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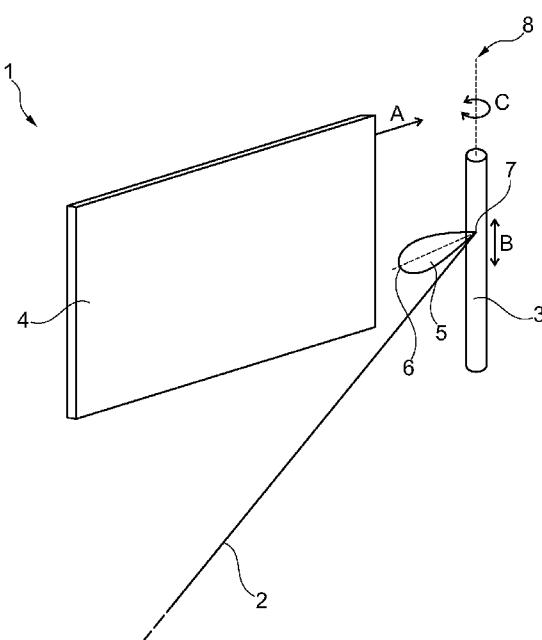
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(54) Title: DEVICE FOR DEPOSITING A MATERIAL BY PULSED LASER DEPOSITION AND A METHOD FOR DEPOSITING A MATERIAL WITH THE DEVICE



(57) Abstract: The invention relates to a device for depositing a material by pulsed laser deposition, the device comprising: - a vacuum chamber; - at least one substrate holder with a substrate, arranged inside the vacuum chamber, the substrate having a first, second and third direction, each of the three directions perpendicular to each other, wherein the substrate is movable by the substrate holder in the first direction; - a target holder with a target, arranged inside the vacuum chamber and wherein the target extends over substantially the full length in the second direction of the substrate and parallel to the substrate; - at least one laser for irradiating the target, thereby creating a plasma of material that deposits on the substrate, wherein the position of incidence of the laser on the target is moveable parallel to the second direction of the substrate; and - a controller for controlling the movement of the substrate holder and the movement of the position of incidence of the laser on the target.

Fig. 1



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Device for depositing a material by pulsed laser deposition and a method for depositing a material with the device

5 The invention relates to a device for depositing a material by pulsed laser deposition and a method for depositing a material with the device.

Using pulsed laser deposition, a target material is irradiated by a laser in a vacuum chamber. Due to the 10 excitation, a plasma plume of material is created, with its central axis perpendicular to the position of incidence on the target. This plasma plume of material is directed at a substrate, on which deposition of the particles in the plasma plume occurs.

15 It would be beneficial to be able to apply pulsed laser deposition on relatively large surface areas in a broad field of applications. However, currently available pulsed laser deposition methods on large surface areas have however not allowed the production of layered structures on other than 20 circular surface areas, for instance for the production of large organic light emitting displays (OLEDs). One such a method restricted to circular substrates as currently available is described in EP 2159300.

It is therefore an object of the invention to provide a 25 device, in which the above-mentioned disadvantages are reduced or even obviated.

This object is achieved with a device for depositing a material by pulsed laser deposition, the device comprising:

30 - a vacuum chamber;
- at least one substrate holder with a substrate, arranged inside the vacuum chamber, the substrate having a first, second and third direction, each of the three directions perpendicular to each other, wherein the substrate is movable by the substrate holder in the first direction;

- a target holder with a target, arranged inside the vacuum chamber and wherein the target extends over substantially the full length in the second direction of the substrate and parallel to the substrate;

5 - at least one laser for irradiating the target, thereby creating a plasma of material that deposits on the substrate, wherein the position of incidence of the laser on the target is moveable parallel to the second direction of the substrate; and

10 - a controller for controlling the movement of the substrate holder and the movement of the position of incidence of the laser on the target.

