

**PATENT COOPERATION TREATY**

**PCT**

**INTERNATIONAL PRELIMINARY REPORT ON PATENTABILITY**

(Chapter I of the Patent Cooperation Treaty)

(PCT Rule 44bis)

|   |  |   |
|---|--|---|
| Applicant's or agent's file reference<br><b>90115796</b>  | <b>FOR FURTHER ACTION</b>  | See item 4 below                        |
| International application No.<br><b>PCT/US2016/014969</b>   | International filing date ( <i>day/month/year</i> )<br><b>26 January 2016 (26.01.2016)</b> | Priority date ( <i>day/month/year</i> ) |
| International Patent Classification (8th edition unless older edition indicated)<br><b>See relevant information in Form PCT/ISA/237</b> |  |   |
| Applicant<br><b>HEWLETT PACKARD ENTERPRISE DEVELOPMENT LP</b>   |  |   |

|  |                                     |   |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |
|--|-------------------------------------|---|---------------------|--------------------------|------------|----------|--------------------------|-------------|--|--------------------------|------------|----------------------------|-------------------------------------|-----------|---|--------------------------|------------|-------------------------|--------------------------|-------------|--|-------------------------------------|--------------|---|
| <p>1. This international preliminary report on patentability (Chapter I) is issued by the International Bureau on behalf of the International Searching Authority under Rule 44 bis.1(a).</p> <p>2. This REPORT consists of a total of 10 sheets, including this cover sheet.</p> <p>In the attached sheets, any reference to the written opinion of the International Searching Authority should be read as a reference to the international preliminary report on patentability (Chapter I) instead.</p>   |                                     |   |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |
| <p>3. This report contains indications relating to the following items:</p> <table> <tr> <td><input checked="" type="checkbox"/></td> <td>Box No. I</td> <td>Basis of the report</td> </tr> <tr> <td><input type="checkbox"/></td> <td>Box No. II</td> <td>Priority</td> </tr> <tr> <td><input type="checkbox"/></td> <td>Box No. III</td> <td>Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</td> </tr> <tr> <td><input type="checkbox"/></td> <td>Box No. IV</td> <td>Lack of unity of invention</td> </tr> <tr> <td><input checked="" type="checkbox"/></td> <td>Box No. V</td> <td>Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement</td> </tr> <tr> <td><input type="checkbox"/></td> <td>Box No. VI</td> <td>Certain documents cited</td> </tr> <tr> <td><input type="checkbox"/></td> <td>Box No. VII</td> <td>Certain defects in the international application</td> </tr> <tr> <td><input checked="" type="checkbox"/></td> <td>Box No. VIII</td> <td>Certain observations on the international application</td> </tr> </table> <p>4. The International Bureau will communicate this report to designated Offices in accordance with Rules 44bis.3(c) and 93bis.1 but not, except where the applicant makes an express request under Article 23(2), before the expiration of 30 months from the priority date (Rule 44bis .2).</p> | <input checked="" type="checkbox"/> | Box No. I   | Basis of the report | <input type="checkbox"/> | Box No. II | Priority | <input type="checkbox"/> | Box No. III | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability | <input type="checkbox"/> | Box No. IV | Lack of unity of invention | <input checked="" type="checkbox"/> | Box No. V | Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement | <input type="checkbox"/> | Box No. VI | Certain documents cited | <input type="checkbox"/> | Box No. VII | Certain defects in the international application | <input checked="" type="checkbox"/> | Box No. VIII | Certain observations on the international application |
| <input checked="" type="checkbox"/>  | Box No. I                           | Basis of the report   |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |
| <input type="checkbox"/>   | Box No. II                          | Priority  |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |
| <input type="checkbox"/>   | Box No. III                         | Non-establishment of opinion with regard to novelty, inventive step and industrial applicability  |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |
| <input type="checkbox"/>   | Box No. IV                          | Lack of unity of invention  |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |
| <input checked="" type="checkbox"/>  | Box No. V                           | Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |
| <input type="checkbox"/>   | Box No. VI                          | Certain documents cited   |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |
| <input type="checkbox"/>   | Box No. VII                         | Certain defects in the international application  |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |
| <input checked="" type="checkbox"/>  | Box No. VIII                        | Certain observations on the international application   |                     |                          |            |          |                          |             |  |                          |            |                            |                                     |           |   |                          |            |                         |                          |             |  |                                     |              |   |

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|   | Date of issuance of this report<br><b>31 July 2018 (31.07.2018)</b> |
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## PATENT COOPERATION TREATY


