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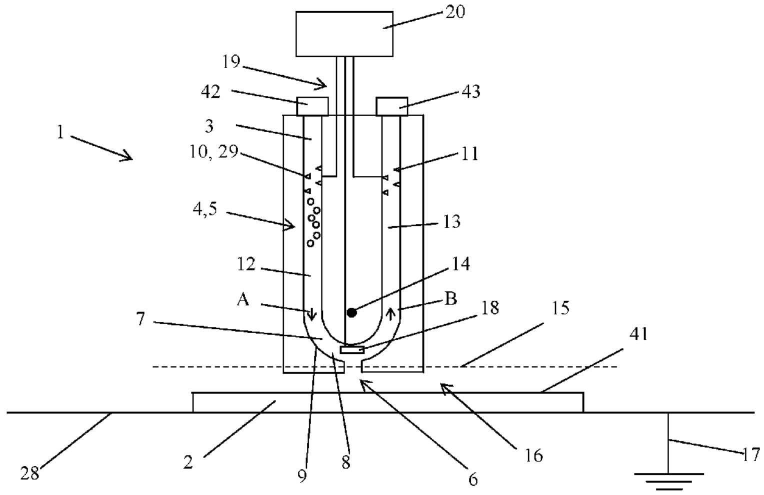

Fig. 1

(57) Abstract: The invention relates to an application nozzle (1) for flux. The nozzle is beneficially used for soldering ribbons to solar cells and can apply a flux agent to an elongated area on the cell in time parallel. The nozzle (1) uses centrifugal as well as electrostatic forces to move the agent (5) toward the workpiece (2). The charge difference between the cell and the agent make the latter stick to the surface of the workpiece.

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Systems and methods for applying particles in a gas flow to a workpiece

[1] The invention relates in general to the application of particles in a gas flow to a workpiece and especially to application nozzles, application nozzle units, systems, stringers and methods for doing so. The invention may be used for applying particles with an electrical charge other than the charge of the workpiece. The inventive devices may be suited to be connected to a gas flow containing the particles. The charge of the particles may be altered in the nozzle or elsewhere in the system.

[2] The inventive idea is especially suited for applying flux in powder form used for soldering or brazing in solid form to a workpiece to be soldered. The nozzle is especially designed for applying flux in time parallel to a large region of a workpiece, particularly in a structured manner. Moreover, the nozzle is especially suited for applying particles to one or multiple elongated areas in time parallel.

[3] The invention is suited for providing a solar cell, also called photovoltaic cell, with a solder ribbon, wire or any other interconnector. In order to manufacture solar modules that can for example be placed on a roof of a building for solar energy generation, several solar cells normally with bus bars are typically connected in series to form so called strings. Nowadays strings may meander forming two dimensional parts of or even the complete matrix. For this the solar cells are electrically interconnected with neighboring solar cells by means of solder ribbons or wires. Solder ribbons are thereby normally connected to the positive terminal of a solar cell and to the negative terminal of the neighboring solar cell, i.e. for normal solar cells (no back contact cells) the solder ribbon is alternatingly connected with the lower side of one solar cell and with the upper side of the neighboring solar cell. The solder ribbons are typically made of copper coated with solder and connected with the bus bars by means of one or more soldering units. A solar cell can have several bus bars, normally three to five, which requires an equal amount of solder ribbons for forming the string. The strings are formed in an apparatus called stringer or tabber or tabber-stringer. A stringer interconnects cells, a tabber only connects the interconnectors to the cells and a tabber-stringer does both. The inventive system may be part of any system for attaching interconnectors to a solar cell.

[4] GB2028171A discloses a powder applicator for applying powder to form side stripes on the interior of can bodies. The powder is carried by a gaseous stream in a supply tube and is directed into an orifice. The orifice constitutes the end of the supply tube. Although the powder is separated from the carrier gas in a loop – forming a dense powder

stream and a separate layer of carrier gas – both, the powder and the carrier gas leave the applicator at the same orifice at the end of the supply tube.

[5] US4715535A discloses a powder spray gun for applying particulate powder material onto a surface. In a discharge conduit the powder material is formed into a concentrated stream, which is accomplished by a 90° bend. A deflector at the end of the conduit deflects the powder material away from the outside bend towards an end cap. Pressurized air is used to in connection with a venturi transfer pump suck a powder stream from a supply conduit and to carry it through the discharge conduit. The air containing the powder material leaves the arrangement via a pie-shaped powder discharge slot.

[6] US4660772A discloses an electrostatic powder spray gun with an arcuate nozzle tube forming a curved passage between an inlet and outlet orifice. A mixture of powder particles and a carrier gas injected into the orifice is subjected to a swirling motion (caused by helical grooves) prior to exiting the outlet orifice. The outlet orifice constitutes the end of the tube and the carrier gas leaves the tube together with the powder particles.

[7] EP1777070A2 discloses a device having a nozzle for coating print products thereby using a mixture of powder and a carrier gas. The nozzle has a duct with a curved portion. A discharge opening for discharging the carrier gas is located in the inside bent of the curved portion. The powder is dispensed at the end of the duct forming the outlet of the nozzle.

[8] US4109027A discloses an electrostatic coating device. A mixture of air and powder is transported to a charging cavity for charging the powder particles. The powder is not separated from the air. Via a valve the mixture is brought into a can for coating its inner walls. Via a passageway and a valve air is returned from the can.

[9] GB2333053A relates to a completely different technical field and discloses a nozzle design for cold cutting steel pipes in environments where conventional flame cutting is unsafe. Here, a mixture of air and sand is transported through a centrifugal balance channel and a vortex chamber. The jet is directed through a discharge opening of the vortex chamber towards the steel pipe.

[10] GB291706A also relates to a completely different technical field and discloses a compressed air centrifugal device for concrete, mortar and sand. The air leaves together with the material the centrifuging nozzle.

[11] US4637339A discloses an electrode arrangement for a coating installation having a supply conduit and a suction conduit. Both conduits open in a volume surrounded by a can.

[12] DE2534866A1 does not relate to a workpiece application nozzle but discloses a device for recovery of plastic powder in powder coating methods. Air mixed with powder is transported through a curved duct. Via a branching-off channel having an increasing curvature radius powder is extracted from the duct. However, a large amount of air is also transported through that channel. The powder collides with a surface prior to be directed via a cone towards a receiving container.

[13] EP2502697A1 discloses a device and method for applying welding flux to interconnection ribbons for photovoltaic cells.

[14] When interconnecting solar cells by brazing or soldering normally flux is applied to facilitate this process. It has been realized that preferably flux should be applied to regions where the solder joint is made only and that flux may be applied without being dissolved in a solvent. See WO2011033451A2 and WO2012069995A2 respectively, which are herewith incorporated in this application by reference. Any inventive idea described in this application may also be combined with subject matter from these two applications.

[15] GB1549 805 discloses an electrostatic powder painting apparatus comprising a powder gun which has the general form of a cyclone separator including a casing having a cylinder composed of an insulating material (for example, glass or plastics) and a conical section, an internal cylinder supported by a ring-like end plate arranged concentrically with the casing, an inlet for powder, containing gas, and a powder discharging port 8. The internal cylinder 6 has an end plate and an outlet for the gas. A needle-like corona discharge electrode is supported by an insulated cylinder which is in tum supported to the freely slidable longitudinally by the end plate. As the particles move along with the flow of air they are forced by the centrifugal force of the rotation of the air in space 38 towards the inner wall 41, where they are forced to the discharge opening by a stream of air. The force exerting the particles from the gun is thus caused by the flow of the air and the electrostatic field.

