PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

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PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing *(day/month/year)*	**28 June 2018 (28.06.2018)**

Applicant's or agent's file reference	**FOR FURTHER ACTION**
01P120301PCT	See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2017/054566	**29 September 2017 (29.09.2017)**	

International Patent Classification (IPC) or both national classification and IPC

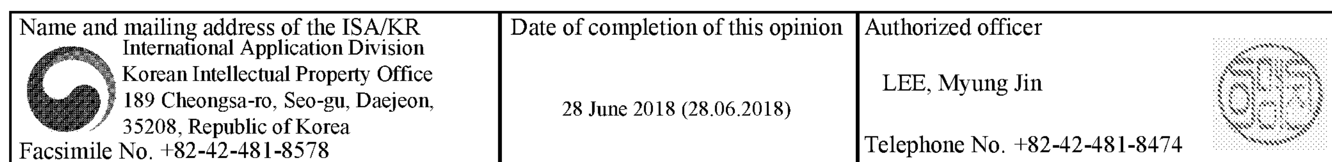
H01L 29/778(2006.01)i, H01L 29/78(2006.01)i, H01L 29/66(2006.01)i

Applicant
INTEL CORPORATION

1. This opinion contains indications relating to the following items:
   - [x] Box No. I Basis of the opinion
   - [ ] Box No. II Priority
   - [x] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - [ ] Box No. IV Lack of unity of invention
   - [x] 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
   - [ ] Box No. VI Certain documents cited
   - [x] Box No. VII Certain defects in the international application
   - [x] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**
   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.

   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.
   For further options, see Form PCT/ISA/220.



Name and mailing address of the ISA/KR	Date of completion of this opinion	Authorized officer
International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea Facsimile No. +82-42-481-8578	28 June 2018 (28.06.2018)	LEE, Myung Jin Telephone No. +82-42-481-8474

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WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

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*.1(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*.1(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*.1(a)).
      - ☐ on paper or in the form of an image file (Rule 13*ter*.1(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:

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Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability

The questions whether the claimed invention appears to be novel, to involve an inventive step (to be non obvious), or to be industrially applicable have not been examined in respect of:

☐ the entire international application

☒ claims Nos. 7,10-11

because:

☐ the said international application, or the said claims Nos. ______ relate to the following subject matter which does not require an international search *(specify)*:

☐ the description, claims or drawings *(indicate particular elements below)* or said claims Nos. ______ are so unclear that no meaningful opinion could be formed *(specify)*:

☐ the claims, or said claims Nos. ______ are so inadequately supported by the description that no meaningful opinion could be formed *(specify)*:

☒ no international search report has been established for said claims Nos. 7,10-11

☐ a meaningful opinion could not be formed without the sequence listing; the applicant did not, within the prescribed time limit:

- ☐ furnish a sequence listing in the form of an Annex C/ST.25 text file, and such listing was not available to the International Searching Authority in the form and manner acceptable to it; or the sequence listing furnished did not comply with the standard provided for in Annex C of the Administrative Instructions.
- ☐ furnish a sequence listing on paper or in the form of an image file complying with the standard provided for in Annex C of the Administrative Instructions, and such listing was not available to the International Searching Authority in the form and manner acceptable to it; or the sequence listing furnished did not comply with the standard provided for in Annex C of the Administrative Instructions.
- ☐ pay the required late furnishing fee for the furnishing of a sequence listing in response to an invitation under Rule 13*ter*.1(a) or (b).

☐ See Supplemental Box for further details.

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	1-6,8-9,12-25	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-6,8-9,12-25	NO
Industrial applicability (IA)	Claims	1-6,8-9,12-25	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: WO 2016-209263 A1 (INTEL CORPORATION) 29 December 2016

D2: US 9240410 B2 (THEN et al.) 19 January 2016

1. Novelty and Inventive Step (PCT Article 33(2) and (3))

1.1 Concerning Claims 1-6, 8-9, 12-17, and 24-25

1.1.1 Independent Claim 1

D1, which is considered to be the closest prior art to the subject matter of **claim 1**, discloses a device, comprising:

a plurality of fins (202) native to a substrate (200), a gallium nitride (GaN) layer (230) on the fins (202) (see claim 1; and figure 2E in D1);

a gate (256) above a polarization layer (240) (see page 10, line 31 - page 11, line 21; and figure 2F in D1); and

an indium gallium nitride (InGaN) doped with Si to form n-type source region (252) and a drain region (254) on opposite sides of the gate (256), wherein the source region (252) and the drain region (254) above the plurality of fins (202) comprise at least one of n-type doped indium gallium nitride and n-type doped gallium nitride (see page 10, line 31 - page 11, line 21; claim 10; and figure 2F in D1).

