reasoning, based on evidence of record, to support the legal conclusion of obviousness.”).

B. Level of Ordinary Skill in the Art

Petitioner argues that at the time of the ’463 patent (2004), a person of ordinary skill in the art would have had “a Ph.D. in electrical engineering, physics, materials science, or a related field, and at least one year of experience in the research, design, and/or development of magnetic/spintronic devices, or the equivalent,” or “a Master’s degree in electrical engineering, physics, materials science, or a related field, and four years of experience in the research, design, and/or development of magnetic/spintronic devices, or the equivalent,” where “[l]ess work experience may be compensated by a higher level of relevant education, and vice versa.” Pet. 29 (citing Ex. 1024 ¶ 25). Patent Owner applies Petitioner’s definition of the level of ordinary skill in the art for purposes of

its Preliminary Response. Prelim. Resp. 17. Based on the record presented, including our review of the '463 patent and the types of problems and solutions described in the '463 patent and cited prior art, we agree with Petitioner's proposed definition of the level of ordinary skill in the art and apply it for purposes of this Decision.

C. Claim Interpretation

We interpret each challenged claim

using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b), including construing the claim in accordance with the ordinary and customary meaning of such claim as understood by one of ordinary skill in the art and the prosecution history pertaining to the patent.

37 C.F.R. § 42.100(b). Petitioner argues that “the claim terms should be given their plain and ordinary meaning and no claim construction is necessary.” Pet. 25–26. Patent Owner does not propose interpretations of any claim terms in its Preliminary Response. We conclude that no express interpretation of any claim term is necessary to determine whether to institute an *inter partes* review in this proceeding. *See Nidec Motor Corp. v. Zhongshan Broad Ocean Motor Co.*, 868 F.3d 1013, 1017 (Fed. Cir. 2017) (“Because we need only construe terms ‘that are in controversy, and *only to the extent necessary* to resolve the controversy,’ we need not construe [a particular claim limitation] where the construction is not ‘material to the . . . dispute.’” (citation omitted) (emphasis added)).

D. Obviousness Ground Based on Bowen, Soukup, and Sunai

Petitioner contends that claims 1 and 2 are unpatentable over Bowen, Soukup, and Sunai under 35 U.S.C. § 103(a), citing the testimony of Jeffrey Bokor, Ph.D., as support. Pet. 29–52 (citing Ex. 1024). Patent Owner responds. Prelim. Resp. 18–64. We are not persuaded that Petitioner has established a reasonable likelihood of prevailing on its asserted ground.

1. Bowen

Bowen discloses that the “magnetoresistance of magnetic tunnel junctions (MTJs) is of uncontested interest for important applications with, in particular, promising perspectives for the fabrication of nonvolatile memories (Magnetic RAM).” Ex. 1026, 1655 (footnote omitted). Bowen “present[s] tunneling experiments on Fe(001)/MgO(20 Å)/FeCo(001) single-crystal epitaxial junctions of high quality grown by sputtering and laser ablation.” *Id.* (Abstract).

Bowen discloses that “numerical calculations of spin-dependent tunneling and [tunnel magnetoresistance ratio (TMR)] have been developed for single crystal MTJs such as Co/Al₂O₃/Co(100), Fe/ZnSe(100), or Fe/MgO(100),” and that “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.” *Id.* (footnotes omitted). Bowen describes that “much work has been expended to characterize the growth and electrical behavior of ultrathin MgO layers,” and presents “experimental results showing large TMR values in Fe(001)/MgO(001)/FeCo(001) epitaxial tunnel junctions.” *Id.*

Tests were performed on single-crystal epitaxially grown structures in a Fe(001)/MgO(001)/FeCo(001) tunnel junction. *Id.* With a barrier layer of 20 Å thickness, Bowen determined a barrier height of 0.9 eV, and calculated a barrier height using “Simmons’ equations” of 1.1 eV for a barrier thickness of 15 Å. *Id.* at 1656.

