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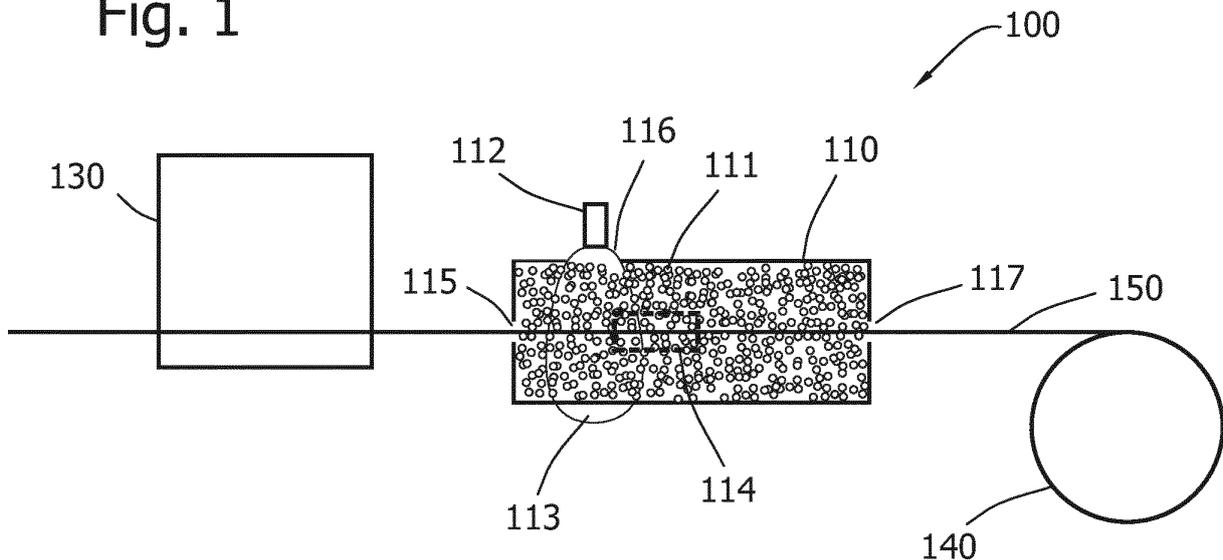
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(54) **Device and method for cleaning the wire of a wire saw**

(57) According to the present disclosure, a device (100, 300, 400, 500, 700), method and use for cleaning a wire (150) of a wire saw adapted for sawing a semiconductor work piece (130) is provided. The device (100, 300, 400, 500, 700) includes a container (110) including

a first opening (115). The container (110) is filled with loose solid particles (111) and adapted such that the wire (150) can pass via the first opening (115) through the loose solid particles (111).

Fig. 1



Description

BACKGROUND OF THE INVENTION

[0001] The subject matter described herein relates generally to cleaning methods and cleaning systems for wire saws, and more particularly, to methods and systems for cleaning a wire of a wire saw adapted for cutting semiconductor materials.

[0002] Generally, wire saws are used for producing thin wafers or dividing materials that are usually cast as ingots and made of, for example, silicon, glass, sapphire, ceramics and other brittle materials. Typically, the wafers produced thereby are used in the production of solar cells or other semiconductor components. In typical wire saws, a wire used for sawing a work piece is provided between two wire guide rolls in order to create a sawing area. The sawing area may include a plurality of sawing wires arranged to form a web-shaped sawing area through which an ingot or work piece may then be moved.

[0003] Typically, the wire used for sawing can be one of two types. The first type includes wires, which by themselves have no or only a minor abrasive effect on a work piece. For example, a steel wire has such a minor or no abrasive effect on a work piece and therefore, generally, requires that a slurry containing an abrasive is fed to the sawing area such that the moving wire can cut the work piece using the abrasive properties of the slurry. The other types of wires are those that themselves have an abrasive effect on the work piece (often called coated wires). For example, wires that contain abrasive particles set on their surface, such as wires impregnated with diamond dust have an abrasive effect on a work piece without the use of a slurry containing an additional abrasive suspended therein.

[0004] The wire saw arrangements for those two types of wires, typically have a different construction, in particular, with respect to the provision and re-use of slurry. The first type of wire saws including wires with no or only minor abrasive effects often recycle the slurry after use in order to re-use the abrasive particles contained in the slurry. For this purpose, elaborate filtration systems are often put in place. Further, the slurries used in such wire saws are typically glycol based. In contrast thereto, the second type of wire saws including wires, which themselves have an abrasive effect may have a simpler construction since generally they do not employ such elaborate filtration systems. Moreover, the slurry in the second type of wire saws may, generally, be water based and thus ecologically friendly.

[0005] Generally, the kerf produced from sawing a work piece may be removed from the sawing area. In wire saws using wires with no or only minor abrasive effects, kerf from sawing the work piece may adhere to the surface of the wire and may generally be removed via the continuous provision of fresh slurry or slurry that is filtered and then re-used. However, a complete removal of kerf from the surface of such wires by using a slurry

alone may not suffice. In wire saws or wire saw arrangements that use wires with an abrasive effect i.e. coated wires, kerf from the work piece may adhere to the coated wires, which may cause a reduction in sawing efficiency, disturb the winding-up of used wire and reduce recycling efficiency of the kerf. This may generally lead to increased material and operational costs.

[0006] For this purpose, it will be appreciated that an easy and efficient removal of the kerf from wires, such as diamond-coated wires, ensuring a continuous high quality sawing of the wire saw as well as an efficient recycling of left-over or waste kerf is desired. Hence, the subject matter described herein pertains to improved cleaning methods and systems, in particular with respect to cleaning the sawing wires of wire saws, in order to achieve the aforementioned high quality sawing, material and operational cost benefits.

BRIEF DESCRIPTION OF THE INVENTION

[0007] In one aspect, a device for cleaning a wire of a wire saw adapted for sawing a semiconductor work piece is provided. The device includes a container including a first opening. The container is filled with loose solid particles, and adapted such that the wire can pass through the first opening and through the loose solid particles.

[0008] In another aspect, a wire saw arrangement for cutting a semiconductor work piece is provided. The wire saw arrangement includes a wire saw including a wire adapted for sawing a semiconductor work piece, and a device for cleaning the wire of the wire saw that includes a container including a first opening. The container is filled with loose solid particles and adapted such that the wire can pass via the first opening through the loose solid particles.

[0009] In yet another aspect, a use of a device for cleaning a wire of a wire saw as described above or a use of a wire saw arrangement for cutting a semiconductor work piece as described above is provided for cleaning and sharpening a wire of a wire saw by moving the wire through the loose solid particles within the container.

[0010] In yet another aspect, a method for cleaning a wire adapted for cutting a semiconductor work piece is provided. The method includes moving the wire through the loose solid particles within the container described above.

[0011] The invention is also directed to an apparatus for carrying out the disclosed methods and including apparatus parts for performing each described method steps. These method steps may be performed by way of hardware components, a computer programmed by appropriate software, by any combination of the two or in any other manner. Furthermore, the invention is also directed to methods by which the described apparatus operates. It includes method steps for carrying out every function of the apparatus.

[0012] Further aspects, advantages and features of the present invention are apparent from the dependent

claims, the description and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] A full and enabling disclosure including the best mode thereof, to one of ordinary skill in the art, is set forth more particularly in the remainder of the specification, including reference to the following accompanying Figs.:

[0014] Fig. 1 is a schematic representation according to embodiments herein showing a device for cleaning a wire of a wire saw, a wire and a work piece.

[0015] Fig. 2 is a schematic view according to embodiments herein of a section of the exemplary device for cleaning a wire of a wire saw shown in Fig. 1.

[0016] Fig. 3 is a schematic representation according to embodiments herein showing a device for cleaning a wire of a wire saw, a wire and a work piece.

[0017] Fig. 4 is a schematic representation according to embodiments herein showing a device for cleaning a wire of a wire saw, a wire and a work piece.

[0018] Figs. 5 and 6 are schematic views according to embodiments herein showing a moveable device for cleaning a wire of a wire saw.

[0019] Figs. 7 and 8 are schematic representations according to embodiments herein showing a moving path of the moveable device for cleaning a wire of a wire saw.

[0020] Fig. 9 is a schematic view of the closed cleaning fluid loop of a device for cleaning a wire of a wire saw according to embodiments herein.

[0021] Fig. 10 is a schematic view according to embodiments herein showing a wire saw arrangement for cutting a semiconductor work piece adapted for cleaning and sharpening the wire(s) used for sawing.