[16] In order for the centrifugal force in the space 38 to be large enough to separate the particle from the flow of air, the same flow has to be fast enough which in turn gives the particles little time to be collected. This results in numerous particles being drained into outlet 10. These particles are lost or need to be recollected.

[17] Further this powder gun is not suitable for applying powder to a large area in time parallel, especially when that area is elongated. Since the separation of the particles depends on the rotary movement of the air flow, the inner wall 41 of the space 38 has to be

cylindrical or conical and cannot be for example too oblong since this would destroy the spiraling of the air.

[18] US 3,976,031, which is considered the closest state of the art, discloses a face-silent discharge electrode which includes plural parallel electrode bars separated from each other at a distance and arranged in a face that is disposed to confront a substrate. A powder coating material is supplied in the space between said electrode and said substrate. An AC voltage is impressed on the electrode bars adjacent each other to generate a silent electric discharge over the entire surface of said face-silent discharge electrode. Concurrently, a DC voltage is impressed between the electrode bars and the substrate so that the powder coating material may adhere to a surface of the substrate to form a layer of uniform thickness.

[19] As can be seen from the embodiment shown in for example figures 4a and 17a, the particles are expelled from the gas by means of the electrical field. In this way the particles are not expelled from the system efficiently and will be lost or have to be collected to be re-used, as can be seen from the duct that is a closed loop in figure 4a.

[20] In both embodiments, the particles are not applied evenly. In Figure 4a more particles will be applied near duct 16 since here there are more particles in the stream. In Figure 17a only in the range near the end of passage 18 (close to the line of reference number 18) the particles experience an additional centrifugal force towards the workpiece. If the dimensions of the system and the speed of the gas flow are such that this leads to a noticeable effect on the particles, relatively more particles will be deposited in this range and this region only.

[21] Thus the state of the art does not disclose a system for efficiently applying all particles from a gas stream and applying them to an elongated area in a homogenous manner.

[22] It is the goal of the current invention to provide a system that can deposit particles more homogeneously over a large range, especially an elongated area, while in doing so removing almost all particles from the gas stream, so that no recollection of particles is needed or at least very few particles need to be recollected or disposed of. In addition the particles may be applied in a structured manner. The invention is especially aimed at applying particles to solar cell, wafer and intermediate stages thereof, but it is not limited to these goods.

[23] This object is achieved by means of an application nozzle for dispensing material such as a flux agent suspended in a gas flow, comprising a duct for guiding the gas flow towards and away from a dispensing opening, the duct having a curved portion which is delimited in its outside bend by a wall portion. The dispensing opening being provided directly adjacent or preferably in that wall portion such that material suspended in the gas flowing through the curved portion experiences a centrifugal force directed towards that wall portion, preferably towards that dispensing opening.Preferably the wall portion itself has a finite radius at least upstream of the discharge opening so that the centrifugal force works on the particles all the way up to the opening. For ease of manufacturing, the bend may however also be less smooth and may for example be rectangular or obtain rectangular portions. Moreover, the bend in the duct for example up stream of the dispensing opening may contain or consist of two straight walls, preferably being perpendicular to each other, the downstream wall preferably having the dispensing opening arranged in it. It was found that the particles are move towards the outside bend well enough. The bend or outer wall portions may be made of one piece of material, preferably an electrically insulating material. The wall portion containing the dispensing opening may be readily replaceable thus allowing quick changing of the used mask for example for cleaning or for altering the pattern of the applied material.

[24] In order for the centrifugal force to have its desired effect, the opening must be located in the outside bend. With duct the hollow channel guiding the flow of gas is meant. The dispensing opening is located downstream of at least part of the wall portion.

[25] The (coating or painting) application nozzle according to the invention is a nozzle for dispensing material to a work piece. The application nozzle has a dispensing opening directly adjacent to or in that wall portion forming the outside bent of the curved portion of the duct. The dispensing opening thus perforates an outside wall of the duct. The dispensing opening is a branch-off from the duct (i.e. the dispensing opening is not the end of the duct). Material experiencing centrifugal force is dispensed via that branch-off. The direction of the centrifugal force in each point is defined by the run of the curved portion. The dispensing opening may be thus located at any position of the wall portion, to which a centrifugal force vector (of a centrifugal force caused by the curved portion) points. With other words: The direction of a centrifugal force (or the direction perpendicular to the run or axis of the duct) intersects with the wall portion at the location of the dispensing opening. As already mentioned the dispensing opening may be located in the outside bend of the curved portion or directly adjacent to the outside bend in downstream direction.

[26] The duct comprises a duct portion upstream of the dispensing opening and a duct portion downstream of the dispensing opening. The duct portion upstream of the dispensing opening guides the gas flow towards the dispensing opening and the duct portion downstream of the dispensing opening guides the gas flow away from a dispensing opening. The duct as such is not interrupted by the dispensing opening, i.e. extends continuously over the dispensing opening. With other words: the duct portion upstream of the dispensing opening and the duct portion downstream of the dispensing opening merge into one another without interruption or discontinuity. As already mentioned, the dispensing opening constitutes a branch-off.

[27] It is preferred that the duct has a laminar flow design (essentially smooth run), i.e. the gas flow in the duct is essentially laminar. Turbulences are avoided. This allows an efficient separation of the material from the gas.

[28] The material leaves the application nozzle through that dispensing opening. The application nozzle could also be denoted as workpiece coating nozzle or workpiece application nozzle, since the material directed via the dispensing opening towards the workpiece forms a coating on the surface of the work piece.

[29] Preferably, the coating or painting application nozzle comprises at least one electrical charging means for electrically charging the material (in form of powder or particles) prior to leaving the nozzle through the dispensing opening.

[30] Preferably, the axis of the dispensing opening and the duct axis of the duct portion overlapping with the dispensing opening enclose an angle between 80° and 100°, preferably an angle of essentially 90°. Such an embodiment ensures, that the material is efficiently separated from the gas flow: The material leaves the application nozzle through the dispensing opening and the gas continues to flow along the duct extending downstream of the dispensing opening. The great advantage is that only a minor or negligible amount of material is contained in the downstream gas flow.

[31] The axis of the dispensing opening extends through the dispensing opening. The axis extends between the inner circumference of the opening (facing to the interior of the duct) and the outer circumference of the opening (facing outwardly). The axis of the dispensing opening may also be defined as the symmetry axis (e.g. in the case of circular or square cross-section) or symmetry plane (e.g. in the case of rectangular or rectangular-like cross-section) of the dispensing opening. With the duct portion overlapping with the dispensing opening that duct portion is meant which is located in the (immediate) region of

the dispensing opening. The duct axis essentially defines the direction of the gas flow in that region.

[32] Preferably, the dispensing opening forms in the wall portion a circumferential edge facing the interior of the duct, wherein preferably the circumferential edge lies within a plane which is essentially parallel to the duct axis of the duct portion overlapping with the dispensing opening. This embodiment further enhances the effect of separating the material from the gas flow, since the gas flow is only marginally influenced by the dispensing opening, whereas the material is forced to move through the dispensing opening by centrifugal force.

[33] Preferably, the dispensing opening is symmetrically arranged with respect to the curved portion of the duct. This allows a space-saving construction of the application nozzle since the duct portion upstream of the dispensing opening and the duct portion downstream of the dispensing opening may be arranged on that side of the application nozzle facing away from the dispensing opening and thus from the work piece to be coated.