2. Soukup

Soukup is an article published in 1970 titled “Voltage-Current Characteristics for Electrical Conduction Through Thin MgO Films.” Ex. 1028, 3229. Soukup addresses the “voltage-current characteristics of Au-MgO-Au thin-film emission diodes formed by electron beam evaporation of Au and MgO.” *Id.* (Abstract). Soukup describes that the “voltage-current characteristics” of these diodes “are consistent with an expression derived for Schottky field emission into the conduction band of the oxide,” but test results “indicate a potential barrier height of about 0.72 eV when determined from the zero-field intercept of the straight line $\log I$ vs $V^{1/2}$ plot and about 0.33 eV when obtained from an Arrhenius plot.” *Id.* Soukup’s measurements were based on “samples . . . fabricated by evaporation of the Au and MgO to form films on a glass substrate.” *Id.* at 3229–3230. Soukup states that “[t]he apparent barrier height determined from the zero-field intercept went up for increasing oxygen pressure and the barrier height determined from the Arrhenius plot went down.” *Id.* at 3229 (Abstract).

3. *Sunai*

Sunai is directed to “a magnetoresistance effect element, magnetic memory, magnetic head, and magnetic reproducing device that can maintain a sufficiently high magnetoresistance ratio and prevent an increase in the reversal magnetic field even when the size is reduced.” Ex. 1030, code (57).

Sunai explains that when using this type of device in solid-state MRAM, “MRAM has a problem in that when the size of the memory cell is reduced to increase the capacity, the magnetic field required to reverse the magnetization direction of the free layer, the so-called reversal magnetic field, becomes larger, and a larger write current is required.” *Id.* ¶¶ 4–5. Sunai further explains that, “in the prior art, when the size of the memory cell is reduced, it is not possible to prevent an increase in the reversal magnetic field of the free layer while maintaining a sufficiently high magnetoresistance ratio.” *Id.* ¶ 9.

Sunai discloses:

In order to solve the above problem, the present invention provides a magnetoresistance effect element comprising a first ferromagnetic layer that maintains the direction of magnetization when a predetermined external magnetic field is not applied, a second ferromagnetic layer that can change the direction of magnetization when the external magnetic field is not applied, and a first tunnel barrier layer interposed between the first ferromagnetic layer and the second ferromagnetic layer, wherein the first ferromagnetic layer, the first tunnel barrier layer, and the second ferromagnetic layer form a ferromagnetic tunnel junction, and wherein the composition of the ferromagnetic material contained in the second ferromagnetic layer is expressed by the general formula $(\text{CoFe})_{100-x}\text{Y}_x$ or the general formula $(\text{CoFeNi})_{100-x}\text{Y}_x$, where Y is at least one element selected from the group consisting of B, Si, Zr, P, Mo, Al, and Nb.

Id. ¶ 11.

Sunai discloses that “[i]n a normal film formation method at room temperature, the lower limit of the film thickness at which a Co₉Fe film that does not contain B can be formed as a continuous film is about 1.5 nm.” *Id.* ¶ 27. But, “when B is added to Co₉Fe, a continuous film can be formed up to a film thickness of about 0.5 nm.” *Id.* ¶ 28. Sunai explains that “[t]he reason that an extremely thin continuous film can be formed when the element Y is added is that the addition of the element Y suppresses the diffusion or movement of atoms that reach the film formation surface during the film formation process, thereby suppressing crystallization.” *Id.* ¶ 30. In contrast, in prior art structures, according to Sunai, “when the film thickness is thinned, island structures are formed in which each island has a diameter of about several nanometers, and although each island is a ferromagnetic material, it exhibits superparamagnetism, in which the magnetization direction fluctuates, resulting in a significantly low magnetoresistance change rate.” *Id.*

