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| <b>PATENT ASSIGNMENT COVER SHEET</b> |
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Electronic Version v1.1  
 Stylesheet Version v1.2

EPAS ID: PAT6748455

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| <b>SUBMISSION TYPE:</b>   | NEW ASSIGNMENT                                   |
| <b>NATURE OF CONVEYANCE:</b>  | ASSIGNMENT                                       |
| <b>CONVEYING PARTY DATA</b>   |  |
| <b>Name</b>   | <b>Execution Date</b>                            |
| HEADWAY TECHNOLOGIES, INC.  | 02/04/2019                                       |
| <b>RECEIVING PARTY DATA</b>   |  |
| <b>Name:</b>  | TAIWAN SEMICONDUCTOR MANUFACTURING COMPANY, LTD. |
| <b>Street Address:</b>  | NO. 8, LI-HSIN RD. 6                             |
| <b>Internal Address:</b>  | HSINCHU SCIENCE PARK                             |
| <b>City:</b>  | HSINCHU  |
| <b>State/Country:</b>   | TAIWAN   |
| <b>Postal Code:</b>   | 300-78   |
| <b>PROPERTY NUMBERS Total: 1</b>  |  |
| <b>Property Type</b>  | <b>Number</b>                                    |
| <b>Application Number:</b>  | 17340780   |
| <b>CORRESPONDENCE DATA</b>  |  |
| <b>Fax Number:</b>  | (214)200-0853                                    |
| <i>Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.</i> |  |
| <b>Phone:</b>   | 214-651-5000                                     |
| <b>Email:</b>   | ipdocketing@haynesboone.com                      |
| <b>Correspondent Name:</b>  | HAYNES AND BOONE, LLP (24061) IP SECTION         |
| <b>Address Line 1:</b>  | 2323 VICTORY AVENUE                              |
| <b>Address Line 2:</b>  | SUITE 700  |
| <b>Address Line 4:</b>  | DALLAS, TEXAS 75219                              |
| <b>ATTORNEY DOCKET NUMBER:</b>  | P2900078/24061.3903US03                          |
| <b>NAME OF SUBMITTER:</b>   | MARCY OGADO                                      |
| <b>SIGNATURE:</b>   | /Marcy Ogado/                                    |
| <b>DATE SIGNED:</b>   | 06/07/2021                                       |
| <b>Total Attachments: 18</b>  |  |
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**EXHIBIT B**  
**Patent Assignment**

Headway Technologies, Inc., a California Corporation, with an office at 682 South Hillview Drive, Milpitas, CA 95035 ("Assignor") is the owner of the patents and patent applications listed in Schedule I hereto (collectively the "Listed Patents"); and

Taiwan Semiconductor Manufacturing Company, Ltd, a Republic of China (Taiwan) company that maintains its principal place of business at No. 8, Li-Hsin Road 6, Hsinchu Science Park, Hsinchu 300-78, Taiwan, R.O.C. ("Assignee"), desires to acquire all right, title and interest in the Listed Patents and the other patents and related rights described below.

For good and valuable consideration, the receipt of which is hereby acknowledged, Assignor does hereby sell, assign, transfer and convey to Assignee and its successors and assigns all right, title and interest that may exist today and in the future to any and all:

- (1) Listed Patents;
- (2) patents and patent applications to which any of the Listed Patents directly or indirectly claims priority anywhere in the world;
- (3) reissues, reexaminations, extensions, continuations, continuations-in-part (except for claims in future continuations-in-part that claim new matter), continuing prosecution applications and divisions of any of the items covered by (1) or (2) above;
- (4) foreign counterparts to any of the items covered by (1), (2) or (3) above, including without limitation utility models, inventors' certificates, industrial design protection and any other form of governmental grants or issuances for the protection of inventions, designs or discoveries;
- (5) inventions, invention disclosures, designs and discoveries described, disclosed or claimed in the items covered by (1) through (4) above;
- (6) patents that issue from any of the items covered by (1) through (5) above;
- (7) claims, causes of action and enforcement rights of any kind, whether currently pending, filed or otherwise, and whether known or unknown, under or arising from any of the items covered by (1) through (6) above, including without limitation all rights to pursue and collect damages, costs, injunctive relief and other remedies for past, current or future infringement thereof and including without limitation rights afforded under 35 U.S.C. § 154(d);
- (8) royalties, income and other payments due as of the date hereof or hereafter under or arising from any of the items covered by (1) through (7) above; and
- (9) rights to apply for, file, register, maintain, extend and renew in any or all countries of the world patents, certificates of invention, utility models, industrial design protection, design patent protection and other governmental grants or issuances of any kind related to any of the items covered by (1) through (8) above.

Assignor shall execute and deliver any instruments, and do and perform any other acts and things as may be reasonably necessary or desirable for effecting and evidencing the assignments contemplated hereby,

including without limitation the execution, acknowledgment and recordation of any instruments.

Assignor hereby authorizes and requests the Commissioner of Patents and Trademarks and any other patent office to issue any and all patents, utility models or other governmental grants or issuances pertaining to any of the items assigned hereunder in the name of Assignee.

The assignments and rights pursuant hereto will inure to the benefit of Assignee and its successors, assigns and other legal representatives and is binding upon Assignor and its successors, assigns, heirs and legal representatives.

Assignor, by its duly authorized representative, has executed this assignment on the date set forth below.

DATE: Feb 4, 2019

Headway Technologies, Inc.

By: WENJIE CHEN  
Printed/Typed Name  
Title: President & CEO  
Signature Wenjie Chen

A notary public or other officer completing this certificate verifies only the identity of the individual who signed the document to which this certificate is attached, and not the truthfulness, accuracy, or validity of that document.

State of California  
County of Santa Clara

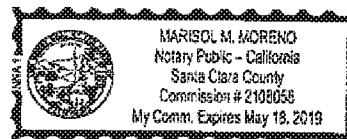
On Feb. 4, 2019 before me, Marisol M. Moreno, Notary Public, personally appeared Wenjie Chen, who proved to me on the basis of satisfactory evidence to be the person(s) whose name(s) is/are subscribed to the within instrument and acknowledged to me that he/she/they executed the same in his/her/their authorized capacity(ies), and that by his/her/their signature(s) on the instrument the person(s), or the entity upon behalf of which the person(s) acted, executed the instrument.

I certify under PENALTY OF PERJURY under the laws of the State of California that the foregoing paragraph is true and correct.

WITNESS my hand and official seal.

[Affix Seal here]

Signature of Notary Public M. Moreno



ACCEPTED:

DATE: March 11, 2019

Taiwan Semiconductor Manufacturing  
Company, Ltd

By: 

Name: Donald R. McKenna  
Printed/Typed Name

Title: Director

## Schedule 1 to Patent Assignment

U.S.