[34] Preferably, a duct portion upstream of the dispensing opening and a duct portion downstream of the dispensing opening define opposite directions of gas flow. In this embodiment the width of the whole application nozzle may be reduced to a large extent.

[35] Preferably, the duct has a U-shaped run and the dispensing opening is arranged in or near the bottom of the U-shaped run. This embodiment allows easily arranging at least two application nozzles adjacent to each other to form an application unit.

[36] Preferably the curved portion is further delimited in its inside bend by an inside wall portion that is curved in the same direction as the wall portion, wherein preferably the duct has in its curved portion essentially constant cross-section. Curved meaning the way the whole duct or wall is bent in that region. Locally the wall may for example be straight. Multiple such straight portions however may form the curved portion.

[37] The curved portion preferably is a bend in the duct, meaning that curved sides of the duct globally have the same curvatures: both rotate around a point on the same side of the duct. Curved sides meaning the sides or walls seen when looking in the plane the duct bends in or put differently in the plane perpendicular to the rotational axis (see below) the stream of air is rotated around. One of the sides or walls thus forming the outside bend and one an inside bend.

[38] Preferably the cross-section of the duct remains more or less unchanged in the curved portion. In another embodiment the cross-sectional area for example does not change by more than a factor four. The cross-sectional area may get smaller in the direction of flow of the gas as to further increase the speed of the gas flow and thus the centrifugal force acting on the suspended particles.

[39] The discharge opening may be located downstream of the wall portion, preferably close of adjacent the wall portion or even in the wall portion so that the centrifugal force works on and accelerates the particle all the way up to the opening, not giving them time to decelerate or even move away from the outside bend for example by diffusion or turbulence.

[40] The term centrifugal force is used loosely in this document. The particles do not experience an actual force pushing them toward the dispensing opening: the centrifugal force is an inertial or fictitious force. The particles only accelerate relative to the gas (an observer moving along with the gas stream) because of their inertia. It is this acceleration and deceleration relative to the flow of gas that is used.

[41] Preferably the centrifugal force gives the particles a speed mainly perpendicular to the wall portion, at least adjacent to the dispensing opening.

[42] The centrifugal force experienced by the particles will accelerate them towards the wall portion in the outer bend. In order to discharge the particles as perpendicularly as possible out of the opening, it is beneficial when the centrifugal force points in a direction perpendicular to that wall and downstream of the wall perpendicular to the plane the opening extends in. This may be achieved by giving the wall portion a continuous radius of around 3 to 8mm. Preferably the duct extends in a continuous manner near the discharge opening.

[43] The material suspended in the flow of air may be a flux agent used for soldering or brazing. Such agents may contain or consist of at least any of the group of carbon acid, such as Dicarbon acid, Adipic- Succinic-, Glutaric-, Pimelic-, Suberic-, Lactic-, citric-, steraic-, cyclohexanecaerboxylic acid, another acid with the right physical and chemical properties or any combination thereof. Preferably the flux agent is suspended in the stream of air in its solid state, thus overcoming the need to heat up the agent. It however may also be present as droplets or in any other form.

[44] The gas flowing through the system may be any suitable gas and preferably is air or compressed air. If desired the gas may be a protective gas such as an inert gas to protect system parts, the workpiece, the material suspended in it or any combination thereof.

[45] Preferably less than 30%, even more preferred less than 10% of the gas flow flows out of the discharge opening. The nozzle may also be abutted on the workpiece to be coated. In that way virtually no gas leaves the application opening. The air flow may be driven by a pressure of 3 bar and may be pulsed, only flowing for example when the application nozzle abuts the workpiece.

[46] Preferably the curved portion rotates the direction of the gas flow around a rotational axis extending in an angle relative to the plane the discharge opening extends in or the front surface of a work piece to be coated, that angle being smaller than 10°, preferably smaller than 5° even more preferred the angle is essentially 0°, the opening extending in a plane parallel to the rotational axis. If the object to be coated or at least its surface to be coated is mainly flat, such as is the case for solar cells, the axis extends in this angle relative the front surface of the object. The plane the opening extends in according to the invention preferably extends mainly parallel to the plane of the front surface of the workpiece to be coated. By changing the (macroscopic) direction of flow this way or at least its component of movement towards the workpiece, the centrifugal force moves particles suspended in the gas flow towards the opening and thus the workpiece in a homogeneous manner over the whole area of the opening, regardless of size of that opening.

[47] Alternatively, the curved portion may rotate the direction of the component of movement towards the opening of the gas flow perpendicular to the plane the opening extend in or perpendicular to the front surface of a work piece to be coated around a rotational axis extending in an angle relative to the plane the discharge opening extends in or the front surface of a work piece to be coated, that angle being smaller than 10°, preferably smaller than 5° even more preferred the angle is essentially 0°. In that way particles will still be propelled towards and away from the opening and thus workpiece in a completely homogenous manner over the whole opening, while loosening design constraints.

[48] The centrifugal force is preferably directed mainly perpendicular to that rotational axis, at least near the opening or over the opening. In the latter case, the opening may be

obstructed by the workpiece to be coated or the opening may just be small enough to bend most of the gas flow as to continue its flow through the duct, thus generating the centrifugal force.

[49] The opening may be covered with a mask, preferably the mask being chargeable with third charge alternating means. In this way the suspended material, also called particles may be applied to a large area with the exemption of those masked regions, thus forming a 1D or 2D pattern. The mask may be interchangeable and be easily detached from the rest of the system so that it may be adapted to the pattern the material should be deposited in. For example, when soldering discrete locations, the material may only be provided to those locations. When applying material to multiple wires extending in front the opening that for example move in a direction perpendicular to the direction the opening extends in, material may only be applied to those wires. A 1D or 2D pattern may also be achieved by pulsing the flow of air while changing the relative position of the nozzle and the workpiece.

[50] In order to prevent material from attaching itself to the mask, the electrostatic charge of the latter may be controllable, as was stated above. By giving the mask or the edges of the discharge opening the same charge as the material suspended in the gas flow, it is prevented that the material attaches itself to these members. By given the material and parts of the system a charge of same polarity, they even repel each other thus preventing clogging even further. Letting gas flow through the system without particles suspended in it may help top remove undesired particles attached to system parts.

[51] Especially solar cells have to be coated with for example a flux agent over an elongated area, preferably intermittently by means of a mask. The duct may therefore have an oblong, preferably mainly rectangular cross-section for forming a sheet of gas flowing towards the opening. In order to achieve the desired homogenous application, the discharge opening may have an oblong shape, mainly extending in a first direction, this direction being mainly parallel to the direction the rotational axis extends in. By doing so the centrifugal forces act by the same amount and in the same way regardless of to position of a particle in the opening. Preferable a sheet of gas flowing past the opening is created that ideally does not flow in the direction of that rotational axis and only bends around the rotational axis forming a U-shape, at least near the opening.

[52] Preferably the particles only experience a centrifugal force in the desired direction: towards the outer bend of the curved wall. Moreover, if the particles are distributed equally

over the gas flow before reaching the curved portion, they will not be redistributed in the direction of the rotational axis. Preferably the macroscopic speed of the gas near the opening only has a component perpendicular to the rotational axis. This is achieved by the direction the duct extends in: it should have little or no component parallel to the rotational axis, at least near the curved portion.