4. *Claims 1 and 2*

Petitioner argues that Bowen, Soukup, and Sunai collectively teach all of the limitations of claim 1. Pet. 29–49. Petitioner contends that Bowen teaches a “tunnel barrier layer” (i.e., the “MgO barrier” layer) disposed on a “ferromagnetic material layer” (i.e., the “Fe bottom electrode”), which a person of ordinary skill in the art would have known is disposed on a “substrate,” as recited in the preamble of claim 1. *Id.* at 30–32. For limitations 1[a]–1[d] pertaining to the “tunnel barrier layer,” Petitioner relies on the teachings of Bowen and Soukup. *Id.* at 32–42. For limitation 1[e] pertaining to the “ferromagnetic material layer,” Petitioner relies on Sunai.

Id. at 43–47. We focus herein on limitations 1[b]–1[d] requiring a “barrier height ϕ in a range of 0.2 to 0.5 e V” that is “obtained by fitting J-V characteristics of a tunnel barrier junction structure to” equation (1), as those limitations are dispositive.

With respect to limitation 1[b], “wherein the tunnel barrier layer has a barrier height ϕ in a range of 0.2 to 0.5 e V,” Petitioner argues that Bowen teaches a barrier height of 0.9 eV for its MgO barrier device, “Soukup observed a ‘barrier height’ within the claimed range of ‘about 0.33 eV’ for its MgO barrier,” and a person of ordinary skill in the art “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 Bowen’s MgO barrier.” *Id.* at 34 (emphasis omitted) (citing Ex. 1026, 1656; Ex. 1024 ¶¶ 125–138; Ex. 1028, 3229 (Abstract), 3231–32, 3236, Fig. 5, Table I). Petitioner also asserts that “[t]he claimed tunnel barrier height range of 0.2 to 0.5 eV . . . would have been obvious.” *Id.* at 36 (citing Ex. 1024 ¶ 133). And Petitioner argues that “according to the ’463 [p]atent, the tunnel barrier height limitation is inherent when there are oxygen vacancy defects as disclosed by both Bowen and Soukup.” *Id.* at 37 (citing Ex. 1026, 1656; Ex. 1028, 3232, 3236).

Next, limitation 1[c] recites that “the barrier height ϕ is obtained by fitting J-V characteristics of a tunnel barrier junction structure to” equation (1): $J = [(2m\phi)^{1/2}/\Delta s](e/h)^2 \times \exp[-(4\pi\Delta s/h) \times (2m\phi)^{1/2}] \times V$. Petitioner argues—and Patent Owner agrees—that equation (1) is Simmons’ formula “from his 1963 paper for calculating tunnel barrier height.” *See id.* at 10 & n.1, 17, 38 (citing Ex. 1031, 1796–97; Ex. 1059, 1); Prelim. Resp. 50, 52, 63; Ex. 1007, col. 7, ll. 21–62. Petitioner contends that Bowen teaches “using Simmons’ formula to approximate its tunnel barrier height,”

“compared [its] measurements with ‘Simmons’ equations,” and “cited to Simmons’ foundational 1963 paper.” Pet. 38–39 (quoting Ex. 1026, 1656). Petitioner further argues that “Soukup recognized ‘Simmons’ model’ was used to evaluate the ‘height and the bias dependence of the insulator potential-energy barrier.’” *Id.* at 39 (quoting Ex. 1028, 3229). Thus, in Petitioner’s view, “[o]ne of skill would have found it obvious over Bowen and Soukup to use Simmons’ formula to calculate the ‘barrier height ϕ .’” *Id.*

Limitation 1[d] recites various variables, and values used for those variables, in equation (1). Petitioner argues that the limitation “uses the same variables from Simmons’ foundational paper” and calculating a barrier height using those variables would have been obvious. *Id.* at 39–40 (citing Ex. 1031, 1794–97). When addressing certain individual variables, such as t_{MgO} of “an actual thickness of the tunnel barrier layer determined using a cross-sectional transmission electron microscope image,” Petitioner relies either on known values from Simmons’ formula or Bowen’s disclosure. *Id.* at 40–42 (citing Ex. 1026, 1656 (describing barrier thicknesses of 20 Å and 15 Å)).