| Issued Patent Number | Title  | First Inventor | Serial Number | File Date  | Issue Date | IBM | Renesas | Remark |
|----------------------|--|----------------|---------------|------------|------------|-----|---------|--------|
| US7321507            | Reference Cell Scheme for MRAM   | Yang           | 11284299      | 11/21/2005 | 1/22/2008  | ○   | ○       |        |
| US7499314            | A Reference Cell Scheme for MRAM   | Yang           | 12002161      | 12/14/2007 | 3/3/2009   | ○   | ○       |        |
| US7480172            | A Novel Programming Scheme for Segmented Word Line MRAM Array  | Shi            | 11339189      | 1/25/2005  | 1/20/2009  | ○   | ○       |        |
| US7265404            | A Novel Bottom Conductor Lead Structure /Method For Fabricating High Performance MTJ for MRAM Applic | Cao            | 11215276      | 8/30/2005  | 9/4/2007   | ○   | ○       |        |
| US7358100            | Improved Bottom Conductor for Integrated MRAM  | Cao            | 11891923      | 8/14/2007  | 4/15/2008  | ○   | ○       |        |
| US7880249            | Spacer Structure In MRAM Cell And Method Of Fabricating The Same                                     | Yuan           | 11290763      | 11/30/2005 | 2/1/2011   | ○   | ○       |        |
| US8422276            | Space Structure in MRAM Cell and Method of Its Fabrication   | Yuan           | 12930955      | 1/20/2011  | 4/16/2013  | ○   | ○       |        |
| US7695548            | MRAM with Super-paramagnetic sensing layer   | Wang           | 11200380      | 8/9/2005   | 4/13/2010  | ○   | ○       |        |
| US8039885            | MRAM with Storage Layer and Super Paramagnetic Sensing Layer   | Wang           | 12861345      | 3/18/2010  | 10/18/2011 | ○   | ○       |        |
| US8062908            | MRAM with Storage Layer and Super Paramagnetic Sensing Layer   | Wang           | 12861365      | 3/18/2010  | 11/22/2011 | ○   | ○       |        |
| US8178383            | MRAM with Storage Layer and Super-Paramagnetic Sensing Layer   | Wang           | 13373127      | 11/4/2011  | 5/15/2012  | ○   | ○       |        |
| US7362644            | A Configurable MRAM  | Yang           | 11313019      | 12/20/2005 | 4/22/2008  | ○   | ○       |        |
| US7345911            | Multi-Bit Thermal Assisted Integrated Storage Layer MRAM Design                                      | Min            | 11353326      | 2/14/2006  | 3/18/2008  | ○   | ○       |        |
| US7588945            | Multi-State Thermally Assisted Storage   | Min            | 12012576      | 2/4/2009   | 9/15/2009  | ○   | ○       |        |
| US7479394            | A Novel Oxidation Structure/Method To Form MgO/NiFe (free layer)-MTJ for high performance MRAM appli | Hong           | 11317388      | 12/22/2005 | 1/20/2009  | ○   | ○       |        |
| US8674486            | Magnetic Random Access Memory with Selective Toggle Memory Cell                                      | Geu            | 12151224      | 5/5/2008   | 3/18/2014  | ○   | ○       |        |
| US7838438            | Bottom Electrode For MRAM Device And Method To Fabricate It  | Hong           | 11528877      | 9/29/2008  | 11/23/2010 | ○   | ○       |        |
| US8273666            | Process to Fabricate Bottom Electrode for MRAM Device  | Xiao           | 12927615      | 11/19/2010 | 9/25/2012  | ○   | ○       |        |
| US8989982            | Bottom Electrode for MRAM Device   | Xiao           | 12927670      | 11/19/2010 | 3/3/2015   | ○   | ○       |        |
| US7458020            | Planar Flux Concentrator For MRAM Devices  | Guo            | 11476485      | 6/28/2006  | 11/25/2008 | ○   | ○       |        |
| US7582942            | Planar Flux Concentrator for MRAM Devices  | Guo            | 12290410      | 10/30/2008 | 9/1/2009   | ○   | ○       |        |
| US7672083            | Hafnium Doped Cap and Free Layer for MRAM Device   | Hong           | 11582244      | 10/17/2006 | 3/2/2010   | ○   | ○       |        |
| US7508042            | Spin Transfer MRAM Device With Magnetic Biasing  | Guo            | 11644132      | 12/22/2008 | 3/24/2009  | ○   | ○       |        |
| US7715224            | MRAM with Enhanced Programming Margin  | Min            | 11787330      | 4/18/2007  | 5/11/2010  | ○   | ○       |        |
| US7885964            | MRAM With Cross-Tie Magnetization  | Min            | 12159241      | 4/25/2008  | 2/8/2011   | ○   | ○       |        |
| US7809543            | Method and Implementation Of Stress Test for MRAM  | Yang           | 11904434      | 9/27/2007  | 10/27/2009 | ○   | ○       |        |
| US7480173            | Spin Transfer MRAM Device With Novel Magnetic Free Layer   | Guo            | 11717347      | 3/13/2007  | 1/20/2009  | ○   | ○       |        |
| US8058697            | Spin Transfer MRAM Device With Novel Magnetic Synthetic Free Layer                                   | Guo            | 11725491      | 3/26/2007  | 11/15/2011 | ○   | ○       |        |
| US8268641            | Spin Transfer MRAM Device with Novel Magnetic Synthetic Free Layer                                   | Guo            | 13373173      | 11/7/2011  | 9/18/2012  | ○   | ○       |        |
| US7852662            | Spin Torque Switching MRAM, SpinRAM, Array   | Yang           | 11788324      | 4/24/2007  | 12/14/2010 | ○   | ○       |        |
| US7508700            | Method Of Magnetic Tunneling Layer Pattern Layout For MRAM   | Zhong          | 11724435      | 3/15/2007  | 3/24/2009  | ○   | ○       |        |
| US8497558            | MRAM With Means of Controlling Magnetic Anisotropy   | Min            | 11973751      | 10/10/2007 | 7/30/2013  | ○   | ○       |        |
| US7663131            | A Novel SyAF Structure To Fabricate Mbit MTJ MRAM  | Hong           | 11715728      | 3/8/2007   | 2/19/2010  | ○   | ○       |        |
| US8865321            | Spin Transfer MrAM Device with Reduced Coefficient of MTJ Resistance Variation                       | Guo            | 11881627      | 7/22/2016  | 1/9/2018   | ○   | ○       |        |
| US7750421            | A High Performance MTJ Element for STT-RAM And Method For Making the Same                            | Hong           | 11880583      | 7/23/2007  | 7/8/2010   | ○   | ○       |        |
| US8435437            | A High Performance MTJ Element for STT-RAM and Method for Making the Same                            | Hong           | 12803191      | 6/21/2010  | 5/7/2013   | ○   | ○       |        |
| US8059898            | A High Performance MTJ Element for STT-RAM and Method for Making the Same                            | Hong           | 12803189      | 6/21/2010  | 11/15/2011 | ○   | ○       |        |
| US8080432            | A High Performance MTJ Element STT-RAM and Method for Making the Same                                | Hong           | 12803190      | 6/21/2010  | 12/20/2011 | ○   | ○       |        |
| US8133745            | Method Of Magnetic Tunneling Layer Processes For Spin-Transfer Torque MRAM Devices                   | Zhong          | 11975045      | 10/17/2007 | 3/13/2012  | ○   | ○       |        |
| US7938027            | Method Of MRAM Fabrication With Zero Electrical Shorting   | Xiao           | 12006889      | 1/7/2008   | 5/3/2011   | ○   | ○       |        |
| US7577021            | Spin Transfer MRAM Device With Separated CPP Assisted Writing  | Guo            | 11966375      | 11/21/2007 | 6/18/2009  | ○   | ○       |        |
| US7755933            | Spin Transfer MRAM Device with Separated CPP Assisted Writing  | Guo            | 12462453      | 8/4/2009   | 7/13/2010  | ○   | ○       |        |
| US7760544            | Spin Transfer MRAM Device with Separated CPP Assisted Writing  | Guo            | 12462434      | 8/4/2009   | 7/20/2010  | ○   | ○       |        |

