

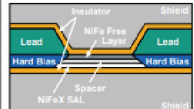
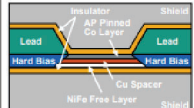
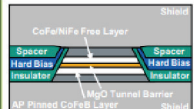
EXHIBIT BB
Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

On information and belief, Western Digital Corporation and Western Digital Technologies, Inc. (collectively, “Western Digital” or “WD”) Accused Products, including their hard disk drives (“HDDs”), infringe U.S. Patent No. 8,319,263.

US 8,319,263	Exemplary Western Digital Infringement
1. A magnetoresistive device having a tunnel barrier junction structure, the magnetoresistive device comprising:	If the preamble is limiting, each of WD’s hard disk drives (the “WD Accused Products”) includes a tunneling magnetoresistive (Tunneling MR) reading head, which is a magnetoresistive (MR) device having a tunnel barrier junction structure as claimed. <i>See, e.g.,</i> Terris presentation (Western Digital presentation): ¹

¹ Bruce D Terris, “Magnetic Recording and Magnetic Memory,” presentation at IEEE Magnetism Society Summer School, Virginia Commonwealth University, June 5, 2019, (Copy accessible at <https://egr.vcu.edu/media/engineering/documents/mne/TerrisSummerSchool2019fordistribution.pdf>)

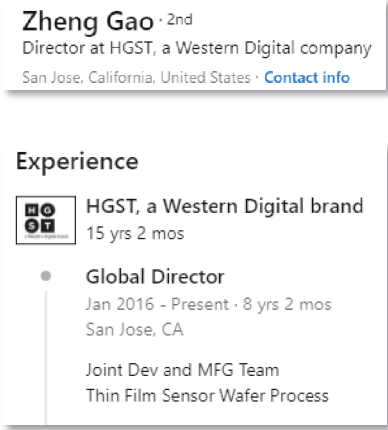
EXHIBIT BB
Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

Year	1 st Density (Gb/in ²)	Sensor Technology	Structure	MR Effect	Sense Current Geometry
1979	0.01 Gb/in ²	Thin-film Inductive		N/A	N/A
1991	0.1 Gb/in ²	MR Sensor		Anisotropic MR	CIP
1997	2 Gb/in ²	Spin Valve		Giant MR	CIP
2006	100 Gb/in ²	Tunnel Valve		Tunneling MR	CPP
?	>1Tb/in ²	?	?	?	?

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² 2023 10-K, available at <https://investor.wdc.com/static-files/9468af6f-967f-4709-bcaf-c0e9510264dd>, at 8.

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement
	who according to LinkedIn is presently Global Director for a “joint Dev and MFG team thin film sensor wafer process” at HGST, a WD company. 
a first ferromagnetic material layer of BCC structure;	On information and belief, the WD Accused Products include a first ferromagnetic material layer of a BCC [Body-Centered Cubic] structure. For example, the Terris presentation contains a slide titled “Read Head Sensor Technologies” which shows that since 2006, a Tunneling MR sensor has a structure that includes a MgO tunnel barrier between a CoFeB layer and a CoFe/NiFe layer.³ The CoFe/NiFe layer is a first ferromagnetic material layer.

³ See *supra*, footnote 1 at 22.