Petitioner has not shown sufficiently that Bowen and Soukup teach or suggest a “barrier height ϕ in a range of 0.2 to 0.5 e V” that is “obtained by fitting J-V characteristics of a tunnel barrier junction structure to” equation (1) with the claimed values, as recited in limitations 1[b]–1[d].³

As Petitioner points out, Bowen teaches a barrier height, obtained using Simmons’ formula, that is outside the claimed range. *See id.* at 34; Prelim. Resp. 20 & n.7; Ex. 1026, 1656 (listing a barrier height of

³ Given this determination, we need not address Patent Owner’s other arguments regarding claim 1. *See* Prelim. Resp. 18–63.

“ $\phi=0.9$ eV” for a barrier layer of 20 Å thickness and a barrier height of “ $\phi\sim 1.1$ eV” for a barrier layer of 15 Å thickness using “Simmons’ equations”). Petitioner’s position is that a person of ordinary skill in the art would have been motivated to “adjust oxygen vacancy defects to increase TMR by lowering the barrier height” of Bowen’s device. Pet. 35–37.

Limitation 1[d] in the claim recites a number of variables used in equation (1). Some are constant values (e.g., m , e , h), but some are not. For example, limitation 1[d] recites that “ V is an applied bias voltage that is 100 mV or smaller.” Petitioner argues that “Bowen measured the barrier height in the claimed range ‘at 10 mV’” and, “[a]s shown in Figure 3, Bowen also applied various bias voltages to its MTJ, including spanning 0 to 100 mV, finding the highest TMR ‘value of 60% at 10 mV.’” *Id.* at 41 (citing Ex. 1026, 1656–57, Fig. 3; Ex. 1024 ¶ 154). Similarly, limitation 1[d] recites that “ t_{MgO} is an actual thickness of the tunnel barrier layer determined using a cross-sectional transmission electron microscope image” and “ Δs is an effective thickness of the tunnel barrier layer that is approximately equivalent to $(t_{MgO}-0.5\text{ nm})$.” Petitioner argues that Bowen “fabricated an Fe/MgO/FeCo MTJ with an MgO barrier of ‘20 Å’ or 2 nm” and “used Simmons’ equations to calculate ‘a barrier thickness $d\sim 15$ Å,’ or 1.5 nm, for [its] MTJ,” yielding an effective thickness (Δs) approximately 0.5 nm less than the actual thickness (t_{MgO}). *Id.* at 41–42 (citing Ex. 1026, 1656; Ex. 1024 ¶¶ 156–157). Petitioner does not explain, however, what impact adjusting oxygen vacancy defects might have on these variables (which in turn would impact the barrier height ϕ obtained using the equation). *See id.* at 34–42. Nor does Petitioner explain, for example, whether a barrier height lower than 0.9 eV would be achievable using

Bowen's disclosed values for applied bias voltage and tunnel barrier layer thickness, or how the values would need to be changed to achieve the intended lower barrier height. *See id.* In other words, Petitioner does not tie the premise of its obviousness theory regarding barrier height to the specific equation that the claim requires be used to obtain the barrier height.

Further, because Bowen's disclosed barrier height is outside the claimed range, Petitioner relies on Soukup's purported teaching of a barrier height of "about 0.33 eV" and contends that a person of ordinary skill in the art would have been motivated to "achieve" that barrier height for the MgO barrier of Bowen's device. *Id.* at 34–36. The data that Petitioner relies on from Soukup for the "about 0.33 eV" barrier height, though, was determined using the slope of an Arrhenius plot, not Simmons' formula. Ex. 1028, 3229 (Abstract), 3231–33, Table I. In Soukup, apparent barrier heights for the samples were determined using (1) the slope of an Arrhenius plot, and (2) the zero-field intercept of the straight line $\log I$ versus $V^{1/2}$ plot. *Id.* at 3229 (Abstract), 3230–32, Fig. 3, Table I. Reproduced below is Table I of Soukup, as annotated by Patent Owner (Prelim. Resp. 39):

TABLE I. Summary of device data.