In its use, the substrate is translated by the movement of the substrate holder in the first direction while, at the same time, the movement of the plasma plume in the second

15 direction perpendicular to the first direction of the plasma plume over the surface creates a layer of target material on the substrate.

Since the plasma plume consists of a distribution of particles, and since the speed of the movement of the plasma plume over the substrate in the second direction is generally larger than the speed of the movement of the substrate in its holder, the movement of the substrate and the position of incidence will generally result in a homogeneous layer of target material on the substrate.

25 The control of the position of incidence of the laser on the target may be varied both by moving the laser in the second direction and/or tilting the laser.

The composition of the target may be homogeneous in order to deposit a layer of one target material, but may as well 30 be inhomogeneous if deposition of different materials in one step on top of each other is desired. To this end, the device may also comprise more than one target, of which the composition may vary per target and/or within the target.

Multiple lasers may be used or and/or one laser may be

split in various beams. In this way, multiple points of incidence are created on the surface of the target. The length of the target in the second direction may for instance be distributed in segments and each of the laser beams will cover 5 at least one segment in the creation of a plasma plume. In that way the amount of target material excited simultaneously may increase and the deposition may take place at a higher rate.

Also, one or more individual points of incidence may be created on the surface of the target which does not 10 substantially move in the second direction over the target surface, such to create a line of target material on the substrate in the first direction.

The first direction may be chosen from the length or width direction of the substrate and the second direction will 15 accordingly be the other direction of the length or width.

In an embodiment of the device according to the invention, the movement of the position of incidence of the laser is linearly linked to the movement of the substrate holder.

20 By linking the movement of the position of incidence on the target to the movement of the substrate by its holder, the homogeneity of the layer deposited by the device on the substrate is further increased. The link between the movement of the position of incidence and the movement of the substrate 25 ensures that the path of the plasma plume over the surface of the substrate will be linear. A non-linear relationship could cause differences in layer thickness over the surface of the substrate which could, in some applications, be a disadvantage. In other applications, differences in layer thickness could 30 however be an advantage.

In a preferred embodiment of the device according to the invention, the controller resets the position of incidence of the laser, when viewed in the direction of movement, to the closest edge of the substrate upon arriving at the distal edge

of the substrate.

The closest edge of the substrate is the edge, where the generated plasma plume starts with depositing particles on the substrate, while the distal edge of the substrate is the edge, 5 where the path of the plasma plume ends. By moving the position of incidence such that the resulting plasma plume moves from the closest edge to the distal edge and back in a repetitive movement, a large area of the substrate may be deposited with target material in a continuous process.

10 In the case that multiple laser beams are used, each of the laser beams may only have to reset along the segment of that laser beam.

In an further preferred embodiment of the device according to the invention, the device further comprises 15 blocking means for blocking deposition of the plasma plume on the substrate during resetting of the position of incidence of the laser on the target.

When the position of incidence reaches the position at which the plume reaches the distal edge of the substrate, the 20 position needs to be reset such that the plume continues at the closest edge. However, the resetting movement causes a difference in the distance between each passage of the plasma plume, thereby possibly negatively influencing the homogeneity of the layer, the homogeneity of defects or the homogeneity of 25 the electrical properties of the resulting layer. By blocking the laser during this resetting movement, the chance of inhomogeneous layers, inhomogeneous damage and inhomogeneous electrical properties is decreased.

These blocking means may for instance comprise a shield, 30 arranged between the target and the substrate or between the laser source and the target or the device may comprise a second substrate, which is deposited with target material during the resetting procedure. The blocking means may also comprise optical means, such as mirrors or prisms or may also comprise

other means to block the laser during the resetting movement. The blocking means may also comprise means to turn off the laser during the resetting movement.

In another embodiment of the device according to the 5 invention, the position of incidence of the laser on the target is also movable in the first direction along the surface of the target.

By varying the position accordingly, the laser may hit different areas of the target. Due to a possible difference in 10 composition of the target, this allows different areas of the target to be deposited on the substrate.

