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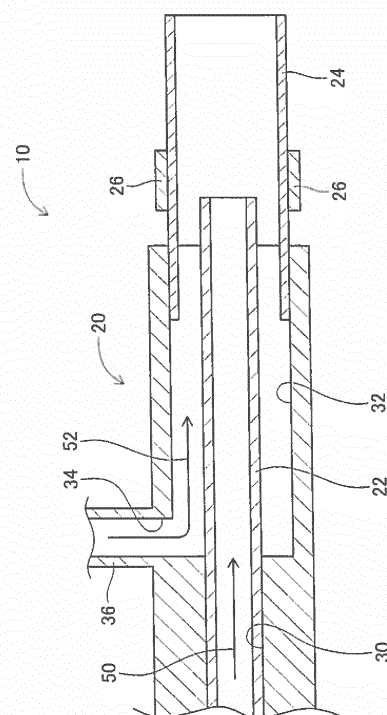
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ATMOSPHERIC-PRESSURE PLASMA GENERATION DEVICE

(57) Atmospheric pressure plasma generator 20 includes: tubular outer tube 20; inner tube 22, with an outer diameter smaller than an inner diameter of the outer tube, that is inserted inside the outer tube, the inner tube being formed from a material with either positive or negative electrical polarity; and electrode 26 with electrical polarity opposite to that of the material of the inner tube, the electrode being provided on an outer circumferential surface of the outer tube, wherein, in a state with processing gas flowing in at least one of a first flow path inside the inner tube and a second flow path between an outer circumferential surface of the inner tube and an inner circumferential surface of the outer tube, processing gas flowing through the at least one of the first flow path and the second flow path is plasmarized by applying an electric current to the electrode.

FIG. 1



Description

Technical Field

[0001] The present invention relates to an atmospheric pressure plasma generator that plasmarizes processing gas supplied inside a tubular member and emits plasma from an end section of the tubular member.

Background Art

[0002] There is a known atmospheric plasma generator that plasmarizes processing gas inside a tubular member and emits plasma from an end section of the tubular member. In detail, one of a pair of electrodes is arranged on an outer circumferential surface of the tubular member, and the other of the pair of electrodes is arranged on an inner circumferential surface of the tubular member. And, with processing gas being supplied inside the tubular member, by applying current to the pair of electrodes, processing gas is plasmarized inside the tubular member and emitted from an end section of the tubular member. An example of an atmospheric pressure plasma generator configured as such is disclosed in the patent literature below.

[0003] Patent literature 1: WO2007/105428

Summary of Invention

Technical Problem

[0004] According to the atmospheric pressure plasma generator disclosed in the above patent literature, it is possible to suitably emit plasma. However, with the atmospheric pressure plasma generator disclosed in the above patent literature, because an electrode is arranged inside the tubular member, there is a problem in that, due to deterioration of the electrode, foreign matter may contaminate a target object of the plasma. Also, if an electrode is not arranged inside the tubular member, in order to prevent foreign matter contaminating a target object of the plasma, there is a problem in that processing gas cannot be suitably plasmarized inside the tubular member. The present invention takes account of such circumstances, and an object thereof is suitably plasmarize processing gas while preventing foreign matter from contaminating a target object of the plasma.

Solution to Problem

[0005] To solve the above problems, a disclosed atmospheric pressure plasma generator includes: a tubular outer tube; an inner tube, with an outer diameter smaller than an inner diameter of the outer tube, that is inserted inside the outer tube, the inner tube being formed from a material with either positive or negative electrical polarity; and an electrode with electrical polarity opposite to that of the material of the inner tube, the electrode

being provided on an outer circumferential surface of the outer tube, wherein, in a state with processing gas flowing in at least one of a first flow path inside the inner tube and a second flow path between an outer circumferential surface of the inner tube and an inner circumferential surface of the outer tube, processing gas flowing through the at least one of the first flow path and the second flow path is plasmarized by applying an electric current to the electrode.