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

^a S = oxide thickness, in Å.

^b S_b = 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.

Annotated Table I of Soukup includes the results of analyses of sample test data, with the column highlighted in yellow showing the barrier heights obtained by a zero-field intercept method and the column highlighted in blue showing barrier heights obtained from the slope of an Arrhenius plot. *See* Ex. 1028, 3233; Prelim. Resp. 38–39.

Dr. Bokor testifies that “Soukup disclosed that Simmons’ formula was used to approximate tunnel barrier height” and “[o]ne of skill would have understood the ‘height and the bias dependence of the insulator potential-energy barrier’ [referenced in Soukup] included the tunnel barrier height.” Ex. 1024 ¶¶ 145–147 (quoting Ex. 1028, 3229; citing Ex. 1024 ¶¶ 45–49). We do not find this testimony persuasive. Although Soukup refers to “Simmons’ model” and the Simmons 1963 paper in its “Introduction,” it does not teach any calculation using Simmons’ formula to obtain a barrier height within the claimed range. *See* Ex. 1028, 3229, 3236 n.1; Prelim. Resp. 63. Soukup plainly recognizes that there are methods of calculating barrier height other than Simmons’ formula, and discusses at length its calculations using two such methods: the Arrhenius plot method and the zero-field intercept method. *See, e.g.*, Ex. 1028, 3229 (Abstract) (“These results . . . indicate a potential barrier height of about 0.72 eV when determined from the zero-field intercept of the straight line $\log I$ vs $V^{1/2}$ plot and about 0.33 eV when obtained from an Arrhenius plot.”), 3232–33. Petitioner does not address whether the 0.33 eV barrier height it relies on from Soukup (determined using the Arrhenius plot method) would still be within the claimed range if calculated using Simmons’ formula. *See* Prelim. Resp. 63. Nor does Petitioner rely on any values from Soukup’s disclosure that would be used as the variables in Simmons’ formula—Petitioner relies

solely on Bowen. *See* Pet. 39–42. Thus, Petitioner’s argument that Bowen and Soukup teach a barrier height within the claimed range, obtained using equation (1), is not persuasive. *See id.* at 34–42.

Finally, to the extent Petitioner relies on inherency, Petitioner has not shown sufficiently that a barrier height of 0.2–0.5 eV, obtained using equation (1), is necessarily present in, or the natural result of, a tunnel barrier layer having some amount of oxygen vacancy defects. *See id.* at 37; *Hospira, Inc. v. Fresenius Kabi USA, LLC*, 946 F.3d 1322, 1329 (Fed. Cir. 2020) (“When the prior art does not expressly disclose a claim limitation, ‘inherency may supply a missing claim limitation in an obviousness analysis.’ . . . Inherency is established in the context of obviousness when ‘the limitation at issue necessarily must be present, or the natural result of the combination of elements explicitly disclosed by the prior art.’”). The ’463 patent discloses that “[w]hen there are oxygen vacancy defects, the potential barrier height of the MgO tunnel barrier is thought to decrease (such as in the range of 0.10 to 0.85 eV; more specifically, 0.2 to 0.5 eV), which is thought to result in an increase in the tunneling current.” Ex. 1007, col. 7, ll. 3–7. The fact that the ’463 patent describes a broader range of 0.10–0.85 eV that includes values *outside* the claimed range of 0.2–0.5 eV shows that the claimed range is not necessarily achieved when oxygen vacancy defects are present. *See* Prelim. Resp. 60. Bowen also contradicts Petitioner’s position. Petitioner argues that Bowen’s MgO barrier layer has “oxygen vacancy defects” and “[o]xygen vacancies are naturally present in every oxide,” but Bowen discloses a barrier height of 0.9 eV, which is *outside* the claimed range. Pet. 15, 37. Thus, the ’463 patent and Bowen both contradict Petitioner’s assertion that a barrier height within the claimed

range of 0.2–0.5 eV, obtained using equation (1), is inherent when there are oxygen vacancy defects.