EXHIBIT BB
Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

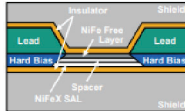
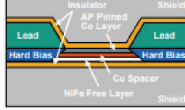
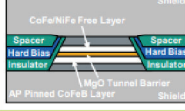
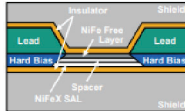
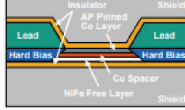
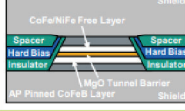
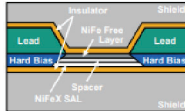
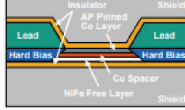
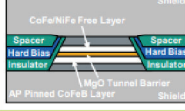
US 8,319,263	Exemplary Western Digital Infringement																																				
	Read Head Sensor Technologies <table><tr><th>Year</th><th>1st Density (Gb/in²)</th><th>Sensor Technology</th><th>Structure</th><th>MR Effect</th><th>Sense Current Geometry</th></tr><tr><td>1979</td><td>0.01 Gb/in²</td><td>Thin-film Inductive</td><td></td><td>N/A</td><td>N/A</td></tr><tr><td>1991</td><td>0.1 Gb/in²</td><td>MR Sensor</td><td></td><td>Anisotropic MR</td><td>CIP</td></tr><tr><td>1997</td><td>2 Gb/in²</td><td>Spin Valve</td><td></td><td>Giant MR</td><td>CIP</td></tr><tr><td>2006</td><td>100 Gb/in²</td><td>Tunnel Valve</td><td></td><td>Tunneling MR</td><td>CPP</td></tr><tr><td>?</td><td>>1Tb/in²</td><td>?</td><td>?</td><td>?</td><td>?</td></tr></table>	Year	1 st Density (Gb/in ²)	Sensor Technology	Structure	MR Effect	Sense Current Geometry	1979	0.01 Gb/in ²	Thin-film Inductive		N/A	N/A	1991	0.1 Gb/in ²	MR Sensor		Anisotropic MR	CIP	1997	2 Gb/in ²	Spin Valve		Giant MR	CIP	2006	100 Gb/in ²	Tunnel Valve		Tunneling MR	CPP	?	>1Tb/in ²	?	?	?	?
Year	1 st Density (Gb/in ²)	Sensor Technology	Structure	MR Effect	Sense Current Geometry																																
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US 8,319,263	Exemplary Western Digital Infringement
	WD's '006 Patent describes a magnetoresistive device 401 that includes a CoFe ferromagnetic nanolayer 413 in the “first free layer 410.” ‘006 Patent, FIG. 4B. CoFe nanolayer 413 has “a body centered cubic (BCC) configuration.” <i>Id.</i>, 10:30-33.

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US 8,319,263	Exemplary Western Digital Infringement
	FIG. 4B <i>See also '006 Patent, claim 14.</i>

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement
	14. A magnetic sensor, comprising: a seed layer; a barrier layer above the seed layer; a free layer above the barrier layer, the free layer comprising: a ferromagnetic nanolayer on the barrier layer, the ferromagnetic nanolayer comprising a crystalline structure that is BCC; an amorphous layer above the ferromagnetic nanolayer, one or more layers between the ferromagnetic nanolayer and the amorphous layer, the one or more layers comprising a crystalline structure that is FCC, wherein the one or more layers between the ferromagnetic nanolayer and the amorphous layer comprise: a first layer comprising CoFe; and a second layer comprising Co; and a non-ferromagnetic capping layer above the free layer. Further, a 2013 presentation by a member of HGST's Read Head Development team describes a "Thin Film Read Magnetic Sensor" with the following structure comprising a MgO layer between ferromagnetic layers including two Co₆₀Fe₂₀B₂₀ (namely, "CoFeB") layers.⁴ The CoFeB layers are ferromagnetic material layers and include a first ferromagnetic material layer. HGST was acquired as a subsidiary of WD in 2012, and since 2018 WD has transitioned away from hard disk drive products using the HGST brand into the WD branding.⁵

⁴ https://nccavs-usergroups.avcs.org/wp-content/uploads/PAG2013/2013_4gao.pdf at 12.

⁵ <https://www.guru3d.com/story/western-digital-moves-away-from-the-hgst-branding>.

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

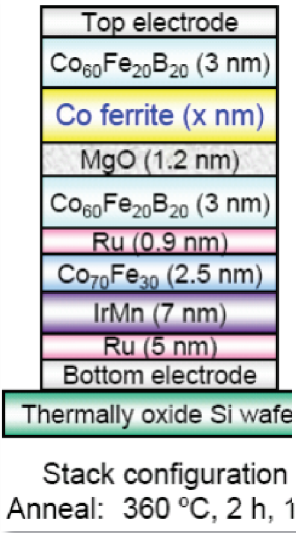
US 8,319,263	Exemplary Western Digital Infringement
	 Stack configuration Anneal: 360 °C, 2 h, 1
a second ferromagnetic material layer of a BCC structure; and	On information and belief, the WD Accused Products include a second ferromagnetic material layer of a BCC structure. For example, WD's '006 Patent describes a magnetoresistive device 401 that includes a CoFe ferromagnetic nanolayer 431 in the "second free layer 430." '006 Patent, FIG. 4B. CoFe nanolayer 431 has "a body centered cubic (BCC) configuration." <i>Id.</i>, 10:30-33.

