PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

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PCT

WRITTEN OPINION OF THE
INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43*bis*.1)

Date of mailing *(day/month/year)*	14 AUG 2020

Applicant's or agent's file reference	FOR FURTHER ACTION
320903-2160	See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2020/031373	04 May 2020	02 May 2019

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

IPC(8) - B41J 2/06; B41J 2/09; C12Q 1/00; C23C 4/12; G01N 27/62; H05K 3/12 (2020.01)
CPC - B41J 2/06; B41J 2/01; B41J 2/09; C12Q 1/00; C23C 4/12; G01N 27/44739; G01N 27/44791; G01N 27/62; G01N 30/6095; H05K 3/125 (2020.08)

Applicant THE BOARD OF TRUSTEES OF THE UNIVERSITY OF ILLINOIS

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☒ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43*bis*.1(a)(i) with regard to novelty, inventive step and industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ 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 66.1*bis*(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/US	Date of completion of this opinion	Authorized officer
Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450, Alexandria, VA 22313-1450 Facsimile No. 571-273-8300	01 August 2020	Blaine R. Copenheaver PCT Helpdesk: 571-272-4300 Telephone No. 571-272-4300

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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(b)).

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. IV Lack of unity of invention

1. ☒ In response to the invitation (Form PCT/ISA/206) to pay additional fees the applicant has, within the applicable time limit:
   - ☐ paid additional fees.
   - ☐ paid additional fees under protest and, where applicable, the protest fee.
   - ☐ paid additional fees under protest but the applicable protest fee was not paid.
   - ☒ not paid additional fees.
2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose not to invite the applicant to pay additional fees.
3. This Authority considers that the requirement of unity of invention in accordance with Rule 13.1, 13.2 and 13.3 is
   - ☐ complied with.
   - ☒ not complied with for the following reasons:

<See Supplemental Box>

4. Consequently, this opinion has been established in respect of the following parts of the international application:
   - ☐ all parts.
   - ☒ the parts relating to claims Nos. 1-14, 16-23

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

1. Statement

Novelty (N)	Claims	1-14, 16-23	YES
	Claims	None	NO
Inventive step (IS)	Claims	1-14, 16-23	YES
	Claims	None	NO
Industrial applicability (IA)	Claims	1-14, 16-23	YES
	Claims	None	NO

2. Citations and explanations:

Claims 1-14 and 16-23 meet the criteria set out in PCT Article 33(2)-(3), because the prior art does not teach or fairly suggest:

Regarding claims 1 and 16, the prior art of record does not teach or fairly suggest, "a first nozzle disposed in between the first e-lens and the upper portion of the first reservoir and being separated from the first e-lens by a first e-lens-to-filament gap, the first nozzle having a first nanodroplet orifice through which nanodroplets generated from matter held in the first reservoir are extracted out of the first reservoir through the first nanodroplet orifice when a first set of preselected voltage signals are applied to the first set of at least first and second electrodes, the first nozzle being precisely aligned with the first lateral gap and having a first nozzle width equal to a distance between innermost edges of side walls of the first nozzle, the first nozzle and the first lateral gap having a common central axis that ensures that the nanodroplets extracted through the first nanodroplet orifice self-align with the first lateral gap, the first nozzle width being less than or equal to 300 nanometers" for claim 1; "the first nozzle having an inlet side disposed in the upper portion of the first reservoir and an exit side disposed in the first e-lens-to-filament gap, the exit side of the first nozzle having side walls that extend away from a common central axis of the first nozzle and the first e-lens, centers of the first nozzle and the first e-lens being precisely aligned along the common central axis such that there is substantially zero misalignment between the centers of the first nozzle and the first e-lens, the first e-lens including at least a first set of at least first and second electrodes that are laterally separated from one another by a first lateral gap having a first gap width, wherein the printable substrate is mounted on a front side of the first nanodroplet printer in alignment with the first nanodroplet printer; and applying a first set of voltage signals to the first set of at least first and second electrodes to cause a nanodroplet to be generated and extracted through a nanodroplet orifice of the first nozzle, the extracted nanodroplet self-aligning to the e-lens due to the first nozzle and the first e-lens being precisely aligned along the common central axis, the e-lens directing the extracted nanodroplet onto the printable substrate to thereby write a structure on the printable substrate" for claim 16, in combination with the remaining aspects of claims 1 and 16, respectively.

Claims 2-14 and 17-23 meet the criteria due to their dependency on novel claims 1 and 16, respectively.

The prior art, as shown below, details some of the aspect of the invention, however, none of the prior art teaches all the missing limitation either alone or in combination as specified.