Based on the record before us, Petitioner has not shown sufficiently that Bowen and Soukup teach or suggest a “barrier height ϕ in a range of 0.2 to 0.5 e V” that is “obtained by fitting J-V characteristics of a tunnel barrier junction structure to” equation (1) with the claimed values, as recited in limitations 1[b]–1[d]. Claim 2 depends from claim 1, and Petitioner does not provide any additional argument regarding limitations 1[b]–1[d]. *Id.* at 49–52. Accordingly, Petitioner has not shown a reasonable likelihood of prevailing on its assertion that claims 1 and 2 are unpatentable over Bowen, Soukup, and Sunai.

E. Obviousness Ground Based on Bowen, Soukup, and Parkin

Petitioner contends that claims 1 and 2 are unpatentable over Bowen, Soukup, and Parkin under 35 U.S.C. § 103(a), citing the testimony of Dr. Bokor as support. Pet. 29–49 (citing Ex. 1024). With respect to limitation 1[e], Petitioner first relies on Sunai, as explained for the asserted ground above, and then “[a]lternatively” relies on Parkin, arguing that it would have been “obvious to replace Bowen’s first ferromagnetic material layer (Fe layer) with Parkin’s crystallized ferromagnetic CoFeB layer to increase TMR.” *Id.* at 43–49 (emphasis omitted). Petitioner does not provide any additional argument as to limitations 1[b]–1[d]. *Id.* Accordingly, for the reasons explained above, Petitioner has not shown a reasonable likelihood of prevailing on its assertion that claims 1 and 2 are unpatentable over Bowen, Soukup, and Parkin. *See supra* Section II.D.4.

F. Obviousness Ground Based on Nagahama, Soukup, and Sunai

Petitioner contends that claims 1 and 2 are unpatentable over Nagahama, Soukup, and Sunai under 35 U.S.C. § 103(a), citing the testimony of Dr. Bokor as support. Pet. 53–67 (citing Ex. 1024). Patent Owner responds. Prelim. Resp. 64–68. We are not persuaded that Petitioner has established a reasonable likelihood of prevailing on its asserted ground.

1. Nagahama

Nagahama describes a “tunnel magnetoresistance element capable of producing a larger magnetoresistive effect” due to “varying only the thickness of a known material having superior magnetic characteristics to increase spin polarization without changing the chemical composition.”

Ex. 1027, code (57). Nagahama relates to

tunnel magnetoresistive elements, and particularly to a ferromagnetic tunnel magnetoresistive element outputting a large signal, a tunnel magnetoresistive element in which the dependence of the magnetoresistive effect on bias voltage is controlled, and a tunnel magnetoresistive element whose crystal orientation is set to the (001) direction of a body-centered cubic lattice, a face-centered cubic lattice, or a tetragonal lattice.

Id. ¶ 1.

Nagahama describes that “[i]n order to achieve a magnetic sensor or ferromagnetic random access memory using this effect, a large magnetoresistive effect is required.” *Id.* ¶ 3. But, Nagahama describes that “the tunnel magnetoresistive effect, first, has a problem in that it is limited by spin polarization.” *Id.* ¶ 4. Thus, “in order to obtain a high magnetoresistive effect, a material with a high spin polarization has to be used.” *Id.* ¶ 6.

