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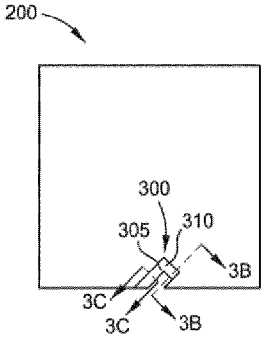


FIG. 3A

(57) Abstract: A method and apparatus for cutting an electronic device is disclosed. In one embodiment, an apparatus for cutting an electronic device on a substrate is described that includes a stage for supporting the substrate having the electronic device thereon, a focused ion beam column fixed in a position over the stage, the focused ion beam column adapted to emit a beam path at an acute angle relative to a plane of a major surface of the substrate, and a microscope positioned adjacent to the focused ion beam column, wherein the stage is limited to movement in an X-Y plane during cutting of the electronic device.

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FOCUSED ION BEAM SYSTEM FOR LARGE AREA SUBSTRATES

BACKGROUND

Field

[0001] Embodiments of the present disclosure generally relate to a focused ion beam system for analyzing electronic devices on large area substrates. More specifically, to methods and apparatus for analyzing thin film transistors (TFTs) on a large area substrate having a plurality of TFTs formed thereon.

Description of the Related Art

[0002] Electronic devices, such as TFTs, photovoltaic (PV) devices or solar cells and other electronic devices have been fabricated on large area substrates, such as thin, flexible media, for many years. The substrates may be made of glass, polymers, or other material suitable for electronic device formation. There is an ongoing effort directed to fabricating the electronic devices on substrates having a surface area much greater than one square meter, such as two square meters, or larger, to produce an end product of a larger size and/or decrease fabrication costs per device (*e.g.*, pixel, TFT, photovoltaic or solar cell, etc.).

[0003] There is often a need to analyze a discrete device that has been determined as being defective, such as a TFT. For example, a transistor that switches an individual pixel may be defective, which causes that pixel to be always on or always off.

[0004] Focused ion beam (FIB) systems have been utilized as an analytical technique in the semiconductor industry, materials science and increasingly in the biological field. In the semiconductor industry, FIB systems use a beam of ions for site-specific analysis of a portion of a die on a wafer (*e.g.*, a "sample"). A wafer having the sample thereon is attached to a movable stage. The stage is typically tilted and/or rotated using the stage such that a major surface thereof is at about a 45 degree angle relative to horizontal (*e.g.*, a plane of the fabrication facility floor). The ions from the FIB system typically cut a two-dimensional rectangular shape in

the sample, with the area of interest being angled relative to the major surface of the wafer. Then, a scanning electron microscope (SEM) is utilized to analyze the area of interest.

[0005] However, large area substrates for TFT fabrication are highly flexible at room temperature. This creates handling challenges such that conventional FIB systems and methods may not be used.

[0006] What is needed is a method and apparatus where FIB techniques can be utilized for large area substrates.

SUMMARY

[0007] A method and apparatus for cutting an electronic device is disclosed. In one embodiment, an apparatus for cutting an electronic device on a substrate is described that includes a stage for supporting the substrate having the electronic device thereon, a focused ion beam column fixed in a position over the stage, the focused ion beam column adapted to emit a beam path at an acute angle relative to a plane of a major surface of the substrate, and a microscope positioned adjacent to the focused ion beam column, wherein the stage is limited to movement in an X-Y plane during cutting of the electronic device.

[0008] In another embodiment, an apparatus for cutting an electronic device on a substrate is disclosed. The apparatus includes a stage for supporting the substrate having the electronic device thereon, a focused ion beam column fixed in a position over the stage, the focused ion beam column adapted to emit a beam path and cut a three dimensional notch in the electronic device, and a microscope positioned adjacent to the focused ion beam column, wherein the stage is limited to movement in an X-Y plane during cutting of the electronic device.

[0009] In another embodiment, a method for cutting an electronic device on a substrate is disclosed. The method includes positioning the substrate on a stage, emitting a beam path from a focused ion beam column fixed at an angle of about

45 degrees relative to a major surface of the substrate, and moving the stage in a single lateral plane to produce a three dimensional notch in the electronic device.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only exemplary embodiments and are therefore not to be considered limiting of its scope, may admit to other equally effective embodiments.