In a preferred embodiment of the device according to the invention, the target is at least partially curved, preferably cylindrical, over the full length in the second direction of the 15 substrate.

When the laser hits the target, a plasma plume is created perpendicular to the tangent of the position of incidence. As such, when moving the position of incidence along the first direction over the target surface, the angle of the 20 resulting plasma plume with respect to the substrate will vary. As a consequence, the distance to be travelled by the particles before reaching the substrate changes. Since the particles in the plasma plume will slow down during the trajectory between the target and the substrate, variation of the position of 25 incidence along the curvature of the target allows tuning of the kinetics, e.g. particle velocity, of the particles when they reach the substrate.

Since the position of incidence will also vary in the second direction along the surface of the target in order to 30 deposit the target material on a large surface area of the substrate, it is preferred that the target has a constant cross-section in the direction parallel to the second direction of the substrate.

In a further preferred embodiment of the device

according to the invention, the target is a cylindrical rod.

A cylindrical rod has a constant cross-section and can be manufactured relatively easy.

Preferably, the target is rotatable around its axis
5 parallel to the second direction of the substrate.

The rotation of the cylindrical rod around the axis allows constant and even ablation of material from the target along its curvature, such that the target will keep its cylindrical shape, despite substantial ablation. Non-constant 10 ablation could lead to unpredictable changes in the curvature of the surface of the target over time, thereby changing the plasma plume angle, whereas rotation of the target prevents such changes, or at least makes these changes more predictable.

In another embodiment of the device according to the 15 invention, the length in the second direction of the substrate is at least 20 centimeters.

The device according to the invention allows the coating of relatively large surface areas, especially for substrates having a length in the second direction of at least 20 20 centimeters. More preferentially, the length is at least 30 centimeters. Most preferentially, the length is at least 50 centimeters.

In yet another embodiment of the device according to the 25 invention, the substrate comprises a glass layer provided with a layer of electroluminescent material.

At least the deposition of the top layer of the layered structure can be built by a device according to the invention. If a relatively large substrate area is chosen, for instance with a second direction of at least 50 centimeters, the device 30 allows the manufacture of large surface area displays.

The object of the invention is further achieved with a method for depositing a material by pulsed laser deposition with a device according to the invention, the method comprising the repetitive steps of:

- moving the substrate in the first direction at a constant speed;

- moving the position of incidence of the laser on the target in the second direction at a constant speed, when viewed 5 in the second direction, from the closest edge of the substrate towards the distal edge of the substrate and

- moving the position of incidence of the laser back, when viewed in the second direction, from the distal edge of the substrate to the closest edge of the substrate, inhibiting 10 deposition of particles on the substrate.

By moving the plasma plume over the substrate from the closest edge to the distal edge and back in a repetitive movement in the second direction in a constant speed that is generally larger than the constant speed of the movement of the 15 substrate, the method will generally result in a homogeneous layer of target material on the substrate.

When the plasma plume would be moved accordingly without inhibiting deposition of particles from the plasma plume, these movements will create an endless V-movement over the substrate 20 surface. Because of this movement, the time between the passage of a plasma plume, e.g. its central axis, will vary in the second direction of the substrate. In the first place, this may lead to inhomogeneity of the layer on the substrate. More importantly, it is especially found that such variation causes a 25 difference in the amount of damage or difference in the electrical properties obtained on the substrate. In order to prevent this, the deposition of the particles from the plasma plume on the substrate is inhibited during the back movement of the position of incidence.

30 By varying the pattern of deposition of the plasma plume over the surface, it is also possible to vary the thickness of the layered structure if required. This may also be achieved by at least temporarily making the movement of the substrate in the first direction non-linear to the movement of the point of

incidence in the second direction.

In general, the use of the device according to the invention may for instance be an advantage in the production of various structures, and especially large surface organic light emitting displays (OLEDs) or TFTs. OLEDs also encompasses transparent OLEDs or top-emitting OLEDs.