[53] In order to better apply the material to the workpiece and especially to make the material stick to the workpiece the inventive nozzle may contain charge altering means for altering the electrostatic charge of the suspended material, the means preferably being located in the duct upstream of the dispensing opening. As long as the suspended material has a charge different from the workpiece, it is attracted there to. The material may be made neutral in the system (or may already be neutral) and thus applied to a charged workpiece. The workpiece may have no net charge and may only have a charge on its surface to be coated, created for example by influence. Preferably the charge altering means are located at a distance (say more than 5 or more than 15 mm) from the curved portion so that the particles are surely charged when they reach the opening.

[54] The charging means for altering the electrostatic charge of the particles may support a DC voltage, AC voltage or any combination thereof. The corona discharge effect may be used, the particles may touch the charging means in order to pick up or donate charge or electrostatic induction may be used, the particles being grounded in one way or the other. These processes may be stimulated or achieved solely by non-electrical means such as a source for UV-radiation or friction.

[55] If needed the exiting of the particles may be supported further by an electrical field other than that originating from the charge difference between the particles and the workpiece. This is for example known from the above cited US 3,976,031. Electrodes for this may be integrated in the inventive system.

[56] The inventive system(s) may be used for dispensing materials onto a workpiece, preferably over a larger area of that workpiece in time parallel (meaning that the position of the system does not have to be changed in order to coat the whole desired area). The workpiece may be mainly flat in at least one direction. Typical workpieces are solar cells, wafers or the like or wires or interconnectors for example used for interconnecting solar cells. Such workpieces may be coated efficiently by using a discharge opening and/or duct having a cross-section with a width larger than its depth, preferably the width being at least 10 times larger ten the depth, even more preferred at least 20 times larger. The width may

for example be 150mm or larger while the depth is 5mm or smaller. Such dimensions agree with needs of the solar industry where elongated wires or ribbons are connected to elongated contact areas on solar cells. Moreover elongated areas on ribbons, wires and cells need to be coated. Such a contact area may for example be a bus bar or any region (possibly without metallization) suitable for connecting interconnectors to. It may also be an array (1D or 2D) of portions of fingers on the solar module. In both cases flux may be applied selectively. In the former case because the ribbon may be soldered to the bus bar in discrete points, in the latter case because it should be prevented as much as possible that flux is applied next to the fingers on the sensitive area of the cell. The width preferably extending in the direction of the rotational axis or in the first direction the dispensing opening extends in.

[57] In a further aspect of the invention, an application nozzle unit is provided comprising at least two, preferably multiple inventive application nozzles, the application nozzles preferably being arranged side-by-side so that their respective rotational axes are mainly in parallel. By integrating multiple application nozzles, space can be saved, while enabling to apply all material necessary in time parallel. For example all bus bars of a solar cell (normally parallel to each other) may be coated at once, thus decreasing production time. Also multiple ribbons or connection wires may be coated at once.

[58] In a further aspect of the invention, a system is provided comprising an inventive application nozzle or application nozzle unit, further comprising a base for holding a workpiece, preferably for holding a solar cell, wafer, ribbon or interconnector, the base preferably being connected to charge altering means for controlling the electrostatic charge of the workpiece. It may further comprise a transportation system such as a conveyer belt for transporting the workpiece to the application nozzle(s). It may also comprise a source for gas with material suspended in it for being connected to the application nozzle or application nozzle unit.

[59] Preferably the system comprises means for moving the application nozzle or application nozzle unit and the base or workpiece relative to each other, preferably so that the application nozzle or application nozzle unit can be brought into contact with the base or workpiece. In that way the distal end of nozzle may be pressed against the workpiece, thus further reducing the flow of air out of the discharge opening.

[60] In a further aspect of the invention a stringer, tabber, tabber stringer or device for interconnecting strings is provided comprising any of an inventive application nozzle, application nozzle unit, system or any combination thereof.

[61] In a further aspect of the invention a method is provided for applying material to a workpiece, the method comprising the steps of:

- locating the application nozzle near a workpiece to be coated
- generating a flow of gas through the duct of that nozzle with particles suspended in that gas,

preferably in that order. Preferably the method further comprises at least one of the following steps:

- moving the application nozzle towards the workpiece or vice versa preferably as to abut on each other; or
- preferably controlling the charge of particles, the workpiece or both

[62] By abutting the nozzle on the workpiece, virtually no air will leave the application nozzle through the discharge opening thus preventing material from being carried away from the actual location it has to be applied and reducing the need for cleaning the workpieces, the application nozzle or system it is integrated in.

[63] The inventive nozzle may preferably be integrated in or form a spray gun or face-silent discharge electrode. It may be used for any kind of coating and painting. The inventive application nozzle may be therefore also denoted as coating or painting application nozzle.

[64] Further embodiments of the invention are indicated in the figures and in the dependent claims. The list of reference marks forms part of the disclosure. The invention will now be explained in detail by the drawings. In the drawings:

Fig. 1 schematically shows a cross sectional view of an embodiment of an application nozzle according to the invention and a workpiece on a base;
Fig. 2 shows the distal end of an embodiment of the inventive nozzle;
Fig. 3 shows an embodiment of the distal end of an embodiment of the inventive application nozzle from below;
Fig. 4 shows the shape the gas flow may have according to the invention in relation to the rotational axis;

Fig. 5 schematically shows an application nozzle unit;
Fig. 6 schematically shows a tabber-stringer using an inventive application nozzle unit; and
Fig. 7 shows geometrical aspects of the embodiment of Fig. 1.

[65] The present invention will be described with reference to exemplary embodiments and the present invention is not limited to a particular embodiment or component parts thereof, except as defined in the appended claims. Embodiments of the present invention may be used with a variety of methods and systems. It will be apparent to one skilled in the art that the present invention may be practiced in a variety of ways within the scope of the claims. Any feature shown in relation to the figures may be applied in general to the invention as described in the claims.

[66] As used herein, the indefinite article (“a”, “an”) denotes the presence of at least one of the referenced item, and the term 'a plurality' denotes the presence of more than one.

[67] Figure 1 shows in a cross-sectional view an embodiment of the inventive application nozzle 1 for coating a workpiece 2 such as a wafer, a solar cell, one or more ribbons or wires or any other object(s). A workpiece 2 is placed near the distal or dispensing end 16 of the nozzle 1. The distal end 16 may also abut on the front surface 41 of the work piece 2. A duct 3 transports particles 5 suspended in a flow of gas 4 towards a dispensing opening 6. Only a few particles 5 are shown. The gas flow 4 extends in the whole duct. Particles 5 are mainly supported upstream 12 of the dispensing opening 6. Downstream 13 of opening 6 only very few particles remain in the gas stream 4. The dispensing opening 6 extends in plane 15.

[68] The flow of gas 4 changes its direction as a consequence of the duct 3 making a bend or curve in its curved portion 7. An outer wall portion 9 of the outside bend 8 of duct 3 exerts force on the gas 4 thus changing its direction from A to B, effectively rotating the flow around rotational axis 14.

[69] Means for altering the electrostatic charge 10 of the material 5 suspended in the gas 4 are provided in the duct 3. If the electrostatic charge of the particles 5 differs from the charge of the workpiece 2, the particles will stick to the workpiece. In general, charge altering means may be used to change or control the electrostatic charge of the particles 5. In the shown embodiment, particles are charged, negatively or positively, and the workpiece is grounded to give it a neutral charge. What charge the particles and the workpiece have is not relevant. As long as the charges are different, the particles will stick to the workpiece. This works particularly well when the particles are electrical insulators. Typically the

controller 20 charges the particles with a charge of at least 1 kV, e.g. 7 kV. The workpiece 2 is kept uncharged by ground connection 17 of the base 28.