Advantageous Effects of Invention

[0006] With the disclosed atmospheric pressure plasma generator, an inner tube is inserted inside an outer tube and the inner tube is formed of a material with either positive or negative electrical polarity. Also, an electrode with electrical polarity opposite to that of the material of the inner tube is provided on an outer circumferential surface of the outer tube. Therefore, by flowing processing gas such that processing gas contacts the inner tube, with the inner tube electrified, by applying an electric current to the electrode provided on the outer circumferential surface of the outer tube, current flows between the electrode and the inner tube. Thus, electrical discharge occurs between the electrode and the inner tube, and processing gas inside the outer tube is plasmarized. In such a manner, with the disclosed atmospheric pressure plasma generator, processing gas is plasmarized inside the outer tube without providing an electrode on the inside of the outer tube. Therefore, even in a case in which the electrode deteriorates, it is possible to prevent foreign matter from contaminating a target object of the the plasma during exposure to plasma. Further, because electrical discharge occurs between the electrode and the inner tube, it is possible to suitably plasmarize processing gas.

Brief Description of Drawings

[0007]

[Fig. 1]

Fig. 1 shows a cross section of an atmospheric pressure plasma generator of a first embodiment.

[Fig. 2]

Fig. 2 shows a cross section of an atmospheric pressure plasma generator of a second embodiment.

Description of Preferred Embodiments

[0008] The following describes in detail referring to the figures an example embodiment of the present invention.

Configuration of atmospheric pressure plasma generator

[0009] Fig. 1 shows an embodiment of the present invention, atmospheric pressure plasma generator 10. Atmospheric pressure plasma generator 10 is for generat-

ing plasma at atmospheric pressure. Atmospheric pressure plasma generator 10 is provided with resin housing 20, Teflon (registered trademark of DuPont, USA) tube 22, glass pipe 24, and electrode 26.

[0010] Housing 20 is approximately cylindrical, and an inner circumferential surface of housing 20 is configured from small diameter section 30, and large diameter section 32 that has a larger diameter than small diameter section 30. Through-hole 34 that pierces large diameter section 32 in the diameter direction is formed at the small diameter section 30 end section of large diameter section 32, and gas introduction pipe 36 is connected to through-hole 34.

[0011] Teflon tube 22 is approximately cylindrical and its outer diameter is slightly smaller than the inner diameter of small diameter section 30 of housing 20. Further, Teflon tube 22 is inserted into small diameter section 30 of housing 20, and an end of Teflon tube 22 protrudes slightly from the end section of housing 20 on the large diameter section 32 side.

[0012] Glass pipe 24 is approximately cylindrical and its outer diameter is slightly smaller than the inner diameter of large diameter section 32 of housing 20. Further, glass pipe 24 is engaged with large diameter section 32 of housing 20, and an end of glass pipe 24 protrudes from the end section of housing 20 on the large diameter section 32 side. Note that, the amount that glass pipe 24 protrudes from the end section of housing 20 may be greater than the protruding amount of Teflon tube 22 from housing 20. That is, the end section of Teflon tube 22 protruding from the end of housing 20 may be positioned inside glass pipe 24 protruding from housing 20.

[0013] Electrode 26 is approximately annular and is provided on an outer circumferential surface of glass pipe 24. The arrangement location of electrode 26 is roughly at a central portion of glass pipe 24 in the axial direction, and electrode 26 faces the end section of Teflon tube 22 sandwiching glass pipe 24.

Generation of plasma by atmospheric pressure plasma generator

[0014] With atmospheric pressure plasma generator 10, thanks to the above configuration, processing gas is supplied to both Teflon tube 22 and gas introduction pipe 36, and plasma is emitted from the end section of glass pipe 24 by applying current to electrode 26. Plasma generation by atmospheric pressure plasma generator 10 is described below in detail.

[0015] With atmospheric pressure plasma generator 10, processing gas is supplied inside Teflon tube 22 from a gas supply device (not shown), and flows inside Teflon tube 22 in the direction of arrow 50. Further, processing gas is supplied in gas introduction pipe 36 from the gas supply give, and flows between the outer circumferential surface of Teflon tube 22 and the inner circumferential surface of housing 20 in the direction of arrow 52. Note that, the processing gas flowing inside Teflon tube 22

and the processing gas flowing inside gas introduction pipe 36 are the same, and that processing gas is a mixture at any given ratio of an inert gas such as nitrogen and a reactive gas such as oxygen from air.