DETAILED DESCRIPTION OF THE INVENTION

[0022] Reference will now be made in detail to the various embodiments, one or more examples of which are illustrated in each Fig. Each example is provided by way of explanation and is not meant as a limitation. For example, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet further embodiments. It is intended that the present disclosure includes such modifications and variations.

[0023] As used herein, the term "work piece" is intended to be representative of a work piece such as an ingot made of silicon, glass, sapphire, ceramics or any other brittle material(s). The work piece is typically cut, sawn or divided in order to obtain bricks or wafers, for instance, for manufacturing solar cells or semiconductor components.

[0024] As used herein the term "wire saw" is intended to be representative of any wire saw machine that uses a metal wire or cable for cutting a work piece e.g. a squarer. Typically, there are two types of wire saw machines: continuous (i.e. endless or loop) and oscillating (or reciprocating). In general, continuous type wire saws are used

to cut silicon wafers for the semiconductor industry.

[0025] As used herein, the term "wire" is intended to be representative of any wire or cable typically used for sawing a work piece. For instance, the wire may have one strand or many strands braided together and depending on the application, diamond material may or may not be used as an abrasive. Generally, a wire may be roughened to be abrasive, abrasive compounds may be bonded to the wire, or for instance diamond-impregnated beads (and spacers) may be threaded onto the surface of the wire. Generally, in the context described herein, the term "a wire" is intended to be representative of at least one wire and should thus not be interpreted to exclude the possibility of there being more than one wire.

As used herein, the term "coated wire" is intended to be representative of any wire or cable, which includes abrasive compounds (e.g. diamond grits) bonded to its surface. For instance, a wire with a diameter from 80 μm to 120 μm may be embedded with diamond grits with a size from 10 μm to 20 μm . However, in embodiments herein, the coated wires may also have a greater or smaller wire diameter and grit size. For instance, wire diameters may be in the ranges from 40 μm to 500 μm or from 60 μm to 400 μm (e.g. in squarer machines the wire diameter may be 350 μm).

[0026] The embodiments described herein include a device for cleaning a wire of a wire saw adapted for sawing a work piece (hereinafter also referred to as "cleaning device"). In particular, the embodiments of the cleaning device described herein are directed to the cleaning of coated wires for use in wire saws, i.e. wires that have a fixed abrasive on their surface, such as diamond-impregnated wires.

[0027] Generally, wire saws that employ coated wires may have a different design than wire saws that use uncoated wires. The reason being that the latter wire saws may need an abrasive slurry in order to provide the abrasive effect that divides work pieces. In contrast thereto, wire saws including coated wires inherently possess abrasive properties (typically, due to abrasive particles affixed to their surface) and may thus use a more environmental friendly water-based sawing fluid since they do not require the extra addition of an abrasive slurry for sawing apart or dividing a work piece.

[0028] Typically, in high performance wire saws using a coated wire for sawing, for example, highly valuable work pieces made of silicon or sapphire, the wire(s) is guided over wire guides that may include wire grooves, which ensure high precision sawing by maintaining the wires in a predetermined position with marginal clearance.

[0029] In embodiments herein a cutting or sawing area is to be understood by one skilled in the art as the area where a work piece is sawn apart or divided. The sawing area is usually positioned between two wire guides. When a plurality of wires is used, a web-structured sawing area may be formed, which may cut a work piece into a plurality of sections or slabs at the same time. Gener-

ally, during the sawing process, the wire(s) may run in a back and forth mode with wire speeds ranging from -20 m/s to 20 m/s. Depending on the profile used, small wire velocities may be used such as 8 m/s at the beginning or end stage of the cutting. Hence, in embodiments herein, the wire(s) may move at speeds from 0 to 20 m/s or from 10 to 15 m/s.

[0030] In wire saws using coated wires, such as diamond-coated wires, it is desirable to remove the kerf that may have lodged to the surface of the wire for the following reasons. The kerf of the work piece that is being cut may adhere to the surface of the wire and may, for instance, cover the diamond grits on the wire. This may increase the flow rate on the wire, thereby increasing the undesirable pairing effect in which two adjacent wires attract each other due to the surface tension of the fluid accumulation on each of their respective surfaces. This pairing effect may cause the wires to pair up and hence damage the work piece and reduce the overall cutting precision.

[0031] In general, cutting precision may be reduced since the kerf on the surface of the coated wire may fill-up or contaminate the grooves in the wire guides thereby causing the wire to jump out of the grooves. Hence, this may damage the work piece and also the wire(s) itself, and thus may considerably reduce cutting efficiency, which in turn may lead to high operating costs per work piece and high wire consumption per work piece(s). In other words, maintaining the cutting efficiency may allow for a higher cutting speed and consequently higher productivity.

[0032] The inventors have surprisingly found out that contrary to the conventional nozzle or spray wire cleaning systems known in the art, the interaction of loose solid particles with the surface of a wire may effectively remove kerf from the entire surface of the wire. In other words, an important finding in this context is that the physical contact or the rubbing between loose solid particles and a wire (e.g. a coated wire) is one of the most effective ways to remove kerf or particles therefrom. In particular, the loose solid particles may easily surround a wire removing kerf and particles from its entire surface as opposed to a fixed brush, which at any given time typically does not achieve such a thorough wire cleaning efficiency.

[0033] Further, the inventors found that the loose solid particles may not only clean a coated wire but with an optimized configuration may sharpen the coated wire, thereby improving its cutting efficiency and overall quality of the cut. As it turns out using loose solid particles as cleaning means for cleaning the wire of a wire saw also helps to reduce the amount of cleaning fluid typically employed for cleaning wires using conventional nozzle or spray cleaning systems.

[0034] In embodiments described herein, a device for cleaning a wire of a wire saw is provided. The cleaning device, typically, includes a container filled with loose solid particles. Generally, the container may be com-

pletely filled with loose solid particles. However, in further embodiments herein, the container may also be partially filled with loose solid particles without losing its ability to effectively clean a wire of a wire saw. In other words the inner space of the container may be filled from 10% to 95%, from 30% to 90% or from 55% to 85% with loose solid particles.

[0035] In yet further embodiments herein, the container of the cleaning device, before being used for the first time, may include a fixed material. During a cleaning process, this fixed material may be broken into pieces, which act as the loose solid particles described herein. In other words, cleaning devices may be delivered to customers including a fixed material inside of the container of the cleaning devices. Once, the cleaning devices are in operation, the fixed material breaks up into pieces as mentioned above. This enables an easy and safe transportation of the cleaning devices.

[0036] The container of the cleaning device, usually, includes at least one opening for allowing a wire to enter the container and be in physical contact with the loose solid particles therein. Generally, a coated wire passes over or through the loose solid particles. The loose solid particles partly or completely surround the wire and rub against its surface, thereby removing any waste particles or left over kerf from, for example, a sawing process in which the coated wire was previously used.

[0037] The loose solid particles within the container are loose, in the sense that they are moveable with respect to one another. This ensures that the coated wire(s) passing within or through the container is always in physical contact with fresh loose solid particles such that the kerf or scrap material adhering to the surface of the coated wire is effectively removed. By the wire movement, the loose solid particles will move their positions and be mixed with each other. Since loose particles may thereby easily surround the wire inside of the container, this may ensure an advantageous cleaning effect spanning the entire surface area of the wire.

[0038] Generally, the loose solid particles have a diameter that may range from 1 μm to 10 mm, from 10 μm to 8 mm or from 50 μm to 6 mm. The loose solid particles described herein are typically sand particles, which may include any finely divided rock or mineral particles (e.g. particles of silica) and mixtures thereof. However, the loose solid particles in the embodiments described herein may also include particles made of any of the following: sand, ceramic, silicon, metal, plastic or any combination thereof.

[0039] The particles may also consist of one type of the previously mentioned materials and be coated by another, such as ceramic, silicon, metal, plastic or any combination thereof. In other words, the particular composition of loose solid particles within the container of the cleaning device may be adjusted to optimize or intensify the cleaning or sharpening effect on the wire to be cleaned. The particular shape (e.g. oval, spherical or irregular) of the loose solid particles may also influence

the cleaning or sharpening efficiency and thus may also be adjusted accordingly. In view thereof, the cleaning device may individually be adapted to the type of wire and to the desired cleaning or sharpening effect.