An OLED comprises a substrate, preferably made of glass, on which two conducting layers are deposited with an emissive electroluminescent layer between those layers. OLEDs are built in layers and the deposition of the second conducting layer on top of the emissive electroluminescent layer may damage the latter, thereby increasing the chance of malfunction of the resulting device, e.g. due to leakage current or short circuiting. Application of currently available pulsed laser deposition methods as such increases the chance of such damages, whereas the current device allows tuning of the particle velocity by variation of the position of incidence. The application of the current device especially in building OLEDs decreases the chance of inhomogeneous damage to the electroluminescent layer. At least the deposition of the top layer of the layered structure can be built by a device according to the invention. If a relatively large substrate area is chosen, for instance with a second direction of at least 50 centimeters, the device allows the manufacture of large surface area displays.

In the production of active thin film transistors (TFTs), the device can be used to apply a high-mobility material such as IGZO (indium gallium zinc oxide), ZTO (zinc tin oxide) or ZnON (zinc oxynitride). The application of the current device in building TFTs especially decreases the chance of inhomogeneous electrical properties of the resulting product.

The controller may comprise means for controlling one or more substrate holders, one or more target holders, laser(s) and which may be programmed to execute an automated deposition

program.

These and other features of the invention will be elucidated in conjunction with the accompanying drawings.

Figure 1 shows a schematic view of an embodiment of the 5 device according to the invention.

Figure 2A and 2B show a top view of an embodiment of the device according to the invention with a variation of the position of incidence along the curvature of the target.

Figure 3 shows a deposition pattern on a substrate 10 according to the invention.

In figure 1, a device 1 is shown comprising a laser 2, a target 3 in the shape of a cylindrical rod and a substrate 4. By hitting the target 3 with the laser 2, a plasma plume 5 of particles with a center 6 is created directed at the substrate 15 4. The substrate 4 is at least movable in the first direction A, whereas the position of incidence 7 of the laser on the target 3 may be changed in the second direction B. The substrate 4 may additionally be rotated around its axis 8 in direction C. By the movement of the substrate 4 in direction A and the simultaneous 20 movement of the position of incidence 7 of the laser 2 over the surface of the target 3 in direction B, the plasma plume 5 is moved in a repeating pattern over the substrate 4.

The movement of the position of incidence 7 of the laser 2 on the target 3 is shown in figures 2A and 2B. In figure 2A, 25 the position of incidence 7 of the laser 2 is chosen such that the resulting plasma plume 5, perpendicular to the tangent 9a of the surface of the target 3 will have a relatively short distance 10a to the substrate 4 compared to figure 2B. In this figure, the position of incidence 7 is chosen more towards the 30 side of the target 3 and as a consequence, the resulting plasma plume 5, also being perpendicular to the tangent 9b of the surface of the target 3, will have a longer distance 10b to the substrate 4. Because of this longer distance 10b, the speed of the particles of the plasma plume 5 hitting the surface of the

substrate 4 will have a lower speed, decreasing the chance of damage to the substrate 4.

Figure 3 shows a pattern of the movement of the center 6 of the plasma plume 5 on a part of the surface of the substrate 4 in an enlarged view for clarity reasons. In this movement, the plasma plume 5 is moved repetitively between a first edge 11 towards a second edge 12 in a trajectory 13 while moving the substrate 4 in a first direction A. On the part 13a of the trajectory from the first edge towards the second edge 12, deposition from the plasma plume 5 takes place on the substrate 4, whereas on the return path 13b, shown in dashed lines, deposition on the substrate 4 will be inhibited. Since the movement of the substrate 4 is constant, the time and distance between subsequent passages 14a,b,c of the plasma plume 5 will be both the same in the second direction B and the first direction A of the substrate 4, thereby reducing the chances of inhomogeneous deposition but, more importantly, inhomogeneous damage to or inhomogeneous electrical properties in the substrate 4.