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|-----------|---|-------|----------|------------|------------|---|---|--|
| US7764536 | Spin Transfer MRAM Device with Separated CPP Assisted Writing   | Guo   | 12462462 | 8/4/2009   | 7/27/2010  | ○ | ○ |  |
| US8334213 | Bottom Electrode Etching Process in MRAM Cell   | Mao   | 12455757 | 6/5/2009   | 12/18/2012 | ○ | ○ |  |
| US8372661 | A High Performance MTJ Element for Conventional MRAM And For STT-RAM And Method For Making The Same           | Hong  | 11981127 | 10/31/2007 | 2/12/2013  | ○ | ○ |  |
| US8749003 | A High Performance MTJ Element for Conventional MRAM and for STT-RAM and a Method for Making the Same         | Hong  | 13764357 | 2/11/2013  | 6/10/2014  | ○ | ○ |  |
| US8057925 | A Low Switching Current Dual Spin Filter (DSF) Element for STT-RAM and Method for Making The Same             | Hong  | 12079445 | 3/27/2008  | 11/15/2011 | ○ | ○ |  |
| US8404367 | Low Switching Current Dual Spin Filter (DSF) Element for STT-RAM and a Method for Making the Same             | Hong  | 13317484 | 10/19/2011 | 3/26/2013  |   |   |  |
| US8726491 | Method of Forming a Spin-Transfer Torque Random Access Memory (STT-RAM) Device                                | Hong  | 13373128 | 11/4/2011  | 5/20/2014  | ○ | ○ |  |
| US7948044 | A Low Switching Current MTJ Element For Ultra-High STT-RAM and Method For Making The Same                     | Hong  | 12082155 | 4/9/2008   | 5/24/2011  | ○ | ○ |  |
| US7782661 | Boosted Gate Voltage Programming For Spin-RAM Array   | Hsu   | 12313487 | 11/20/2008 | 8/24/2010  | ○ | ○ |  |
| US8248841 | Boosted Gate Voltage Programming for Spin-Torque MRAM Array   | Yang  | 12806094 | 8/5/2010   | 8/21/2012  | ○ | ○ |  |
| US8133561 | Structure and Method To Fabricate High Performance MTJ Devices For Spin-Transfer Torque (STT) - RAM           | Hong  | 12284068 | 9/18/2008  | 3/20/2012  | ○ | ○ |  |
| US7929370 | A Novel Spin Momentum Transfer MRAM Design  | Min   | 12313798 | 11/24/2008 | 4/19/2011  | ○ | ○ |  |
| US7957163 | Single Bit Line SMT MRAM Array Architecture and the Programming Method  | Yang  | 12387537 | 5/4/2009   | 8/7/2011   | ○ | ○ |  |
| US7804706 | Bottom Electrode Mask Design For Ultra-Thin Interlayer Dielectric Approach in MRAM Devices Fabricati          | Zhong | 12313117 | 11/17/2008 | 9/26/2010  | ○ | ○ |  |
| US7994597 | A Novel MRAM Design With Coupling Valve Switching Mechanism   | Min   | 12381667 | 3/13/2009  | 8/6/2011   | ○ | ○ |  |
| US7884433 | Method fo High Density Spin-Transfer Torque MRAM Process  | Zhong | 12290495 | 10/31/2008 | 2/8/2011   | ○ | ○ |  |
| US8324693 | High Density Spin-Transfer Torque MRAM Process  | Zhong | 12830333 | 1/4/2011   | 12/4/2012  | ○ | ○ |  |
| US8183061 | A High Density Spin-Transfer Torque MRAM Process  | Zhong | 12931648 | 2/7/2011   | 5/22/2012  | ○ | ○ |  |
| US8018756 | Gate Drive Voltage Boost Schemes For Memory Array   | Yang  | 12459655 | 7/6/2009   | 9/13/2011  | ○ | ○ |  |
| US7985572 | Magnetic Memory Capable Of Minimizing Gate Voltage Stress In Unselected Memory Cells                          | Yang  | 12583255 | 8/17/2008  | 7/26/2011  | ○ | ○ |  |
| US9170879 | Scrubbing the Accumulated Read Error in A Memory System   | Yang  | 12456923 | 6/24/2008  | 10/27/2015 | ○ | ○ |  |
| US7808027 | A Novel Free Layer/Capping Layer For High Performance MRAM MTJ  | Hong  | 12319971 | 1/14/2009  | 10/5/2010  | ○ | ○ |  |
| US8609262 | STT-RAM with A Magnetic Tunnel Junction Written in Thermally Assisted Method                                  | Hong  | 12460412 | 7/17/2009  | 12/17/2013 | ○ | ○ |  |
| US9331271 | Structure and Method to Fabricate High Performance MTJ Devices for Spin-Transfer Torque (STT)-RAM Application | Hong  | 14098604 | 12/8/2013  | 5/3/2016   | ○ | ○ |  |
| US7863060 | Method of Double Patterning and Etching Magnetic Tunnel Junction Structures for Spin-Transfer Torque          | Belen | 12383298 | 3/23/2009  | 1/4/2011   | ○ | ○ |  |
| US8437181 | Shared Bit Line Array With Switch Transistors Between the Bit Lines   | Yang  | 12803523 | 8/29/2010  | 5/7/2013   | ○ | ○ |  |
| US8565014 | Shared Bit Line SMT MRAM Array with Shunting Transistors Between the Bit Lines                                | Yang  | 13887287 | 5/4/2013   | 10/22/2013 | ○ | ○ |  |
| US8576618 | Shared Bit Line SMT MRAM Array with Shunting Transistors Between the Bit Lines                                | Yang  | 13887288 | 5/4/2013   | 11/5/2013  | ○ | ○ |  |
| US8570793 | Shared Bit Line SMT MRAM Array with Shunting Transistors Between the Bit Lines                                | Yang  | 13887289 | 5/4/2013   | 10/29/2013 | ○ | ○ |  |
| US8654577 | Shared Bit Line SMT MRAM Array with Shunting Transistors Between the Bit Lines                                | Yang  | 13887291 | 5/4/2013   | 2/18/2014  | ○ | ○ |  |
| US7919407 | Method of High Density Field Inducted MRAM Process  | Tom   | 12590845 | 11/17/2009 | 4/5/2011   | ○ | ○ |  |
| US9343463 | Method of High Density Memory Fabrication   | Tom   | 12586900 | 9/29/2008  | 5/17/2016  | ○ | ○ |  |
| US8274819 | Read Disturb Free SMT Reference Cell Scheme II  | Yang  | 12656226 | 2/4/2010   | 8/25/2012  | ○ | ○ |  |
| US8138562 | A Novel Bit Line Preparation Method in MRAM Fabrication   | Mao   | 12559193 | 10/20/2009 | 3/20/2012  | ○ | ○ |  |

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|-----------|---|--------|----------|------------|------------|---|---|--|
| US8722543 | Composite Hard Mask With Upper Sacrificial Dielectric Layer for the Patterning and Etching of Nanometer Size MRAM Devices     | Belen  | 12804840 | 7/30/2010  | 5/13/2014  | ○ | ○ |  |
| US8422287 | A pulse field assisted spin momentum transfer MRAM design   | Min    | 12807611 | 9/8/2010   | 4/16/2013  | ○ | ○ |  |
| US8133909 | Method to Fabricate Thin Metal Via Interconnects on Copper Wires in MARM Devices  | Mao    | 12806361 | 6/11/2010  | 3/13/2012  | ○ | ○ |  |
| US8605520 | Replaceable, Predict-Tracking Reference Lines   | Pu     | 12824184 | 9/22/2010  | 12/10/2013 | ○ | ○ |  |
| US8493357 | Reference Cell Architectures for Small Memory Array Block Activation  | Sunaga | 12925492 | 10/22/2010 | 7/16/2013  | ○ |   |  |
| US8217684 | Fast and Accurate Current Driver with Zero Standby Current and Features for Boost and Temperature Compensation for MRAM Write | Yuh    | 12925004 | 10/12/2010 | 7/10/2012  | ○ |   |  |
| US8785036 | Improved Magnetic Tunnel Junction for MRAM Applications   | Cao    | 12930877 | 1/19/2011  | 7/22/2014  | ○ |   |  |
| US9224940 | Magnetic Tunnel Junction for MRAM Applications  | Cao    | 14315436 | 6/26/2014  | 12/29/2015 | ○ |   |  |
| US9455400 | Magnetic Tunnel Junction for MRAM Applications  | Cao    | 14879949 | 12/28/2015 | 9/27/2016  |   |   |  |
| US8693273 | Averaging for MRAM Sense Amplifiers Method and Apparatus for Scrubbing  | Yuh    | 13345116 | 1/5/2012   | 4/9/2014   |   |   |  |
| US8775865 | Accumulated Disturb Data Errors in Array of SMT MRAM Mem Cells Inc Rewriting Ref Bits   | Yang   | 13136292 | 7/29/2011  | 7/8/2014   |   |   |  |
| US8492169 | Improved Magnetic Tunnel Junction for MRAM Applications   | Cao    | 13136929 | 8/15/2011  | 7/23/2013  |   |   |  |
| US8738004 | Magnetic Tunnel Junction for MRAM Applications  | Wei    | 13841741 | 7/16/2013  | 8/27/2014  |   |   |  |
| US8900884 | MTJ Element for STT MRAM  | Witold | 13525502 | 6/18/2012  | 12/2/2014  |   |   |  |
| US8921961 | Storage Element for STT MRAM Applications   | Kula   | 13617432 | 9/14/2012  | 12/30/2014 |   |   |  |
| US8991503 | STT-MRAM Reference Layer Having Substantially Reduced Stray Field and Consisting of a Single Magnetic Domain                  | Beach  | 13421863 | 3/16/2012  | 3/17/2015  |   |   |  |
| US8968895 | MRAM Cell With Flat Topography and Controlled Bit Line to Free Layer Distance and Method of Manufact                          | Han    | 10732013 | 12/10/2003 | 11/29/2005 | ○ | ○ |  |
| US7335960 | MRAM Cell with Flat Topography and Controlled Bit Line to Free Layer Distance and Method of Manufact                          | Han    | 11178262 | 7/12/2005  | 2/26/2008  | ○ | ○ |  |
| US6974708 | Oxidation Structure/Method to Fabricate a High-Performance Magnetic Tunneling Junction MRAM                                   | Hong   | 10820391 | 4/8/2004   | 12/13/2005 | ○ | ○ |  |
| US7045841 | Oxidation Structure/Method to Fabricate a High-Performance Magnetic Tunneling Junction MRAM                                   | Hong   | 11268352 | 11/7/2005  | 5/16/2006  | ○ | ○ |  |
| US6979586 | Magnetic Random Access Memory Array with Coupled Soft Adjacent Magnetic Layer   | Guo    | 10872916 | 6/21/2004  | 12/27/2005 | ○ | ○ |  |
| US7085183 | Adaptive Algorithm for MRAM Manufacturing   | Yang   | 10889911 | 7/13/2004  | 9/1/2006   | ○ | ○ |  |
| US7045368 | MRAM Cell Structure and Method of Fabrication   | Hong   | 10849311 | 6/19/2004  | 5/16/2006  | ○ | ○ |  |
| US7476919 | MRAM Cell Structure and Method of Fabrication   | Hong   | 11418910 | 5/5/2006   | 1/13/2009  | ○ | ○ |  |
| US7811912 | A Novel Underlayer For High Performance Magnetic Tunneling Junction MRAM  | Hong   | 10881445 | 6/30/2004  | 11/3/2009  | ○ | ○ |  |
| US7999360 | A Novel Underlayer for High Performance Magnetic Tunneling Junction MRAM  | Hong   | 12589466 | 10/23/2009 | 6/16/2011  | ○ | ○ |  |
| US8673854 | A Novel Underlayer for High Performance Magnetic Tunneling Junction MRAM  | Hong   | 12589466 | 10/23/2009 | 3/16/2014  | ○ | ○ |  |
| US7241632 | Method of Fabricating MRAM Cell Structure Containing Sidewall Spacers   | Yang   | 11106320 | 4/14/2005  | 7/10/2007  | ○ | ○ |  |
| US7544983 | MTJ read head with sidewall spacers   | Yang   | 11825032 | 7/3/2007   | 6/9/2009   | ○ | ○ |  |
| US7978505 | Heat Assisted Switching and Separated Read-Write MRAM   | Zhou   | 12322107 | 1/29/2009  | 7/12/2011  | ○ | ○ |  |
| US8184411 | MTJ incorporating CoFe/Ni multilayer film with perpendicular anisotropy for MRAM application                                  | Zhang  | 12589614 | 10/26/2009 | 5/22/2012  | ○ | ○ |  |
| US8456883 | Method of Spin Torque MRAM Process Integration  | Liu    | 13482157 | 5/29/2012  | 6/4/2013   |   |   |  |
| US8660158 | Minimal Thickness SAF Structure with Perpendicular Magnetic Anisotropy for STT-MRAM   | Beach  | 13808780 | 9/11/2012  | 10/14/2014 |   |   |  |
|           | Minimal Thickness Synthetic Antiferromagnetic (SAF) Structure with Perpendicular Magnetic Anisotropy for STT-MRAM             | Beach  | 14499507 | 9/18/2014  |            |   |   |  |
| US8772051 | Fabrication Method for Embedded Magnetic Memory   | Zhong  | 13766890 | 2/14/2013  | 7/8/2014   |   |   |  |