[70] In the shown embodiment, the first charge alternating means 10 also form diffusor means 29. Diffusor means 29 homogenize the flow of gas 4 and distribute the particles 5 more evenly in the gas 4.

[71] As the gas flow 4 flows through the duct 3, it flows through the curved portion 7 and experiences a centripetal force. The particles 5 - which are free to move in the gas - will accelerate towards the outer wall portion 9 of the bend 7 under influence of the centrifugal force. This will be explained in more detail in relation to figure 2.

[72] As the flow of air 4 passes the dispensing opening 6, it travels further towards second charge altering means 11. These means may make the remaining particles electrically neutral in order not to transport electrostatic charge to the surroundings. They may also be part of a recollection system: by giving the charge altering means a charge different from the charge of the particles, the particles will stick to them. A recollection system may for example be used to recollect particles if the system is not operating correctly or for example during set-up when the particles are not charged correctly. It may also be used the few particles that do not leave the dispensing opening 6. However few particles these are, over the years, particles may accumulate in undesired places.

[73] By making the charge of the first 10 and/or second 11 charge alternating means equal to the charge of the particles 5 when no gas flows or no particles are present in the gas flow, particles may be removed from the first 11 and or second 12 charge alternating means, respectively. The first and/or second charge alternating means may use any known technology for (de-)charging particles. A controller 20 is attached to the first and or second charge alternating means by connection wires for controlling them. If the first and or second charge alternating means are merely electrodes, the wires 19 support the currents and voltage used for (de-)charging.

[74] An additional electrode 18 is provided to give the particles 5 an additional acceleration towards the dispensing opening 6 and thus towards the workpiece 2.

[75] A connector 42 for connecting the nozzle 1 to a source for gas is shown as well as a connector 43 for an outlet o the gas.

[76] Figure 2 shows how a single particle 5' at two different times is accelerated relative to the gas towards the dispensing opening 6 extending in plane 15. The arrows a_I and a_{II}

indicate the direction of the respective accelerations. As the particle 5' moves from a first position I towards a second position II, rotating around rotational axis 14, the inertia of the particle makes the particle move towards the outside bend 8 and the wall portion 9. Since the gas 4 is accelerated towards the rotational axis 14 perpendicular to the plane of the drawing (by wall portion 9), the particle 5' experiences a force (drag) away from the wall portion 9. Nevertheless, a net particle transport towards the outside bend 8 and finally the dispensing opening 6 will take place. The gas 4 near the dispensing opening 6 will therefore contain a much higher particle concentration then the average particle concentration in the duct 3.

[77] As the particle 5' moves past the dispensing opening 6, it comes under the influence of the electrical field of the workpiece 2. This electrical field may be created by the charge of the particle 5', by an additional electrode 18', the charge of the (electrically insolated) base, the workpiece 2 or a combination thereof. In the embodiment of figure 2, the electrode 18' is integrated in the wall 39 of the inside bend 38 of duct 3, so that the flow of gas is not hindered.

[78] Figure 3 shows an inventive nozzle 1 in the direction looking upward from the workpiece 2 and perpendicular to the plane 15 the opening 6 extends in (see figure 2). The dispensing opening 6 is an elongated slit (width W, extending in a first direction 40 and depth D) that in this embodiment is masked with a mask 21 with openings 22. The particles 5 leave the stream of gas only through the openings 22. The mask 21 is attached to charge alternating means 37. By giving the mask 21 the same charge as the particle, the latter will not deposit on the mask.

[79] Figure 4 shows the general shape of the flow of gas 4 according to the invention (not showing the housing delimiting the duct): an elongated U-shape. The duct 3 bends around the rotational axis 14. The duct 3 has the dispensing opening (not shown) near the bottom of the U. The U-shape does not have to be as smooth as in the embodiment shown and may for example be rectangular. Moreover the bend in the duct for example up stream of the dispensing opening may consist of two straight walls, preferably being perpendicular to each other.

[80] Figure 5 shows an embodiment of an application nozzle unit 27 containing two application nozzles according to the invention with respective dispensing openings 6' and 6''. The respective ducts 3' and 3'' rotate the respective gas streams around respective

rotational axes 14' and 14". In this way, two elongated areas (extending perpendicularly to the plane of the drawing) on a workpiece 2 may be coated in time parallel.

[81] Figure 6 shows an embodiment of a system 30 according to the present invention forming a tabber-stringer 30. Solar cells 31 are retrieved from a storage for solar cells 32. The cells 31 are transported by a conveying unit 33 to a unit 34 containing an application nozzle 1 or application nozzle unit 27 (not shown) according to the invention. The cells are thus locally coated with flux particles. In a next step the cells are moved to a soldering unit 35 where ribbons (not shown) from a ribbon reservoir 36 are soldered to the cells 31. The ribbons are selectively connected to one or two cells 31 thus forming a string of solar cells (not shown).

[82] Fig. 7 shows geometrical aspects of the embodiment of Fig. 1. Here, the axis 44 of the dispensing opening 6 and the duct axis 46 of the duct portion 49 overlapping with the dispensing opening 6 enclose an angle of essentially 90°. However, also angles between 80° and 100° would be possible to achieve an excellent effect on the separation process of material from the gas.

[83] The dispensing opening 6 forms in the wall portion 9 a circumferential edge facing the interior of the duct 3. Here, the circumferential edge lies within a plane 45 which is essentially parallel to the duct axis 46 of the duct portion 49 overlapping with the dispensing opening 6.

[84] As can be seen from Fig. 1 and 7 the dispensing opening 6 is symmetrically arranged with respect to the curved portion 7 of the duct 3. Also, a duct portion 47 upstream of the dispensing opening 6 and a duct portion 48 downstream of the dispensing opening 6 define opposite directions of gas flow 4 (indicated in Fig. 7 by arrows). The duct 3 of the present embodiment has a U-shaped run and the dispensing opening 6 is arranged in or near the bottom of the U-shaped run.

[85] As can be seen from all embodiments, the dispensing opening is a branch-off (i.e. a branching-off from the duct). The duct of the coating or painting application nozzle continuously extends over the dispensing opening (i.e. the duct is not interrupted by the dispensing opening). With other words: the duct portion upstream of the dispensing opening and the duct portion downstream of the dispensing opening merge into one another preferably without interruption or discontinuity.

[86] The invention is not restricted to the embodiments shown. Single or multiple combinations thereof are possible. Features of the shown embodiment may also be applicable to other concepts and embodiments, shown and not shown in the figures, and more particularly to the invention as described in the claims.