[0040] Typically, in the embodiments herein, the container includes at least one opening that provides the wire(s) access to the loose solid particles within the container. Generally, the wire(s) is moved through the loose solid particles for removing any kerf or scrap particles that may have adhered to the wire(s) surface. The wire(s) may enter and leave the container from the same opening. For instance, multiple wires, e.g. from 2 to 10 wires, from 10 to 100 wires, from 100 to 1000 wires, or more than 1000 wires may be able to access the loose solid particles within the container via the at least one opening of the container at the same time. In other words, the cleaning device may provide access for multiple wires, which may move parallel to one another through the container of the cleaning device.

[0041] In further embodiments herein, the container may provide access to a cleaning fluid supply system to provide a cleaning fluid. The cleaning fluid may be provided via the aforementioned at least one opening or may be provided via a second or a plurality of openings in the container.

[0042] The cleaning fluid supply system may include a pump for providing a cleaning fluid under pressure, as well as a nozzle to distribute the cleaning fluid over a large surface area of the loose solid particles. In embodiments herein, the cleaning fluid supply system may be moveable or a plurality of nozzles may be provided to ensure an even distribution of the cleaning fluid within the container.

[0043] The cleaning fluid may function as a cooling medium for dissipating the frictional heat of the wire produced in the sawing or cleaning process. Typically, the cleaning fluid further facilitates the removal of the kerf by the loose solid particles from the coated wire.

[0044] Generally, the cleaning fluid containing the kerf from the cleaned wire may also be removed from the container. For the purpose thereof, the container may include a further opening from which the cleaning fluid including the kerf is removed under the influence of gravity or via an active suction mechanism (e.g., including a pump(s)). Subsequently, the kerf may be removed from the cleaning fluid via filters (e.g. cross-flow filter systems, dead-end filter systems, stack filters, rotary filters, planar-array filters etc.) or centrifuges (e.g., drum centrifuge decanters) and collected for future recycling. The cleaning fluid may then be reused in the cleaning device. Hence, the cleaning device may include an easy to use closed cleaning fluid loop, which maximizes cleaning fluid efficiency and minimizes costs.

[0045] According to embodiments herein, the cleaning fluid may be water based and optionally electrically conductive or non-conductive (see below for more details). The cleaning fluid may further include one or more of the following additives: an anticorrosive (for protecting the

wire saw), bactericides, fungicides, pH buffers, surface tension modifiers and any combinations thereof. For example, in embodiments herein, the cleaning fluid may include commercial products, wherein a mixture of a few percentages, for example, of 5% cleaning chemical (soap) and antifoaming agent in deionized water may be used. In further embodiments herein, the cleaning fluid may include, for example, 2.5% cleaning chemicals with 0.1% polymer, 0.05% complexing agent, antifoaming agent, and surfactant. Therein, the complexing agent may be used to react on a particular material's surface in order to prevent other materials from attaching to that surface and the surfactant may be used to change the surface tension.

[0046] Surface tension modifiers, typically suppress the so-called pairing effect due to their ability of reducing the surface tension of, for example, the cleaning fluid as follows. Typical wire saws employ a plurality of wires running close to each other (a few tenths of a millimeter) in grooves of a guiding roller. The surface tension of the cleaning fluid left over on the cleaned wires may thus attract two adjacent wires leading to the undesired pairing effect, which may damage the work piece. Hence, by reducing the surface tension of the sawing fluid, the pairing effect may be reduced.

[0047] In embodiments herein, when the cleaning fluid is provided in a closed fluid system any expensive additive in the cleaning fluid may be re-used after the aforementioned removal or filtration of the kerf, thereby further reducing the operating costs.

[0048] In general, the container of the cleaning device described herein may have many different configurations, some of which are described hereinafter. For instance, the container of the cleaning device may include a first, a second and a third opening. In general, a wire may be guided into the container via the first opening, a cleaning fluid may be provided via the second opening and the wire may be guided out of the container via the third opening. However, the container of the cleaning device may equally be configured with fewer openings (e.g. one or two) or with more than three openings depending on its particular use (e.g., if multiple wires are cleaned at the same time). In general, the container of the cleaning device may be configured as rectangular-shaped box. However, it may also be in the shape of, for instance, a cylinder.

[0049] Generally according to embodiments herein, the coated wire to be cleaned may pass through the loose solid particles within the container of the cleaning device at speeds from 5 to 10 m/s or from 10 to 15 m/s. The loose solid particles rub against the surface of the moving wire, thereby removing any scrap material or kerf from the coated wire, thus cleaning and sharpening the coated wire. According to further aspects described below, the cleaning device may be configured such that it is also moveable.

[0050] For instance, in some embodiments herein, the cleaning device may be configured to move in a direction

that is different than the moving direction of the wire(s) (as understood herein, the wire generally moves along its own longitudinal axis). The result of this type of movement of the cleaning device or its container ensures that fresh loose solid particles are continuously provided to the surface of the wire(s) in order to warrant an optimum cleaning and sharpening effect over longer periods of time. Generally, in embodiments herein it is also conceivable that the one or more wires are moved within the cleaning device (in addition to their movement along their longitudinal axis) in order to achieve the same aforementioned effects.

[0051] Hence, in general, the cleaning device may be moved with respect to the wire that moves along its own longitudinal axis or the wire, which moves along its own longitudinal axis, may be moved with respect to the cleaning device within container of said cleaning device or both. In either case, the described movement (of the cleaning device or wire) may typically be in a direction other than the moving direction of the wire along its own longitudinal axis, for example, perpendicular to the moving direction of the wire along its longitudinal axis.

[0052] In embodiments herein that include a wire saw or wire saw arrangement for sawing a work piece, the cleaning device may be configured to move parallel with or in a parallel direction to the moving work piece as it is sawed by being pushed through the sawing area. The cleaning device may, for instance, move in a perpendicular direction to the moving direction of the work piece. In embodiments, the cleaning device may move in a direction other than the axial direction of the moving wire. This movement of the cleaning device may be performed even in the absence of a work piece to be cut. Hence, the cleaning device may clean the coated wire either when a work piece is being cut or else during times when a new work piece is loaded into the wire saw or wire saw arrangement. Moreover, the cleaning device may also clean the wire when the wire stops moving (See more details below).

[0053] The cleaning device may also clean a wire in the absence of a wire saw or in the absence of a wire saw arrangement. In such embodiments, the cleaning device may also be moveable with respect to the axial moving direction of the wire. In particular, the moving direction of the cleaning device with respect to at least one moving wire according to embodiments may be described as follows.

[0054] During a cleaning or sharpening process or cleaning and sharpening process, the cleaning device may be continuously moved such that a distance between an inner-wall of the cleaning device parallel to the axial moving direction of the wire and the wire changes continuously. In other words, assuming that the wire is only moving in its axial direction, the cleaning device may be continuously moved in a direction other than in the axial moving direction of the wire exclusively. This ensures that the wire is always surrounded by fresh loose solid particles, which optimizes the cleaning and sharp-

ening effect of the cleaning device.

[0055] In general, a continuous movement of the cleaning device may include that the position of the longitudinal axis of a wire within the container of the cleaning device is continuously changed.

[0056] In yet further embodiments described herein, the cleaning device may continuously move on a circular or elliptical path with respect to the wire or around the wire, which itself may be moving along its axial direction through the cleaning device. Generally, the cleaning device would be moving such that the wire remains surrounded by the loose solid particles within the container of the cleaning device at all times. Depending on the shape of the container of the cleaning device, the distance between a wire moving through the cleaning device and an inner-wall of the cleaning device may remain constant even during the continuous circular or elliptical motion of the cleaning device.

[0057] In even further embodiments herein, the cleaning device or its container may rotate around its own longitudinal axis. Generally, in cases when the cleaning device or container rotates in such a manner, a wire is positioned to pass through the cleaning device or container at a different position than along the central longitudinal axis of the cleaning device or container. This particular movement of the device or container may be performed independently or combined with any of the movements described above.

[0058] In other embodiments herein, the cleaning device may include a device for mixing the loose solid particles within the container of the cleaning device. This mixing device may provide a similar optimized cleaning and sharpening effect of the wire(s) as was described above with respect to continuously moving the cleaning device. Hence, a mixing device may be provided to a stationary cleaning device for moving the loose solid particles.

[0059] In other words, a cleaning device that is fixed in a particular position may be provided with a mixing device to achieve a similar cleaning and sharpening effect as is achieved when employing a moveable cleaning device or container. In further embodiments, the mixing device may also be provided to a cleaning device that is moveable.

