(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
16 February 2006 (16.02.2006)

PCT

(10) International Publication Number
WO 2006/017465 A1

(51) International Patent Classification[7]: G01R 31/26, H01L 29/06

(21) International Application Number: PCT/US2005/027344

(22) International Filing Date: 1 August 2005 (01.08.2005)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/910,060 2 August 2004 (02.08.2004) US

(71) Applicant *(for all designated States except US)*: AGILENT TECHNOLOGIES, INC. [US/US]; 395 Page Mill Road, Palo Alto, CA 94306 (US).

(72) Inventors: NYSTROM, Michael; 1842 Charmeran Avenue, San Jose, CA 95124 (US). HOFLER, Gloria, E.; 863 Cumberlland Drive, Sunnyvale, CA 94087 (US).

(74) Agent: KRAUSE-POLSTORFF, Juergen; Agilent Technologies, Inc., Intellectual Property, Administration, M/S DL-429, P.O. Box 7599, Loveland, CO 80537-0599 (US).

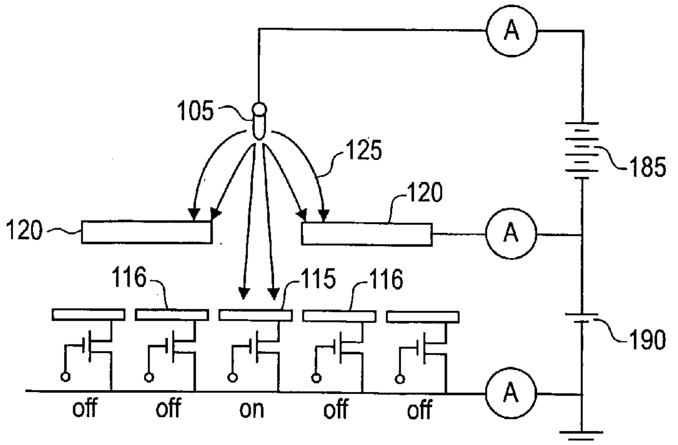
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHOD AND APPARATUS FOR NON-CONTACT ELECTRICAL PROBE



(57) Abstract: Methods and apparatus for non-contact electrical probes are described. In accordance with the invention, non-contact electrical probes use negative or positive corona discharge. Non-contact electrical probes are suited for tesing of OLED flat panel displays.

WO 2006/017465 A1

METHOD AND APPARATUS FOR NON-CONTACT ELECTRICAL PROBE

BACKGROUND

There are a number of techniques for measuring voltages on a flat panel display which comply with the requirement that there be no electrical contact on the active area of the flat panel display to avoid contamination of the electrode surfaces although the electrical contact may be made at the edges of the flat panel display. For example, an electron beam may be used to image the surface with voltage differences appearing as contrast differences. However, testing of the thin film circuitry for Organic Light Emitting Diode (OLED) flat panel requires measuring the current because the OLED pixel brightness is controlled using a current signal as opposed to a voltage signal used to control brightness for Liquid Crystal Display (LCD) pixel

Typically, it is more difficult to measure currents. One typical technique is to incorporate an additional capacitor per pixel on the OLED display circuit and to measure the charging of this capacitor. This technique typically adds complexity to the circuit that will not be used once testing is complete. Another typical technique uses an electron beam as a non-contact probe but this technique requires placing the flat panel under test into a vacuum chamber which adds cost and time to the test procedure.

SUMMARY

In accordance with the invention, a non-contact probe permits electrical current to flow through a small gas gap to the surface of a device under test at atmospheric pressure. The non-contact probe typically includes a sharp electrode and a flat electrode where current flowing from the sharp electrode passes through a hole

in the flat electrode and is captured by the device under test. The device under test is typically located beneath the aperture in the flat electrode and the voltage drop between the flat electrode and the device under test controls the current flowing to the device under test.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1a shows an embodiment in accordance with the invention.

FIG. 1b shows an embodiment in accordance with the invention.

FIG. 1c shows a close up of the sharp electrode positioned with respect to the flat electrode.

FIG. 2 shows an embodiment in accordance with the invention.

FIG. 3 shows an embodiment in accordance with the invention with a thin wire electrode.