Nagahama discloses a magnetoresistive element “which includes a (001)-highly-oriented lower ferromagnetic electrode layer, a (001)-highly-oriented MgO barrier layer, and a (001)-highly-oriented upper ferromagnetic electrode layer on the MgO double underlayer.” *Id.*

¶ 73. Figure 17, reproduced below, illustrates this embodiment:

FIG. 17

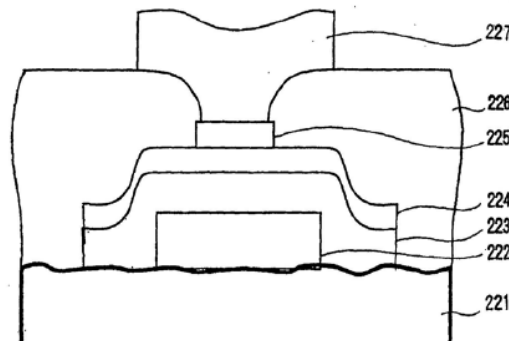


Figure 17 depicts “a sectional view of a high-quality tunnel magnetoresistive element having an amorphous (001)-highly-oriented MgO composite underlayer on a polycrystalline metal electrical wire with a rough surface.”

Id. ¶ 19. In Figure 17, “reference numeral 221 designates a lower electrical wire; 222, a MgO double underlayer; 223, a lower ferromagnetic electrode; 224, a barrier layer; 225, an upper ferromagnetic electrode; 226, an electrical insulating layer; and 227, an upper electrical wire.” *Id.* ¶ 76.

2. Claims 1 and 2

Petitioner argues that Nagahama, Soukup, and Sunai collectively teach all of the limitations of claim 1. Pet. 53–66. Petitioner contends that Nagahama teaches a “tunnel barrier layer” (i.e., the “(001)-highly-oriented MgO barrier layer”) disposed on a “ferromagnetic material layer” (i.e., the “lower ferromagnetic electrode”) disposed on a “substrate” (shown in

Figure 17 above), as recited in the preamble of claim 1. *Id.* at 53–56.

Similar to its asserted grounds based in part on Bowen, Petitioner relies on the teachings of Nagahama and Soukup for limitations 1[a]–1[d] pertaining to the “tunnel barrier layer” and the teachings of Sunai for limitation 1[e] pertaining to the “ferromagnetic material layer.” *Id.* at 53–65.

With respect to limitation 1[b], “wherein the tunnel barrier layer has a barrier height ϕ in a range of 0.2 to 0.5 e V,” Petitioner argues that Nagahama teaches “an MgO MTJ,” Soukup teaches a barrier height of “about 0.33 eV,” and an ordinarily skilled artisan “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.” *Id.* at 57–60 (citing Ex. 1027 ¶¶ 73–76; Ex. 1024 ¶¶ 198–200; Ex. 1028, 3229 (Abstract), 3231–32, Fig. 5, Table I). Petitioner also asserts that the claimed barrier height range would have been obvious “[f]or the same reasons explained” for the Bowen-based grounds. *Id.* at 59 (citing Ex. 1024 ¶ 208). And Petitioner argues that “[a]s explained” for the Bowen-based grounds, the ’463 patent shows that the “limitation is inherent when there are oxygen vacancy defects.” *Id.*

With respect to limitation 1[c] reciting Simmons’ formula, Petitioner argues that “Nagahama taught an MgO MTJ,” “[s]killed artisans were . . . aware that Simmons’ formula was used to approximate the barrier height of an MTJ,” and “Soukup recognized ‘Simmons’ model’ was used to evaluate the ‘height and the bias dependence of the insulator potential-energy barrier,” referencing its earlier arguments for the Bowen-based grounds. *Id.* at 60–61. Petitioner contends that “[b]ecause those of skill understood that Simmons’ formula was the operative equation for calculating barrier height,

one of skill would have found it obvious over Nagahama and Soukup to use Simmons' formula to calculate" the barrier height. *Id.* at 61. With respect to limitation 1[d], Petitioner similarly refers to its earlier Bowen analysis and contends that "application of Simmons' formula . . . would have been within the knowledge of a skilled artisan as expressly referenced by Nagahama." *Id.* at 61–62 (citing Ex. 1027 ¶ 14, where Nagahama cites Bowen).