From the  
INTERNATIONAL SEARCHING AUTHORITY

# PCT

WRITTEN OPINION OF THE  
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

|  |   |   |  |
|--|---|---|--|
| To:<br>PAGAR, PREETAM<br><br>HEWLETT PACKARD ENTERPRISE 3404 E. HARMONY<br>ROAD MAIL STOP 79 FORT COLLINS CO 80528 USA   |   | Date of mailing<br>(day/month/year) <b>26 October 2016 (26.10.2016)</b> |  |
| Applicant's or agent's file reference<br>90115796  |   | <b>FOR FURTHER ACTION</b><br>See paragraph 2 below                      |  |
| International application No.<br><b>PCT/US2016/014969</b>  | International filing date (day/month/year)<br><b>26 January 2016 (26.01.2016)</b> | Priority date(day/month/year)   |  |
| International Patent Classification (IPC) or both national classification and IPC<br><b>H01L 45/00(2006.01)i, H01L 45/02(2006.01)i</b>   |   |   |  |
| Applicant<br><b>HEWLETT PACKARD ENTERPRISE DEVELOPMENT LP</b>  |   |   |  |
| <p>1. This opinion contains indications relating to the following items:</p> <p><input checked="" type="checkbox"/> Box No. I Basis of the opinion</p> <p><input type="checkbox"/> Box No. II Priority</p> <p><input type="checkbox"/> Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability</p> <p><input type="checkbox"/> Box No. IV Lack of unity of invention</p> <p><input checked="" type="checkbox"/> Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement</p> <p><input type="checkbox"/> Box No. VI Certain documents cited</p> <p><input type="checkbox"/> Box No. VII Certain defects in the international application</p> <p><input checked="" type="checkbox"/> Box No. VIII Certain observations on the international application</p> <p>2. <b>FURTHER ACTION</b></p> <p>If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.</p> <p>If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.</p> <p>For further options, see Form PCT/ISA/220.</p> |   |   |  |

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|---|--|---|---|
| Name and mailing address of the ISA/KR<br>International Application Division<br>Korean Intellectual Property Office<br>189 Cheongsa-ro, Seo-gu, Daejeon,<br>35208, Republic of Korea<br>Facsimile No. +82-42-481-8578 | Date of completion of this opinion<br><br>26 October 2016 (26.10.2016) | Authorized officer<br><br>KIM, Do Weon<br><br>Telephone No. +82-42-481-5560 |  |
|---|--|---|---|

**WRITTEN OPINION OF THE  
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

**PCT/US2016/014969**

**Box No. I Basis of this opinion**

1. With regard to the **language**, this opinion has been established on the basis of :

- the international application in the language in which it was filed
- a translation of the international application into \_\_\_\_\_ which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

2.  This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.I(a))

3.  With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of a sequence listing:

- a.  forming part of the international application as filed:
- in the form of an Annex C/ST.25 text file.
  - on paper or in the form of an image file.
- b.  furnished together with the international application under PCT Rule 13*ter*.I(a) for the purposes of international search only in the form of an Annex C/ST.25 text file.
- c.  furnished subsequent to the international filing date for the purposes of international search only:
- in the form of an Annex C/ST.25 text file (Rule 13*ter*.I(a)).
  - on paper or in the form of an image file (Rule 13*ter*.I(b) and Administrative Instructions, Section 713).

4.  In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additional copies is identical to that forming part of the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

**WRITTEN OPINION OF THE  
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

**PCT/US2016/014969**

**Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement**

1. Statement

|                               |        |             |     |
|-------------------------------|--------|-------------|-----|
| Novelty (N)                   | Claims | <u>1-15</u> | YES |
|                               | Claims | <u>NONE</u> | NO  |
| Inventive step (IS)           | Claims | <u>NONE</u> | YES |
|                               | Claims | <u>1-15</u> | NO  |
| Industrial applicability (IA) | Claims | <u>1-15</u> | YES |
|                               | Claims | <u>NONE</u> | NO  |

2. Citations and explanations :

Reference is made to the following documents:

D1: US 9177916 B1 (INTERMOLECULAR, INC.) 03 November 2015

D2: US 2003-0227803 A1 (EIJI NATORI et al.) 11 December 2003

1. Novelty and Inventive Step

1.1. Claim 1

D1, which is considered to be the closest prior art to the subject matter of claim 1, discloses a stable threshold switching material for selectors employed in resistive memories, the material being amorphous ("the selector is a layer of amorphous silicon (a-Si) doped with fluorine (F)", see column 5, lines 9-18 in D1).

Claim 1 differs from D1 in that the material has a composition given by  $(V, Nb)_{1-x}(Si, Hf, W)_xO_y$ , where  $0 < x < 1$  and  $y$  is within a range of 1.5 to 3. However, it can be easily derived by a person skilled in the art from the feature of D2 in analogous art ("As examples of paraelectrics shown by  $ABO_x$  in which the B site is at least one of Ge and Si and the A site is at least one of Ca, Sr, Ln (in particular, La, Nd, and Sm have a significant effect of improving single orientation of crystals), Nb, Mn, Pb,  $CaSiO_3$ ,  $SrSiO_3$ ,  $NbSiO_4$ ,  $MnSiO_4$ ,  $PbSiO_7$ , and the like can be given", see paragraph [0049] in D2).