[0060] In yet further embodiments herein, the cleaning device may include a voltage supply unit, which may electrically charge the loose solid particles, thereby improving the cleaning efficiency of the cleaning device by increasing its kerf removal performance.

[0061] Further embodiments may include magnetically charging the loose solid particles. In embodiments herein, where loose solid particles are magnetically charged, the container of the cleaning device may be made of a nonmagnetic material.

[0062] In embodiments herein, if the loose solid particles are electrically charged, the container of the cleaning device may be made of a dielectric or electrically insulating material. Generally, the wire saw or wire saw ar-

rangement retro-fitted with such a cleaning device may also have or be retro-fitted with dielectric wire guiding rollers. Further alterations to the wire saw or wire saw arrangement may be necessary to facilitate electrically charging the loose solid particles without electrically charging the entire system or for preventing short circuits.

[0063] Fig. 1 is a schematic representation of an exemplary device for cleaning a wire of a wire saw. The cleaning device 100 includes a container 110 filled with loose solid particles 111. The loose solid particles may include particles of sand, ceramic, silicon, metal, plastic and any combinations thereof. The cleaning device generally includes a first opening 115 through which a wire (that is usually a coated wire) may enter into the container 110.

[0064] The cleaning device 100 may further include a cleaning fluid supply system 112, which provides a cleaning fluid 113 to the inside of the container 110. For this purpose, the container 110 may include a second opening 116 through which the cleaning fluid 113 is supplied. In general, the cleaning fluid 113 may facilitate the removal of kerf from the surface of a wire 150, which is achieved by the physical interaction between the loose solid particles 111 rubbing against the surface of said wire 150.

[0065] Typically, the cleaning fluid is water based and thus ecologically friendly. In embodiments herein, the cleaning fluid may also function as a coolant. Thereby, any heat from the wire may be dissipated, thus cooling the wire. In general, any type of coolant may be used such as water based, for instance, deionized water and diethylene glycol (DEG) or polyethylene glycol (PEG) based coolant, however, the coolant may have a high thermal capacity, low viscosity, low-cost, be nontoxic, chemically inert, and neither cause or promote corrosion of either the cleaning device or the wire. Optionally, the coolant may either be electrically conductive or electrically non-conductive (i.e. be an electrical insulator). In embodiments herein various additives may be added to the cleaning fluid (e.g., anti-corrosives, bactericides, fungicides, pH buffers, surface tension modifiers) to improve the cleaning efficiency of the cleaning device and to prevent any damages to the work piece, wire or cleaning device.

[0066] In embodiments herein, generally the container of a cleaning device may include a single opening through which a coated wire or multiple coated wires may enter into the cleaning device, move through the loose solid particles and exit the cleaning device through the same opening. Moreover, a cleaning supply system may provide a cleaning fluid to the inside of the container through that same opening. Optionally, the container may further include an outlet for removing used cleaning fluid. The used cleaning fluid may be filtered, whereby any scrap particles removed from the coated wire may be collected and recycled. The filtered cleaning fluid may then be re-used or re-supplied to the container of the cleaning device. Hence, a closed loop cleaning fluid supply system

may continuously provide fresh cleaning fluid to the inside of the cleaning device.

[0067] In yet further embodiments herein, the container of the cleaning device may provide at least one opening per wire, i.e. in embodiments herein where multiple wires are cleaned and sharpened at the same time, the container of the cleaning device may have at least one separate opening per wire or one opening for a set of wires (a set of wires may for instance include 2 to 10 wires, 10 to 100 wires, 100 to 1000 wires or more wires).

[0068] In the exemplary embodiment shown in Fig. 1, the cleaning device 100 includes a third opening 117 through which the cleaned wire 150 may exit the container 110 of the cleaning device 100. Hence, in general the wire 150 to be cleaned moves from the first opening 115 through the loose solid particles 111 within the container 110 of the cleaning device and exits said container 110 through the third opening 117. Through the physical interaction between the wire and the loose solid particles, the wire is cleaned and any kerf on the wire may be removed effectively. Moreover, the grits attached to the surface of a coated wire to be cleaned by the cleaning device may also be sharpened by the loose solid particles.

[0069] Typically, the wire may travel through the loose solid particles within the container of the cleaning device at speeds from 0 to 20 m/s or from 10 to 15 m/s. These high-speed cleaning rates allow for a wire to be cleaned even during a sawing process.

[0070] Fig. 1 further shows a work piece 130 which may be cut by the moving wire 150 and a roller 140, which generally guides the wire 150. The roller 140 typically includes guiding grooves (not shown in the Figs.) for precisely guiding the wire 150, thus allowing for high precision sawing even when a plurality of wires positioned adjacent to one another are being used. The wire, roller and work piece are typically not a part of the cleaning device as described herein.

[0071] The cleaning device 100 shown in Fig. 1 may typically be used independently from any other device to clean a coated wire (e.g. a diamond coated wire). However, in embodiments herein and as is partly shown in Fig. 1, the cleaning device may also be installed in a wire saw. It is intended that any type of wire saw may be retro-fitted with one or more cleaning devices described herein.

[0072] Typically, the one or more cleaning devices may be positioned before or after the sawing area of a wire saw or both before and after the sawing area. In some sawing processes, high sawing accuracy is paramount and thus a cleaning device may be provided before the sawing area. Thereby, any residual dirt particles on the coated wire, for instance from guiding rollers or other devices installed before the sawing area may be removed effectively. Further, generally the construction of the cleaning device is simple and compact, thus allowing for an easy installation or easy exchange of parts.

[0073] Exemplary section 114 of Fig. 1 is shown in more detail in Fig. 2. This section shows in more detail

how loose solid particles may interact with the surface of a coated wire e.g. a diamond coated wire, thereby removing any scrap material or kerf from said diamond coated wire. In other words, as coated wire 150 moves through the loose solid particles 111 (in the direction indicated by the arrows), the loose solid particles 111 are agitated and rub against its surface, thereby removing kerf or scrap material 220 therefrom. The grits 210, which are attached to the surface of the coated wire, may also be sharpened during said cleaning process. Typically, a cleaning fluid 113 may assist the removal of kerf 220 and may provide further effects such as cooling or disinfection of the wire.

[0074] Fig. 3 shows a further embodiment of the cleaning device described herein. The cleaning device 300 shown in Fig. 3 includes a cleaning fluid supply system 112, which is movable with respect to the container 110 of the cleaning device 300. The double sided arrow 310 indicates a reciprocating movement of the cleaning fluid supply system 112. However, in further embodiments herein, the cleaning fluid supply system may move in any direction of a coordinate system (X, Y and Z) as shown in Fig. 3. In general, the moving cleaning fluid supply system 112 may ensure a homogenous distribution of cleaning fluid 113 throughout the container 110 of the cleaning device 300.

[0075] Cleaning device 300 may further optionally include a cover 118 with a moveable or displaceable opening 116. Such an opening in the cover 118 may continuously provide an equal sized opening 116 for the cleaning fluid 113 of the moving cleaning fluid supply system 112. Providing such a cover 118 with an opening 116 that may move parallel to the moveable cleaning fluid supply system 112 may prevent contamination of the inside of the container 110 by the environment surrounding said container.

[0076] Further, the cleaning device shown in Fig. 3 may include a voltage supply unit 320, which may electrically charge the loose solid particles 111 within the container 110 of the cleaning device 300. Generally, cleaning devices that provide such an electrical charge to the loose solid particles may require the use of an electrically conductive cleaning fluid or electrically non-conductive cleaning fluid depending on the type of material used for the loose solid particles.

[0077] Typically, the wire saw or wire saw arrangement employing such cleaning devices may include electrically insulated guiding rollers and further electrically insulated portions to avoid short circuits or prevent electrical hazards to maintenance personal. The containers of such cleaning devices may be made of a dielectric material or at least its outside may be covered with a dielectric material. In embodiments, at least the inside of the container may be made of an electrically conductive material whereas its outside may be made of an electrically non-conductive material.

[0078] Not limited to any one of the embodiments herein, the cleaning device may further include a mixing de-

vice for agitating or mixing the loose solid particles. In the cleaning device 300 of Fig. 3, the mixing device 370 may be positioned within the container 110 of the cleaning device 300. Optionally, the mixing device may be moveable with respect to the container 110. According to further embodiments herein, more than one mixing device may be used for agitating the loose solid particles within the container of the cleaning device.