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US 8,319,263	Exemplary Western Digital Infringement
	FIG. 4B <i>See also '006 Patent, claim 15.</i>

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement
	14. A magnetic sensor, comprising: a seed layer; a barrier layer above the seed layer; a free layer above the barrier layer, the free layer comprising: a ferromagnetic nanolayer on the barrier layer, the ferromagnetic nanolayer comprising a crystalline structure that is BCC; an amorphous layer above the ferromagnetic nanolayer, one or more layers between the ferromagnetic nanolayer and the amorphous layer, the one or more layers comprising a crystalline structure that is FCC, wherein the one or more layers between the ferromagnetic nanolayer and the amorphous layer comprise: a first layer comprising CoFe; and a second layer comprising Co; and a non-ferromagnetic capping layer above the free layer. 15. The magnetic sensor of claim 14, wherein the crystalline structure of the one or more layers between the ferromagnetic nanolayer and the amorphous layer is grown as FCC or HCP on the ferromagnetic nanolayer from a material having a crystalline structure that is BCC. Further, the sensor structure illustrated in the Terris presentation which includes a MgO tunnel barrier between a CoFeB layer and a CoFe/NiFe layer.⁶ The CoFeB layer is a second ferromagnetic material layer.

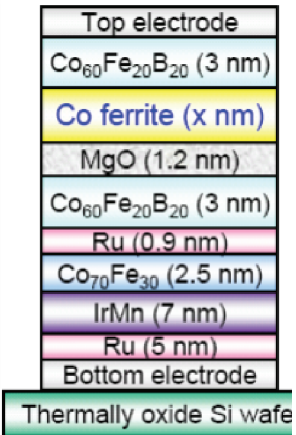
⁶ See *supra*, footnote 1 at 22.

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US 8,319,263	Exemplary Western Digital Infringement
	In addition, a 2013 presentation by a member of HGST's Read Head Development team describes a "Thin Film Read Magnetic Sensor" with the following structure comprising a MgO layer between ferromagnetic layers including two CoFeB layers.⁷ The CoFeB layers are ferromagnetic material layers and include a second ferromagnetic material layer.

⁷ See *supra*, footnote 4.

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement
	 Stack configuration Anneal: 360 °C, 2 h, 1
a tunnel barrier layer located between the first and second ferromagnetic material layers, and	The WD Accused Products include a tunnel barrier layer located between the first and second ferromagnetic material layers. For example, WD uses MgO (magnesium oxide) as a tunnel barrier in the TMR read heads of its hard disk drives, located between said first ferromagnetic material layer and said second ferromagnetic material layer. For instance, the Terris presentation contains a slide titled “Read Head Sensor Technologies” which appears to show that since 2006, a Tunneling MR sensor has a structure that includes a MgO tunnel barrier between a CoFeB layer and a CoFe/NiFe layer.⁸

⁸ See *supra*, footnote 1 at 22.

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US 8,319,263	Exemplary Western Digital Infringement
	WD's '006 Patent illustrates a barrier layer 420 in FIG. 4B that is described as including "MgO with (001) crystalline texture." '006 Patent, 10:7-13.

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement
	FIG. 4B The ferromagnetic nanolayers 413, 431 interface with the barrier layer 420 and promote the crystalline texture of the barrier layer 420, such as a barrier layer that includes MgO with (001) crystalline texture. In one embodiment, which <i>See also '006 Patent, claim 8.</i> 8. The magnetic sensor of claim 1, wherein the barrier layer comprises MgO.

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement
	Further, the 2013 presentation by HGST describe a MgO layer.⁹ The same presentation cites Dr. Yuasa's 2004 publication in a slide titled "TMR Barrier from Year 2004."¹⁰ Top electrode $\text{Co}_{60}\text{Fe}_{20}\text{B}_{20}$ (3 nm) Co ferrite (x nm) MgO (1.2 nm) $\text{Co}_{60}\text{Fe}_{20}\text{B}_{20}$ (3 nm) Ru (0.9 nm) $\text{Co}_{70}\text{Fe}_{30}$ (2.5 nm) IrMn (7 nm) Ru (5 nm) Bottom electrode Thermally oxide Si wafer Stack configuration Anneal: 360 °C, 2 h, 1
wherein the tunnel barrier layer comprises: a single-crystalline magnesium oxide layer in which (001) crystal plane is preferentially oriented or a poly-crystalline magnesium oxide layer in	Publicly available information indicates WD uses MgO as a tunnel barrier in the TMR read heads of its hard disk drives, located between said first ferromagnetic material layer and said second ferromagnetic material layer. On information and belief, the MgO tunnel barrier is 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.