DETAILED DESCRIPTION OF THE INVENTION

FIGs. 1a and 1b show non-contact probe 100 in accordance with the invention. An atmospheric pressure plasma forms around the tip of sharp electrode 105 where the electric field is sufficiently high due to geometric effects. FIG. 1c shows sharp electrode 105 and flat electrode 120 separated by distance D, typically in the range of about 1 mm to 10 mm with the tip of sharp electrode 105 having radius of curvature r. An electrode is "sharp" for the purposes of this application when the tip radius of curvature r of sharp electrode 105 is less than about D/5. Typical materials for sharp electrode 105 include steel, copper, platinum, nickel titanium alloy and chrome or sharp electrode 105 may be a Spindt tip, see U.S. Patent No. 3,755,704 incorporated by reference. The high curvature ensures a high potential gradient around sharp electrode 105 for the generation of the atmospheric pressure plasma. Typical potentials for sharp electrode 105 are greater than about 1000 V. Sharp electrode 105 is typically a needle-like electrode and is typically used to test a single device or a small number of devices.

Flat electrode 120 captures most of charged species 125 that travel across the gap between sharp electrode 105 and flat electrode 120. Flat electrode 120 is typically made from a material chosen for manufacturability such as nickel, stainless steel or silicon. Aperture 101, typically about 10 μm to 300 μm in diameter, in flat electrode 120 allows a portion of charged species 125 that have traveled across the gap from sharp electrode 105 to flat electrode 120 to travel past flat electrode120 to device under test 115. The gap between flat electrode 120 and device under test 115 is sufficiently small to ensure that the current flows to device under test 115 and not to adjacent devices 116 not under test. A typical size range for this gap is between about 0.1 mm to about 1 mm and is typically on the order of about 100 μm. Gap sizes smaller than about 100 μm are typically discouraged because the probability that contamination on flat electrode 120 may be transferred to device under test 115 is considerably increased and also contamination trapped between device under test 115 and sharp electrode 105 may cause damage to either device under test 115 or sharp electrode 105. For sharp electrode 105, aperture 101 is typically square or round in shape as shown in FIG. 2. Flat electrode 120 is typically kept at or near ground potential. The typical impedance between flat electrode 120 and device under test 115 is typically less than about 100 KΩ and no greater than about 10 MΩ.

Device under test 115 may be an electrode on the surface of an OLED flat panel display and is electrically coupled to bias voltage supply 190 using device under test interface 116 (see FIG. 2). Device under test 115 is typically biased relative to flat electrode 120 to control the amount of current, typically in the range from about 1 μA to 10 μA, flowing to the surface of device under test 115 from sharp electrode 105 as indicated in FIG. 2. Typical bias voltages are less than about 100 V. Other devices requiring contactless electrical probes may also be tested in accordance with the invention.

Steering structure 110 may be included in the gap region between sharp electrode 105 and flat electrode 120 as shown in FIG. 1a. Steering structure 110 functions to increase the portion of charged species 125 that pass through aperture 101. Steering structure 110 may be electrostatic or electromagnetic in nature to control the path of charged species 125 from the plasma creation region to flat electrode 120. If steering structure 110 is electrostatic in nature, such as one or more metal rings kept at a fixed voltage, the electric field is typically distorted to modify the path of charged species 125. If steering structure 110 is electromagnetic in nature, such as a permanent magnet or electromagnet, the resulting magnetic field is typically used to focus charged species 125 with the resulting Lorentz force.

FIG. 3 shows an embodiment in accordance with the invention where sharp electrode 105 has been replaced by thin wire electrode 305 to measure a row of devices under test 315. The radius of wire electrode 305 is typically less than 20% of the distance between wire electrode 305 and flat electrode 320. Note that aperture 101 is replaced by slit-like aperture 301 in flat electrode 320. Devices under test 315 are electrically coupled to bias voltage supply 390 using device under test interface 316. Devices under test 315 are typically biased relative to flat electrode 320 to control the amount of current, typically in the range from about 1 μA to 10 μA, flowing to the surface of device under test 315 from thin wire electrode 305 as indicated in FIG. 3. Typical bias voltages are less than about 100 V. Other devices requiring contactless electrical probes may also be tested in accordance with the invention.

