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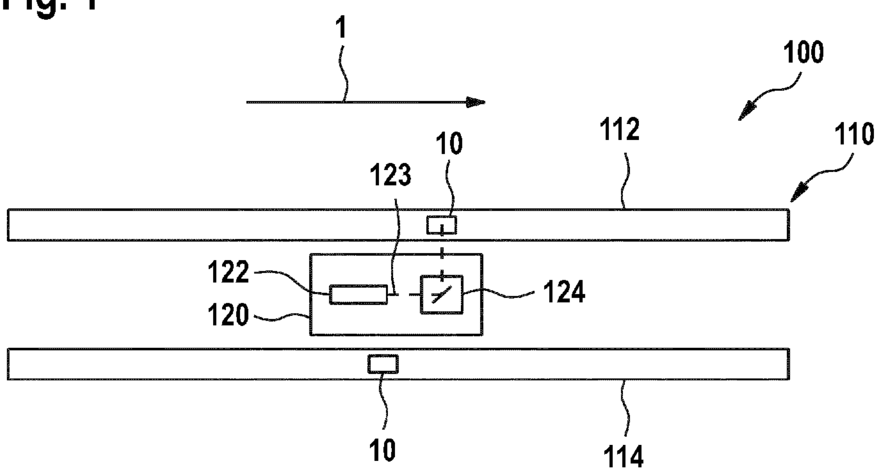
Fig. 1



(57) Abstract: The present disclosure provides an apparatus (100) for processing of substrates (10) used in the manufacture of solar cells. The apparatus (100) includes a transport arrangement (110) having at least a first transport line (112) and a second transport line (114) configured for transportation of the substrates (10), and a substrate processing arrangement (120) at the transport arrangement (110). The substrate processing arrangement (120) includes a laser device (122) configured to provide a laser beam for processing of the substrates (10), and a deflection device (124) having a first operational state and a second operational state, wherein the deflection device (124) is configured to direct the laser beam towards the first transport line (112) in the first operational state and towards the second transport line (114) in the second operational state.

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APPARATUS FOR PROCESSING OF SUBSTRATES USED IN THE MANUFACTURE OF SOLAR CELLS, SYSTEM FOR THE MANUFACTURE OF SOLAR CELLS, AND METHOD FOR PROCESSING OF SUBSTRATES USED IN THE MANUFACTURE OF SOLAR CELLS

FIELD

[0001] Embodiments of the present disclosure relate to an apparatus for processing of substrates used in the manufacture of solar cells, a system for the manufacture of solar cells, and a method for processing of substrates used in the manufacture of solar cells. Embodiments of the present disclosure particularly relate to an apparatus, a system and a method for the manufacture of shingled solar cells.

BACKGROUND

[0002] Solar cells are photovoltaic (PV) devices that convert sunlight directly into electrical power. An apparatus for processing of solar cells may have a line configuration with multiple transport lines, wherein a plurality of process stations can be provided along the transport lines. In order to increase a throughput of the apparatus, a plurality of transport lines can be arranged in parallel, each transport line having respective process stations. Such an apparatus consumes considerable space for installation. Further, costs are generated, e.g., in regard to operation and maintenance.

[0003] In view of the above, new apparatuses for processing of substrates used in the manufacture of solar cells, systems for the manufacture of solar cells, and methods for processing of substrates used in the manufacture of solar cells, that overcome at least some of the problems in the art are beneficial. The present disclosure particularly aims at providing an apparatus, system and method that can provide a high throughput and/or reduce a complexity.

SUMMARY

[0004] In light of the above, an apparatus for processing of substrates used in the manufacture of solar cells, a system for the manufacture of solar cells, and a method for processing of substrates used in the manufacture of solar cells are provided. Further aspects, benefits, and features of the present disclosure are apparent from the claims, the description, and the accompanying drawings.