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|------------|---|----------|----------|------------|------------|---|---|--------------------|
| US6917536  | Adaptive Reference Scheme for Magnetic Memory Applications  | Jan      | 13560176 | 10/25/2012 | 12/23/2014 |   |   |                    |
| US9343132  | MRAM Write Pulses to Dissipate Intermediate State Domains   | Lee      | 13999523 | 5/22/2013  | 5/17/2016  |   |   |                    |
| US9747865  | Improved Adaptive Reference Scheme for Magnetic Memory Applications   | Jan      | 14980050 | 12/28/2015 | 8/29/2017  |   |   |                    |
|            | Improved Adaptive Reference Scheme for Magnetic Memory Applications   | Jan      | 15686448 | 8/25/2017  |            |   |   |                    |
| US9805816  | Implementation of One Time Programmable Memory using a MRAM Stack Design  | Jan      | 15078182 | 3/23/2016  | 10/31/2017 |   |   |                    |
| US8780299  | Seed Layer for Improving the Thermal Budget of the PMA Layer for Embedded MRAM Applications   | Zhu      | 14949232 | 11/23/2015 | 10/3/2017  |   |   |                    |
|            | Seed Layer for Improving the Thermal Budget of the PMA Layer for Embedded MRAM Applications   | Zhu      | 15707373 | 9/18/2017  |            |   |   |                    |
|            | A Writing Scheme to Reduce Back Hopping for STT-MRAM  | Liu      | 15616116 | 6/7/2017   |            |   |   |                    |
| US966529   | MgO Insertion in Free Layer for Magnetic Memory Applications  | Iwata    | 15461779 | 3/17/2017  | 5/8/2018   |   |   |                    |
|            | MgO Insertion in Free Layer for Magnetic Memory Applications  | Iwata    | 15972284 | 5/7/2018   |            |   |   |                    |
| US9871195  | Spacer Assisted Ion Beam Etching of Spin Torque Magnetic Random Access Memory   | Yang     | 15465644 | 3/22/2017  | 1/16/2018  |   |   |                    |
|            | STT-MRAM Heat Sink and Magnetic Shield Structure Design for More Robust Read/Write Performance  | Zhong    | 15857782 | 12/29/2017 |            |   |   |                    |
|            |   |          |          | 8/29/2018  |            |   |   | Remark, it is #137 |
|            | Initialization Process for Magnetic Random Access memory  | Lee      | 15818148 | 11/20/2017 |            |   |   |                    |
|            | Self-Adaptive Halogen Treatment to Improve Photoresist pattern and MRAM Device uniformity   | Yang     | 15885240 | 8/24/2017  |            |   |   |                    |
|            | High Thermal Stability by Doping of Oxide Capping Layer for Spin Torque Transfer (STT) Magnetic Random Access Memory  | Jan      | 15728818 | 10/10/2017 |            |   |   |                    |
| US10134982 | Free Layer Sidewall Oxidation and Spacer Assisted Magnetic Tunnel Junction (MTJ) Etch for High Performance Magnetoresistive Random Access Memory (MRAM) Devices | Yang     | 15789150 | 10/20/2017 | 11/20/2018 |   |   |                    |
|            | Nitride Capping Layer for Spin Torque Transfer (STT)-Magnetoresistive Random Access Memory (MRAM)   | Iwata    | 15881035 | 1/26/2018  |            |   |   |                    |
|            | CMP Stop Layer and Sacrifice Layer for High-Yield Small Size MRAM Devices   | Yang     | 15891767 | 2/8/2018   |            |   |   |                    |
|            | Multiply Spin-Coated Ultra-Thick Hybrid Hard Mask for Sub 60nm MRAM Devices   | Yang     | 15898086 | 2/19/2018  |            |   |   |                    |
|            | Fabrication of Large Height Top Metal Electrode for Sub 60nm MRAM Devices   | Yang     | 15902415 | 2/22/2018  |            |   |   |                    |
|            | Metal/Dielectric/Metal Hybrid to Define Ultra-large Height Top Electrode for Sub 60nm MRAM Devices  | Yang     | 15902381 | 2/22/2018  |            |   |   |                    |
|            | Novel Free Layer Structure of Magnetoresistive Memory (MRAM) for Metal Mo or W Capping Layer  | Fukuzawa | 15933479 | 3/23/2018  |            |   |   |                    |
|            | Ion Beam Etching Fabricated Sub 30nm Vias to Reduce Conductive Material Re-Deposition for Sub 60nm MRAM Devices   | Yang     | 16047512 | 4/6/2018   |            |   |   |                    |
|            | Highly Selective Ion Beam Etch Hard Mask for Sub 60nm MRAM Devices  | Yang     | 15951873 | 4/12/2018  |            |   |   |                    |
|            | Highly Physical Ion Resistive Spacer to Define Chemical Damage Free Sub 60nm MRAM Devices   | Yang     | 15988244 | 5/22/2018  |            |   |   |                    |
|            | Sub 60nm Etchless MRAM Devices by Ion Beam Etching Fabricated T-shaped Bottom Electrode   | Yang     | 16008629 | 6/14/2018  |            |   |   |                    |
|            | Under-cut Via Electrode for Sub 60nm Etchless MRAM Devices by Decoupling the Via Etch Process   | Yang     | 16008650 | 6/14/2018  |            |   |   |                    |
| US7122386  | Pad/D/D Structure   | Tomg     | 11231674 | 9/21/2005  | 10/17/2006 | ○ | ○ |                    |
| US9450119  | Magnetic Tunnel Junction Patterning Using Ta/TaN as Hard Mask   | Tomg     | 11378555 | 3/17/2006  | 5/26/2013  | ○ | ○ |                    |
| US7528457  | A Novel Method To Form Non-magnetic NiFeMg Cap for the NiFe(free)-MTJ Stack to Enhance dRVR   | Hong     | 11404446 | 4/14/2006  | 5/5/2009   | ○ | ○ |                    |
| US7595520  | Paramagnetic NiFeHf Capping Layer Is Deposited By Co-Sputtering of NiFe and Hf  | Hong     | 11496691 | 7/31/2006  | 9/29/2009  | ○ | ○ |                    |
| US8378330  | A Novel Capping Layer for a Magnetic Tunnel Junction Device to Enhance dRVR and a Method of Making  | Hong     | 12584190 | 9/1/2009   | 2/19/2013  | ○ | ○ |                    |