With reference to FIGs. 1a- 2, operationally sharp electrode 105 is biased at a high voltage, typically greater than 1000 V with respect to flat electrode 120. An atmospheric plasma is generated in the resulting large electric fields in the vicinity of sharp electrode 105. Gas, such as, for example, argon mixed with hydrogen, argon mixed with a forming gas comprised of nitrogen and hydrogen, argon mixed with oxygen or nitrogen with amounts of ammonia typically less than about one percent, is flowed past sharp electrode 105 towards device under test 115 and to provide the local atmosphere at atmospheric pressure. Argon or nitrogen alone may also be used. The gas is typically flowed from the region of sharp electrode 105 or thin wire electrode 305 through aperture 101 or aperture 301 past device under test 115 or devices under test 315, respectively. The mass flow of the gas also operates to enhance current flow through apertures 101 and 301. A negative or positive corona may be used. If a negative corona is used, electronegative species are typically only a small portion of the gas because negative ions make the plasma noisy which is typically undesirable. Note that negative coronas can only be maintained in a gas with electronegative molecules. Charged species 125 are accelerated towards flat electrode 120 while an equal number of oppositely charged species are accelerated towards sharp electrode 105 creating a current between flat electrode 120 and sharp electrode 105 through high voltage supply 185. In an embodiment in accordance with the invention, this current may be monitored and used as a feedback signal to high voltage supply 185 to reduce the current variation which results in measurement noise.

A portion of charged species 125 pass through aperture 101 in flat electrode 120. After passing through aperture 101, charged species 125 are accelerated towards device under test 115 because of the bias voltage that is maintained between flat electrode 120 and device under test 115 using bias voltage supply 190. A portion of charged species 125 that passes through aperture 101 are captured by device under test 115 and produce a current. By adjusting the bias voltage, the number of charged species 125 that are drawn through aperture 101 can typically be increased.

Similarly for the embodiment in accordance with the invention shown in FIG. 3, the charged species (not shown) pass through aperture 301 in flat electrode 320 while an equal number of oppositely charged species are accelerated towards thin wire electrode 305 creating a current between flat electrode 320 and thin wire electrode 305 through high voltage supply 385. After passing through aperture 301, the charged species are accelerated towards devices under test 315 because of the bias voltage that is maintained between flat electrode 320 and devices under test 315 using a bias voltage supply 390. A portion of the charged species that passes through aperture 301 are captured by devices under test 315 and produce a current. By adjusting the bias voltage, the number of charged species that are drawn through aperture 301 can typically be increased.

While the invention has been described in conjunction with specific embodiments, it is evident to those skilled in the art that many alternatives, modifications, and variations will be apparent in light of the foregoing description. Accordingly, the invention is intended to embrace all other such alternatives, modifications, and variations that fall within the spirit and scope of the appended claims.

CLAIMS

1. An apparatus for non-contact testing of a device under test comprising: an electrode (105, 305) comprising a radius of curvature (r); a flat electrode (120, 320) comprising a first face, a second face and an aperture (101, 301), said first face of said flat electrode (120, 320) separated from said electrode (105, 305) by a first gap (D) and positioned such that said aperture (101, 301) is aligned with said electrode (105, 305); and a device under test interface (116, 316) is separated from said second face of said flat electrode (120, 320) by a second gap.

2. The apparatus of Claim 1 wherein said radius of curvature (r) is less than about one fifth of said first gap (D).

3. The apparatus of Claim 1 wherein said electrode (105, 305) is comprised of nickel.

4. The apparatus of Claim 1 wherein said flat electrode (120, 320) is comprised of stainless steel.

5. The apparatus of Claim 1 wherein said electrode (105) is a Spindt tip.

6. The apparatus of Claim 1 wherein said aperture (101, 301) has a diameter in the range from about 10 μm to 300 μm.

7. The apparatus of Claim 1 further comprising a steering structure (110) disposed in said first gap (D).

8. The apparatus of Claim 7 wherein said steering structure (110) is electromagnetic.

9. The apparatus of Claim 1 configured to generate a positive corona.

10. The apparatus of Claim 1 wherein said electrode (305) is a thin wire electrode.

11. The apparatus of Claim 10 wherein said aperture (301) is a slit-like aperture.

12. The apparatus of Claim 1 further comprising a device under test (115, 315) electrically coupled to said device under test interface (116,316).