⁹ See *supra*, footnote 4.

¹⁰ See *supra*, footnote 4 at 10.

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement																
which (001) crystal plane is preferentially oriented, and	For example, a 2022 report published by Seagate and Western Digital describes “CoFeB/MgO/CoFeB-based stack,” “[c]ontinued optimization of MgO MTJ stack,” “improved low RA FeCo/MgO stack” and “improved tunnel barrier quality” in the context of “future reader designs, challenges, and []potential solution paths.” Ex. J at 1, 6, 7. TABLE VI READER ROADMAP TECHNOLOGY CHALLENGES <table><tr><th>Reader Challenges</th><th>Key Issues</th><th>Possible Solutions</th><th>Important Research Projects</th></tr><tr><td>Signal</td><td>MR ~ 100% is required near RA 0.2 ohm.um² for 2.4 Tbpsl. (assumes 3dB from TDMR) MR >> 100% is required near RA 0.1 ohm.um² for 4.0 Tbpsl. (assumes 3dB from TDMR)</td><td>- Continued optimization of MgO MTJ stack. - Improved/new electrode-barrier/spacer materials and process for increased spin polarization, filtering.</td><td>- Understand Low RA/ high MR limits for practical MgO MTJ. - Optimized materials/ process for improved low RA FeCo/MgO stack. - What's after MgO to meet requirements for RA ~ 0.1, high MR? - Improved/new spacer materials for TMR, GMR with oxide/ metal/ semiconductor spacers and high spin polarization FM (e.g. Heusler) electrodes. - Demo high MR and good uniformity of nano-oxide spacer at 10nm scale.</td></tr><tr><td>Noise</td><td>Thermal magnetic noise increases rapidly with shrinking Freelay (FL) volume Shot Noise and Johnson Noise increase for smaller TMR devices. Preamp noise can be dominant near 1k Ohms</td><td>- Reduce Freelay damping constant - Maximize Freelay saturation magnetization with good anisotropy and low magnetostriction - Improved tunnel barrier quality for reduced Shot noise, lower RA for reduced Johnson noise (TMR). - Low RA, Lower preamp noise.</td><td>- engineered Freelay and cap materials/ interfaces for reduced damping - engineer magnetically soft Freelay materials near 2.4T - see above</td></tr><tr><td>SNR</td><td>In thermal magnetic noise limit, Spin Valve SNR scales as FL Ms x Utilization / damping</td><td>Improved FL materials engineering for high Ms, optimized utilization and low damping. - New device concepts for 4+ Tbpsl with high SNR</td><td>- develop lower noise preamp for high impedance, high frequency reader (e.g. 1k Ohm, 3 GHz) - engineer Freelay with very high Ms, low damping and soft magnetics. - Fundametl modeling and experimental validation scaling behavior and SNR for NLSV, STO and other promising reader concepts. - Demonstrate stable STO operation at 10 nm scale. Develop/ verify high SNR detection method. Scale design for high linear densities. - Model and characterize scaling of signal/ noise in NLSV to 10nm scale with <10nm thick channel. Develop very high impedance, high freq detector preamp. Evaluate feasibility of Graphene based NLSV.</td></tr></table> See Ex. J at 6 (annotations added) Further, the Findings of Fact, Conclusions of law, and Decision in the American Arbitration Association Case No. 651600012907 dated November 18, 2011 (“Arbitration Decision”),¹¹ state that WD, through wrongful conduct, introduced an MgO TMR head product into the market. The Arbitrator found that:	Reader Challenges	Key Issues	Possible Solutions	Important Research Projects	Signal	MR ~ 100% is required near RA 0.2 ohm.um ² for 2.4 Tbpsl. (assumes 3dB from TDMR) MR >> 100% is required near RA 0.1 ohm.um ² for 4.0 Tbpsl. (assumes 3dB from TDMR)	- Continued optimization of MgO MTJ stack. - Improved/new electrode-barrier/spacer materials and process for increased spin polarization, filtering.	- Understand Low RA/ high MR limits for practical MgO MTJ. - Optimized materials/ process for improved low RA FeCo/MgO stack. - What's after MgO to meet requirements for RA ~ 0.1, high MR? - Improved/new spacer materials for TMR, GMR with oxide/ metal/ semiconductor spacers and high spin polarization FM (e.g. Heusler) electrodes. - Demo high MR and good uniformity of nano-oxide spacer at 10nm scale.	Noise	Thermal magnetic noise increases rapidly with shrinking Freelay (FL) volume Shot Noise and Johnson Noise increase for smaller TMR devices. 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Reader Challenges	Key Issues	Possible Solutions	Important Research Projects														
Signal	MR ~ 100% is required near RA 0.2 ohm.um ² for 2.4 Tbpsl. (assumes 3dB from TDMR) MR >> 100% is required near RA 0.1 ohm.um ² for 4.0 Tbpsl. (assumes 3dB from TDMR)	- Continued optimization of MgO MTJ stack. - Improved/new electrode-barrier/spacer materials and process for increased spin polarization, filtering.	- Understand Low RA/ high MR limits for practical MgO MTJ. - Optimized materials/ process for improved low RA FeCo/MgO stack. - What's after MgO to meet requirements for RA ~ 0.1, high MR? - Improved/new spacer materials for TMR, GMR with oxide/ metal/ semiconductor spacers and high spin polarization FM (e.g. Heusler) electrodes. - Demo high MR and good uniformity of nano-oxide spacer at 10nm scale.														
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SNR	In thermal magnetic noise limit, Spin Valve SNR scales as FL Ms x Utilization / damping	Improved FL materials engineering for high Ms, optimized utilization and low damping. - New device concepts for 4+ Tbpsl with high SNR	- develop lower noise preamp for high impedance, high frequency reader (e.g. 1k Ohm, 3 GHz) - engineer Freelay with very high Ms, low damping and soft magnetics. - Fundametl modeling and experimental validation scaling behavior and SNR for NLSV, STO and other promising reader concepts. - Demonstrate stable STO operation at 10 nm scale. Develop/ verify high SNR detection method. Scale design for high linear densities. - Model and characterize scaling of signal/ noise in NLSV to 10nm scale with <10nm thick channel. Develop very high impedance, high freq detector preamp. Evaluate feasibility of Graphene based NLSV.														