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|-----------|---|-------|----------|------------|------------|---|---|--|
| US6176622 | A Process For Manufacturing A Magnetic Tunnel Junction (MTJ) Device   | Hong  | 12857775 | 1/27/2010  | 5/15/2012  | ○ | ○ |  |
| US7598579 | A Novel Magnetic Tunnel Junction (MTJ) To Reduce Spin Transfer Magnetization Switching Current                    | Hong  | 11899875 | 1/30/2007  | 10/6/2009  | ○ | ○ |  |
| US8269292 | A Novel Magnetic Tunnel Junction (MTJ) To Reduce Spin Transfer Magnetization Switching Current                    | Hong  | 12584946 | 9/15/2009  | 9/18/2012  | ○ | ○ |  |
| US6456893 | A Novel Magnetic Tunnel Junction (MTJ) To Reduce Spin Transfer Magnetization Switching Current                    | Hong  | 12584971 | 9/15/2009  | 6/4/2013   | ○ | ○ |  |
| US7695551 | Composite Hard Mask For the Patterning/Etching Of Nanometer-size Magnetic Multilayer-based device                 | Xiao  | 11901999 | 9/20/2007  | 4/13/2010  | ○ | ○ |  |
| US8105948 | Method Of Exposing Magnetic Tunnel Junction Structure Using Chemical Mechanical Polishing                         | Zhong | 12070286 | 2/14/2008  | 1/31/2012  | ○ | ○ |  |
| US8169816 | Design and Fabrication Methods of Partial Cladded Write Line to Enhance Write Margin for Magnetic Ra              | Min   | 12584952 | 9/15/2009  | 5/1/2012   | ○ | ○ |  |
| US8470462 | Structure/Method for Enhancing Interfacial Perpendicular Anisotropy in CoFe(B)/MgO/CoFeB Magnetic Tunnel Junction | Hong  | 12927939 | 11/30/2010 | 6/25/2013  | ○ |   |  |
| US9159908 | Composite magnetic free layer within magnetic tunnel junction for MRAM application                                | Cao   | 13066222 | 5/5/2011   | 10/13/2015 | ○ |   |  |
| US8541855 | Co/Ni Multilayers with Improved Out-of-plane Anisotropy for Magnetic Device Applications                          | Jan   | 13068398 | 5/10/2011  | 9/24/2013  | ○ |   |  |
| US8508006 | Co/Ni Multilayers with Improved Out-of-plane Anisotropy for Magnetic Device Applications                          | Jan   | 13561201 | 7/30/2012  | 5/13/2013  |   |   |  |
| US9373780 | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 13955035 | 7/31/2013  | 6/21/2016  | ○ |   |  |
| US869281  | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 13955039 | 7/31/2013  | 4/15/2014  | ○ |   |  |
| US8687649 | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 14244943 | 4/4/2014   | 3/24/2015  | ○ |   |  |
| US8878323 | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 14032593 | 9/20/2013  | 11/4/2014  | ○ |   |  |
| US9373777 | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 14529242 | 10/31/2014 | 6/21/2016  | ○ |   |  |
| US8475733 | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 14529246 | 10/31/2014 | 10/25/2016 | ○ |   |  |
| US9373778 | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 14529251 | 10/31/2014 | 6/21/2016  | ○ |   |  |
| US9391265 | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 14529254 | 10/31/2014 | 7/12/2016  | ○ |   |  |
| US8687847 | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 14244937 | 4/4/2014   | 3/24/2015  | ○ |   |  |
| US8687849 | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 14244940 | 4/4/2014   | 3/24/2015  | ○ |   |  |
| US862348  | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan   | 14032599 | 9/20/2013  | 2/24/2015  | ○ |   |  |
| US868784  | Magnetic element with improved out-of-plane anisotropy for spintronics applications                               | Jan   | 12931866 | 2/11/2011  | 4/14/2015  | ○ |   |  |
| US8582927 | Multilayers having reduced perpendicular demagnetizing field using moment dilution for spintronics applications   | Jan   | 13066172 | 5/4/2011   | 11/26/2013 | ○ |   |  |
| US9046411 | Multilayers Having Reduced Perpendicular Demagnetizing Field Using Moment Dilution for Spintronic Application     | Jan   | 14047130 | 10/7/2013  | 6/2/2015   | ○ |   |  |
| US8823118 | Spin Torque transfer MTJ fabricated with a composite tunneling barrier layer                                      | Hong  | 13344292 | 1/5/2012   | 9/2/2014   |   |   |  |
| US871365  | High thermal stability reference structure with out-of plane anisotropy for Magnetic Device                       | Wang  | 13406972 | 2/28/2012  | 10/26/2014 |   |   |  |
| US9472752 | High Thermal Stability Reference Structure with Out-of-Plane Anisotropy for Magnetic Device Applications          | Wang  | 14493416 | 9/23/2014  | 10/16/2016 |   |   |  |

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| US9466789  | High Thermal Stability Reference Structure with Out-of-Plane Anisotropy for Magnetic Device Applications                          | Wang        | 14511273  | 10/10/2014 | 10/11/2016 |   |   |  |
|            | Reduction of Capping Layer Resistance Area Product for Magnetic Device Applications   | Jan         | 13441158  | 4/8/2012   |            |   |   |  |
| US9946934  | High Thermal Stability Free Layer with High Out-of-Plane Anisotropy for Magnetic Device Applications                              | Wang        | 13409456  | 3/1/2012   | 2/3/2015   |   |   |  |
| US8952760  | High Thermal Stability Free Layer Structure with Out-of-Plane Anisotropy for Magnetic Device Applications                         | Wang        | 13448557  | 4/17/2012  | 10/7/2014  |   |   |  |
| US8748197  | Reverse Partial Etching Scheme for Magnetic Device Applications   | Wang        | 13419507  | 3/14/2012  | 6/10/2014  |   |   |  |
|            | Improve MTJ CD Variation by HM Trimming   | Shen        | 15/988183 | 5/22/2018  |            |   |   |  |
| US9929958  | Method to Make Small Isolated Features with Pseudo-Planarization for TMR and MRAM   | Han         | 10719723  | 11/21/2003 | 8/16/2005  | ○ | ○ |  |
| US9524511  | Novel Method to Connect a Magnetic Device to CMOS Transistor  | Zhong       | 13571675  | 8/10/2012  | 9/3/2013   |   |   |  |
|            | Multi-layer Structure for Reducing Film Roughness in Magnetic Devices   | Zhu         | 15589755  | 5/19/2017  |            |   |   |  |
| US9860177  | Method to Minimize MTJ Sidewall Damage and Bottom Electrode Redeposition using ISE Trimming                                       | Annapragada | 14/548378 | 9/9/2015   | 5/23/2017  |   |   |  |
|            | Perpendicularly Magnetized Ferromagnetic Layers having an Oxide Interface Allowing for Improved Control of the Oxidation          | Thomas      | 15/196807 | 6/29/2016  |            |   |   |  |
| US9673385  | Seed Layer for Growth of <111> Magnetic Materials   | Liu         | 15/079469 | 3/24/2016  | 6/8/2017   |   |   |  |
| US9880473  | New Surface Treatment Method for DARC to Shrink Photo Resist CD   | Haq         | 15/189295 | 6/22/2016  | 1/30/2018  |   |   |  |
|            | Scanning Ferromagnetic Resonance for Wafer-Level Characteristics of Magnetic Thin Films and Multilayers                           | Guisan      | 15/463074 | 3/20/2017  |            |   |   |  |
|            | Protective Passivation Layer for Magnetic Tunnel Junctions  | Iwata       | 15/463113 | 3/20/2017  |            |   |   |  |
| US9972777  | MTJ Device Process/Integration Method with Pre-Patterned Seed Layer   | Haq         | 15/479497 | 4/5/2017   | 5/15/2018  |   |   |  |
|            | Post Treatment to Reduce Shunting Devices for Physical Etching Process  | Wang        | 15/479514 | 4/5/2017   |            |   |   |  |
| US9935261  | Dielectric Encapsulation Layer for Magnetic Tunnel Junction (MTJ) Devices using Radio Frequency (RF) Sputtering                   | Patel       | 15/479522 | 4/5/2017   | 4/3/2018   |   |   |  |
|            | A Method to Remove Sidewall Damage after MTJ Etching  | Zhongjian   | 15/465642 | 3/22/2017  |            |   |   |  |
|            | Combined Physical and Chemical Etch to Reduce Magnetic Tunnel Junction (MTJ) Sidewall Damage                                      | Shen        | 15/595484 | 5/15/2017  |            |   |   |  |
|            | SiO <sub>2</sub> /Ny-based Encapsulation Layer for Magnetic Tunnel Junctions  | Sundar      | 15/619825 | 6/12/2017  |            |   |   |  |
| US10014465 | Maintaining Coercive Field After High Temperature Anneal for Magnetic Device Applications with Perpendicular Magnetic Anisotropy  | Liu         | 15/477268 | 4/3/2017   | 7/3/2018   |   |   |  |
|            | Maintaining Coercive Field After High Temperature Anneal for Magnetic Device Applications with Perpendicular Magnetic Anisotropy  | Liu         | 15/022662 | 6/29/2018  |            |   |   |  |
| US10038138 | High Temperature Volatilization of Sidewall Materials from Patterned Magnetic Tunnel Junctions                                    | Patel       | 15/728639 | 10/10/2017 | 7/13/2018  |   |   |  |
| US10043851 | Improve Etch Selectivity by Introducing Oxidants to Noble Gas During Physical MTJ Etching   | Shen        | 15/688113 | 8/3/2017   | 8/7/2018   |   |   |  |
|            | Low Resistance MgO Capping Layer for Perpendicularly Magnetized magnetic Tunnel Junctions   | Patel       | 15/841479 | 12/14/2017 |            |   |   |  |
|            | Etch-Less Self-Aligned Magnetic Tunnel Junction (MTJ) Device Structure  | Haq         | 15/653160 | 7/19/2017  |            |   |   |  |
|            | Pulse Writing in Perpendicular Magnetic Recording   | Tang        | 15/933486 | 3/23/2018  |            |   |   |  |
|            | Electrical Testing Apparatus for Spintronics Devices  | Jan         | 15/902407 | 2/22/2018  |            |   |   |  |
|            | Improving MTJ Device Performance by Controlling Device Shape  | Haq         | 15/910494 | 11/13/2017 |            |   |   |  |
|            | Ferromagnetic Resonance (FMR) Electrical Testing Apparatus for Spintronic Devices   | Jan         | 15/875004 | 1/19/2018  |            |   |   |  |
| US10153427 | Improved Magnetic Tunnel Junction (MTJ) Performance by Introducing Oxidants to Methanol with or without Noble Gas during MTJ Etch | Shen        | 15/858129 | 12/29/2017 | 12/11/2018 |   |   |  |