Claims

1. Device for depositing a material by pulsed laser deposition, the device comprising:

- 5 - a vacuum chamber;
- at least one substrate holder with a substrate, arranged inside the vacuum chamber, the substrate having a first, second and third direction, each of the three directions perpendicular to each other, wherein the substrate is movable by
- 10 the substrate holder in the first direction;
- a target holder with a target, arranged inside the vacuum chamber and wherein the target extends over substantially the full length in the second direction of the substrate and parallel to the substrate;
- 15 - at least one laser for irradiating the target, thereby creating a plasma of material that deposits on the substrate, wherein the position of incidence of the laser on the target is moveable parallel to the second direction of the substrate; and
- a controller for controlling the movement of the substrate holder and the movement of the position of incidence of the laser on the target.

2. Device according to claim 1, wherein the movement of the position of incidence of the laser is linearly linked to the movement of the substrate holder.

- 25 3. Device according to claim 2, wherein the controller resets the position of incidence of the laser, when viewed in the direction of movement, to the closest edge of the substrate upon arriving at the distal edge of the substrate.

- 30 4. Device according to claim 3, further comprising blocking means for blocking deposition of the plasma plume on the substrate during resetting of the position of incidence of the laser on the target.

5. Device according to any of the claims, wherein the position of incidence of the laser on the target is also movable

in the first direction along the surface of the target.

6. Device according to claim 5, wherein the target is at least partially curved, preferably cylindrical, over the full length in the second direction of the substrate.

5 7. Device according to claim 6, wherein the target is a cylindrical rod.

8. Device according to claim 7, wherein the target is rotatable around its axis parallel to the second direction of the substrate.

10 9. Device according to any of the preceding claims, wherein the length in the second direction of the substrate is at least 20 centimeters.

15 10. Device according to any of the preceding claims, wherein the substrate comprises a glass layer provided with a layer of electroluminescent material.

11. Method for depositing a material by pulsed laser deposition with a device according to any of the preceding claims, the method comprising the repetitive steps of:

20 - moving the substrate in the first direction at a constant speed;

- moving the position of incidence of the laser on the target in the second direction at a constant speed, when viewed in the second direction, from the closest edge of the substrate towards the distal edge of the substrate and

25 - moving the position of incidence of the laser back, when viewed in the second direction, from the distal edge of the substrate to the closest edge of the substrate, inhibiting deposition of particles on the substrate.