The subject matter of claim 1 differs from D1 in a polarization charge inducing layer above a terminal structure, the polarization charge inducing layer comprising a second III-N material. However, the feature is virtually suggested by the combined features of D1 and D2 (GaN n-channel transistors can also employ 2DEG, which may be located at the abrupt hetero-interface formed by epitaxial deposition of a charge-inducing film with larger

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Box No. VII Certain defects in the international application

The following defects in the form or contents of the international application have been noted:

Claims 7 and 10-11 do not comply with the third sentence of PCT Rule 6.4(a), because multiple dependent claims should not serve as a basis for any other multiple dependent claim.

Claims 4 and 24 do not comply with PCT Rule 6.1(a) since they are so close in content that they both cover the same invention.

Claims 5 and 25 do not comply with PCT Rule 6.1(a) since they are so close in content that they both cover the same invention.

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:

Claim 1 relates to a device, but claims 2-3, 5-6, 8-9, 12-17, and 25, dependent on claim 1, relate to a semiconductor structure. As claims 2-3, 5-6, 8-9, 12-17, and 25 do not clearly define the matter for which protection is sought, these claims do not meet the requirement of PCT Article 6.
(Note: The written opinion have been established on the assumption that the phrase 'the semiconductor structure' in claims 2-3, 5-6, 8-9, 12-17, and 25 is considered to be 'The device'.)

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of : Box No. V

spontaneous and piezoelectric polarization (referred to herein as the polarization layer (240)), wherein the polarization layer materials may include AlN, AlGaN, InAlN, or InAlGaN (see page 4, lines 15-33; and figure 2F in D1); and a semiconductor layer (215) functions as a charge inducing layer (see column 4, line 60 - column 5, line 5; and figures 2A-2C in D2)). Accordingly, claim 1 would have been obvious over D1 in view of D2. Therefore, claim 1 lacks an inventive step under PCT Article 33(3).

1.1.2 Dependent Claims 2-6, 8-9, 12-17, and 24-25

The additional feature of **claim 2** is virtually suggested by the feature of D1 (the fins (230) can be formed with widths of less than 100nm and heights greater than 20nm (see page 13, lines 12-31; and figure 2F in D1)).

The additional feature of **claim 3** is virtually suggested by the feature of D1 (trenches (205) may be formed with varying widths and depths, and the fins (202) may be formed to have varying widths and heights, depending on the end use or target application (see page 6, line 18 - page 7, line 4; and figure 2A in D1)).

The additional feature of **claims 4 and 24** are virtually suggested by the feature of D1 (any number of fins may be formed, such as one, two, ten, hundreds, thousands, millions, etc., depending on the end use or target application (see page 6, line 18 - page 7, line 4; and figure 2A in D1)).

The additional features of **claims 5-6 and 25** are virtually suggested by the feature of D1 (indium gallium nitride (InGaN) doped with Si to form n-type source region (252) and drain region (254) are located above the plurality of fins (202); and trenches (205) may be formed with varying widths and depths, and the fins (202) may be formed to have varying widths and heights, depending on the end use or target application and any number of fins may be formed, such as one, two, ten, hundreds, thousands, millions, etc., depending on the end use or target application (see page 6, line 18 - page 7, line 4; page 10, line 31 - page 11, line 21; and figures 2A, 2F in D1)).

The additional feature of claim **8** is virtually suggested by the feature of D1 (GaN n-channel transistors can also emply 2DEG, which may be located at the abrupt hetero-interface formed

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by epitaxial deposition of the charge-inducing film with larger spontaneous and piezoelectric polarization (see page 4, lines 15-32 in D1)).

Claim 9 specifies that a source structure and a drain structure comprise faceted crystals having sidewalls that are approximately 60 degrees with respect to an uppermost surface of a first or a second plurality of fins. However, the feature comes within the scope of the customary practice followed by a person skilled in the art.

The additional feature of **claim 12** is virtually suggested by the feature of D1 (the polarization layer (240) above each additional GaN layer, wherein each polarization layer (240) is one of aluminum nitride, aluminum gallium nitride, indium aluminum nitride, and indium aluminum gallium nitride (see claim 6; and figure 2F in D1)).

The additional feature of **claim 13** is virtually suggested by the feature of D1 (a transistor includes at least one of the following geometries: HEMT, pHEMT, 2DEG, 3DEG, FET, MQW, and super-lattice architecture (see page 19, lines 10-17 in D1)).

The additional feature of **claim 14** is virtually suggested by the feature of D1 (indium gallium nitride (InGaN) doped with Si to form n-type source region (252) and drain region (254) are located above the plurality of fins (202) (see page 10, line 31 - page 11, line 21; and figure 2F in D1)).

The additional feature of **claim 15** is virtually suggested by the feature of D1 (a layer (236) is a graded layer including GaN that was uniformly graded with increasing indium (In) up to a percentage of approximately 5-20% (or approximately 10%) (see page 8, line 30 - page 9, line 23; and figure 2C" in D1)).