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|           | Improvement of MTJ Device Performance by Adding Stress Modulation Layer to MTJ Device Structure  | Haq      | 15/968035 | 5/1/2018   |           |  |  |  |
| US8710603 | Engineered Magnetic Layer Having Improved Perpendicular Anisotropy Using Glassing Agents for Spintronics Applications                    | Jan      | 13408656  | 2/29/2012  | 4/29/2014 |  |  |  |
| US898260  | Engineered Magnetic Layer Having Improved Perpendicular Anisotropy Using Glassing Agents for Spintronics Applications                    | Jan      | 13548859  | 7/13/2012  | 4/15/2014 |  |  |  |
| US9252710 | Free Layer with Out-of-Plane Anisotropy for Magnetic Device Applications   | Wang     | 1366169   | 11/27/2012 | 2/2/2016  |  |  |  |
| US9437268 | Free Layer with Out-of-Plane Anisotropy for Magnetic Device Applications   | Wang     | 14866871  | 10/19/2015 | 9/6/2016  |  |  |  |
| US8981505 | Mg Discontinuous Insertion Layer for Improving MTJ Shunt   | Moriyama | 13739016  | 1/11/2013  | 3/17/2015 |  |  |  |
| US9082960 | Fully Compensated Synthetic Antiferromagnet for Spintronics Applications   | Jan      | 13863542  | 4/16/2013  | 7/14/2015 |  |  |  |
| US9147333 | Hybridized Oxide Capping Layer for Perpendicular Magnetic Anisotropy   | Pi       | 13935826  | 7/5/2013   | 9/29/2015 |  |  |  |
| US9236558 | Hybridized Oxide Capping Layer for Perpendicular Magnetic Anisotropy   | Pi       | 14842038  | 9/1/2015   | 1/12/2016 |  |  |  |
| US9276201 | Hybridized Oxide Capping Layer for Perpendicular Magnetic Anisotropy   | Pi       | 14867047  | 9/29/2015  | 9/1/2016  |  |  |  |
| US9425387 | Maintain Coercive Field after High Temperature Anneal for Magnetic Device Applications with Perpendicular Magnetic Anisotropy            | Liu      | 14847433  | 9/8/2015   | 8/23/2016 |  |  |  |
| US9490054 | Seed Layer for Multilayer Magnetic Materials   | Jan      | 13549327  | 10/11/2012 | 11/8/2016 |  |  |  |
|           | Improved Seed Layer for Multilayer Magnetic Materials  | Jan      | 15344618  | 11/7/2016  |           |  |  |  |
|           | Multiple Hard Mask Patterning to Fabricate 20nm and Below MRAM Devices   | Yang     | 15790849  | 10/23/2017 |           |  |  |  |
|           | Dual Magnetic Tunnel Junction Stack Design   | Sundar   | 16133864  | 9/18/2018  |           |  |  |  |
|           | Improved CD Uniformity of Island Photo Resist Pattern (Isolated) Using Alternating Phase Shifting Mask                                   | Haq      | 16133869  | 9/18/2018  |           |  |  |  |
|           | Self-Aligned Encapsulation Hard Mask to Separate Physically Under-Etched MTJ Cells to Reduce Conductive Re-Deposition                    | Yang     | 16113079  | 8/27/2018  |           |  |  |  |
|           | Large Height Tree-Like Sub 30nm Vias to Reduce Conductive Material Re-Deposition for Sub 60nm MRAM Devices                               | Yang     | 16113088  | 8/27/2018  |           |  |  |  |
|           | Highly Physical Etch Resistive Photoresist Mask to Define Large Height Sub 30nm Via and Metal Hard Mask for MRAM Devices                 | Yang     | 16133855  | 9/18/2018  |           |  |  |  |
|           | Dual Magnetic Tunnel Junction Devices for Magnetic Random Access Memory (MRAM)   | Sundar   | 16056791  | 8/7/2018   |           |  |  |  |
|           | Multi-Probe Ferromagnetic Resonance (FMR) Apparatus for Wafer Level Characterization of Magnetic Films                                   | Guisan   | 16056783  | 8/7/2018   |           |  |  |  |
|           | Improved Magnetic Layer for Magnetic Random Access Memory (MRAM) by Moment Enhancement   | Jan      | 16109083  | 8/22/2018  |           |  |  |  |
|           | Avoiding Oxygen Plasma Damage During Hard Mask Etching in Magnetic Tunnel Junction (MTJ) Fabrication Process                             | Shen     | 16/056770 | 8/7/2018   |           |  |  |  |
|           | Method for Measuring Saturation Magnetization of Magnetic Films and Multilayer Stacks  | Guisan   | 16/161166 | 10/16/2018 |           |  |  |  |
|           | Monolayer-by-Monolayer Growth of MgO Layers Using Mg Sublimation and Oxidation   | Patel    | 16161161  | 10/16/2018 |           |  |  |  |
|           | Multiple Spacer Assisted Physical Etching of Sub 60nm MRAM Devices   | Yang     | 16161139  | 10/16/2018 |           |  |  |  |
|           | Multilayer Structure for Reducing Film Roughness in Magnetic Devices   | Zhu      | 16173201  | 10/29/2018 |           |  |  |  |
|           | Cooking for PMA (Perpendicular Magnetic Anisotropy) Enhancement of STT-MRAM (Spin-Torque Transfer-Magnetic Random Access Memory) Devices | Liu      | 16184528  | 11/8/2018  |           |  |  |  |
| US6950480 | Method of Forming a Magnetic Tunneling Junction (MTJ) MRAM Device and a TMR Read Head  | Hong     | 10848310  | 5/19/2004  | 11/1/2005 |  |  |  |
| US7238979 | Method of Forming a Magnetic Tunneling Junction (MTJ) MRAM   | Hong     | 11238049  | 5/19/2004  | 7/3/2007  |  |  |  |
| US803293  | Method to Reduce Magnetic Film Stress for Better Yield   | Zhong    | 13489258  | 5/11/2012  | 8/12/2014 |  |  |  |

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| US8933542 | Method to Reduce Magnetic Film Stress for Better Yield  | Zhong    | 14454324 | 8/7/2014   | 1/13/2015  |  |  |   |
|           | Seed Layer for PMA Thin Film  | Moriyama | 13883545 | 4/16/2013  |            |  |  |   |
|           | Reduction of Barrier Resistance X Area (RA) Product and Protection of (PMA) for Magnetic Device Applications      | Liu      | 14278243 | 5/15/2014  |            |  |  |   |
| US9987350 | MTJ Etching with Improved Uniformity and Profile by Adding Passivation Step                                       | Shen     | 14726545 | 5/31/2015  | 2/8/2018   |  |  |   |
| US9842988 | Magnetic Tunnel Junction with Low Defect Rate after High Temperature Anneal for Magnetic Device Applications      | Liu      | 14803111 | 7/20/2015  | 12/12/2017 |  |  |   |
|           | Magnetic Tunnel Junction with Low Defect Rate after High Temperature Anneal for Magnetic Device Applications      | Liu      | 15835592 | 12/8/2017  |            |  |  |   |
|           | Physical Cleaning with In-Situ Dielectric Encapsulation Layer for Spintronic Device Application                   | Wang     | 14813854 | 7/30/2015  |            |  |  |   |
|           | Title<br>Multilayer Structure for Reducing Film Roughness in Magnetic Devices                                     | Zhu      | 16221868 | 12/17/2018 |            |  |  | HT15-008_CIPB_CON<br>Contin of s/n 16173201 |
|           | Minimal Thickness Synthetic Antiferromagnetic (SAF) Structure with Perpendicular Magnetic Anisotropy for STT-MRAM | Beach    | 16258770 | 1/28/2019  |            |  |  | HT12-0116B<br>Div of s/n 14489507           |