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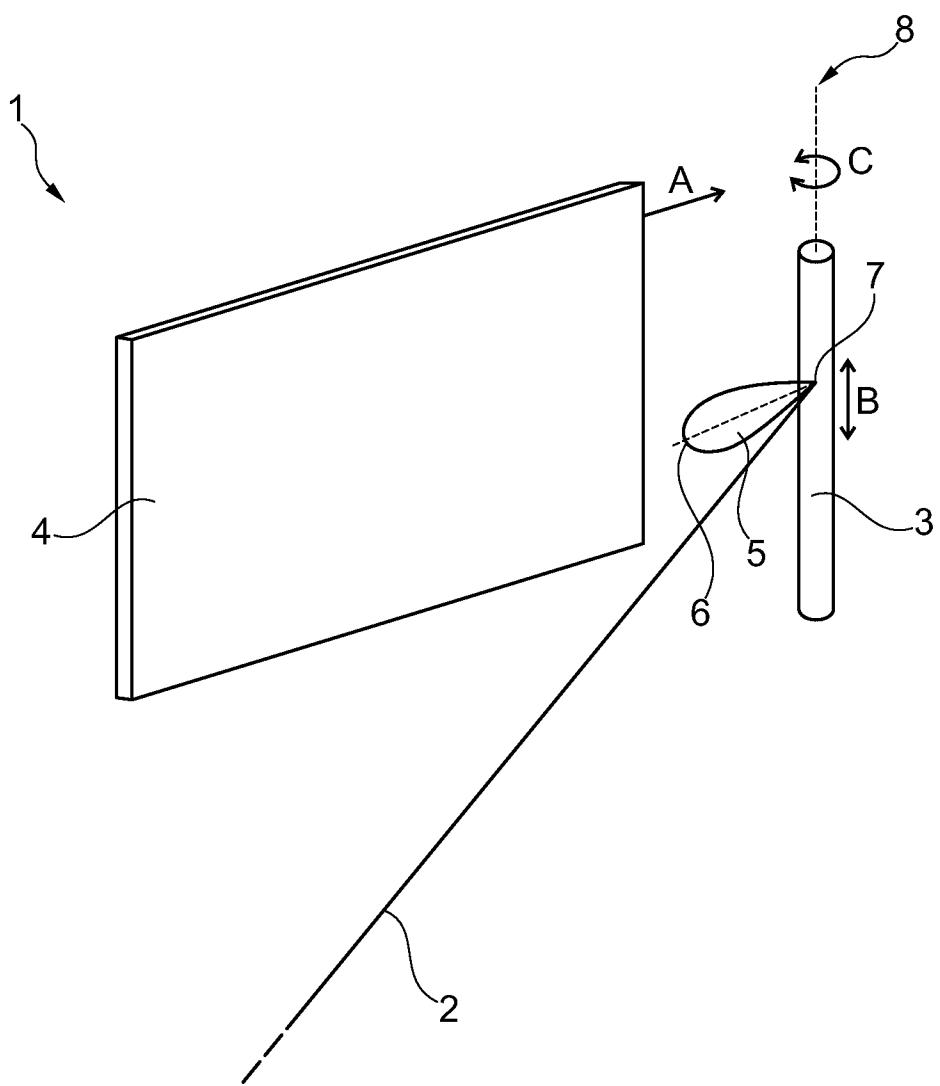


Fig. 1

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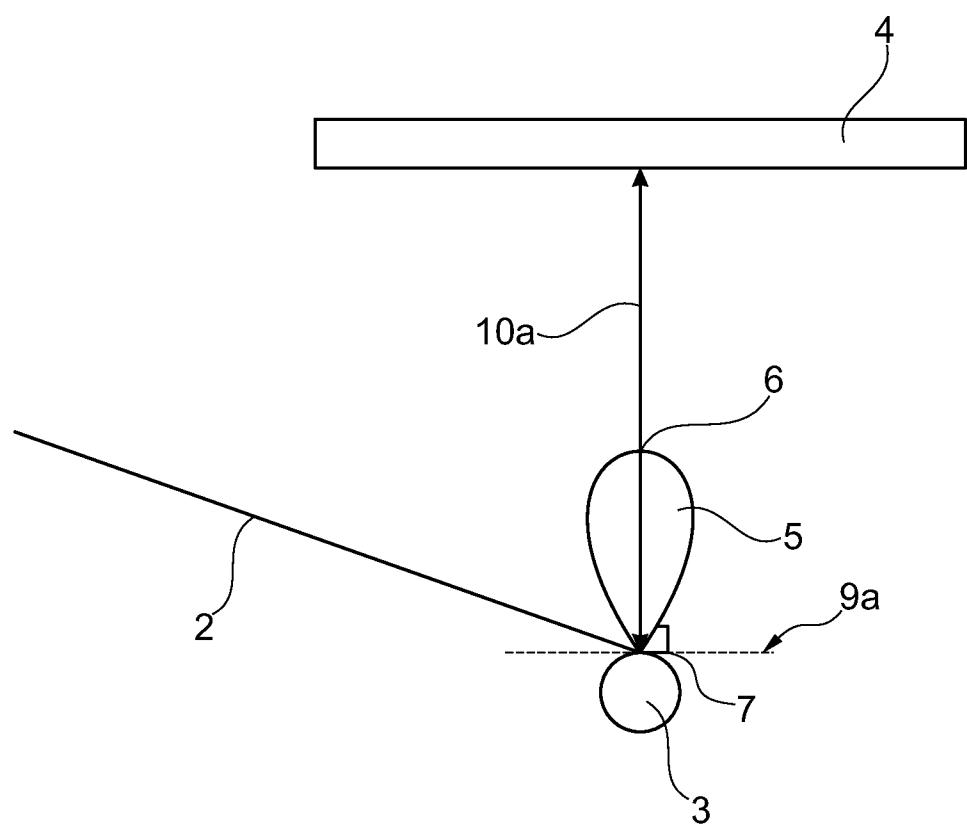