¹¹ Available at https://amlawdaily.typepad.com/01302012western_interim.pdf.

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US 8,319,263	Exemplary Western Digital Infringement
	96. Because of the wrongful conduct by Western Digital and Dr. Mao, Western Digital was able to introduce an MgO TMR head product into the market approximately nine months earlier than they otherwise would have been able to do so. Arbitration Decision at 27. In addition, the Terris presentation contains a slide titled “Read Head Sensor Technologies” which appears to show that since 2006, a Tunneling MR sensor has a structure that includes a MgO tunnel barrier between a CoFeB layer and a CoFe/NiFe layer.¹² WD’s ’006 Patent also illustrates a barrier layer 420 in FIG. 4B that is described as including “MgO with (001) crystalline texture.” ’006 Patent, 10:7-13.

¹² See *supra*, footnote 1 at 22.

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US 8,319,263	Exemplary Western Digital Infringement
	The ferromagnetic nanolayers 413, 431 interface with the barrier layer 420 and promote the crystalline texture of the barrier layer 420, such as a barrier layer that includes MgO with (001) crystalline texture. In one embodiment, which <i>See also '006 Patent, claim 8.</i> 8. The magnetic sensor of claim 1, wherein the barrier layer comprises MgO.

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US 8,319,263	Exemplary Western Digital Infringement
	<i>See also id.</i>, 11:54-57: TiOx, or other suitable electrically insulating materials. In certain embodiments, the barrier layer 420 is formed to a thickness of about 10 Å or less. In some embodiments, the barrier layer is MgO due to the promotion of (001) texture from the CoFe ferromagnetic nanolayers 413, 431 and the boron layers 412, 432. Furthermore, the 2013 presentation by HGST describe a MgO layer.¹³ The same presentation cites Dr. Yuasa's 2004 publication in a slide titled "TMR Barrier from Year 2004."¹⁴ Stack configuration Anneal: 360 °C, 2 h, 1

¹³ *See supra*, footnote 4.

¹⁴ *See supra*, footnote 4 at 10.