[0011] Figure 1A is a schematic sectional view of one embodiment of a focused ion beam system.

[0012] Figure 1B is another schematic sectional view of the focused ion beam system of Figure 1A.

[0013] Figures 2A-2B depict an electronic device that has been cut by a conventional method.

[0014] Figures 3A-3C are various views of an electronic device that has been cut by methods and apparatus as disclosed herein.

[0015] Figure 4 is a schematic sectional view of a metrology system.

[0016] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0017] The present disclosure generally relates to a focused ion beam (FIB) system for analyzing electronic devices on large area substrates. The large area substrates as used herein include a major surface having a surface area greater than one square meter, such as two square meters, or larger. The FIB system as described herein is exemplarily disclosed for analyzing a thin film transistor (TFT) on the large area substrate. However, the FIB system and method as disclosed herein may be utilized in analyzing other electronic devices on large area substrates.

[0018] Figure 1A is a schematic sectional view of one embodiment of a focused ion beam (FIB) system 100. Figure 1B is another schematic sectional view of the FIB system 100 of Figure 1A. The FIB system 100 shown in Figure 1A is performing a cutting process 105A where a large area substrate 110, having a transistor 115 thereon, is cut. The FIB system 100 shown in Figure 1B is performing an analyzing mode 105B where the cut transistor 115 is analyzed.

[0019] The large area substrate 110 is positioned on a stage 120. The stage 120 has a major surface 125 that supports the large area substrate 110 in an orientation that a plane of the major surface 125 is parallel to the Y direction.

[0020] The stage 120 is movable at least in a lateral direction (in the X direction and/or the Y direction). The stage 120 supports the large area substrate 110 such that a major surface 130 of the large area substrate 110 is parallel to the major surface 125 of the stage 120. Thus, a plane 135 of the major surface 130 of the large area substrate 110 is parallel to the Y direction.

[0021] The FIB system 100 also includes a focused ion beam (FIB) column 140 that emits a beam of ions. The FIB column 140 is supported such that a beam path 145 of the FIB column 140 is directed at an angle α relative to the plane 135 of the major surface 130 of the large area substrate 110. The angle α of the beam path 145 is acute, such as about 40 degrees to about 50 degrees relative to the

plane 135 of the major surface 130 of the large area substrate 110. In one example, the angle α is about 45 degrees relative to the plane 135 of the major surface 130 of the large area substrate 110.

[0022] The beam path 145 of the FIB column 140 is configured to cut a three-dimensional volume 150 in the transistor 115 and/or the large area substrate 110. The three-dimensional volume 150 is formed by moving the stage 120, having the large area substrate 110, laterally (in the X direction and the Y direction) relative to the FIB column 140. The three-dimensional volume 150 is cut in one plane (the X-Y plane).

[0023] The FIB system 100 also includes a microscope 155. The microscope 155 is utilized to analyze the three-dimensional volume 150 of the transistor 115 as shown in Figure 1B. The microscope 155 may be a scanning electron microscope that has a viewing path 160. The viewing path 160 is oriented at an angle that is orthogonal to the plane 135 of the major surface 130 of the large area substrate 110.

[0024] After performing the cutting process 105A as shown and described in Figure 1A, the stage 120 is moved in the Y direction such that the three-dimensional volume 150 of the transistor 115 is below the microscope 155 as shown in Figure 1B. In the analyzing process 105B, the stage 120 may move laterally so the viewing path 160 of the microscope 155 scans the three-dimensional volume 150. In the three-dimensional volume 150, a cross-section of the transistor 115 is visible to the microscope 155. For example, source and drain regions, and an active layer, as well as a cross-section of the large area substrate 110, is visible to the microscope 155. Movement of the stage 120 may be limited to movement in an X-Y plane during the cutting process 105A.