Fig. 2A

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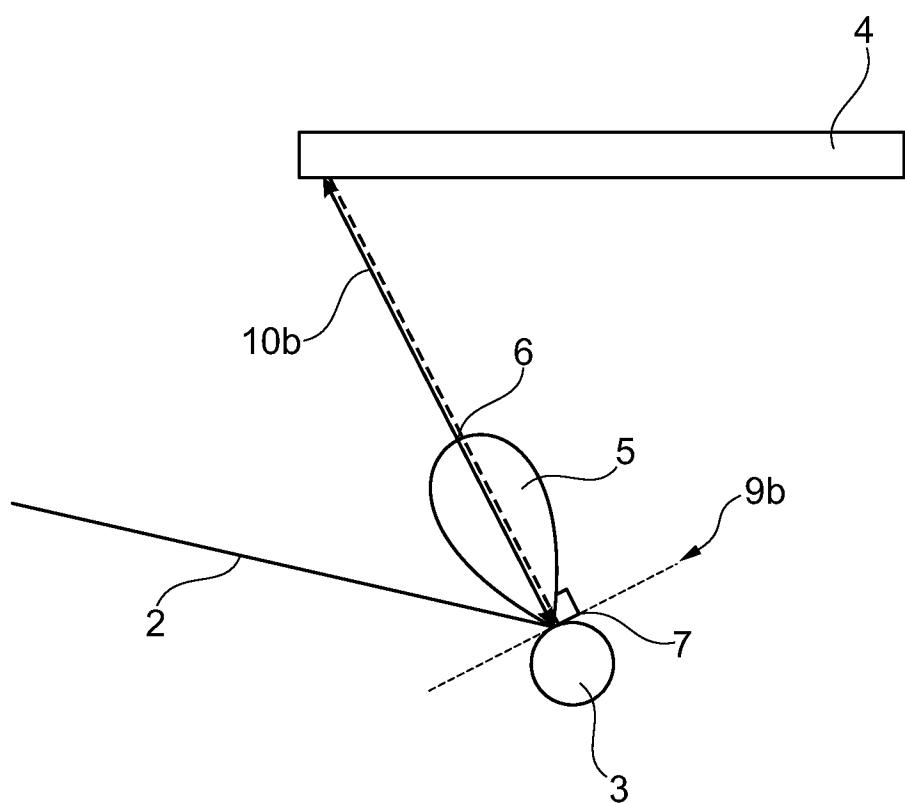