Rogers et al. (US 2011/0187798 A1) teaches a flow regulation device comprising at least a first nanodroplet generation/control device having a reservoir for holding matter to be extracted (generating reliable droplet size in the 100 nm or less range , para. 0068. Drop-on-demand uses pulses, generated either thermally or piezoelectricity, to eject solution droplets from a reservoir through a nozzle, para. 0154); at least a first set of at least first and second electrodes (a pair of leading electrodes and a pair of lagging electrodes, the droplet oscillates with the electric field oscillation along the direction of printing, para. 0289); applying a first set of voltage signals to the first set of at least first and second electrodes to cause a nanodroplet to be generated and extracted through a first nozzle, and directing the extracted nanodroplet onto a printable substrate to thereby write a structure on the printable substrate (this provides an ability to print on non-conducting substrates or dielectrics as well as providing additional printing flexibility. FIG. 32 is a numerical experiment showing the electric field generated by a nozzle having integrated electrode and counter-electrode pair and indicates such a geometry is capable of providing a focused electric field between the nozzle and substrate. FIG. 33 provides a summary of the basic configuration of such a system, as well illustrating some differences in the basic configuration of inkjet printing (FIG. 33A), eject printing with a nonintegrated electrode nozzle (FIG. 33B) and eject printing with an integrated-electrode nozzle (FIG. 33C), para. 0287). However, Rogers et al. does not teach or fairly suggest, "a first nozzle disposed in between the first e-lens and the upper portion of the first reservoir and being separated from the first e-lens by a first e-lens-to-filament gap, the first nozzle having a first nanodroplet orifice through which nanodroplets generated from matter held in the first reservoir are extracted out of the first reservoir through the first nanodroplet orifice when a first set of preselected voltage signals are applied to the first set of at least first and second electrodes, the first nozzle being precisely aligned with the first lateral gap and having a first nozzle width equal to a distance between innermost edges of side walls of the first nozzle, the first nozzle and the first lateral gap having a common central axis that ensures that the nanodroplets extracted through the first nanodroplet orifice self-align with the first lateral gap, the first nozzle width being less than or equal to 300 nanometers" for claim 1; "the first nozzle having an inlet side disposed in the upper portion of the first reservoir and an exit side disposed in the first e-lens-to-filament gap, the exit side of the first nozzle having side walls that extend away from a common central axis of the first nozzle and the first e-lens, centers of the first nozzle and the first e-lens being precisely aligned along the common central axis such that there is substantially zero misalignment between the centers of the first nozzle and the first e-lens, the first e-lens including at least a first set of at least first and second electrodes that are laterally separated from one another by a first lateral gap having a first gap width, wherein the printable substrate is mounted on a front side of the first nanodroplet printer in alignment with the first nanodroplet printer; and applying a first set of voltage signals to the first set of at least first and second electrodes to cause a nanodroplet to be generated and extracted through a nanodroplet orifice of the first nozzle, the extracted nanodroplet self-aligning to the e-lens due to the first nozzle and the first

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Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

<Box No. IV Lack of unity of invention>

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1. In order for all inventions to be examined, the appropriate additional examination fees must be paid.

Group I, claims 1-14 and 16-23, are drawn to an atomic-to-nanoscale matter emission/flow regulation device comprising at least a first nanodroplet generation/control device.

Group II, claim 15, is drawn to a method of fabricating an atomic-to-nanoscale matter emission/flow regulation device comprising: a first substrate comprising a first semiconductor material.

The inventions listed as Groups I-II do not relate to a single general inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: the special technical feature of the Group I invention: a first nanodroplet generation/control device having a front side, a back side and a first reservoir disposed in between the front side and the back side for holding matter to be extracted, the first nanodroplet generation/control device comprising at least a first nanodroplet column system comprising: an upper portion of the first reservoir; a first electrostatic lens (e-lens) disposed in between the upper portion of the first reservoir and the front side of the first nanodroplet generation/control device, the first e-lens including at least a first set of at least first and second electrodes that are laterally separated from one another by a first lateral gap having a gap width; and a first nozzle disposed in between the first e-lens and the upper portion of the first reservoir and being separated from the first e-lens by a first e-lens-to-filament gap, the first nozzle having a first nanodroplet orifice through which nanodroplets generated from matter held in the first reservoir are extracted out of the first reservoir through the first nanodroplet orifice when a first set of preselected voltage signals are applied to the first set of at least first and second electrodes, the first nozzle being precisely aligned with the first lateral gap and having a first nozzle width equal to a distance between innermost edges of side walls of the first nozzle, the first nozzle and the first lateral gap having a common central axis that ensures that the nanodroplets extracted through the first nanodroplet orifice self-align with the first lateral gap as claimed therein is not present in the invention of Group II. The special technical feature of the Group II invention: forming one or more first layers of insulation on the front side of the first substrate, said one or more first layers of insulation having a thickness equal to a length of a first electrostatic lens (e-lens)-to-filament gap; forming one or more first patterned metal layers on a top surface of said one or more first layers of insulation, said one or more first patterned metal layers having at least a first gap therein that extends through said one or more first metal layers and has a first gap width, wherein opposite sides of said one or more metal layers that define the first gap comprise first and second electrodes of a first e-lens of the atomic-to-nanoscale matter emission/flow regulation device; using said one or more first patterned metal layers having said at least a first gap therein as a mask during an etching process to etch at least a second gap in said one or more first layers of insulation, the second gap extending through said one or more layers of insulation and having a width equal to the gap width, the first and second gaps being laterally aligned; and using said one or more first metal layers and said one or more first layers of insulation having the first and second gaps therein, respectively, as a mask during an etching process to etch a nozzle in the front side of the first substrate that extends into the first reservoir, the nozzle having an inlet side disposed inside of the first reservoir and an exit side disposed in the second gap, the nozzle and the first and second gaps having a common central axis, said one or more layers of insulation separating the nozzle from the e-lens by a distance equal to the length of the e-lens-to-filament gap as claimed therein is not present in the invention of Group I.