Accordingly, it would be obvious for a person skilled in the art to combine the disclosures of D1 and D2, thereby arriving at the claim. Therefore, claim 1 lacks an inventive step under PCT Article 33(3).

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**WRITTEN OPINION OF THE  
INTERNATIONAL SEARCHING AUTHORITY**

International application No.

**PCT/US2016/014969**

**Box No. VIII Certain observations on the international application**

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

The 'x-1' of 'Nb<sub>x</sub>-1SixO<sub>y</sub> alloy, where x is within a range of 0.01 to 0.9' used in claim 2 and [0024], [0025],[0032],[0036] of the description is unclear. Therefore, the description of the present invention does not meet the requirements of PCT Article 5 and claim 2 does not meet the requirements of PCT Article 6.

[Note: The Authority has established this written opinion on the assumption that the 'Nb<sub>x</sub>-1SixO<sub>y</sub>' is 'Nb<sub>1-x</sub>SixO<sub>y</sub>'.]

**Supplemental Box**

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Continuation of : Box No. V

1.2. Claims 2-7

Claims 2-7 are directly or indirectly dependent on claim 1.

The additional feature of claim 2 can be easily derived from the feature of D2 ("As examples of paraelectrics shown by  $ABO_x$  in which the B site is at least one of Ge and Si and the A site is at least one of Ca, Sr, Ln (in particular, La, Nd, and Sm have a significant effect of improving single orientation of crystals), Nb, Mn, Pb,  $CaSiO_3$ ,  $SrSiO_3$ ,  $NbSiO_4$ ,  $MnSiO_4$ ,  $PbSiO_7$ , and the like can be given", see paragraph [0049]).

The additional features of claims 3 and 4 can be easily derived from the feature of D1 ("Provided are resistive switching memory cells having selectors and methods of fabricating such cells", see column 1, lines 38-58).

The additional feature of claim 5 can be easily derived from the feature of D1 ("a resistive switching memory cell includes a first layer disposed over a substrate, a second layer disposed over the first layer such that the first layer is disposed between the second layer and the substrate", see column 1, line 59 - column 2, line 12, and "the second layer includes one of hafnium oxide, zirconium oxide, tantalum oxide, titanium oxide, aluminum oxide, or silicon oxide. More specifically, the second layer may include a first sub-layer including silicon oxide and a second sub-layer including hafnium oxide", see column 2, lines 42-48).

The additional feature of claim 6 can be easily derived from the feature of D1 ("a schematic representation of ReRAM cell (100) including a first electrode (102), a second electrode (106), and a resistive switching layer (104) disposed in between the first electrode (102) and the second electrode (106)", see column 7, lines 34-44 and figures 1A-1C).

The additional feature of claim 7 can be easily derived from the feature of D1 ("an electrode (310) may include one or more of titanium (Ti), tungsten (W),

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Supplemental Box

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tantalum (Ta), cobalt (Co), molybdenum (Mo), nickel (Ni), vanadium (V), hafnium (Hf) aluminum (Al), copper (Cu), platinum (Pt), palladium (Pd), iridium (Ir), or ruthenium (Ru)", see column 13, lines 4-17 and figures 3A, 3B).

Accordingly, it would be obvious for a person skilled in the art to combine the disclosures of D1 and D2, thereby arriving at the claims. Therefore, claims 2-7 lack an inventive step under PCT Article 33(3).

1.3. Claim 8

D1, which is considered to be the closest prior art to the subject matter of claim 8, discloses a method for manufacturing a stable threshold switch comprising:

a memory element and a selector, one electrode contacting the resistive memory, an other electrode contacting the selector, and an intermediate electrode between the memory element and the selector ("a schematic representation of ReRAM cell (100) including a first electrode (102), a second electrode (106), and a resistive switching layer (104) disposed in between the first electrode (102) and the second electrode (106)", see column 7, lines 34-44 and figures 1A-1C in D1),

the method including forming in either order the memory element and the selector ("Provided are resistive switching memory cells having selectors and methods of fabricating such cells", see column 7, lines 34-44 and figures 1A-1C in D1),

wherein the selector is formed in an amorphous state ("the selector is a layer of amorphous silicon (a-Si) doped with fluorine (F)", see column 5, lines 9-18 in D1).