[0016] Further, Teflon tube 22 is formed from a fluoropolymer, and the fluoropolymer is a material with negative electrical polarity. A material with negative electrical polarity is a material which is easily charged as a cathode and, for example, in a case of static electricity caused by friction, material for which the electrical polarity is negative is charged as a cathode. Therefore, when processing gas flows inside Teflon tube 22, or between the outer circumferential surface of Teflon tube 22 and the inner circumferential surface of housing 20, Teflon tube 22 is charged as a cathode. Specifically, for example, when measuring the electric potential on the outer circumferential surface of glass pipe 24 with processing gas flowing inside Teflon tube 22, the electric potential on the outer circumferential surface of glass pipe 24 was -11 volts. Also, when measuring the electric potential on the outer circumferential surface of glass pipe 24 with processing gas flowing between the outer circumferential surface of Teflon tube 22 and the inner circumferential surface of housing 20, the electric potential on the outer circumferential surface of glass pipe 24 was -77 volts. Further, when measuring the electric potential on the outer circumferential surface of glass pipe 24 with processing gas flowing between the outer circumferential surface of Teflon tube 22 and the inner circumferential surface of housing 20 and flowing inside Teflon tube 22, the electric potential on the outer circumferential surface of glass pipe 24 was -50 volts. Note that, the electric potential of Teflon tube 22 while processing gas was flowing was too low to be measured.

[0017] In this manner, when processing gas flows so as to contact Teflon tube 22, Teflon tube 22 is charged as a cathode. Therefore, when processing gas is supplied to Teflon tube 22 and gas introduction pipe 36 and positive electric voltage is applied to electrode 26, electric current flows between Teflon tube 22 and electrode 26. In this case, electrical discharge occurs between Teflon tube 22 and electrode 26, and processing gas flowing from inside Teflon tube 22 to inside glass pipe 24, and processing gas flowing from between the outer circumferential surface of Teflon tube 22 and the inner circumferential surface of housing 20 to inside glass pipe 24 is plasmarized. By this, atmospheric pressure plasma generator 10 emits plasma from the leading end of glass pipe 24.

[0018] With a conventional atmospheric pressure plasma generator, generally, one of a pair of electrodes is arranged on the outer circumferential surface of glass pipe 24 and the other electrode of the pair is arranged on the inner circumferential surface of glass pipe 24, and processing gas inside glass pipe 24 is plasmarized by positive electric voltage being applied to the electrode and negative electric voltage being applied to the other electrode. Therefore, with a conventional atmospheric

pressure plasma generator, the electrode arranged on the outer circumferential surface of glass pipe 24 deteriorates, and due to deterioration of the electrode, foreign matter may contaminate a target object of the plasma. However, with atmospheric pressure plasma generator 10, because electrical discharge occurs between Teflon tube 22 and electrode 26, it is not necessary to arrange an electrode on the inside of glass pipe 24. Therefore, by performing plasma processing with atmospheric pressure plasma generator 10, it is possible to prevent foreign matter from contaminating a target object of the plasma.

[0019] Also, with atmospheric pressure plasma generator 10, processing gas flows not only inside Teflon tube 22, but also between the outer circumferential surface of Teflon tube 22 and the inner circumferential surface of housing 20, and that processing gas is plasmarized. This enables a large amount of processing gas to be plasmarized, meaning that plasma is emitted efficiently.

[0020] Second embodiment Fig. 2 shows a second embodiment, atmospheric pressure plasma generator 70. Atmospheric pressure plasma generator 70 of the second embodiment is provided with the same configuration elements as atmospheric pressure plasma generator 10 of the first embodiment, except for the electrode. Therefore, the same reference numbers are given to configuration elements that are the same as configuration elements of atmospheric pressure plasma generator 10 and descriptions of those items are omitted.

[0021] Atmospheric plasma generator 70 is provided with pair of electrodes 72 and 74. Each of the pair of electrodes 72 and 74 is approximately annular and electrodes 72 and 74 are provided on an outer circumferential surface of glass pipe 24 slightly separated from each other. Electrode 72 is provided roughly at a central portion of glass pipe 24 in the axial direction and electrode 74 is provided between electrode 72 and the end of glass pipe 24 at the side protruding from housing 20. Note that, electrode 72 faces the end section of Teflon tube 22 sandwiching glass pipe 24.