Groups I and II lack unity of invention because even though the inventions of these groups require the technical feature of an atomic-to-nanoscale matter emission/flow regulation device comprising: a first reservoir for holding matter to be extracted, this technical feature is not a special technical feature as it does not make a contribution over the prior art.

Specifically, US 2011/0155574 to Golvochenko teaches an atomic-to-nanoscale matter emission/flow regulation device comprising: a first reservoir for holding matter to be extracted (Paras. [0033], [0037-0038]).

Since none of the special technical features of the Group I or II inventions are found in more than one of the inventions, unity of invention is lacking.

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Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

e-lens being precisely aligned along the common central axis, the e-lens directing the extracted nanodroplet onto the printable substrate to thereby write a structure on the printable substrate" for claim 16.

LI-COR, Inc. (US 2017/0219522 A1) teaches a flow regulation device comprising at least a first droplet generation/control device having a reservoir for holding matter to be extracted (Shown is a capillary electrophoresis solution reservoir 201 that holds a capillary electrophoresis solution 202, para. 0071. The dispensing apparatus can be configured as in the device 100 of FIG. 1 to dispense droplets 209 that can comprise a mixture of the capillary electrophoresis solution 202 and the sheath liquid 205, para. 0073); at least a first set of at least first and second electrodes (A first electrode 210 is in fluid connection with the capillary electrophoresis solution 202. A second electrode 211 is in fluid connection with the sheath liquid 205, para. 0073); applying a first set of voltage signals to the first set of at least first and second electrodes to cause a nanodroplet to be generated and extracted through a first nozzle (A voltage potential can be applied through the capillary electrophoresis tube between the first and second electrodes. The power for applying a voltage can supply an electric field having voltages of about 1 V/cm to 2000 V/cm., para. 0096. The dispensing can generate the formation of droplets exiting the nozzle outlet, para. 0097). However, LI-COR, Inc. does not teach or fairly suggest, "a first nozzle disposed in between the first e-lens and the upper portion of the first reservoir and being separated from the first e-lens by a first e-lens-to-filament gap, the first nozzle having a first nanodroplet orifice through which nanodroplets generated from matter held in the first reservoir are extracted out of the first reservoir through the first nanodroplet orifice when a first set of preselected voltage signals are applied to the first set of at least first and second electrodes, the first nozzle being precisely aligned with the first lateral gap and having a first nozzle width equal to a distance between innermost edges of side walls of the first nozzle, the first nozzle and the first lateral gap having a common central axis that ensures that the nanodroplets extracted through the first nanodroplet orifice self-align with the first lateral gap, the first nozzle width being less than or equal to 300 nanometers" for claim 1; "the first nozzle having an inlet side disposed in the upper portion of the first reservoir and an exit side disposed in the first e-lens-to-filament gap, the exit side of the first nozzle having side walls that extend away from a common central axis of the first nozzle and the first e-lens, centers of the first nozzle and the first e-lens being precisely aligned along the common central axis such that there is substantially zero misalignment between the centers of the first nozzle and the first e-lens, the first e-lens including at least a first set of at least first and second electrodes that are laterally separated from one another by a first lateral gap having a first gap width, wherein the printable substrate is mounted on a front side of the first nanodroplet printer in alignment with the first nanodroplet printer; and applying a first set of voltage signals to the first set of at least first and second electrodes to cause a nanodroplet to be generated and extracted through a nanodroplet orifice of the first nozzle, the extracted nanodroplet self-aligning to the e-lens due to the first nozzle and the first e-lens being precisely aligned along the common central axis, the e-lens directing the extracted nanodroplet onto the printable substrate to thereby write a structure on the printable substrate" for claim 16.

Claims 1-14 and 16-23 meet the criteria set out in PCT Article 33(4), and thus have industrial applicability because the subject matter claimed can be made or used in industry.