Claim 8 differs from D1 in that the selector has a composition given by  $(V, Nb)_{1-x}(Si, Hf, W)_xO_y$ , where  $0 < x < 1$  and  $y$  is within a range of 1.5 to 3. However, it can be easily derived by a person skilled in the art from the feature of D2 in analogous art ("As examples of paraelectrics shown by  $ABO_x$  in which the B site is at least one of Ge and Si and the A site is at least one of Ca, Sr, Ln (in particular, La, Nd, and Sm have a significant effect of improving single orientation of crystals), Nb, Mn, Pb,  $CaSiO_3$ ,  $SrSiO_3$ ,  $NbSiO_4$ ,  $MnSiO_4$ ,  $PbSiO_7$ , and the like can be given", see paragraph [0049] in D2).

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**Supplemental Box**

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Accordingly, it would be obvious for a person skilled in the art to combine the disclosures of D1 and D2, thereby arriving at the claim. Therefore, claim 8 lacks an inventive step under PCT Article 33(3).

1.4. Claims 9-12

Claims 9-12 are directly or indirectly dependent on claim 8.

The additional features of claims 9-11 can be easily derived from the features of D1 and D2 ("Any suitable deposition technique may be used to form the resistive switching layer, such as an atomic layer deposition (ALD) process or a physical vapor deposition (PVD) process. For example, an oxide may be deposited using a PVD target sputtered in an oxygen containing environment", see column 13, lines 33-48 and figure 4 in D1, and "As examples of paraelectrics shown by  $ABO_x$  in which the B site is at least one of Ge and Si and the A site is at least one of Ca, Sr, Ln (in particular, La, Nd, and Sm have a significant effect of improving single orientation of crystals), Nb, Mn, Pb,  $CaSiO_3$ ,  $SrSiO_3$ ,  $NbSiO_4$ ,  $MnSiO_4$ ,  $PbSiO_7$ , and the like can be given", see paragraph [0049] in D2).

The additional feature of claim 12 can be easily derived from the feature of D2 ("As examples of paraelectrics shown by  $ABO_x$  in which the B site is at least one of Ge and Si and the A site is at least one of Ca, Sr, Ln (in particular, La, Nd, and Sm have a significant effect of improving single orientation of crystals), Nb, Mn, Pb,  $CaSiO_3$ ,  $SrSiO_3$ ,  $NbSiO_4$ ,  $MnSiO_4$ ,  $PbSiO_7$ , and the like can be given", see paragraph [0049]).

Accordingly, it would be obvious for a person skilled in the art to combine the disclosures of D1 and D2, thereby arriving at the claims. Therefore, claims 9-12 lack an inventive step under PCT Article 33(3).

1.5. Claim 13

D1, which is considered to be the closest prior art to the subject matter of

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claim 13, discloses an array of stable threshold switches comprising a plurality of memory cells, each memory cell comprising:

a memory element and a selector ("Provided are resistive switching memory cells having selectors and methods of fabricating such cells", see column 1, lines 38-58 in D1),

wherein each selector is amorphous ("the selector is a layer of amorphous silicon (a-Si) doped with fluorine (F)", see column 5, lines 9-18 in D1).

Claim 13 differs from D1 in that each selector has a composition given by  $(V, Nb)_{1-x}(Si, Hf, W)_xO_y$ , where  $0 < x < 1$  and  $y$  is within a range of 1.5 to 3. However, it can be easily derived by a person skilled in the art from the feature of D2 in analogous art ("As examples of paraelectrics shown by  $ABO_x$  in which the B site is at least one of Ge and Si and the A site is at least one of Ca, Sr, Ln (in particular, La, Nd, and Sm have a significant effect of improving single orientation of crystals), Nb, Mn, Pb,  $CaSiO_3$ ,  $SrSiO_3$ ,  $NbSiO_4$ ,  $MnSiO_4$ ,  $PbSiO_7$ , and the like can be given", see paragraph [0049] in D2).

Accordingly, it would be obvious for a person skilled in the art to combine the disclosures of D1 and D2, thereby arriving at the claim. Therefore, claim 13 lacks an inventive step under PCT Article 33(3).

1.6. Claims 14 and 15

Claims 14 and 15 are dependent on claim 13.

The additional features of claims 14 and 15 can be easily derived from the feature of D1 ("a ReRAM cell includes multiple resistive switching layers provided in between a crossing pair of signal lines (504) and (506)", see column 14, lines 32-44 and figures 5A, 5B, and "five sets of signal lines (514a-b) and (516a-c) are shared by four ReRAM arrays (512a-c), wherein each ReRAM array is supported by two sets of signal lines, e.g., array (512a) is supported by (514a) and (516a)", see column 15, lines 1-13 and figures 5A, 5B).

Accordingly, it would be obvious for a person skilled in the art to combine the

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disclosures of D1 and D2, thereby arriving at the claims. Therefore, claims 14 and 15 lack an inventive step under PCT Article 33(3).

2. Industrial Applicability

Claims 1-15 are industrially applicable under PCT Article 33(4).