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| 1                    |         |   |               |             |            |            |         |
| 2                    | 4936862 | Reference Cell Scheme for MRAM  | Yang          | 2006-314866 | 11/21/2006 | 3/2/2012   | ○ ○     |
| 3                    | 5305584 | Spacer Structure in MRAM Cell And Method Of Fabricating The Same  | Yuan          | 2006-323676 | 11/30/2006 | 7/5/2013   | ○ ○     |
| 4                    | 5357367 | A Configurable MRAM   | Yang          | 2006-342730 | 12/20/2006 | 6/6/2013   | ○ ○     |
| 5                    | 5068988 | A Novel Oxidation Structure/Method To Form MgO/NiFe(free layer)-MTJ for high performance MRAM appli               | Hong          | 2006-346048 | 12/22/2006 | 8/24/2012  | ○ ○     |
| 6                    | 5066034 | A Novel Method To Form Non-magnetic NiFeMg Cap for the NiFe(free)-MTJ Stack to Enhance dR/R                       | Hong          | 2007-106461 | 4/13/2007  | 8/24/2012  | ○ ○     |
| 7                    | 5346453 | Paramagnetic-NiFeHf Capping Layer Is Deposited By Co-Sputtering of NiFe and Hf                                    | Hong          | 2007-199432 | 7/31/2007  | 8/23/2013  | ○ ○     |
| 8                    | 5006154 | Barium Doped Cap and Free Layer for MRAM Device   | Hong          | 2007-270566 | 10/17/2007 | 8/1/2012   | ○ ○     |
| 9                    | 5582526 | Spin Transfer MRAM Device With Novel Magnetic Synthetic Free Layer  | Guo           | 2008-80560  | 3/26/2008  | 8/20/2014  | ○ ○     |
| 10                   | 5317524 | Spin Torque Switching MRAM, SpinRAM Array   | Yang          | 2008-114686 | 4/24/2008  | 7/19/2013  | ○ ○     |
| 11                   | 5451977 | A Novel SyAF Structure To Fabricate Mbit MTJ MRAM   | Hong          | 2008-60230  | 3/10/2008  | 1/15/2014  | ○ ○     |
| 12                   | 5279384 | A High Performance MTJ Element for STT-RAM And Method For Making the Same   | Hong          | 2008-190225 | 7/23/2008  | 5/31/2013  | ○ ○     |
| 13                   | 5537791 | Method Of Magnetic Tunneling Layer Processes For Spin-Transfer Torque MRAM Devices                                | Zhong         | 2008-266948 | 10/17/2008 | 5/8/2014   | ○ ○     |
| 14                   | 5460906 | Spin Transfer MRAM Device with Separated CPP Assisted Writing   | Guo           | 2010-534834 | 5/21/2010  | 1/24/2014  | ○ ○     |
| 15                   | 5433284 | A Low Switching Current MTJ Element For Ultra-High STT-RAM and Method For Making The Same                         | Hong          | 2009-85227  | 4/8/2009   | 12/13/2013 | ○ ○     |
| 16                   | 5571096 | Boosted Gate Voltage Programming for Spin-RAM Array   | Hsu           | 2011-537409 | 6/20/2011  | 7/4/2014   | ○ ○     |
| 17                   | 5470179 | Gate Drive Voltage Boost Schemes For Memory Array   | Yang          | 2010-154347 | 7/6/2010   | 2/7/2014   | ○ ○     |
| 18                   | 5771370 | STT-RAM with A Magnetic Tunnel Junction Written in Thermally Assisted Method                                      | Hong          | 2010-163362 | 7/20/2010  | 7/3/2015   | ○ ○     |
| 19                   | 5674819 | A Read Disturb Free SMT MRAM Reference Cell Circuit   | Yang          | 2012-551977 | 8/3/2012   | 1/9/2015   | ○ ○     |
| 20                   | 5735691 | Magnetic Element with Improved Out-of-Plane Anisotropy for Spintronic Applications                                | Jan           | 2013-553563 | 8/8/2013   | 4/24/2015  | ○ ○     |
| 21                   | 5674744 | MAGNETIC MEMORY STRUCTURE AND TUNNEL MAGNETORESISTANCE EFFECT REPRODUCTION HEAD AND MANUFACTURING METHOD THEREFOR | Hong          | 2012-232207 | 10/19/2012 | 1/9/2015   | ○ ○     |
| 22                   | 4563160 | MRAM Cell With Flat Topography and Controlled Bit Line to Free Layer Distance and Method of Manufact              | Han           | 2004-357266 | 12/9/2004  | 8/6/2010   | ○ ○     |
| 23                   | 5377547 | A Novel Buffer (Seed) Layer for Making a High-Performance Magnetic Tunneling Junction MRAM                        | Hong          | 2011-041736 | 2/28/2011  | 10/4/2013  | ○ ○     |
| 24                   | 5178788 | Adaptive Algorithm for MRAM Manufacturing   | Yang          | 2010-169760 | 7/29/2010  | 1/18/2013  | ○ ○     |
| 25                   | 5179787 | Adaptive Algorithm for MRAM Manufacturing   | Yang          | 2010-169759 | 7/28/2010  | 1/18/2013  | ○ ○     |
| 26                   | 5153061 | A Novel Underlayer For High Performance Magnetic Tunneling Junction MRAM  | Hong          | 2005-192226 | 6/30/2005  | 12/14/2012 | ○ ○     |
| 27                   | 5038317 | Method of Fabricating MRAM Cell Structure Containing Sidewall Spacers   | Yang          | 2006-112650 | 4/14/2006  | 7/13/2012  | ○ ○     |

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| EP1901810            | A Configurable MRAM   | Yang           | 08392018.5    | 2006/12/20 | 2010/5/19  | ○   | ○       |
|                      | A Novel Oxidation Structure/Method To Form MgO/NiFe(free layer)-MTJ for high performance MRAM appli               | Hong           | 08392019.3    | 2008/12/20 |            | ○   | ○       |
| EP1888058            | Paramagnetic-NiFe/Hf Capping Layer Is Deposited By Co-Sputtering of NiFe and Hf                                   | Hong           | 07392004.3    | 2007/7/30  | 2009/12/9  | ○   | ○       |
| EP1818147            | Helium Doped Cap and Free Layer for MRAM Device   | Hong           | 07392007.6    | 2007/9/27  | 2017/12/13 | ○   | ○       |
|                      | MRAM with Enhanced Programming Margin   | Min            | 08392002.5    | 2008/3/27  |            | ○   | ○       |
| EP1988198            | Spin Torque Switching MRAM, SpinRAM, Array  | Yang           | 08392003.3    | 2008/3/27  | 2012/6/17  | ○   | ○       |
| EP1988130            | A Novel SyAF Structure To Fabricate Mini MTJ MRAM   | Hong           | 08392008.2    | 2008/3/7   | 2013/10/2  | ○   | ○       |
| EP2073285            | A High Performance MTJ Element for STT-RAM And Method For Making the Same   | Hong           | 08392010.8    | 2008/7/9   | 2015/4/29  | ○   | ○       |
|                      | Boosted Gate Voltage Programming for Spin-RAM Array   | Hsu            | 08827846.6    | 2009/10/19 |            | ○   | ○       |
|                      | Gate Drive Voltage Boost Schemes for Memory Array II  | Yang           | 10810283.3    | 2010/7/2   |            | ○   | ○       |
|                      | Method and Apparatus for Scrubbing Accumulated Data Errors from a Memory System                                   | Yang           | 10792437.5    | 2011/12/26 |            | ○   | ○       |
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| EP2412003            | METHOD OF DOUBLE PATTERNING AND ETCHING MAGNETIC TUNNEL JUNCTION STRUCTURES FOR SPIN-TRANSFER TORQUE MRAM DEVICES | Belen          | 10756454.4    | 2011/10/24 | 2017/10/18 | ○   | ○       |
|                      | Shared Bit Line SMT MRAM Array with Shunting Transistors Between the Bit Lines                                    | Yang           | 11803933.8    | 2011/6/28  |            | ○   | ○       |
|                      | A Read Disturb Free SMT MRAM Reference Cell Circuit   | Yang           | 11740139.8    | 2012/7/28  |            | ○   | ○       |
|                      | A Novel Bit Line Preparation Method in MRAM Fabrication   | Guomin         | 10825330.3    | 2012/5/20  |            | ○   | ○       |
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|                      | Reference Cell Architectures for Small Memory Array Block Activation  | Suanga         | 11834756.6    | 2013/5/21  |            | ○   |         |
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|                      | Co/Ni Multilayers with Improved Out-of-Plane Anisotropy for Magnetic Device Applications                          | Jan            | 13748182.6    | 2013/7/30  |            | ○   |         |
|                      | Magnetic Element with Improved Out-of-Plane Anisotropy for Spintronic Applications                                | Jan            | 12744881.9    | 2012/2/10  |            | ○   |         |
| EP2705518            | Multilayers Having Reduced Perpendicular Demagnetizing Field using Moment Dilution for Spintronic Applications    | Jan            | 12779816      | 2012/4/28  | 2017/4/19  | ○   |         |
| EP2898044            | Storage Element for STT MRAM Applications   | Kula           | 13766212      | 2013/9/13  | 2018/1/10  | ○   | ○       |
|                      | Storage Element for STT MRAM Applications   | Kula           | 18150684.1    | 2018/1/9   |            | ○   | ○       |
| EP2820681            | High Thermal Stability Reference Structure with Out-of-Plane Anisotropy for Magnetic Device Applications          | Wang           | 13754577      | 2013/1/24  | 2017/12/20 |     |         |
| EP2834919            | Reduction of Capping Layer Resistance Area Product for Magnetic Device Applications                               | Jan            | 13772601.4    | 2013/3/27  | 2017/11/15 |     |         |
| EP2820649            | High Thermal Stability Free Layer with High Out-of-Plane Anisotropy for Magnetic Device Applications              | Wang           | 13755686      | 2013/2/27  | 2017/11/15 |     |         |
| 2839501              | Free Layer with High Thermal Stability for Magnetic Device Applications by Insertion of a Boron Doping Layer      | Wang           | 13777528.4    | 2013/4/17  | 2018/12/21 |     |         |
| EP1624458            | Adaptive Algorithm for MRAM Manufacturing   | Yang           | 05392005.4    | 2005/8/14  | 2013/4/23  | ○   | ○       |
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| 34 |                      | MTJ Incorporating CoFe/N Multilayer Film with Perpendicular Magnetic Anisotropy for MRAM Application | Zhang          | 10827271      | 2010/10/26 |            | ○   | ○       |
| 35 |                      | Improved Seed Layer for Multilayer Magnetic Materials  | Jan            | 13783498.2    | 2012/10/11 |            |     |         |
| 36 |                      | An Adaptive Reference Scheme for magnetic Memory Applications  | Jan            | 13786114.2    | 2013/10/23 |            |     |         |
| 37 |                      | Implementation of One Time Programmable Memory using a MRAM Stack Design                             | Jan            | 16715700.7    | 2016/3/22  |            |     |         |
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| 3 | 10-1144337           | Adaptive Algorithms for MRAM Manufacturing                                    | Yang           | 10-2005-0063471 | 7/13/2005  | 4/30/2012  | <input type="checkbox"/> | <input type="checkbox"/> |
| 4 | 10-1204659           | Adaptive Algorithms for MRAM Manufacturing                                    | Yang           | 10-2011-0140587 | 12/22/2011 | 11/20/2012 | <input type="checkbox"/> | <input type="checkbox"/> |
| 5 | 10-1166356           | A Novel Underlayer For High Performance Magnetic Tunneling Junction MRAM      | Hong           | 10-2005-0058088 | 6/30/2005  | 7/11/2012  | <input type="checkbox"/> | <input type="checkbox"/> |
| 6 | 10-1395476           | Adaptive Algorithms for MRAM Manufacturing                                    | Yang           | 10-2011-0140582 | 12/22/2011 | 2/14/2014  | <input type="checkbox"/> | <input type="checkbox"/> |