[0005] According to an aspect of the present disclosure, an apparatus for processing of substrates used in the manufacture of solar cells is provided. The apparatus includes a transport arrangement having at least a first transport line and a second transport line configured for transportation of the substrates, and a substrate processing arrangement at the transport arrangement. The substrate processing arrangement includes a laser device configured to provide a laser beam for processing of the substrates, and a deflection device having a first operational state and a second operational state, wherein the deflection device is configured to direct the laser beam towards the first transport line in the first operational state and towards the second transport line in the second operational state.

[0006] According to a further aspect of the present disclosure, a system for the manufacture of solar cells is provided. The system includes one or more process stations, and the apparatus for processing of substrates used in the manufacture of solar cells according to the embodiments described herein. At least one process station of the one or more process stations includes the substrate processing arrangement.

[0007] According to another aspect of the present disclosure, a method for processing of substrates used in the manufacture of solar cells is provided. The method includes directing a laser beam towards a first transport line for substrate processing using a deflection device having a first operational state, and changing the first operational state of the deflection device into a second operational state to direct the laser beam towards a second transport line for substrate processing.

[0008] Embodiments are also directed at apparatuses for carrying out the disclosed method and include apparatus parts for performing each described method aspect. These method aspects 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, embodiments according to the disclosure are also directed at methods for operating the described apparatus. The methods for operating the described apparatus include method aspects for carrying out every function of the apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments. The accompanying drawings relate to embodiments of the disclosure and are described in the following:

FIG. 1	shows a schematic top view of an apparatus for the processing of substrates used in the manufacture of solar cells according to embodiments described herein;
FIG. 2A and B	show schematic views illustrating the first operational state and the second operational state of the apparatus for the processing of substrates used in the manufacture of solar cells according to embodiments described herein;
FIG. 3	shows a schematic top view of a system for the manufacture of solar cells according to embodiments described herein;
FIG. 4	shows a flow chart of a method for the processing of substrates used in the manufacture of solar cells according to embodiments described herein; and
FIG. 5	shows a schematic view of a process sequence according to embodiments described herein.

DETAILED DESCRIPTION OF EMBODIMENTS

[0010] Reference will now be made in detail to the various embodiments of the disclosure, one or more examples of which are illustrated in the figures. Within the following description of the drawings, the same reference numbers refer to same components. Generally, only the differences with respect to individual embodiments are described. Each example is provided by way of explanation of the disclosure and is not meant as a limitation of the disclosure. Further, features illustrated or described as part of one embodiment can be used on or in conjunction with other embodiments to yield yet a further embodiment. It is intended that the description includes such modifications and variations.

[0011] In an apparatus for processing of solar cells, two transport lines can be provided for parallel processing of a plurality of solar cells. A plurality of process stations can be provided along each of the transport lines. Each process station can be provided twice, i.e., one for each of the two transport lines. Providing a respective process station for each of the transport lines increases a footprint of the apparatus and consumes considerable space for installation. Further, costs are generated, e.g., in regard to operation and maintenance, since each of the process stations is present twice.

[0012] The present disclosure uses a laser device for substrate processing, such as laser scribing, together with a deflection device that can deflect a laser beam provided by the laser device. The deflection device can direct the laser beam to either the first transport line or the second transport line, depending on an operational state of the deflection device. Switching the operational state can redirect the laser beam from the first transport line to the second transport line, or vice versa. The same laser device can be used for processing of substrates positioned on both the first transport line and the second transport line. A complexity and/or a footprint of the apparatus can be reduced. A duty cycle of the laser device can be increased.

[0013] FIG. 1 shows a schematic top view of an apparatus 100 for processing of substrates 10 used in the manufacture of solar cells according to embodiments described herein. The substrates 10 can be wafers, such as silicon wafers.