[0025] Figures 2A-2B depict an electronic device 200 that has been cut by a conventional method. The conventional method tilts and/or rotates the underlying substrate (not shown) having the electronic device 200 thereon relative to

horizontal on a stage (not shown). The electronic device 200 is also rotated and/or tilted relative to a fixed FIB column (not shown). The FIB column cuts the electronic device 200 to produce a two-dimensional notch 205. During this cutting, a beam path (not shown) of the FIB column is positioned at an angle of up to about 90 degrees relative to the major surface of the electronic device 200.

[0026] The two dimensional notch 205 is more clearly seen in the sectional view of Figure 2B. The two dimensional notch 205 includes walls 210 on each side of an angled surface 215. The angled surface 215 is a plane that is typically viewed by a microscope (not shown). The surface roughness (average surface roughness (Ra)) of the walls 210 have a higher surface roughness as they are not parallel to the FIB scan direction but defined by the scan start and scan end position. The angled surface 215 roughness Ra may be about 5 nanometers to about 10 nanometers or greater. The walls 210 are at a 90 degree angle relative to the major surface of the electronic device 200 and are viewable by the microscope with reduced resolution or image quality due to the steep viewing angle. Thus, the only plane that is viewable with full microscope resolution and a lower surface roughness is the angled surface 215.

[0027] Figures 3A-3C are various views of an electronic device 200 that has been cut by methods and apparatus as disclosed herein. An apparatus for cutting the electronic device 200 is shown in Figure 1A.

[0028] According to embodiments described herein, the method of cutting the electronic device 200 produces a three-dimensional notch 300. The three dimensional notch 300 is the same as the three-dimensional volume 150 shown in Figures 1A and 1B. The three dimensional notch 300 includes a plurality of angled surfaces, such as a first angled surface 305 and a second angled surface 310. The first angled surface 305 and the second angled surface 310 are planes that are viewed by a microscope (not shown). The first angled surface 305 and the

second angled surface 310 may be adjacent to each other. In addition, the three-dimensional notch 300 includes a single wall 315.

[0029] Each of the first angled surface 305 and the second angled surface 310 include an angle 320. The angle 320 may be the same for both of the first angled surface 305 and the second angled surface 310. The angle 320 may be about 45 degrees. The single wall 315 may be angled at about 90 degrees relative to the major surface of the electronic device 200 and is not viewable by the microscope. A roughness (Ra) of the first angled surface 305 and the second angled surface 310 may be about 2 nanometers to about 0.1 nanometers, or less.

[0030] Figure 4 is a schematic sectional view of a metrology system 400. The metrology system 400 includes a vacuum chamber 405 having the stage 120 described in Figures 1A and 1B therein. The stage 120 supports the large area substrate 110 having an electronic device (not shown) thereon. The vacuum chamber 405 is fluidly coupled with a vacuum pump 410 that maintains a negative pressure in the vacuum chamber 405.

[0031] The FIB column 140 and the microscope 155 are at least partially positioned in the vacuum chamber 405 above the stage 120. The metrology system 400 also includes a secondary electron detector 415. The secondary electron detector 415 is utilized for imaging during cutting of the electronic device using the FIB column 140.

[0032] The method and apparatus described herein can cut an electronic device without the need tilt and/or rotate the electronic device as well as the underlying substrate. The method and apparatus described herein also produces a plurality of surfaces that may be viewed by a microscope. The three dimensional notch 300 as disclosed herein allows cross-sectional viewing of the source and drain regions, and an active layer as well a portion of the underlying substrate in three dimensions.

[0033] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. An apparatus for cutting an electronic device on a substrate, the apparatus comprising:

a stage for supporting the substrate having the electronic device thereon;

a focused ion beam column fixed in a position over the stage, the focused ion beam column adapted to emit a beam path at an acute angle relative to a plane of a major surface of the substrate; and

a microscope positioned adjacent to the focused ion beam column, wherein the stage is movable in an X-Y plane during cutting of the electronic device.

2. The apparatus of claim 1, wherein the beam path cuts a three dimensional notch in the electronic device.

3. The apparatus of claim 2, wherein the three dimensional notch includes a plurality of angled surfaces that are viewable by the microscope.