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| 3 |                      | Implementation of One Time Programmable Memory using a MRAM Stack Design | Jan            | 201680052700.2 | 2017/11/15 |            | Pending |

| Headway<br>Docket Number | Attorney Ref.<br>Number | Title   | First Inventor | Assignee | Priority Date | Serial Number | File Date | Issued<br>Patent<br>Number | Issue Date | Status |
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| HT17-025                 |                         | FERROMAGNETIC RESONANCE (FMR) ELECTRICAL TESTING APPARATUS FOR SPINTRONIC DEVICES                 | Jin            | Headway  | 19-Jan-18     | 108101891     | 17-Jan-19 |                            |            |        |
| HT17-037                 |                         | NITRIDE CAPPING LAYER FOR SPIN TORQUE TRANSFER (STT)-MAGNETORESISTIVE RANDOM ACCESS MEMORY (MRAM) | Iwata          | Headway  | 26-Jan-18     | 108102192     | 23-Jan-19 |                            |            |        |

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| MgO Insertion into Free Layer for Magnetic Memory Applications  | Iwata    | PCT/US2018/019841 | 2/27/2018   | HT2016025PCT     | 9/17/2019                       |  |
| Protective Passivation Layer for Magnetic Tunnel Junctions  | Iwata    | PCT/US2018/020075 | 2/28/2018   | HT2018014PCT     | 9/20/2019                       |  |
| Scanning Ferromagnetic Resonance (FMR) for Wafer-Level Characterization of Magnetic Films and Multilayers                     | Guisan   | PCT/US2018/020381 | 3/1/2018    | HT2016012PCT     | 9/20/2019                       |  |
| Spacer Assisted Ion Beam Etching of Spin Torque Magnetic Random Access Memory   | Yang     | PCT/US2018/020594 | 3/2/2018    | HT2017007PCT     | 9/22/2019                       |  |
| Method to Remove Sidewall Damage after MTJ Etching  | Teng     | PCT/US2018/020854 | 3/5/2018    | HT2017004PCT     | 9/22/2019                       |  |
| Maintaining Coercive Field after High Temperature Anneal for Magnetic Device Applications with Perpendicular Magnetic Anisot  | Liu      | PCT/US2018/021007 | 3/6/2018    | HT2017009PCT     | 10/3/2019                       |  |
| MTJ Device Process/Integration Method with Pre-Patterned Seed Layer   | Haq      | PCT/US2018/021286 | 3/7/2018    | HT2017001PCT     | 10/5/2019                       |  |
| Dielectric Encapsulation Layer for Magnetic Tunnel Junction (MTJ) Devices Using Radio Frequency (RF) Sputtering               | Patel    | PCT/US2018/021248 | 3/7/2018    | HT2017003PCT     | 10/5/2019                       |  |
| Post Treatment to Reduce Shunting Devices for Physical Etching Process  | Wang     | PCT/US2018/021452 | 3/8/2018    | HT2017002PCT     | 10/5/2019                       |  |
| Combined Physical and Chemical Etch to Reduce Magnetic Tunnel Junction (MTJ) Sidewall Damage                                  | Shen     | PCT/US2018/032196 | 5/11/2018   | HT2017005PCT     | 11/15/2019                      |  |
| Multilayer Structure for Reducing Film Roughness in Magnetic Devices  | Zhu      | PCT/US2018/032637 | 5/15/2018   | HT2015006CIP_PCT | 11/19/2019                      |  |
| Etch-Less Self-Aligned Magnetic Tunnel Junction (MTJ) Device Structure  | Haq      | PCT/US2018/035101 | 5/30/2018   | HT2017015PCT     | 1/18/2020                       |  |
| Silicon Oxynitride Based Encapsulation Layer for Magnetic Tunnel Junctions  | Sunder   | PCT/US2018/035097 | 5/30/2018   | HT2017008PCT     | 12/12/2019                      |  |
| High Thermal Stability by Doping of Oxide Capping Layer for Spin Torque Transfer (STT) Magnetic Random Access Memory (MRAM) A | Jan      | PCT/US2018/055043 | 10/9/2018   | HT2017034PCT     | 4/10/2020                       |  |
| High Temperature Volatilization of Sidewall Materials from Patterned Magnetic Tunnel Junctions                                | Patel    | PCT/US2018/055042 | 10/9/2018   | HT2017010PCT     | 4/10/2020                       |  |
| Multiple Hard Mask Patterning to Fabricate ZONM and Below MRAM Devices  | Yang     | PCT/US2018/056480 | 10/18/2018  | HT2017027PCT     | 4/23/2020                       |  |
| Free Layer Sidewall Oxidation and Spacer Assisted Magnetic Tunnel Junction (MTJ) Etch for High Performance Magnetoresistive R | Yang     | PCT/US2018/056447 | 10/18/2018  | HT2017036PCT     | 4/20/2020                       |  |
| Initialization Process for Magnetic Random Access Memory (MRAM) Production  | Lee      | PCT/US2018/059803 | 11/9/2018   | HT2017022PCT     | 5/20/2020                       |  |
| Improving MTJ Device Performance by Controlling Device Shape  | Haq      | PCT/US2018/059802 | 11/8/2018   | HT2017023PCT     | 5/13/2020                       |  |
| Low Resistance MgO Capping Layer for Perpendicularly Magnetized Magnetic Tunnel Junctions                                     | Patel    | PCT/US18/064425   | 12/7/2018   | HT2017014PCT     | 6/14/2020                       |  |
| Improved Magnetic Tunnel Junction (MTJ) Performance by introducing Oxidants to Methanol with or without Noble Gas During MTJ  | Shen     | PCT/US2018/064423 | 12/7/2018   | HT2017051PCT     | 6/28/2020                       |  |
| STT-MRAM Heat Sink and Magnetic Shield Structure Design for More Robust Read/Write Performance                                | Zhong    | PCT/US2018/067951 | 12/28/2018  | HT2017008PCT     | 6/29/2020                       |  |
| Ferromagnetic Resonance (FMR) Electrical Testing Apparatus for Spintronic Devices   | Jan      | PCT/US2019/013963 | 1/17/2019   | HT2017025PCT     | 7/15/2020                       |  |
| Nitride Capping Layer for Spin Torque Transfer (STT)-Magnetoresistive Random Access Memory (MRAM)                             | Iwata    | PCT/US2019/015129 | 1/25/2019   | HT2017037PCT     | 7/26/2020                       |  |