Fig. 2B

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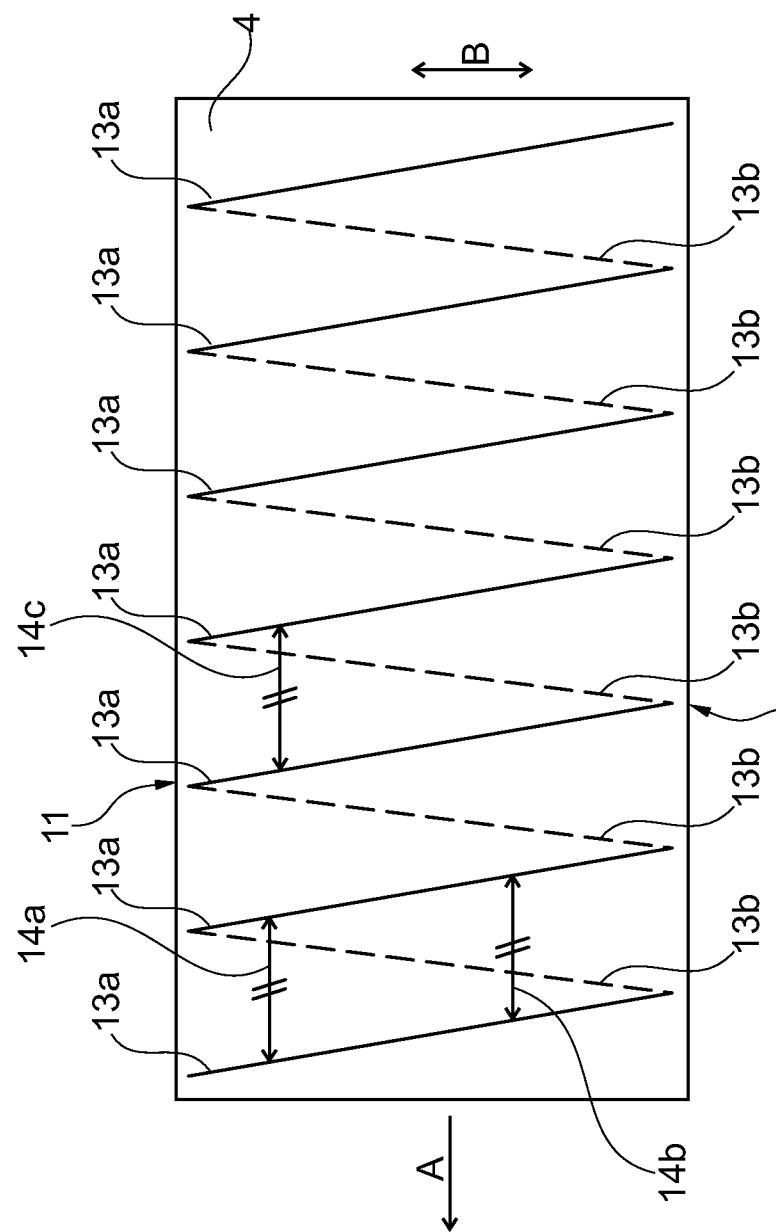


Fig. 3

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2015/053356

A. CLASSIFICATION OF SUBJECT MATTER
INV. C23C14/28 C23C14/50
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)
C23C

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 063 455 A (JEONG HYO SOO [KR] ET AL) 16 May 2000 (2000-05-16)	1,9,10
A	column 4, line 3 - column 5, line 27; claims 1,4; figures 1,2 column 3, lines 7-20	2-8,11
A	----- US 5 084 300 A (ZANDER WILLI [DE] ET AL) 28 January 1992 (1992-01-28) column 3, line 22 - column 4, line 5; figure 1	1-11
A	----- EP 2 159 300 A1 (SOLMATES B V [NL]) 3 March 2010 (2010-03-03) cited in the application claims; figure 1	1-11



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 30 April 2015	Date of mailing of the international search report 08/05/2015
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Patterson, Anthony

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No PCT/EP2015/053356

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US 6063455	A 16-05-2000	CN US	1158911 A 6063455 A	10-09-1997 16-05-2000
US 5084300	A 28-01-1992	DE DE EP JP US	3914476 C1 59007423 D1 0396099 A1 H0356670 A 5084300 A	21-06-1990 17-11-1994 07-11-1990 12-03-1991 28-01-1992
EP 2159300	A1 03-03-2010	AT CN DK EP ES HR JP JP KR KR PT SI US WO	537277 T 102131952 A 2159300 T3 2159300 A1 2378906 T3 P20120120 T1 5193368 B2 2012500901 A 20110047249 A 20130054465 A 2159300 E 2159300 T1 2011236601 A1 2010023174 A1	15-12-2011 20-07-2011 27-02-2012 03-03-2010 19-04-2012 31-05-2012 08-05-2013 12-01-2012 06-05-2011 24-05-2013 08-03-2012 31-05-2012 29-09-2011 04-03-2010