4. The apparatus of claim 3, wherein each of the plurality of angled surfaces are about 45 degrees relative to the plane of the major surface of the substrate.

5. The apparatus of any of claims 2 to 4, wherein the three dimensional notch includes a single wall that is not viewable by the microscope.

6. The apparatus of claim 5, wherein the single wall is angled at about 90 degrees relative to the plane of the major surface of the substrate.

7. The apparatus of any of claims 1 to 6, wherein the microscope has a viewing path that is oriented at about 90 degrees relative to the plane of the major surface of the substrate.

8. An apparatus for cutting an electronic device on a substrate, the apparatus comprising:

a stage for supporting the substrate having the electronic device thereon;

a focused ion beam column fixed in a position over the stage, the focused ion beam column adapted to emit a beam path and cut a three dimensional notch in the electronic device; and

a microscope positioned adjacent to the focused ion beam column, wherein the stage is limited to movement in an X-Y plane during cutting of the electronic device.

9. The apparatus of claim 8, wherein the microscope has a viewing path that is oriented at about 90 degrees relative to the plane of a major surface of the substrate.

10. The apparatus of any of claims 8 to 9, wherein the beam path is fixed at an acute angle relative to a plane of a major surface of the substrate.

11. The apparatus of any of claims 8 to 10, wherein the three dimensional notch includes a plurality of angled surfaces that are viewable by the microscope.

12. The apparatus of claim 11, wherein each of the plurality of angled surfaces are about 45 degrees relative to the plane of the major surface of the substrate.

13. The apparatus of any of claims 8 to 12, wherein the three dimensional notch includes a single wall that is not viewable by the microscope.

14. The apparatus of claim 13, wherein the single wall is angled at about 90 degrees relative to the plane of the major surface of the substrate.

15. The apparatus of any of claims 8 to 14, wherein the electronic device is a transistor.

16. A method for cutting an electronic device on a substrate, the method comprising:

positioning the substrate on a stage;

emitting a beam path from a focused ion beam column fixed at an angle of about 45 degrees relative to a major surface of the substrate; and

moving the stage in a single lateral plane to produce a three dimensional notch in the electronic device.

17. The method of claim 16, further comprising:
moving the stage in the single lateral plane adjacent to a microscope.

18. The method of claim 17, further comprising using the microscope to view a plurality of angled surfaces in the three dimensional notch.

19. The method of claim 18, wherein each of the plurality of angled surfaces are angled at about 45 degrees relative to the plane of the major surface of the substrate.

20. The method of any of claims 17 to 19, wherein the microscope has a viewing path that is angled about 90 degrees relative to the plane of the major surface of the substrate.