[0022] With atmospheric pressure plasma generator 70 with such a configuration, negative electric voltage is applied to electrode 72 and positive electric voltage is applied to electrode 74 with processing gas being supplied to Teflon tube 22 and glass introduction pipe 36. By this, electric current flows between electrode 72 and electrode 74, and between electrode 74 and Teflon tube 22. In this case, electrical discharge occurs between electrode 72 and electrode 74, and between electrode 74 and Teflon tube 22, and processing gas flowing from inside Teflon tube 22 to inside glass pipe 24, and processing gas flowing from between the outer circumferential surface of Teflon tube 22 and the inner circumferential surface of housing 20 to inside glass pipe 24 is plasmarized. By this, similarly to atmospheric pressure plasma generator 10, atmospheric pressure plasma generator 70 emits plasma from the leading end of glass pipe 24.

[0023] In this manner, with atmospheric pressure plasma generator 70, a pair of electrodes 72 and 74 is used,

and that pair of electrodes 72 and 74 is provided on the outer circumferential surface of glass pipe 24, and electrical discharge occurs between electrode 74 and Teflon tube 22 inside glass pipe 24. Therefore, similarly to atmospheric pressure plasma generator 10, with atmospheric pressure plasma generator 70, because no electrode is provided inside on the inside of glass pipe 24, it is possible to prevent foreign matter from contaminating a target object of the plasma.

[0024] Note that, atmospheric pressure plasma generator 10 is an example of an atmospheric pressure plasma generator. The item configured from housing 20 and glass pipe 24 is an example of an outer tube. Teflon tube 22 is an example of an inner tube. Electrode 26 is an example of an electrode. Atmospheric pressure plasma generator 70 is an example of an atmospheric pressure plasma generator. Electrode 72 is an example of a second electrode. Electrode 74 is an example of an electrode.

[0025] Further, the present invention is not limited to the above example embodiments, and various changed or improved methods of embodiment are possible based on the knowledge of someone skilled in the art. Specifically, for example, in an above embodiment, a fluoropolymer is used as a material with negative electrical polarity, and possible materials include silicon, vinyl chloride, acrylic, polyurethane; polypropylene, polyester, rubber, and so on. That is, instead of Teflon tube 22, a tubular member formed from a material such as silicon, vinyl chloride, or the like may be used.

[0026] Also, in an embodiment above, Teflon tube 22 formed from a material with negative electrical polarity is provided on the inside of housing 20, but a tubular member formed from a material with positive electrical polarity may be provided instead of Teflon tube 22. However, in a case in which a tubular member formed from a material with positive electrical polarity is provided instead of Teflon tube 22, negative electric voltage must be applied to electrode 26. By this, electrical discharge occurs between the tubular member formed from a material with positive electrical polarity and electrode 26, and the same effects as the above atmospheric pressure plasma generator 10 are achieved. Note that, as a material with positive electrical polarity, for example, glass, nylon, or the like may be used.

[0027] Also, in an embodiment above, the processing gas supplied to Teflon tube 22 and the processing gas supplied to gas introduction pipe 36 are the same, but different processing gases may be supplied to Teflon tube 22 and gas introduction pipe 36. Further, in an embodiment above, processing gas supplied to Teflon tube 22 and gas introduction pipe 36 is gas in which an inert gas such as nitrogen is mixed with an active gas in the air such as oxygen at a given ratio, but the processing gas may be only an inert gas, or only a reactive gas.

[0028] Also, in an embodiment above, processing gas is supplied to both Teflon tube 22 and to gas introduction pipe 36, but processing gas may be supplied to one of

Teflon tube 22 and gas introduction pipe 36. That is, processing gas may be only supplied to Teflon tube 22 and that processing gas plasmarized, or processing gas may only be supplied between the outer circumferential surface of Teflon tube 22 and the inner circumferential surface of housing 20, and that processing gas plasmarized.

Reference Signs List

[0029] 10: atmospheric pressure plasma generator; 20: housing (outer tube); 22: Teflon tube (inner tube); 24: glass pipe (outer tube); 26: electrode; 70: atmospheric pressure plasma generator; 72: electrode (second electrode); 74: electrode

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Claims

1. An atmospheric pressure plasma generator comprising: 20

a tubular outer tube;
 an inner tube, with an outer diameter smaller than an inner diameter of the outer tube, that is inserted inside the outer tube, the inner tube being formed from a material with either positive or negative electrical polarity; and
 an electrode with electrical polarity opposite to that of the material of the inner tube, the electrode being provided on an outer circumferential surface of the outer tube,
 wherein, in a state with processing gas flowing in at least one of a first flow path inside the inner tube and a second flow path between an outer circumferential surface of the inner tube and an inner circumferential surface of the outer tube, processing gas flowing through the at least one of the first flow path and the second flow path is plasmarized by applying an electric current to the electrode.