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement
wherein the tunnel barrier layer has a tunnel barrier height ϕ in a range of 0.2 to 0.5 eV.	On information and belief, the tunnel barrier layer in WD Accused Products has an M-center type oxygen vacancies that drive tunnel barrier height into a range of 0.2 to 0.5 eV. The tunnel barrier in the WD Accused Products has oxygen vacancy defects. For example, WD's '006 Patent describes oxygen vacancies in the MgO barrier due to presence of B in the free layer. '006 Patent, 7:54-63. layer 330. For the highest TMR, amorphous CoFeB is commonly used in the free layer to achieve the proper crystallization of an MgO barrier in the sputtered magnetic tunnel junctions; likewise, amorphous CoB can be used to achieve an appropriate TMR. However, the presence of B in the free layer may cause oxygen vacancies in the MgO barrier, which may result in decreased TMR and increased interlayer coupling. Aspects disclosed herein facilitate increased TMR and decreased interlayer coupling even if B is present in the free layer. In addition, in the arbitration between Seagate and WD, on information and belief the Seagate products reflecting its alleged Trade Secret 3 had a MgO barrier layer formed from a tri-layer Mg/MgO/Mg structure; forming the final MgO barrier layer uses an anneal process, which would distribute oxygen atoms throughout the tri-layer structure to form a uniform MgO barrier layer; and this results in oxygen vacancy defects in the MgO barrier layer at least because there are fewer O atoms than Mg atoms in the Mg/MgO/Mg tri-layer structure. Arbitration Decision at 10:

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement
	<i>Trade Secret 3</i> 19. Seagate asserts that its use of a trilayer barrier layer in a TMR reader constructed by depositing a layer of magnesium (Mg), followed by a layer of magnesium oxide (MgO), followed by another layer of magnesium (Mg) is a trade secret. Seagate further asserts that three to four Seagate employees spent almost two years working on this development and that its use of a trilayer barrier layer significantly improved the performance of its reader, resulting in signal-to-noise and yield improvements. 20. In June 2007, Seagate made public its use of an Mg/MgO/Mg barrier layer in a TMR reader. At that time, a patent application Seagate filed with the United States Patent and Trademark Office that disclosed this use was published. In addition, in May 2007, a patent application Headway Technologies, Inc. filed with the United States Patent and Trademark Office that disclosed the use of “a tunnel barrier having a Mg/MgO/Mg configuration” was published. Furthermore, in that arbitration Seagate contended that WD had used Seagate’s alleged tri-layer “secret,” indicating that WD’s HDDs copied Seagate’s tri-layer Mg/MgO/Mg structure.¹⁵

¹⁵ In the Arbitration Decision, the arbitrator did not reach the issue of whether WD misappropriated the alleged tri-layer trade secret (Trade Secret 3) because of a finding that Seagate did not adequately prove alleged Trade Secret 3 qualified for trade secret protection. Arbitration Decision at 10-11. Nothing in the Arbitration Decision indicates that WD proffered any evidence that its design did not use the tri-layer structure, however.

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Claim Chart for U.S. Patent No. 8,319,263 and Western Digital