For the same reasons explained above with respect to the Bowen-based grounds, Petitioner has not shown sufficiently that Nagahama and Soukup teach or suggest a "barrier height ϕ in a range of 0.2 to 0.5 e V" that is "obtained by fitting J-V characteristics of a tunnel barrier junction structure to" equation (1) with the claimed values, as recited in limitations 1[b]–1[d].⁴ *See supra* Section II.D.4; Prelim. Resp. 68. Nagahama does not teach a specific barrier height, so Petitioner relies on Soukup's "about 0.33 eV" disclosure and argues that a person of ordinary skill in the art would have been motivated to "achiev[e]" that barrier height for the MgO barrier of Nagahama's device. Pet. 57–59. Soukup's data, however, was calculated using two different methods, not Simmons' formula. *See supra* Section II.D.4. Petitioner does not make any additional arguments regarding Soukup, or the combined teachings of Nagahama and Soukup, than it did for the Bowen-based grounds. *See* Pet. 53–62.

Accordingly, based on the record before us, Petitioner has not shown sufficiently that Nagahama and Soukup teach or suggest a "barrier height ϕ in a range of 0.2 to 0.5 e V" that is "obtained by fitting J-V characteristics of a tunnel barrier junction structure to" equation (1) with the claimed values,

⁴ Given this determination, we need not address Patent Owner's other arguments regarding claim 1. *See* Prelim. Resp. 64–68.

as recited in limitations 1[b]–1[d]. Claim 2 depends from claim 1, and Petitioner does not provide any additional argument regarding limitations 1[b]–1[d]. *Id.* at 66–67. Accordingly, Petitioner has not shown a reasonable likelihood of prevailing on its assertion that claims 1 and 2 are unpatentable over Nagahama, Soukup, and Sunai.

G. Obviousness Ground Based on Nagahama, Soukup, and Parkin

Petitioner contends that claims 1 and 2 are unpatentable over Bowen, Soukup, and Parkin under 35 U.S.C. § 103(a), citing the testimony of Dr. Bokor as support. Pet. 53–67 (citing Ex. 1024). With respect to limitation 1[e], Petitioner first relies on Sunai, as explained for the asserted ground above, and then “[a]lternatively” relies on Parkin, arguing that, “[f]or the same reasons discussed” for the asserted ground based on Bowen, Soukup, and Parkin, it would have been “obvious to replace Nagahama’s first ferromagnetic material layer with Parkin’s crystallized CoFeB layer.” *Id.* at 62–66 (emphasis omitted). Petitioner does not provide any additional argument as to limitations 1[b]–1[d]. *Id.* Accordingly, for the reasons explained above, Petitioner has not shown a reasonable likelihood of prevailing on its assertion that claims 1 and 2 are unpatentable over Nagahama, Soukup, and Parkin. *See supra* Section II.F.2.

III. CONCLUSION

Based on the arguments and evidence presented by the parties, we conclude that Petitioner has not demonstrated a reasonable likelihood of prevailing with respect to at least one claim of the ’463 patent challenged in the Petition. Therefore, we do not institute an *inter partes* review.

IV. ORDER

In consideration of the foregoing, it is hereby:

ORDERED that the Petition is denied and no *inter partes* review is instituted.

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Patent 9,123,463 B2

FOR PETITIONER:

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

FOR PATENT OWNER:

Gerald B. Hrycyszyn
Jie Xiang
Thomas A. Franklin
Richard F. Giunta
Adam R. Wichman
WOLF GREENFIELD & SACKS, P.C.
ghrycyszyn-ptab@wolfgreenfield.com
jxiang-ptab@wolfgreenfield.com
tfranklin-ptab@wolfgreenfield.com
rgiunta-ptab@wolfgreenfield.com
awichman-ptab@wolfgreenfield.com