[0079] The cleaning device 400 shown in Fig. 4 may include multiple cleaning fluid supply systems 112. The aforementioned multiple cleaning fluid supply systems may collectively be a single cleaning fluid supply system with separate nozzles that homogeneously distribute the cleaning fluid 113 in the container 110 of cleaning device 400. Optionally, the cleaning fluid supply system with multiple separate nozzles may also be configured such that it is moveable with respect to the container of a cleaning device.

[0080] In embodiments, the container 110 of the cleaning device 400 may include dividers 410 or dividing walls which separates container 110 into two or more separate compartments. In Fig. 4 three such compartments are shown 420, 430 and 440. Each compartment may include loose solid particles of a different size, i.e. with a different diameter. For instance the first compartment 420 may include loose solid particles with a larger diameter than the particles in the second compartment 430, which in its turn may include loose solid particles with a larger diameter than the loose solid particles in the third compartment 440. Such a graded or grouped arrangement of solid particle by size may improve the cleaning and sharpening effect of the cleaning device 400. Further, the loose solid particles in the respective compartments may be made of or coated by a different material.

[0081] In embodiments herein, each compartment may also include mixtures of loose solid particles with different sizes or the graded sequence of compartments from larger to smaller loose solid particles may be reversed or changed in that a compartment with a larger particle size may be followed by a compartment with a smaller particle size, which in its turn may then be followed by a compartment with again a larger particle size.

[0082] Further, the separate compartments 420, 430, 440 may include separate cleaning fluid supply systems 112. Each of these supply systems may provide a different cleaning fluid or a cleaning fluid that includes different additives. In the case that different supply systems are used, each may then also be a closed loop system, i.e. the cleaning fluid of one compartment may be isolated from the cleaning fluid in the other compartment(s).

[0083] Figs. 5 and 6 show an exemplary moveable cleaning device 500. The container 110 of cleaning device 500 may move parallel and in the same direction as the work piece 130 being pushed through the sawing area during a sawing process. In general, an actuator 630 may facilitate the movement of either, or both the container and the cleaning device. Typically, the work piece is moved against a wire, which is moving along its

own longitudinal axis at high speeds. As seen in Figs. 5 and 6, the work piece 130 is moving in a generally downward direction indicated by the arrow 610 with respect to the wire 150 (i.e. the work piece is moving along direction Y in the coordinate system shown in the Figs.). Similarly, the container of the cleaning device may also be moving in a downward direction with respect to the wire 150 indicated by arrow 620 (i.e. also along direction Y).

[0084] In general, the cleaning device 500 may move in a direction other than the longitudinal axial direction of the wire 150. This type of movement of the cleaning device ensures that fresh loose solid particles are always surrounding the coated wire, i.e. the cleaning and sharpening effect may be continuously maintained at an optimum level.

[0085] Further, the movement of a cleaning device may be described in terms of a coordinate system with coordinates X, Y, and Z. For instance, the longitudinal axis of the wire may be defined as the x-axis. Typically, in such a case, a cleaning device would not exclusively be moving in a direction parallel to the x-axis, even though, in embodiments herein such a movement may be possible depending on the configuration of the cleaning device. For instance, in embodiments where the container includes a mixing device for continuously mixing the loose solid particles within the container a movement of said cleaning device exclusively along the x-axis (as defined above) may be possible.

[0086] In general, the cleaning device may move in the Y and Z directions or any combination thereof with respect to the longitudinal axis of the wire being defined as the X direction (i.e. horizontally, vertically or both with respect to the longitudinal axis of the wire).

[0087] Typically, in embodiments herein, the container 110 of the cleaning device 100 may be arranged such that the earth's gravity causes the kerf removed from the cleaned wire to move towards the bottom of the container 110 from where it may be easily removed via an outlet (not shown in these Figs.). In yet further embodiments, a pump or suction system may be used for easily removing the used cleaning fluid and kerf from the container of a cleaning device irrespective of the earth's gravity (not shown in the Figs.).

[0088] Figs. 7 and 8 illustrate further embodiments of a cleaning device. In the exemplary cleaning device 700, the container 110 may be provided in the shape of a cylinder or tube filled with loose solid particles 111. The wire 150 may pass through the cylindrically-shaped container 110 in a longitudinal direction thereof. Not limited to this embodiment, the cylindrically-shaped container 110 may move along a circular path, such as the circular path 710 around the moving coated wire 150, thereby ensuring that fresh loose solid particles 111 may continuously be provided to rub against the surface of the wire 150.

[0089] In principal, any type of movement of the cleaning device such as a rotating or reciprocating movement is conceivable as long as a provision of fresh loose solid

particles is warranted. In other words, the cleaning device may move along a predetermined or random path with respect to a coated wire moving through the container of said cleaning device so as to continuously provide fresh loose solid particles to the surface of the coated wire.

[0090] Fig. 9 shows a schematic representation of a closed cleaning fluid loop 910 of a cleaning device according to embodiments herein. The cleaning device 100 may include an inlet 930, through which fresh cleaning fluid is provided to the inside of the cleaning device 100. Used cleaning fluid including any scrap material or kerf removed from a wire may leave the cleaning device via an outlet 940.

[0091] The cleaning fluid may then flow through a filtration device 920, which separates the kerf or scrap materials (e.g. silicon particles from a silicon ingot that has been cut by the wire in a sawing process) from the cleaning fluid. The removed kerf may be recycled and the material re-used to form new work pieces for further processing. This may reduce the overall production costs of, for instance, silicon wafers.

[0092] Generally, the filtration device may include one or more filters or centrifuges that enable the removal of the kerf from the cleaning fluid. Additives in the cleaning fluid may pass through the filtration device 920 without being filtered out. Since additives may be expensive, this enables an efficient re-use which may further reduce costs.

[0093] Further, the filtration device 920 may include one or more pumps 950 that facilitate the transportation of the cleaning fluid around the closed cleaning fluid loop 910. The pump(s) may also be positioned outside of the filtration device 920, e.g. at the inlet 930 and or outlet 940 of the cleaning device 100.

[0094] Fig. 10 shows a wire saw arrangement 1000 for cutting a work piece adapted for cleaning and sharpening the wire(s) of a wire saw according to embodiments herein. The wire saw arrangement 1000 includes four rollers 140 for guiding the wire 150. The exemplary wire saw arrangement 1000 includes two sawing areas for sawing two work pieces 130 simultaneously. Cleaning devices 100 may be positioned before and after the sawing areas such that the wire used for sawing apart the work pieces is cleaned before and after cutting the work pieces.

[0095] In the embodiment illustrated in Fig. 10, six cleaning devices may be included in the wire saw arrangement 1000. However, in further embodiments herein, a wire saw arrangement may include anywhere from one to eight or more cleaning devices in order to maintain the sawing wire(s) free of kerf for high precision sawing over long periods of time. For instance, in embodiments two cleaning devices may be utilized, one arranged before the sawing area and the other after the sawing area. In further embodiments, the number of cleaning devices employed may be equal to the number of work pieces that are being cut at the same time.

[0096] In further embodiments herein, at least one cleaning device may be arranged external to a cutting

room. Thus, one or more wires may be cleaned and sharpened before entering the cutting room, i.e. between the cutting room and wire supply spool. The wire(s) may be cleaned and sharpened by one or more cleaning devices after exiting the cutting room, i.e. between the cutting room and the wire take-up spool.

[0097] As mentioned previously, the wire(s) may be processed, i.e. cleaned and sharpened separately from the cutting process. In such cases, for example, the wire(s) may be processed by running them through one or more cleaning devices arranged between the supply spool and take-up spool directly without them passing through the cutting room.

[0098] According to further embodiments herein, a method for cleaning and sharpening a coated wire may include moving a coated wire through loose solid particles within a container of a cleaning device.

[0099] Typically, during the cleaning and sharpening process, the coated wire may continuously be moving in its longitudinal axial direction through the loose solid particles within the container. However, in yet further embodiments, the coated wire may be continuously moving through the loose solid particles in a direction other than its longitudinal axial direction.

[0100] In yet further embodiments, the method of cleaning and sharpening the coated wire may include sawing one or more work pieces. Typically, during the sawing process, the coated wire may continuously move through the loose solid particles of at least one cleaning device. Optionally, the wire may move through the loose solid particles of two, four, five or more cleaning devices. Further, in embodiments herein, the wire may move through loose solid particles of a cleaning device at times other than during the sawing of a work piece.