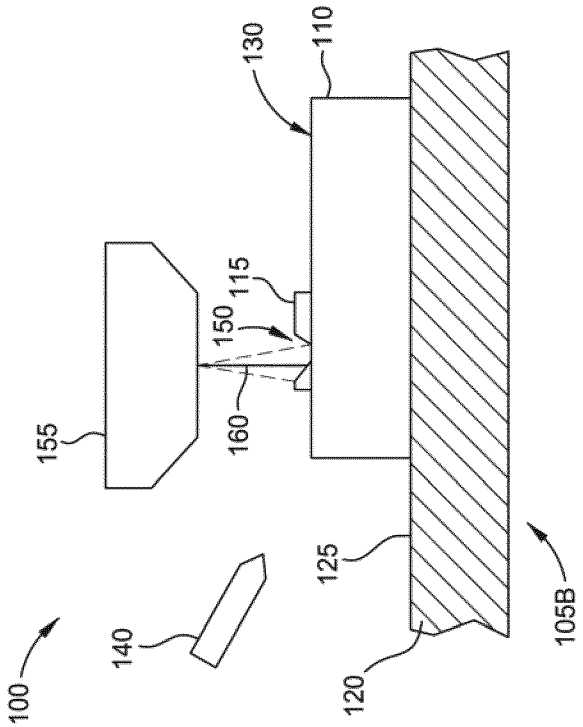

130
110
115
150
160
155
140
125
120
105B
100

FIG. 1B

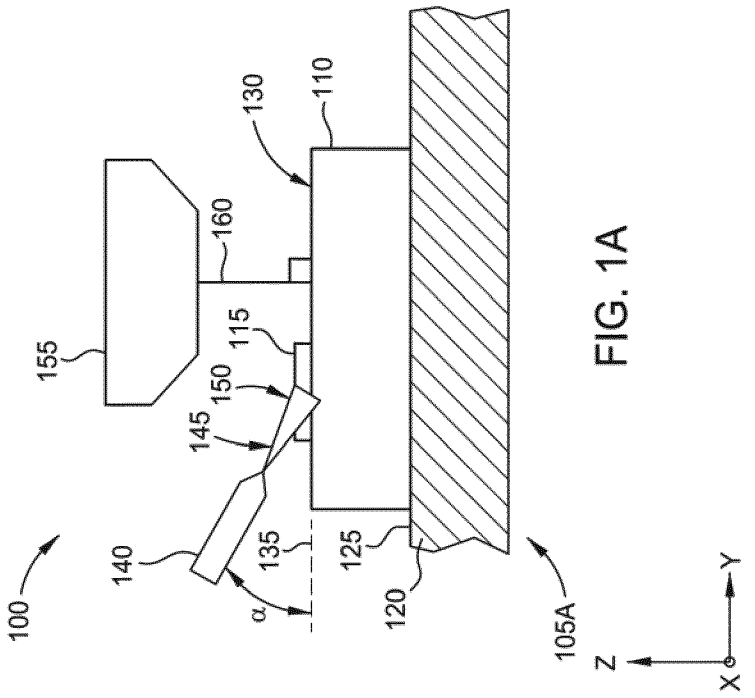

130
110
160
115
155
150
145
140
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α
125
120
105A
100
Z
Y
X

FIG. 1A

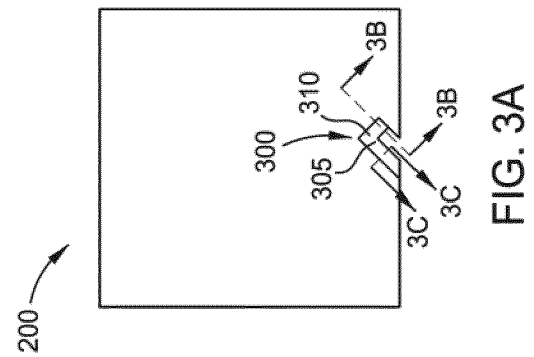


FIG. 3A

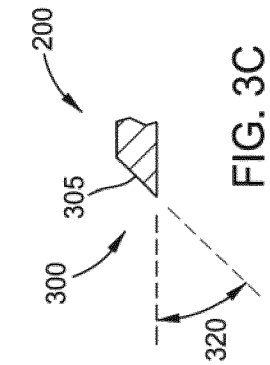


FIG. 3C

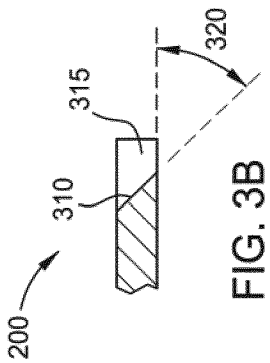


FIG. 3B

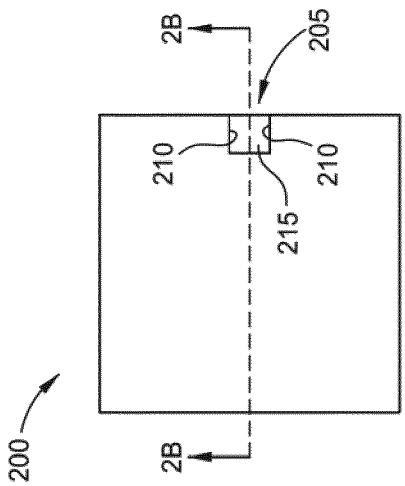


FIG. 2A
(PRIOR ART)