US 8,319,263	Exemplary Western Digital Infringement																														
	WD has also disclosed its use of a MgO tunnel barrier in its read/write heads, as discussed above regarding the previous limitation and incorporated here. Therefore, there are oxygen vacancies in the magnesium oxide in WD Accused Products. There are two types of oxygen vacancies in MgO: a single point defect/oxygen vacancy (also known as an “F center” vacancy); and a paired oxygen vacancy (also known as an “M center” vacancy). <i>See</i> e.g. Ex. L at 143902-2; Ex. N at 2. Two F centers can form a pair of oxygen vacancies, which becomes an M center. <i>See</i> Ex. L at 143902-2. Research studies, through both theoretical and experimental investigations, have focused on the “impact of defects” on “[e]pitaxial or textured MgO-based MTJs [that have] applications [in] read-heads or hard disk drives.” <i>See</i> e.g. Ex. N, at 2. These studies consistently confirmed that M center in MgO has an energy position of 0.4 eV relative to the fermi level (E_F), which results in the MgO having an M-center driven tunnel barrier height in a range of 0.2 to 0.5 eV. <i>See</i>, e.g.: Table 2 Magnetotransport addressing in voltage-temperature space of select oxygen vacancy localized states. <table><tr><th>Defect</th><th>Energy position (eV)</th><th>Thermal onset (K)</th><th>I_P trend</th><th>I_{AP} trend</th><th>TMR trend</th></tr><tr><td>M</td><td>0.4</td><td>35-90/130/250</td><td>?/?/?</td><td>?/?/Up</td><td>Resilient/low decrease/decrease</td></tr><tr><td>F⁺⁺</td><td>0.7</td><td>80</td><td>Up</td><td>Up and faster</td><td>Large decrease</td></tr><tr><td>F/F⁺</td><td>1.05-1.2</td><td>35</td><td>Up</td><td>Up and fast</td><td>Decrease</td></tr><tr><td>F[*]</td><td>1.6</td><td>70/130</td><td>Subtle up/subtle up</td><td>Subtle up/subtle up</td><td>Small decrease/small decrease</td></tr></table> TMR, tunnelling magnetoresistance ratio. Summary of findings on defect-mediated localized states within MgO tunnel barriers, and their impact on the qualitative trend of I_P, I_{AP} and TMR with increasing temperature within, as necessary, several temperature regimes shown in Fig. 1a. Ex. N, Table 2, at 6 (Study to “understand which defect species are present in the MgO tunnel barriers of [FeCoB/MgO/FeCoB] MTJ stacks. <i>Id.</i> at 3, 7) (annotations added) for $T > 200$ K. Referring to Supplementary Fig. 2d, this trend is especially marked in the relative TMR thermal decrease for $T > 250$ K. This might reflect the impact of <u>the M ground state at 0.4 eV away from E_F</u>²⁵. Ex. N, at 6 (annotations added)	Defect	Energy position (eV)	Thermal onset (K)	I_P trend	I_{AP} trend	TMR trend	M	0.4	35-90/130/250	?/?/?	?/?/Up	Resilient/low decrease/decrease	F ⁺⁺	0.7	80	Up	Up and faster	Large decrease	F/F ⁺	1.05-1.2	35	Up	Up and fast	Decrease	F [*]	1.6	70/130	Subtle up/subtle up	Subtle up/subtle up	Small decrease/small decrease
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	Our combined experiments and theory reveal a discrepancy in the energy position of the localized states. Experiments using $\text{Fe}_{0.4}\text{Co}_{0.4}\text{B}_{0.2}$ (FeCoB) FM electrodes [8, 9] pegged the dominant 1.1 eV barrier height within $30 < T(K) < 80 \text{ K}$ to the F center's ground state, the dominant 0.8 eV barrier height within $80 < T(K) < 250$ to the F center's excited state (i.e. unoccupied, above E_F), and the <u>dominant 0.4 eV barrier height for $T(K) > 250$ to the M center's anti-bonding ground state.</u> Ex. M, at 2 (Study of MgO-based MTJs FeCoB electrodes) (annotations added) AFM) to shift from 0.5 eV to 1.1 eV [25]. Also, increasing the annealing temperature of MTJ stacks with a MgO barrier grown by oxidizing a Mg layer <u>decreased the barrier height from 0.8 V to 0.4 eV.</u> Both results can be understood as decreasing and increasing the ratio of M to F centers, respectively. Indeed, adding oxygen should reduce the number of M centers (as paired oxygen vacancies), while annealing enables F centers to coalesce into M centers thanks to a much lower formation energy [9]. <i>Id.</i>, at 5 (annotations added) with possible defect control²⁷ can now explicitly confirm, we expect that a <u>sufficient density of M centres would lower ϕ_P to that centre's energy position of $\sim 0.4 \text{ eV}$ from E_F</u> (see Table 1), thereby yielding $\phi_P < \phi_{AP}$ and larger values of TMR. This shows how the effective barrier height of a MTJ reflects the energy position of all defects within the barrier dielectric relative to E_F, as weighed by the thermal activation of a given defect species within a precise temperature range. We thus resolve the contradiction <i>Id.</i>, at 7 (annotations added)