[0101] Generally, in embodiments herein, the method may include moving the cleaning device or container of the cleaning device in a direction other than the longitudinal axial direction of the wire, which is moving through the loose solid particles within the container. For instance, the cleaning device or container of the cleaning device may be moved in a continuous reciprocating manner such that fresh loose solid particles are continuously provided to the surface of the coated wire. In further embodiments, the cleaning device or container thereof may continuously move in a circular or elliptical motion along a circular or elliptical path.

[0102] In yet further embodiments herein, the method for cleaning a wire may further include adding cleaning fluid to the container of a cleaning device filled with loose solid particles via a cleaning fluid supply system and possibly filtering the used cleaning fluid collected from said container of the cleaning device. Optionally, in the above-mentioned cleaning method, the cleaning fluid supply system may be moved with respect to the container of the cleaning device. Moving the cleaning fluid supply system may include periodically or continuously moving it for a pre-determined amount of time.

[0103] Optionally, in embodiments herein, the method

for cleaning a wire may include electrically or magnetically charging the loose solid particles. In yet further embodiments, the above cleaning method may include mixing or agitating the loose solid particles within the container of a cleaning device by the use of, for example, a mixing device.

[0104] The above-described systems and methods facilitate a cleaning and sharpening of a wire, generally used in wire saws. The method enables a continuous high precision sawing of a work piece and may generally prevent damages to the work piece by, for instance, inaccurate positioning of the sawing wire(s). Inaccurate positioning of sawing wire(s) may occur if the groove(s) of a guiding roller are clogged by kerf or scrap particles, which in the worst case may lead to the wire(s) jumping out of the grooves thereby causing considerable inaccuracies in the sawing process or even the destruction of a work piece. Due to the additional recycling of the scrap materials or kerf removed from the surface of the wire(s), costs per work piece may be reduced. Additionally, due to the simple construction of the cleaning device maintenance, installation or replacement of parts due to normal wear through use of said cleaning device may be performed easily. Thus, in general the operating costs and wire consumption per work piece may be reduced by using a cleaning device as outlined herein.

[0105] Exemplary embodiments of systems and methods for a cleaning device including a container filled with loose solid particles are described above in detail. The systems and methods are not limited to the specific embodiments described herein, but rather, components of the systems and steps of the methods may be utilized independently and separately from other components and steps described herein. For example, the cleaning device may be used for cleaning a wire separately from a wire saw or, one or more cleaning devices may be arranged in a wire saw or wire saw arrangement. Hence, the exemplary cleaning device described herein can be implemented and utilized in connection with many different sawing systems.

[0106] Although specific features of various embodiments of the invention may be shown in some drawings and not in others, this is for convenience only. In accordance with the principles of the invention, any feature of a drawing may be referenced or claimed in combination with any feature of any other drawing.

[0107] This written description uses examples to disclose the invention, including the best mode, and also to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. While various specific embodiments have been disclosed in the foregoing, those skilled in the art will recognize that the spirit and scope of the claims allows for equally effective modifications. Especially, mutually non-exclusive features of the embodiments described above may be combined with each other. The patentable scope of the invention is defined by the claims, and may include other examples

that occur to those skilled in the art. Such other examples are intended to be within the scope of the claims if they have structural elements that do not differ from the literal language of the claims, or if they include equivalent structural elements with insubstantial differences from the literal language of the claims.

Claims

1. A device (100, 300, 400, 500, 700) for cleaning a wire (150) of a wire saw adapted for sawing a semiconductor work piece (130), the device comprising:

a container (110) including a first opening (115), wherein the container (110) is filled with loose solid particles (111), and adapted such that the wire (150) can pass through the first opening (115) and through the loose solid particles (111).

2. The device (100, 300, 400, 500, 700) for cleaning a wire (150) of a wire saw according to claim 1, wherein the loose solid particles (111) are particles chosen from the following list of materials: sand, ceramic, silicon, metal, plastic or any combinations thereof.

3. The device (100, 300, 400, 500, 700) for cleaning a wire (150) of a wire saw according to any of the preceding claims, wherein the loose solid particles (111) have a diameter from 1 μm to 10 mm, typically from 10 μm to 8 mm or typically from 50 μm to 6 mm.

4. The device (100, 300, 400, 500, 700) for cleaning a wire (150) of a wire saw according to any of the preceding claims, further comprising a cleaning fluid supply system (112).

5. The device (100, 300, 400, 500, 700) for cleaning a wire (150) of a wire saw according to claim 4, wherein the container (110) comprises a second opening (116) adapted for allowing cleaning fluid (113) from the cleaning fluid supply system (112) to enter into the container (110).

6. The device (100, 300, 400, 500, 700) for cleaning a wire (150) of a wire saw according to any of the preceding claims, further comprising one or more of a device (320) for electrically and magnetically charging the loose solid particles (111).

7. The device (100, 300, 400, 500, 700) for cleaning a wire (150) of a wire saw according to any of the preceding claims, wherein the container (110) is moveable.

8. A wire saw arrangement (1000) for cutting a semiconductor work piece (130) comprising:

a wire saw including a wire (150) adapted for sawing a semiconductor work piece (130), and a device (100, 300, 400, 500, 700) for cleaning the wire (150) of the wire saw according to any of the preceding claims.

9. The wire saw arrangement (1000) for cutting a semiconductor work piece according to claim 8, wherein the wire (150) adapted for sawing a semiconductor work piece (130) is a diamond wire.

10. A use of a device (100, 300, 400, 500, 700) for cleaning a wire (150) of a wire saw according to any of claims 1 to 7 or a use of a wire saw arrangement (1000) for cutting a semiconductor work piece (130) according to any of claims 8 to 9 for cleaning and sharpening a wire (150) of a wire saw by moving the wire (150) through the loose solid particles (111) within the container (110).

11. A method for cleaning a wire (150) adapted for cutting a semiconductor work piece (130), the method comprising:

moving the wire (150) through the loose solid particles (111) within the container (110) according to claim 1.

12. The method for cleaning a wire (150) according to claim 11, further comprising cutting a work piece (130) with the wire (150).

13. The method for cleaning a wire (150) according to any of the preceding claims, wherein moving the wire (150) through the loose solid particles (111) within the container (110) comprises any one or more of the elements from the following list: continuously moving the wire (150) in its axial direction through the loose solid particles (111) and continuously moving the wire (150) through the loose solid particles (111) in a direction other than in its axial direction.

14. The method according to any of the preceding claims, further comprising continuously moving the container (110) with respect to the wire (150), in particular, continuously moving the container (110) in a direction other than in the axial direction of the wire (150) within the container (110).

15. The method for cleaning a wire (150) according to any of the preceding claims, further comprising any one or more of the elements from the following list:

adding a cleaning liquid (113) to the loose solid particles (111), electrically charging the loose solid particles (111) and magnetically charging the loose solid particles (111).