List of reference signs:

1 Application nozzle
2 Workpiece
3 Duct
3' Duct
3'' Duct
4 Gas, gas stream, flow of gas
5 Particles
5' Particle
6 Dispensing opening
6' Dispensing opening
6'' Dispensing opening
7 Curved portion of the duct
8 Outside bend
9 Wall portion
10 First charge alternating means
11 Second charge alternating means
12 upstream
13 downstream
14 Rotational axis
14' Rotational axis
14'' Rotational axis
15 Plane of dispensing opening
16 Distal end of nozzle
17 Ground connection
18 Electrode
18' Integrated electrode
19 Connection wires
20 Controller
21 Mask
22 opening in mask
23 Divider wall portion
24 Outer wall portion
25 Outer wall portion
stringer or device for interconnecting strings
31 Solar cell
32 Storage
33 conveying system
34 unit with application nozzle
35 soldering unit
36 Ribbon reservoir
37 Third charge alternating means
38 Inside bend
39 Inside wall portion
40 First direction
41 Front surface of workpiece
42 Connector for inlet for gas flow
43 Connector for outlet for gas flow
44 Axis of the dispensing opening
45 Plane of the circumferential edge of the dispensing opening
46 Duct axis
47 Duct portion upstream of the dispensing opening
48 Duct portion downstream of the dispensing opening
49 Duct portion overlapping with the dispensing opening
a_I Direction of acceleration in position I
a_{II} Direction of acceleration in position II

26 Front wall

27 Application nozzle unit

28 Base

29 Diffusor means

30 System, Stringer, tabber, tabber

A Flow towards the dispensing opening

B Flow away from the dispensing opening

D Depth of the duct

I First position of particle

II Second position of particle

F_{CF} Centrifugal force

W Width of the duct

Claims

1. Coating or painting application nozzle (1) for dispensing material (5) such as a flux agent suspended in a gas flow (4) to a work piece (2), comprising a duct (3, 3', 3'') for guiding the gas flow (4) towards (A) and away (B) from a dispensing opening (6, 6', 6''), the duct (3, 3', 3'') having a curved portion (7) which is delimited in its outside bend (8) by a wall portion (9),
characterized in that the dispensing opening (6, 6', 6'') is provided directly adjacent or preferably in that wall portion (9) forming the outside bend (8) of the curved portion (7) such that material (5) suspended in the gas (4) flowing through the curved portion (7) experiences a centrifugal force (F_{CF}) directed towards that wall portion (9), preferably towards that dispensing opening (6, 6', 6'').

2. Application nozzle according to claim 1, wherein the curved portion (7) being delimited in its inside bend (38) by an inside wall portion (39) that is curved in the same direction as the wall portion (9), wherein preferably the duct (3, 3', 3'') has in its curved portion (7) essentially constant cross-section.

3. Application nozzle according to any of the preceding claims, characterized in that the curved portion (7) rotates the direction of the gas flow (4) around a rotational axis (14, 14', 14'') extending in an angle relative to the plane (15) the discharge opening (6, 6', 6'') extends in or the front surface (41) of a work piece (2) to be coated, that angle being smaller than 10°, preferably smaller than 5° even more preferred the angle is essentially 0°.

4. Application nozzle according to any of the preceding claims, characterized in that that the curved portion (7) rotates the direction of the component of movement towards the dispensing opening (6, 6', 6'') of the gas flow (4) perpendicular to the plane (15) the dispensing opening (6, 6', 6'') extends in or perpendicular to the front surface (41) of a work piece (2) to be coated around a rotational axis (14, 14', 14'') extending in an angle relative to the plane (15) the discharge opening (6, 6', 6'') extends in or the front surface (41) of a work piece (2) to be coated, that angle being smaller than 10°, preferably smaller than 5° even more preferred the angle is essentially 0°.

5. Application nozzle according to any of the preceding claims, characterized in that the duct (3, 3', 3'') has an oblong, preferably mainly rectangular cross-section for forming a sheet of gas flowing towards the dispensing opening (6, 6', 6'').

6. Application nozzle according to any of the preceding claims, characterized in that the discharge opening (6, 6', 6'') has an oblong shape, mainly extending in a first direction (40) mainly parallel to the direction the rotational axis (14, 14', 14'') extends in.

7. Application nozzle according to any of the preceding claims, characterized that it contains charge altering means (10, 11) for altering the electrostatic charge of the suspended material, the charge altering means (10, 11) preferably being located in the duct (3).

8. Application nozzle according to any of the preceding claims, characterized that the discharge opening (6, 6', 6'') and/or the duct (3, 3', 3'') has a cross-section with a width larger than its depth, preferably the width being at least 10 times larger than the depth, even more preferred at least 20 times larger.

9. Application nozzle according to any of the preceding claims, characterized in that the discharge opening (6, 6', 6'') is covered with a mask (21), preferably the mask (21) being chargeable with third charge alternating means (37).

10. Application nozzle according to any of the preceding claims, wherein the axis (44) of the dispensing opening (6, 6', 6'') and the duct axis (46) of the duct portion (49) overlapping with the dispensing opening (6, 6', 6'') enclose an angle between 80° and 100°, preferably an angle of essentially 90°.

11. Application nozzle according to any of the preceding claims, wherein the dispensing opening (6, 6', 6'') forms in the wall portion (9) a circumferential edge facing the interior of the duct (3, 3', 3''), wherein preferably the circumferential edge lies within a plane (45) which is essentially parallel to the duct axis (46) of the duct portion (49) overlapping with the dispensing opening (6, 6', 6'').

12. Application nozzle according to any of the preceding claims, wherein the dispensing opening (6, 6', 6'') is symmetrically arranged with respect to the curved portion (7) of the duct (3, 3', 3'').

13. Application nozzle according to any of the preceding claims, wherein a duct portion (47) upstream of the dispensing opening (6, 6', 6'') and a duct portion (48) downstream of the dispensing opening (6, 6', 6'') define opposite directions of gas flow (4).

14. Application nozzle according to any of the preceding claims, wherein the duct (3, 3', 3'') has a U-shaped run and the dispensing opening (6, 6’, 6’’) is arranged in or near the bottom of the U-shaped run.

15. Application nozzle unit (27) comprising at least two, preferably multiple application nozzles (1) according to any of the preceding claims, the application nozzles (1) preferably being arranged side-by-side so that their respective rotational axes (14', 14'') are mainly in parallel.

16. System (30) comprising an application nozzle (1) according to any of the claims 1 to 14 or an application nozzle unit (27) according to claim 15, further comprising a base (28) for holding a workpiece (2), preferably for holding a solar cell, wafer, ribbon or interconnector, the base (28) preferably being connected to charge altering means (17) for controlling the electrostatic charge of the workpiece (2).

17. System (30) according to claim 16, comprising means for moving the application nozzle (1) or application nozzle unit (27) and the base (28) or workpiece (2) relative to each other, preferably so that the application nozzle (1) or application nozzle unit (27) can be brought into contact with the base (28) or workpiece (2).

18. Stringer, tabber, tabber stringer or device for interconnecting strings (30) comprising an application nozzle (1) according to any of the claims 1 to 14, or an application nozzle unit (34) according to claim 15, or a system (30) according to claim 16 or 17, or any combination thereof.

19. Method for using an application nozzle according to any of the claims 1 to 14, comprising:
- locating the application nozzle (1) near or onto a workpiece (2) to be coated; and
- generating a flow of gas (4) through the duct (3, 3', 3'') of that application nozzle (1) with particles (5) suspended in that gas (4).

20. Method according to claim 19, comprising at least one of the following steps:
- moving the application nozzle (1) towards the workpiece (2) or vice versa, preferably as to abut on each other;
- preferably controlling the charge of particles (5), the workpiece (2) or both.