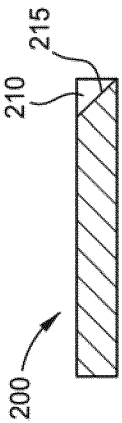


FIG. 2B
(PRIOR ART)

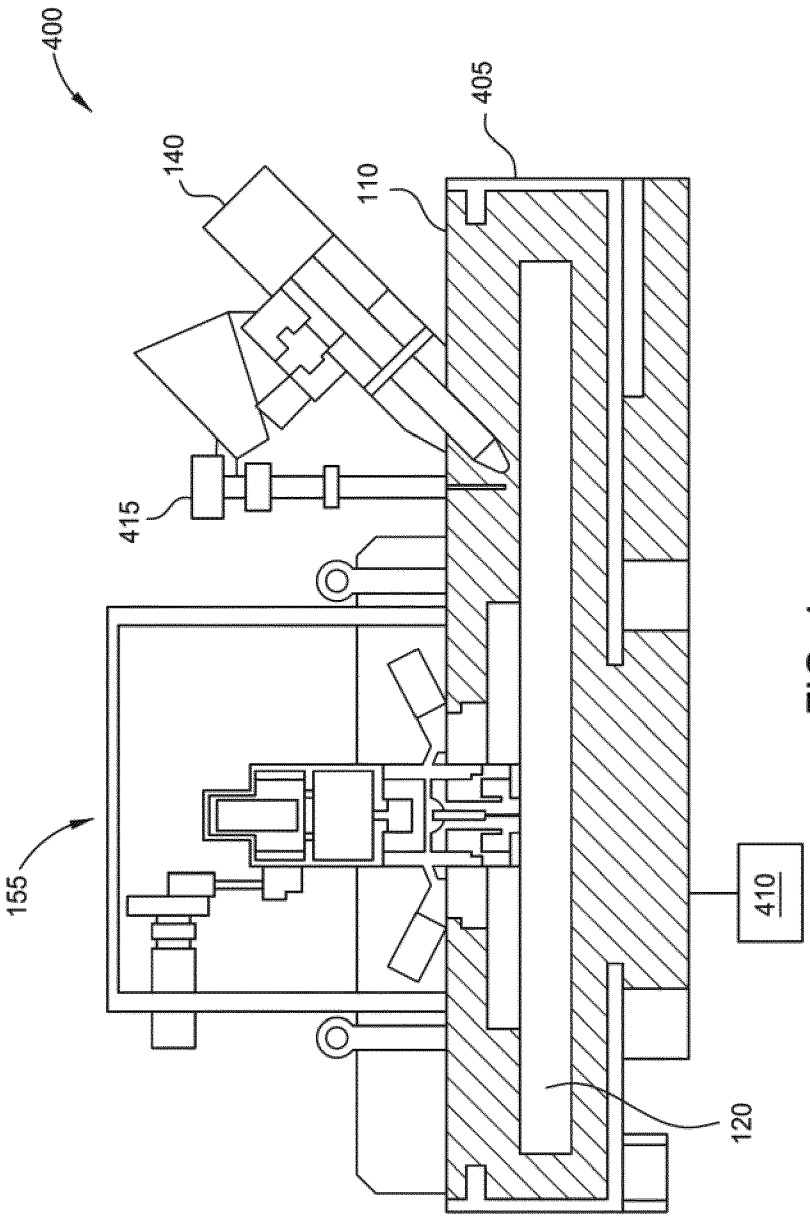


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/077105

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01J37/305 H01J37/31 H01J37/302 H01J37/304
ADD.

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)
H01J

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)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2005/139768 A1 (BLOESS HARALD [DE]) 30 June 2005 (2005-06-30) paragraphs [0009], [0011], [0040]	1-20

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
21 January 2020	29/01/2020

Name and mailing address of the ISA/	Authorized officer
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Form PCT/ISA/210 (second sheet) (April 2005)

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 2013/328246 A1 (WELLS ANDREW B [US] ET AL) 12 December 2013 (2013-12-12) figures 4,5	1-20
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
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