Fig. 1

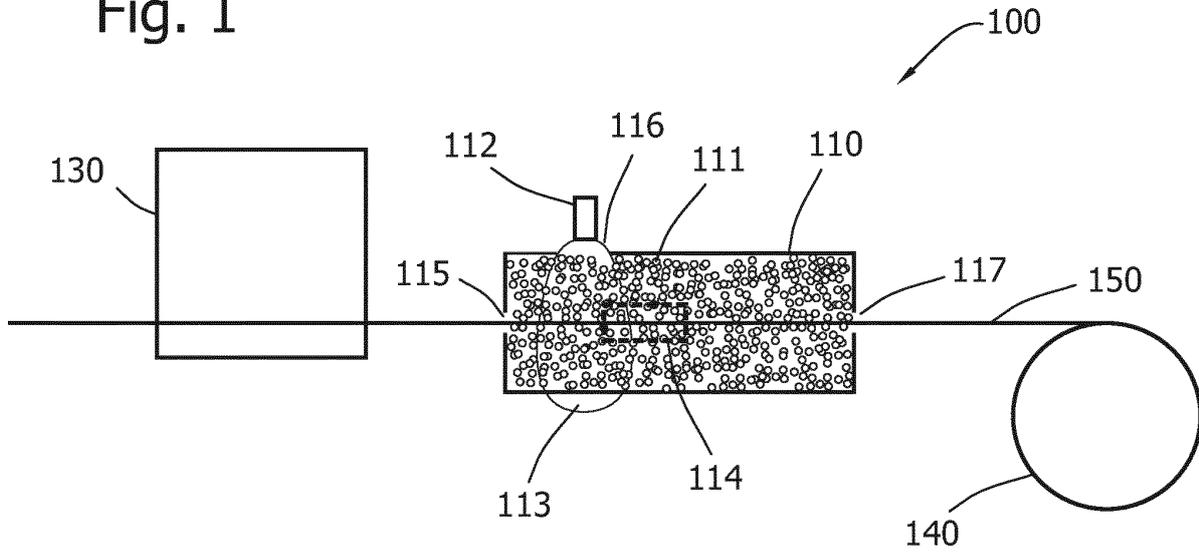
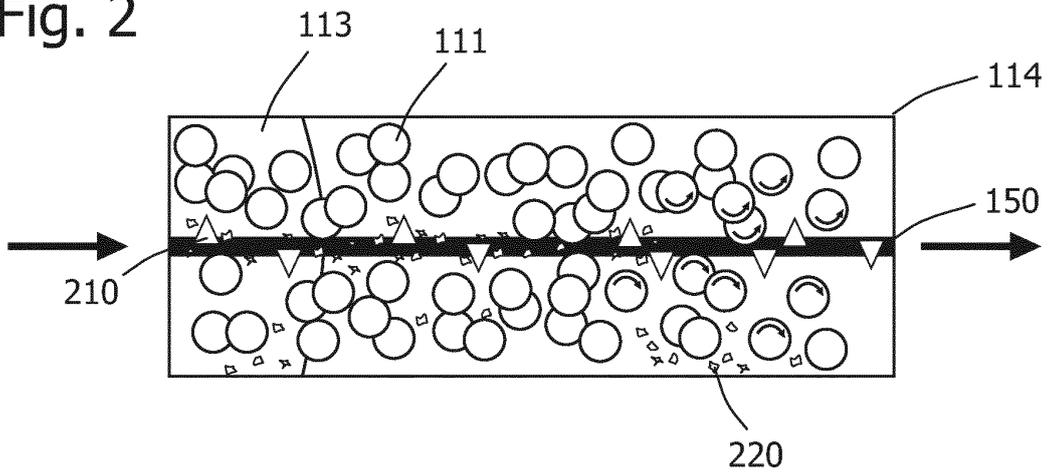
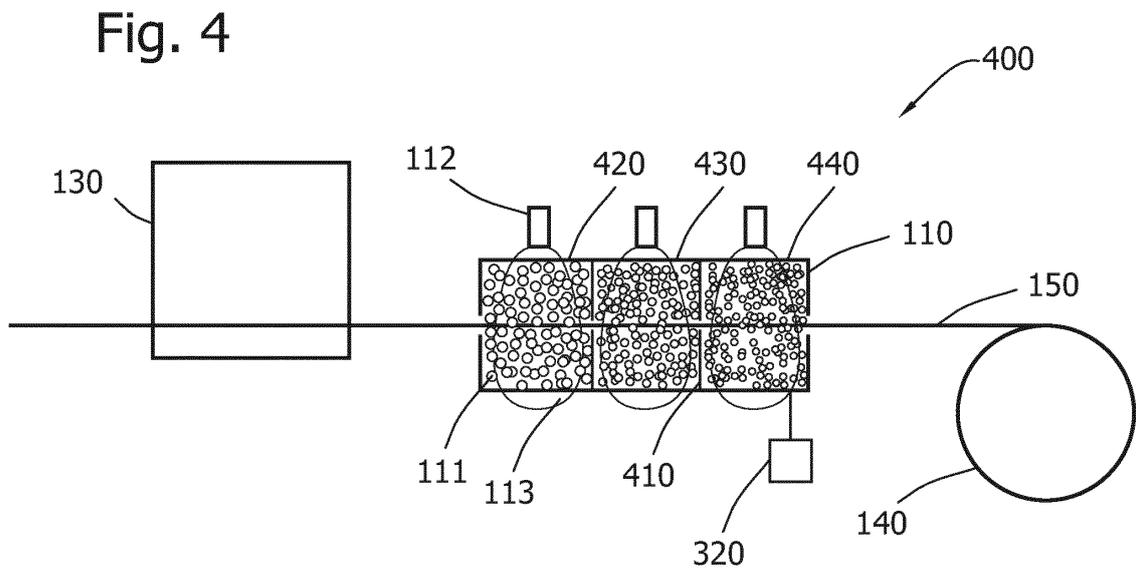
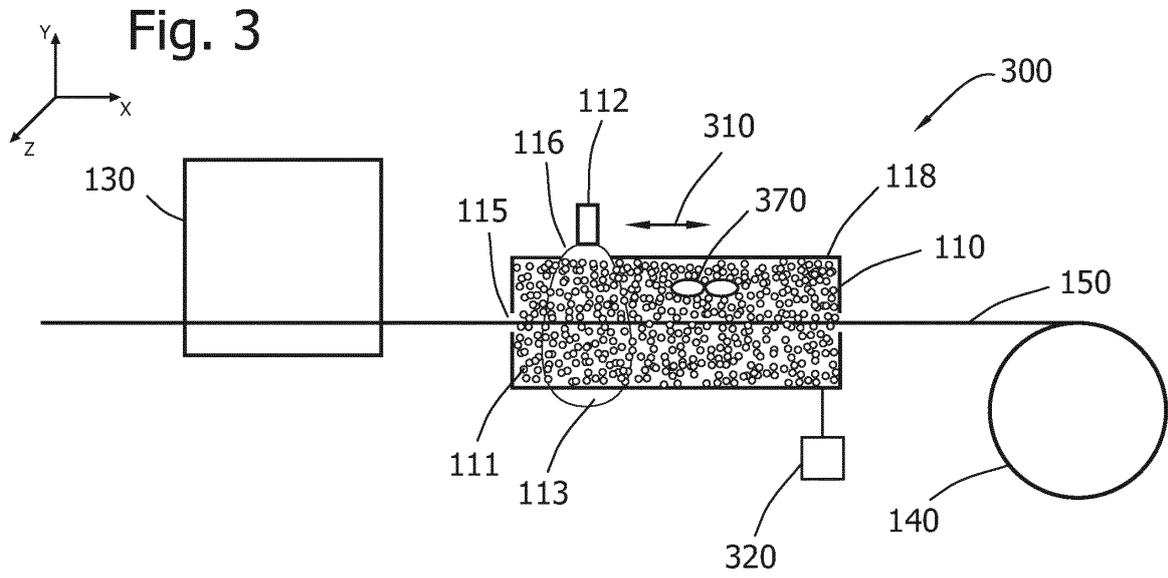
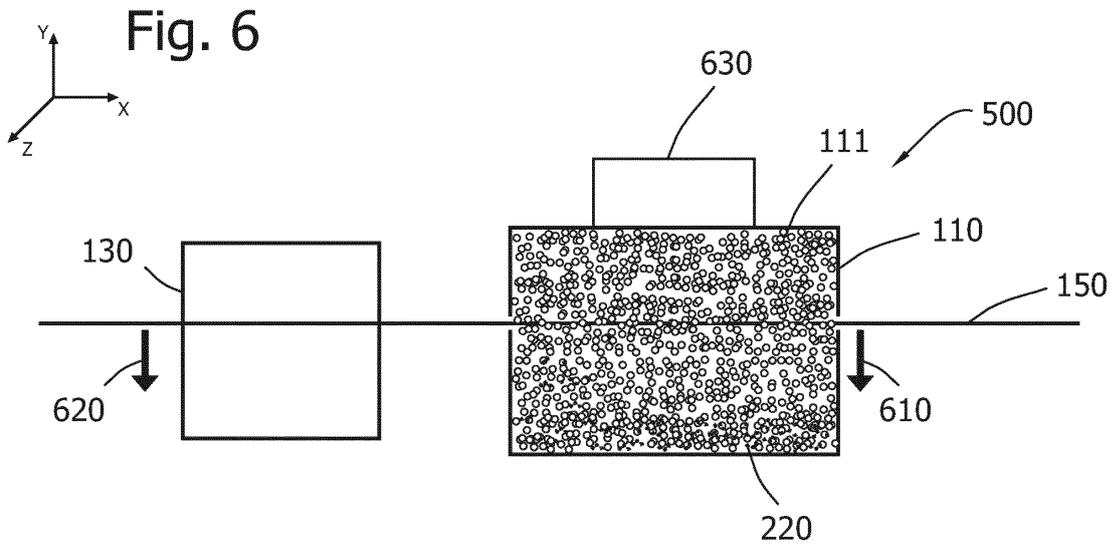
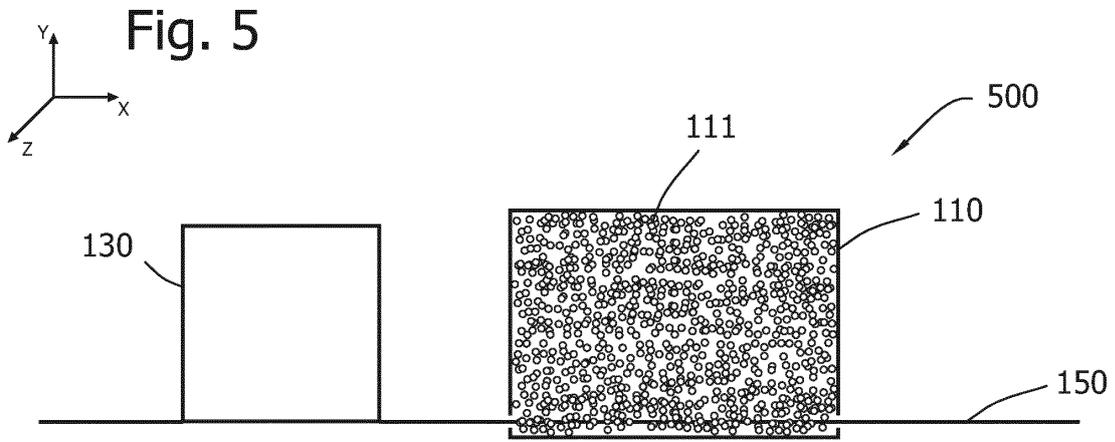