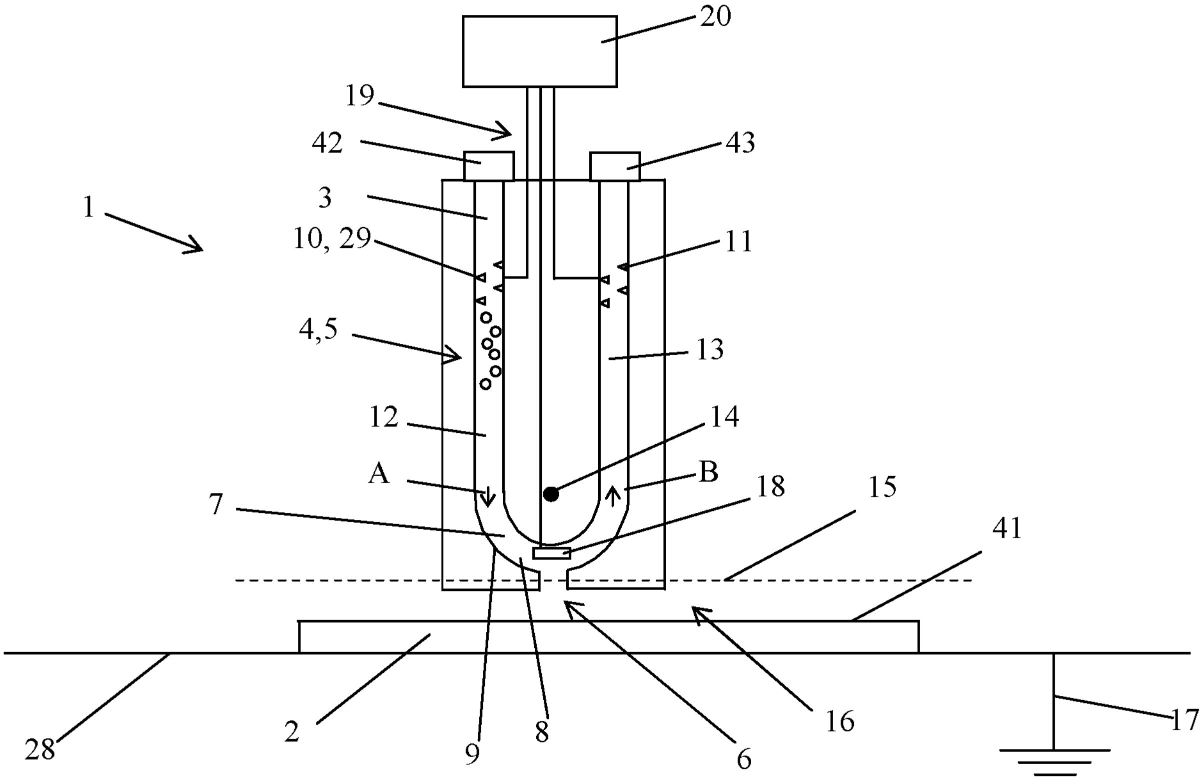
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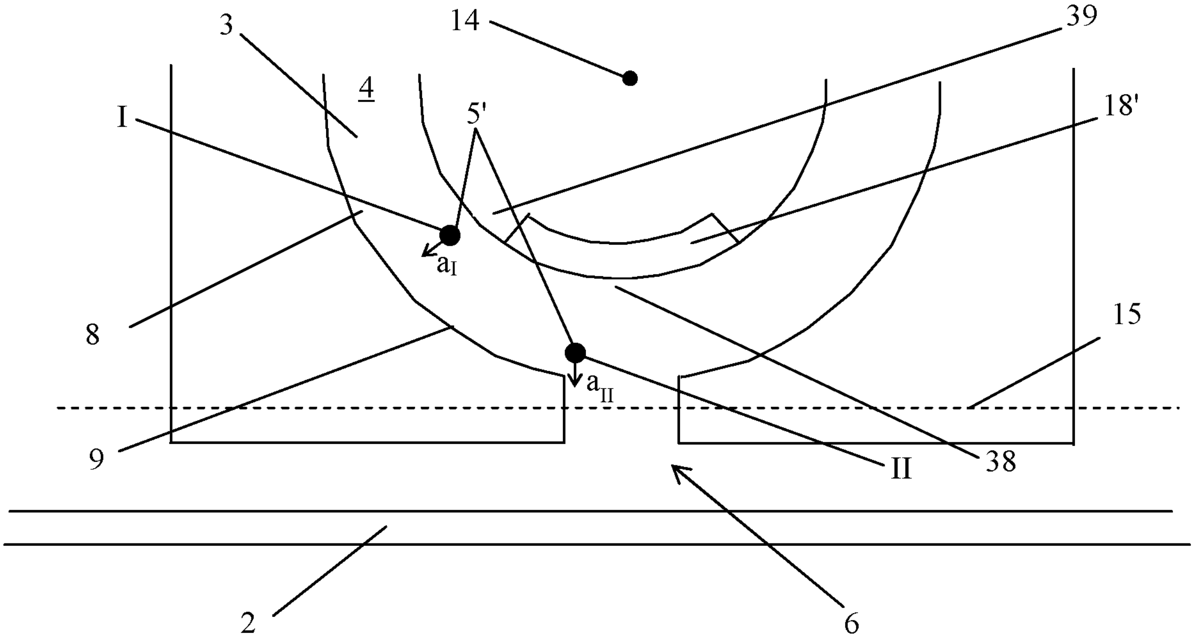
Fig. 1


3
14
39
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18'
8
a_I
15
9
a_{II}
II
38
2
6