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2. The atmospheric pressure plasma generator according to claim 1, wherein the inner tube is formed from a material with negative electrical polarity and the electrode is a positive electrode. 45
3. The atmospheric pressure plasma generator according to claim 1 or 2, wherein, in a state with processing gas flowing in both the first flow path and the second flow path, processing gas flowing through the first flow path and the second flow path is plasmarized by applying an electric current to the electrode. 50
4. The atmospheric pressure plasma generator according to any one of the claims 1 to 3, further comprising: 55

prising:

a second electrode with the same electrical polarity as the material of the inner tube, provided on the outer circumferential surface of the outer tube, wherein, in a state with processing gas flowing in at least one of the first flow path and the second flow path, processing gas flowing through the at least one of the first flow path and the second flow path is plasmarized by applying an electric current to the electrode and the second electrode.

FIG. 1

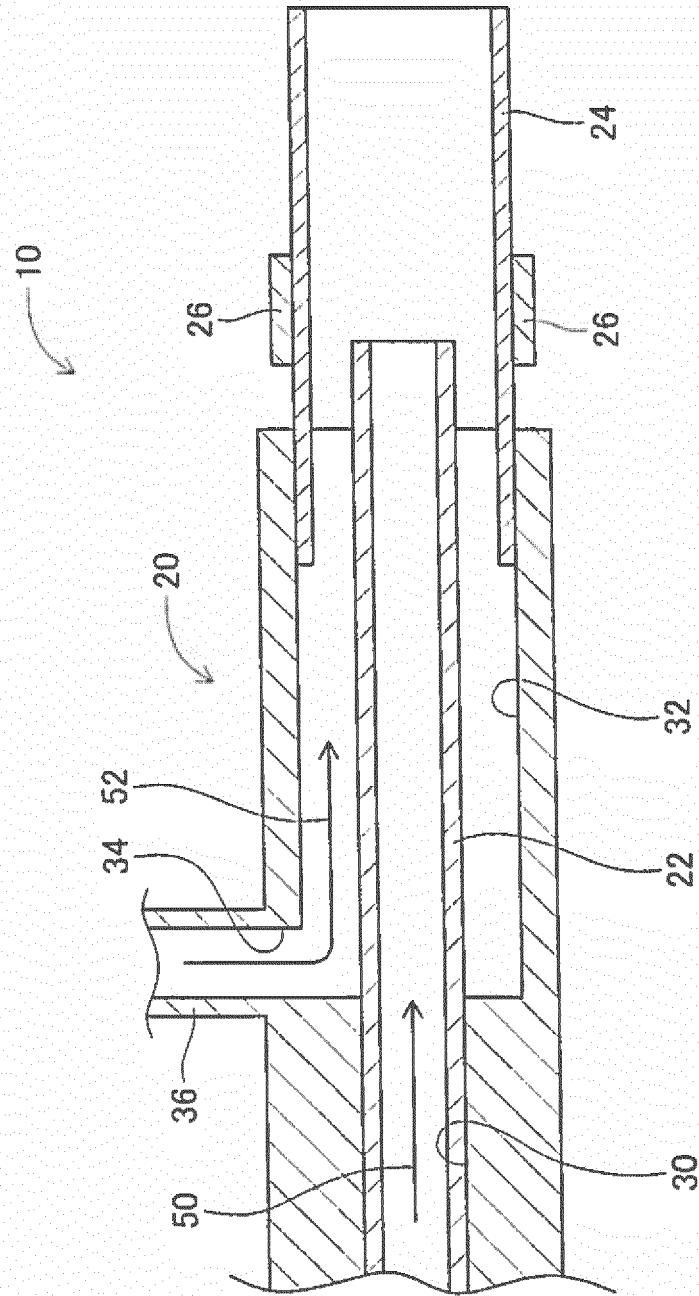
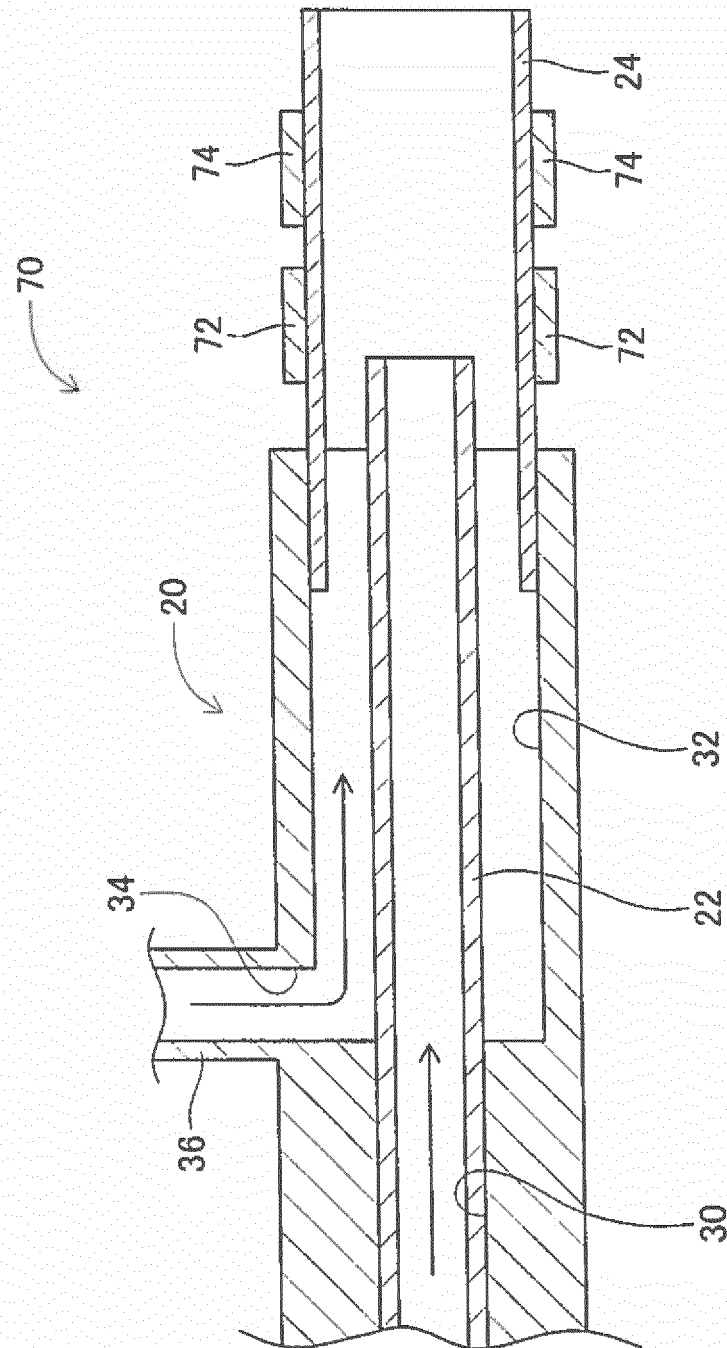