Fig. 2







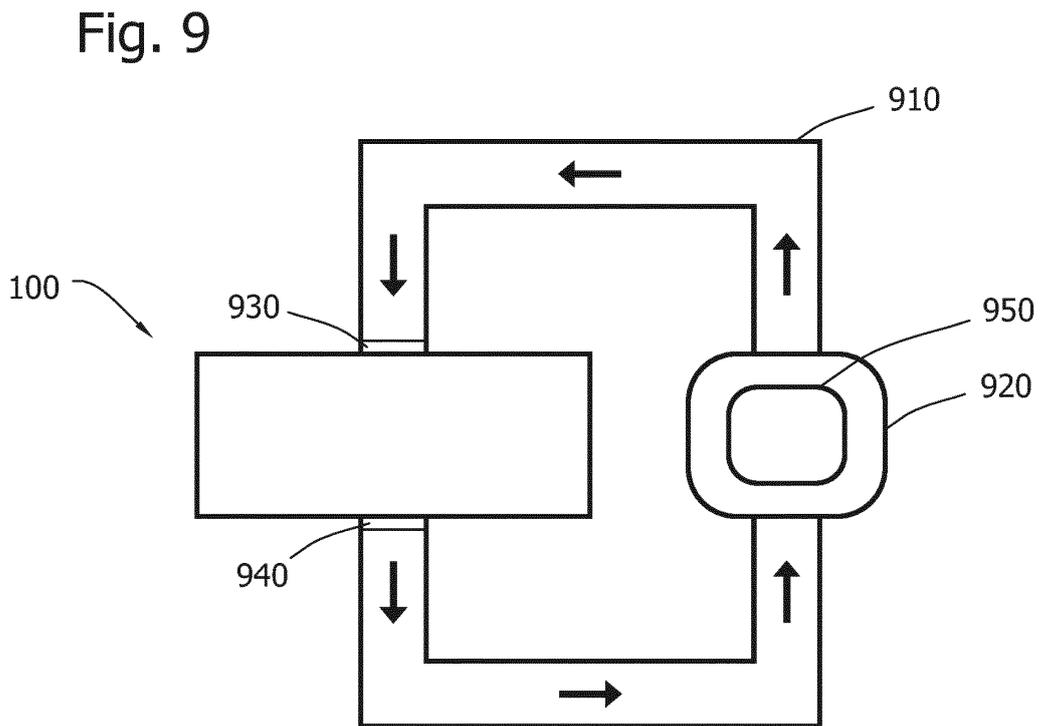
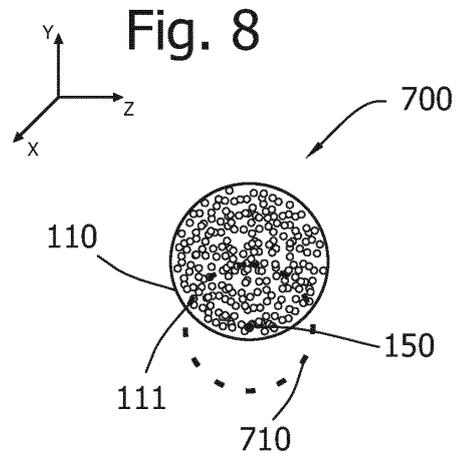
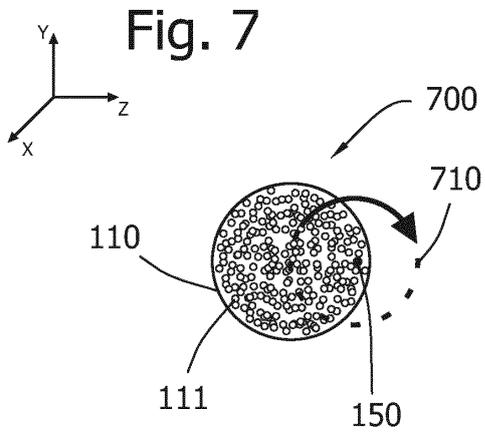
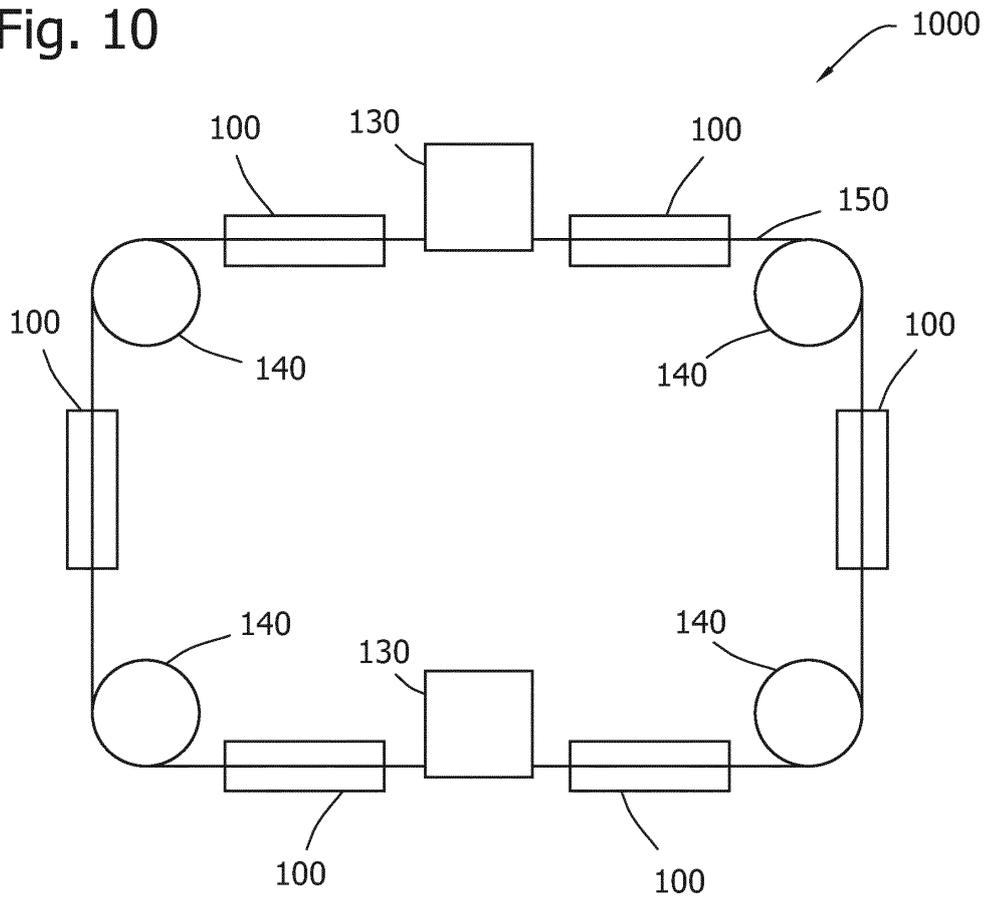


Fig. 10





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