Fig. 2

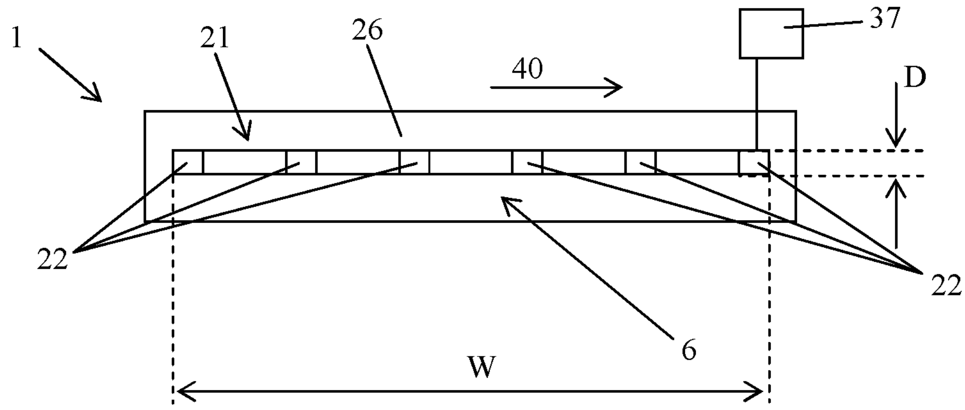

Fig. 3

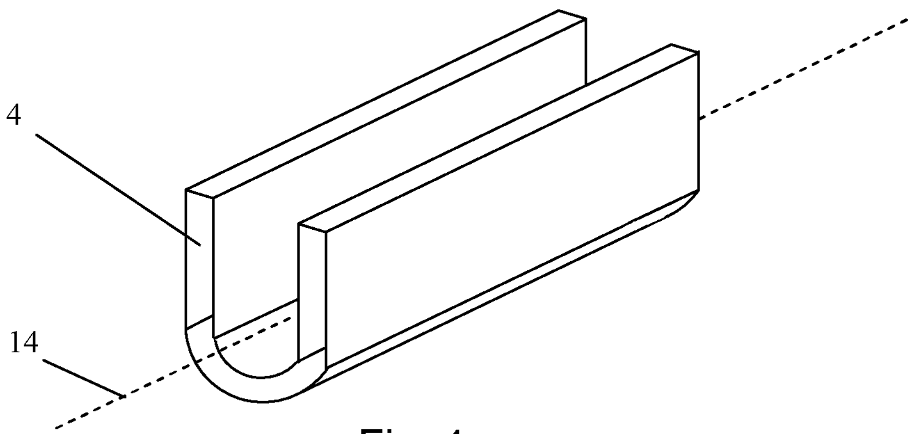

Fig. 4

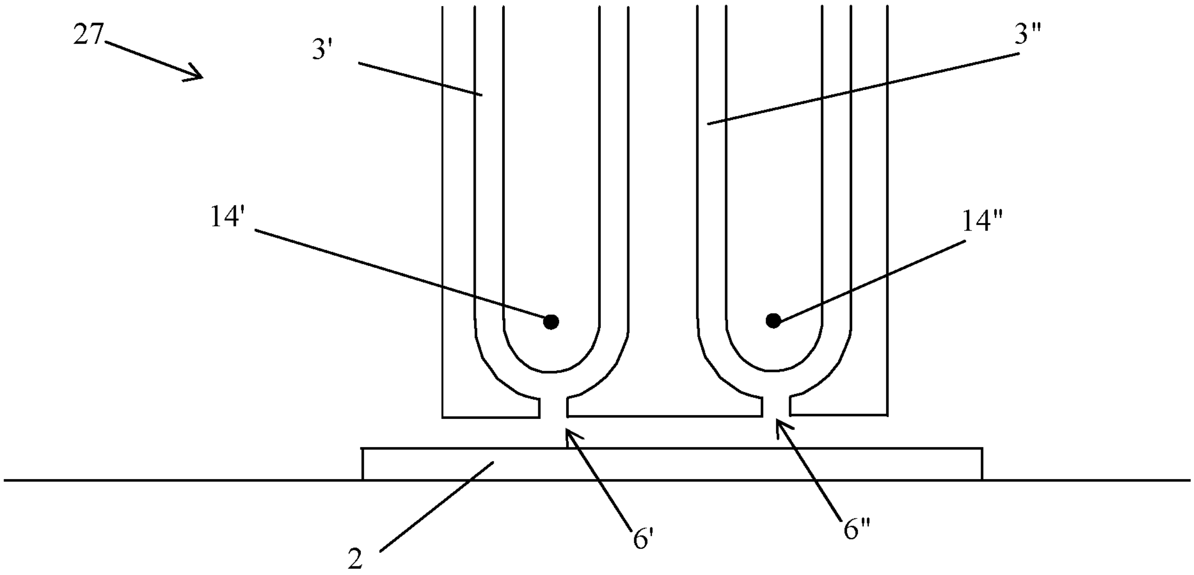

Fig. 5

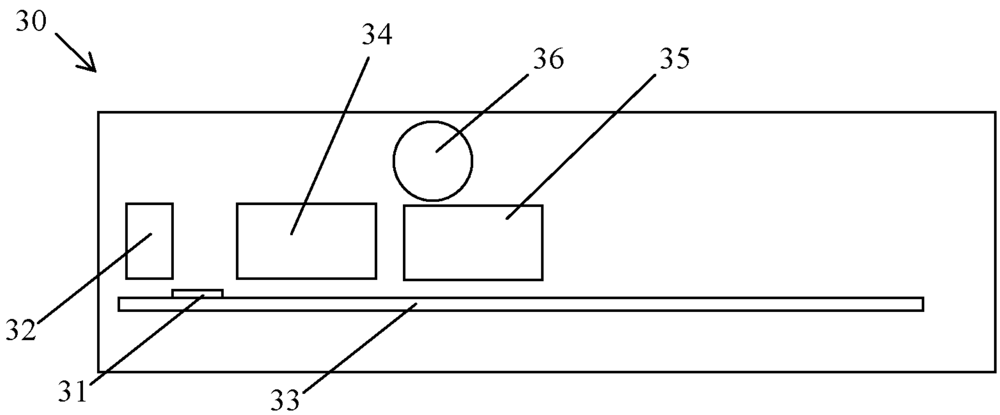

Fig. 6

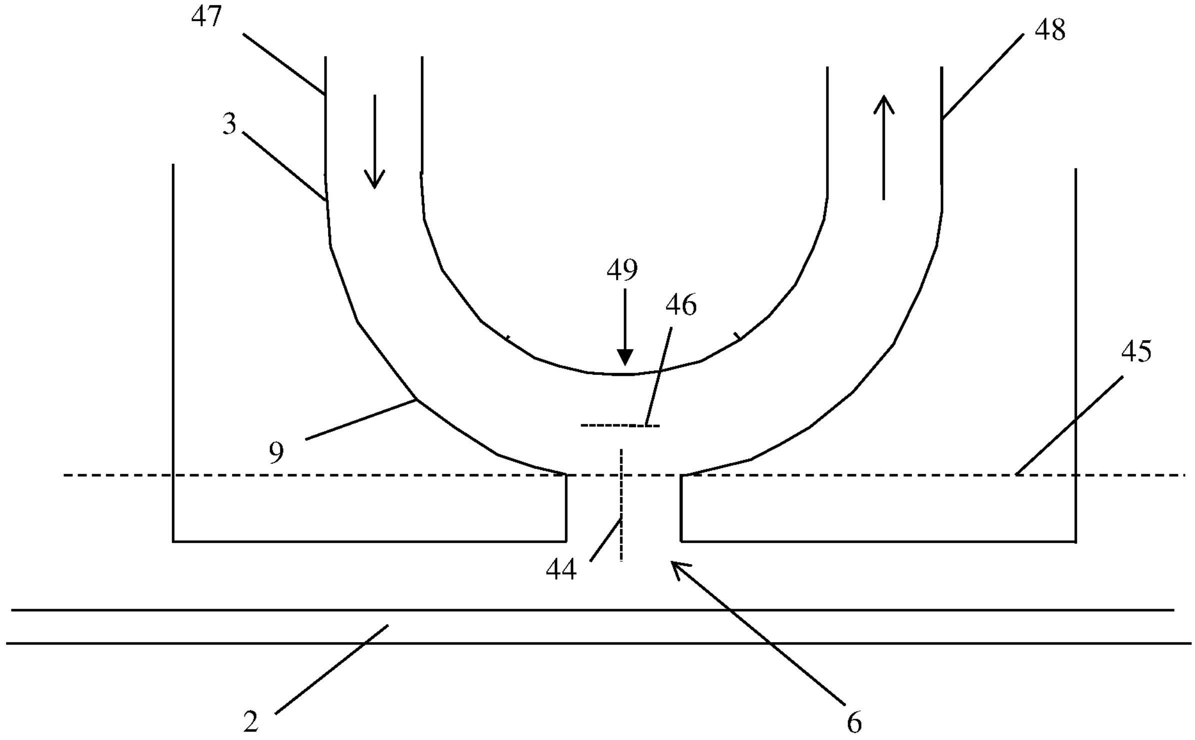

Fig. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/063311

A. CLASSIFICATION OF SUBJECT MATTER
INV. B23K3/08 H01L31/18 B05B5/03
ADD. B05B7/02

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)
B23K B05B B24C

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.
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Y	page 1, line 49 - line 57; figure 4	18
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X	US 4 715 535 A (MULDER DOUGLAS C [US]) 29 December 1987 (1987-12-29) column 6, line 27 - line 44; figure 1	1-9,12, 14-17, 19,20
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-/--

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

[X] 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 but published on or after the international filing date

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"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	Date of mailing of the international search report
14 November 2014	27/11/2014

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Gineste, Bertrand

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2014/063311

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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