The additional feature of **claim 16** is virtually suggested by the feature of D1 (an annealing process may be carried out on the gate dielectric layer to improve its quality when a high-k material is used (see page 12, lines 1-20 in D1)).

The additional feature of **claim 17** is virtually suggested by the feature of D2 (a gate conductor (250) includes a work function metal (see column 7, lines 33-49; and figure 4D in D2)).

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Accordingly, claims 2-6, 8-9, 12-17, and 24-25 would have been obvious over D1 in view of D2. Therefore, claims 2-6, 8-9, 12-17, and 24-25 lack an inventive step under PCT Article 33(3).

1.2 Concerning Claims 18-22

1.2.1 Independent Claim 18

D1, which is considered to be the closest prior art to the subject matter of **claim 18**, discloses a method of fabricating a semiconductor structure, the method comprising:

forming a gallium nitride (GaN) layer (230) above a substrate (200) (see claim 1; and figure 2E in D1);

forming a shallow trench isolation (STI) material (210) between a plurality of fins (202) (see page 7, line 21 - page 8, line 11; and figure 2C in D1);

forming a source region (252) and a drain region (254) etching to remove a polarization layer (240) (see page 10, line 31 - page 11, line 21; and figure 2F in D1); and

forming a gate dielectric layer to improve quality; and forming a gate (256) between the source region (252) and the drain region (254) (see page 10, line 31 - page 11, line 21; page 12, lines 1-20; and figures 2E-2F in D1).

The subject matter of claim 18 differs from D1 in: forming a polarization charge inducing layer comprising a second III-N material above a first layer (hereinafter referred to as 'Feature 1'); and patterning a layer comprising a first III-N material and the polarization charge inducing layer and forming a central body, a first plurality of fins adjacent to a first side of the central body, and a second plurality of fins adjacent to a second side of the central body, opposite the first side (hereinafter referred to as 'Feature 2'). However, the Feature 1 is virtually suggested by the combined features of D1 and D2 (GaN n-channel transistors can also employ 2DEG, which may be located at the abrupt hetero-interface formed by epitaxial deposition of a charge-inducing film with larger spontaneous and piezoelectric polarization (referred to herein as the polarization layer (240)), wherein the polarization layer materials may include AlN, AlGaN, InAlN, or InAlGaN (see page 4, lines 15-33; and figure 2F in D1); and a semiconductor layer (215) functions as a charge inducing layer (see column 4, line 60 - column 5, line 5; and figures 2A-2C in D2)). In addition, the Feature 2 is virtually suggested by the feature of D1 (the plurality of fins (202) are formed

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native to the substrate (200), the gallium nitride (GaN) layer (230) on the fins (202); and completion (120) of the formation of a transistor structure includes etching and patterning the III-N layer (e.g., the GaN layers (230)) into the fins (202), forming the trenches (260) (see page 12, line 21 - page 13, line 11; claim 1; and figures 1, 2C, 2E, 2F' in D1)). Accordingly, claim 18 would have been obvious over D1 in view of D2. Therefore, claim 18 lacks an inventive step under PCT Article 33(3).

1.2.2 Dependent Claims 19-22

The additional feature of **claim 19** is virtually suggested by the feature of D1 (STI material (210) is deposited between the fins (202) prior to depositing the GaN layer (230) on the fins (202); and a recess process (106) may include any suitable wet or dry etch process (see page 7, lines 15-20; claim 22; and figures 1, 2C in D1)).

The additional feature of **claim 20** is virtually suggested by the feature of D1 (the S/D regions (252, 254) can be formed by masking the structure and etching to remove the polarization layer (240) in the S/D regions (252, 254), followed by epitaxial regrowth of n-type S/D material (see page 10, line 31 - page 11, line 21; and figures 2E-2F in D1)).

Claim 21 specifies that a process of growing a third III-N material comprises growing to merge slanted sidewalls to form an apex. However, the feature comes within the scope of the customary practice followed by a person skilled in the art.

Claim 22 specifies that the process of growing the third III-N material further comprises forming the third III-N material on portions of exposed sidewalls of a patterned polarization charge inducing layer and the first III-N material. However, the feature comes within the scope of the customary practice followed by a person skilled in the art.

Accordingly, claims 19-22 would have been obvious over D1 in view of D2. Therefore, claims 19-22 lack an inventive step under PCT Article 33(3).

1.3 Independent Claim 23

Claim 23 relates to a system, and the technical features of claim 23 essentially correspond to

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those of claim 1, except for additional features comprising: a processor; and a radio transceiver coupled to the processor. However, the added features can be easily derived from the feature of D1 (a processor (1004); and a communication chip (1006) (see page 16, lines 17-25; and figure 5 in D1)). Therefore, claim 23 would have been obvious over D1 in view of D2 and lacks an inventive step under PCT Article 33(3).

2. Industrial Applicability (PCT Article 33(4))

Claims 1-6, 8-9, and 12-25 are industrially applicable under PCT Article 33(4).