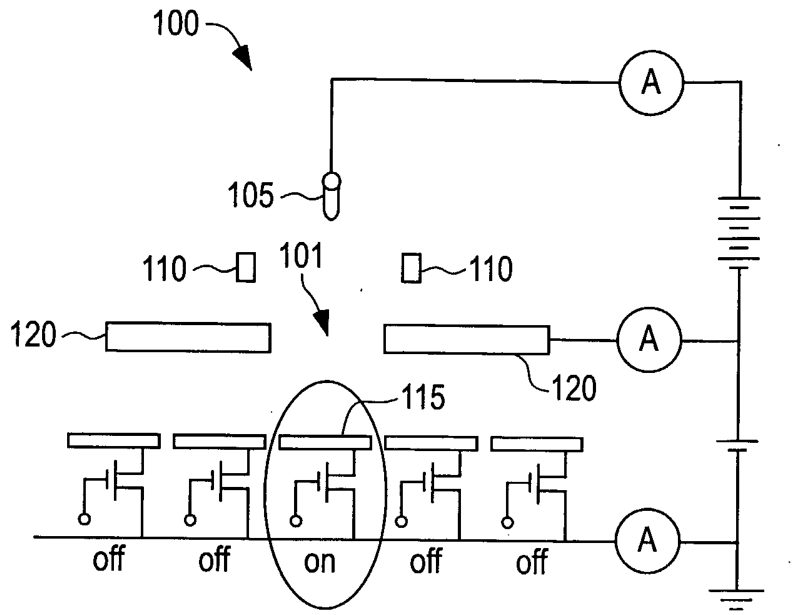


Figure 1A

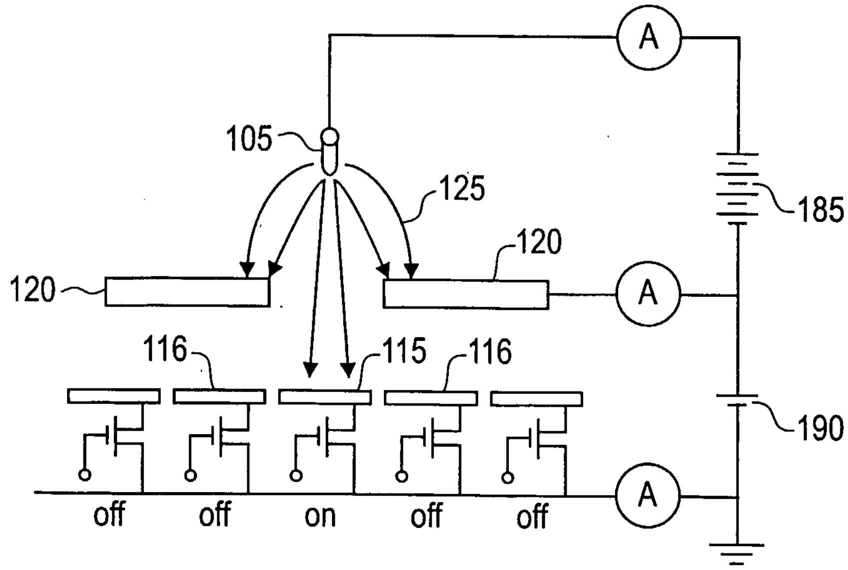


Figure 1B

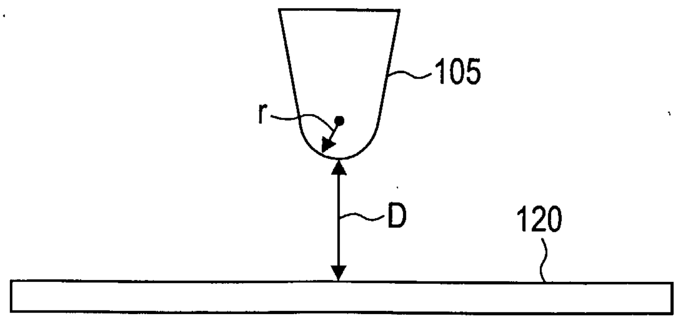


Figure 1C

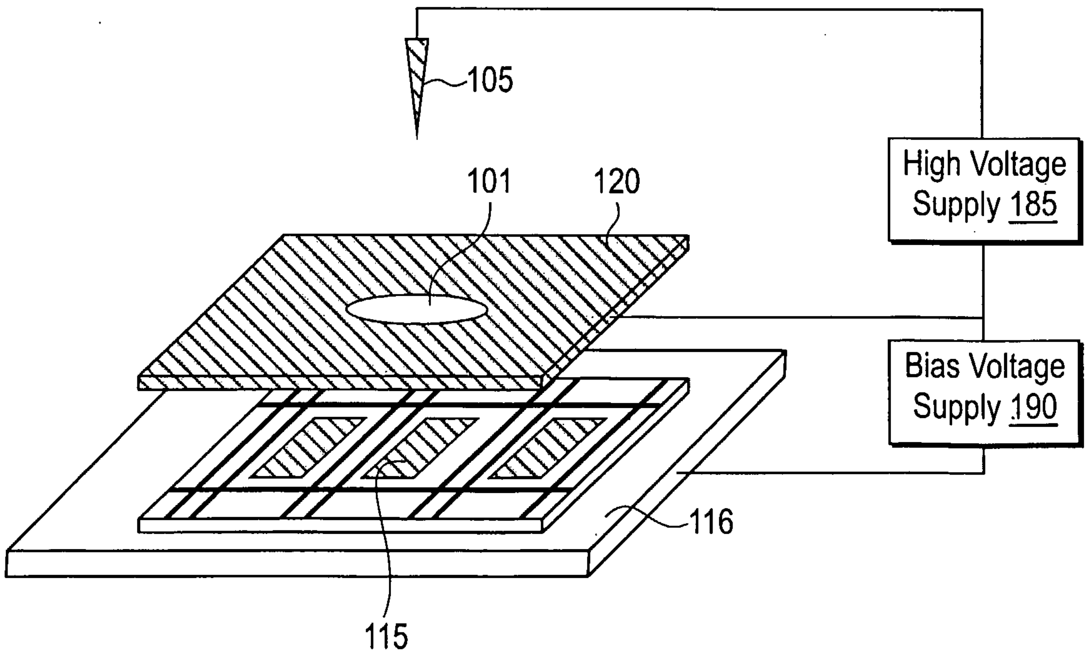


Figure 2

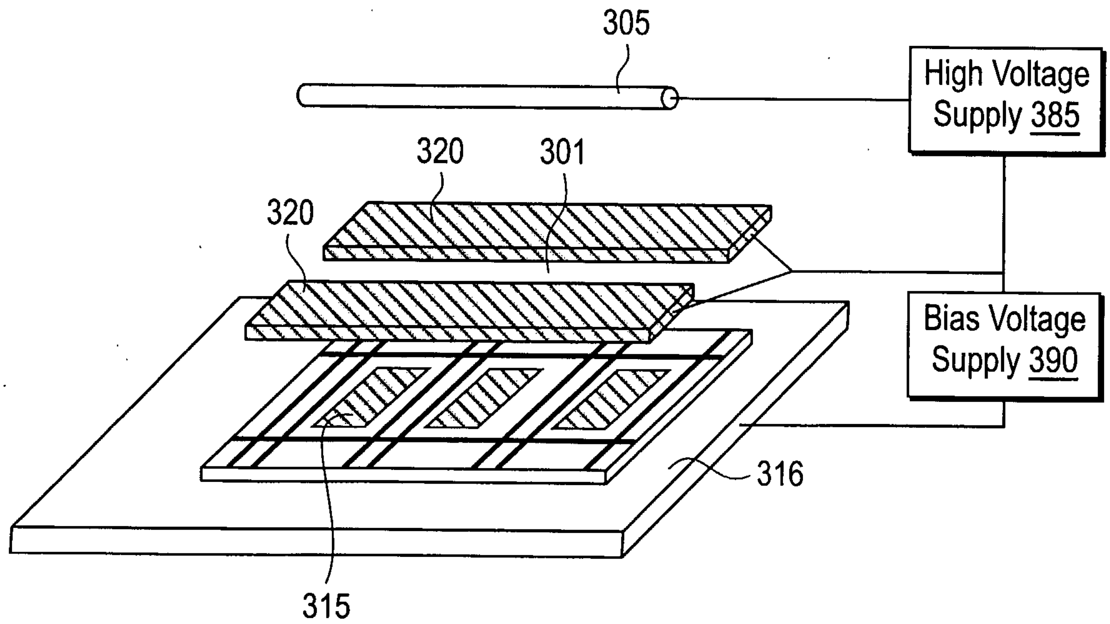

305
High Voltage
Supply 385
320
301
320
Bias Voltage
Supply 390
316
315

Figure 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US05/27344

A. CLASSIFICATION OF SUBJECT MATTER
IPC(7) : G01R 31/26; H01L 29/06
US CL : 257/10; 324/158
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : 257/10; 324/158

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,091,691 (Kamieniecki et al.) 25 February 1992 (25.02.1992), fig. 2-4.	1-12

Y	US 5,719,406 (Cisneros et al.) 17 February 1998 (17.02.1998), col. 3, lines 19-22.	

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search 12 October 2005 (12.10.2005)	Date of mailing of the international search report 10 NOV 2005
Name and mailing address of the ISA/US Mail Stop PCT, Attn: ISA/US Commissioner for Patents P.O. Box 1450 Alexandria, Virginia 22313-1450 Facsimile No. (703) 305-3230	Authorized officer Lydia Dell for Jimmy Nguyen Telephone No. 571-272-1965