FIG. 2



INTERNATIONAL SEARCH REPORT

International application No.

PCT/JP2015/052191

A. CLASSIFICATION OF SUBJECT MATTER

H05H1/24 (2006.01) i

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)

H05H1/24

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

Jitsuyo Shinan Koho 1922-1996 Jitsuyo Shinan Toroku Koho 1996-2015
 Kokai Jitsuyo Shinan Koho 1971-2015 Toroku Jitsuyo Shinan Koho 1994-2015

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.
A	JP 2010-218997 A (Shibaura Mechatronics Co., Ltd.), 30 September 2010 (30.09.2010), paragraphs [0049] to [0071]; fig. 3 (Family: none)	1-4
A	JP 8-030968 A (Semiconductor Energy Laboratory Co., Ltd.), 02 February 1996 (02.02.1996), paragraphs [0086] to [0087]; fig. 1 & US 5932302 A	1-4

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

* Special categories of cited documents:

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Date of the actual completion of the international search
31 March 2015 (31.03.15)Date of mailing of the international search report
07 April 2015 (07.04.15)Name and mailing address of the ISA/
Japan Patent Office
3-4-3, Kasumigaseki, Chiyoda-ku,
Tokyo 100-8915, Japan

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Form PCT/ISA/210 (second sheet) (July 2009)

REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- WO 2007105428 A [0003]