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	Our results, therefore, explicitly ascribe the experimental barrier heights of 0.4 eV to the presence of paired oxygen vacancies within the MgO barrier. Ex. L, at 143902-13 These DOS-based considerations thus describe how M centers can promote the formation of an extended state across the tunnel barrier near E_F that forms an effective tunnel barrier of low height for Fermi level electrons. To explicitly unravel Ex. O, at 2 (Study of MgO-based MTJs with FeCo and with FeCoB electrodes.) but not the AP state. This means that the enhanced spintronic response of our MTJs with $T_a = 300$ °C compared to those with $T_a = 200$ °C is in part due to a Δ_1 tunneling transmission channel in the MTJ's P state that is driven by the <u>M₂-defined barrier height</u> per our theory. This explanation is also supported by an inelastic electron tunneling spectroscopy signature at <u>0.4 eV measured^[13]</u> in only the MTJ's P state that was tentatively attributed^[15] to the M ground state. Finally, this decrease <i>Id.</i>, at 3 (annotations added) In contrast to M center, F center has been found to “decrease the resulting TMR [performance metric],” and “the general conclusion is that [F-type] vacancies should degrade the TMR ratio [performance metric].” <i>See</i> Ex. L at 143902-2; <i>see also</i> Ex. N at 7. On information and belief, the MgO in the WD Accused Products has oxygen deficiencies dominated by M center oxygen vacancies, and which results in a tunnel barrier height in a range of 0.2 to 0.5 eV. As discussed above, an MgO layer that has been annealed and the MgO grown by oxidizing an Mg layer are both known to increase the M to F center ratio. As discussed above, on information and belief WD uses an MgO barrier layer formed from annealing a tri-layer Mg/MgO/Mg structure, which

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	would distribute oxygen atoms throughout the metal Mg layer of the tri-layer structure to form a uniform MgO barrier layer (namely, grown by oxidizing a Mg layer). AFM) to shift from 0.5 eV to 1.1 eV [25]. Also, increasing the annealing temperature of MTJ stacks with a <u>MgO barrier grown by oxidizing a Mg layer</u> decreased the <u>barrier height from 0.8 V to 0.4 eV</u>. Both results can be understood as decreasing and increasing the ratio of <i>M</i> to <i>F</i> centers, respectively. Indeed, adding oxygen should reduce the number of <i>M</i> centers (as paired oxygen vacancies), while <u>annealing enables <i>F</i> centers to coalesce into <i>M</i> centers</u> thanks to a much lower formation energy [9]. <i>See Ex. M, at 5 (annotations added)</i> higher for transport across <i>M</i> centers than <i>F</i> centers. Since the calculated formation energy of an <i>M</i> center of 14.53 eV is lower than that of two <i>F</i> centers (14.65 eV) by 0.12 eV,⁶⁷ <u>annealing can induce the preferential presence of <i>M</i> centers over <i>F</i> centers</u>, which in turn promotes higher spintronic performance.⁴⁷ This annealing-induced <i>See Ex. L, at 143902-14 (annotations added)</i> An HGST (a WD company) patent filed in 2015 and issued in 2015 (U.S. Patent No. 9,177,573, the “573 Patent”) also describes that “[t]he MgO barrier layer is typically formed by sputter deposition and subsequent <i>annealing</i>, which forms the crystalline structure. It has been found that when boron (B) is used in one or more of the reference and free ferromagnetic layers, higher tunneling magnetoresistance ($\Delta R/R$ or TMR) is observed after <i>annealing</i>.” ’573 Patent, 2:2-8. As further evidence this limitation is met, a tunnel barrier height as claimed is the result of oxygen vacancy defects, as explained in the also-asserted U.S. Patent No. 7,884,403 (“the ’403 Patent”). For example, the ’403 Patent attributes the low barrier height and increase in tunneling current to oxygen vacancy defects. ’403 Patent, 6:47-7:2 (“when there are oxygen vacancy defects, a potential barrier height Φ of the MgO tunnel barrier is thought to decrease (such as in the range of 0.10 to 0.85

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	eV; more specifically, 0.2 to 0.5 eV), which is thought to result in an increase in the tunneling current.”). Moreover, a later-published 2016 study examined the “presence, and impact on magnetotransport, of oxygen vacancies in MgO” in an attempt to explain Dr. Yuasa’s reported “high TMR values [] observed concomitantly with tunnelling barrier heights of much lower amplitude than the 3.9eV expected from the MgO.” <i>See</i> Ex. K at 3 and 8. The study concluded that “[t]his combination of high TMR and low RA-product, []cannot be explained by standard theory,” and “confirms that defect-induced barrier heights are required.” <i>See</i> Ex. K at 8. Further, as discussed above, in the arbitration Seagate contended that WD had used Seagate’s alleged tri-layer “secret,” indicating that WD’s HDDs copied Seagate’s tri-layer Mg/MgO/Mg structure, and WD never proffered evidence that its HDDs did not have such a tri-layer structure. Arbitration Decision at 10-11, 27. On information and belief, the presence of such a tri-layer structure indicates that the magnesium oxide in WD’s HDDs has oxygen vacancy defects at least because there are fewer O atoms than Mg atoms in the Mg/MgO/Mg tri-layer structure.