[0014] The apparatus 100 includes a transport arrangement 110 having at least a first transport line 112 and a second transport line 114 configured for transportation of the substrates 10, and a substrate processing arrangement 120 at the transport arrangement 110. The substrate processing arrangement 120 includes a laser device 122 configured to provide a laser beam 123 for processing of the substrates 10, and a deflection device 124 having a first operational state and a second operational state. The deflection device 124 is configured to direct the laser beam 123 towards the first transport line 112 in the first operational state and towards the second transport line 114 in the second operational state.

[0015] The apparatus 100 can direct a same laser beam provided by one single laser device towards both the first transport line 112 and the second transport line 114 e.g. to alternately process substrates transported on the first transport line 112 and the second transport line 114. In particular, instead of using two laser devices working separately on each transport line, the present disclosure uses a single laser device and delivers the laser beam 123 to one side and the other side by switching the operational state of the deflection device 124. In some implementations, the switching of the operational state can include a switching of a position or orientation of a mirror. A duty cycle of the laser device 122 can be increased. As an example, during the movement of a substrate on one transport line the laser device can process a substrate on the other transport line.

[0016] According to some embodiments, the first transport line 112 and the second transport line 114 can extend next to each other and/or substantially parallel to each other. The substrate processing arrangement 120 can be provided between the first transport line 112 and the second transport line 114. In some embodiments, the substrate processing arrangement 120 can be provided above and/or can extend over at least a part of the first transport line 112 and the second transport line 114.

[0017] The transport arrangement 110 can be configured for transportation of the substrates e.g. along an essentially linear path. In particular, the first transport line 112 can provide a first transport direction and the second transport line 114 can provide a second transport direction (in the following referred to as “the transport direction 1”). The first transport direction and the second transport direction can be substantially parallel to each other. The transport directions provided by the first transport line 112 and the second transport line 114 can be, or correspond to, the transport direction 1. The transport direction 1 can be a substantially horizontal direction.

[0018] The term “substantially parallel” relates to a substantially parallel orientation e.g. of the transport lines and/or the transport directions, wherein a deviation of a few degrees, e.g. up to 1° or even up to 5°, from an exact parallel orientation is still considered as “substantially parallel”. The deviation could be caused by, for example, manufacturing tolerances of the apparatus 100.

[0019] The term “horizontal direction” is understood to distinguish over “vertical direction”. That is, the “horizontal direction” relates to a substantially horizontal direction, wherein a deviation of a few degrees, e.g. up to 5° or even up to 10°, from an exact horizontal direction is still considered as a “ substantially horizontal direction”. The vertical direction can be substantially parallel to the force of gravity.

[0020] According to some embodiments, the first transport line 112 and/or the second transport line 114 can be conveyors, such as belt conveyors. The belt conveyor can include a roller rotatable around a rotational axis and one or more belts provided on the roller. The one or more belts are configured for supporting the substrates 10 during transportation of the substrates 10 in the transport direction 1, which can be the substantially horizontal direction.

[0021] According to further embodiments, the first transport line 112 and/or the second transport line 114 includes one or more guide rails and shuttles movable along the one or more guide rails. The shuttles are configured for supporting and transporting the substrates 10 along the guide rails.

[0022] According to some embodiments, which can be combined with other embodiments described herein, the apparatus 100 includes a controller configured to change or switch the operational state of the deflection device 124. In particular, the controller can be configured to change the first operational state into the second operational state and to change the second operational state into the first operational state. The switching of the operational states is further explained with respect to FIGs. 2A and B.

[0023] In some implementations, the first transport line 112 and the substrate(s) positioned thereon are essentially stationary when the laser beam 123 is directed towards the first transport line 112 for substrate processing. Likewise, the second transport line 114 and the substrate(s) positioned thereon can be essentially stationary when the laser beam 123 is directed towards the second transport line 114 for substrate processing. Substrate processing, such as laser scribing, can be performed with the substrate(s) being stationary, i.e., not moving. A quality, such as a precision, of the substrate processing can be improved. As an example, an alignment of the features generated on the substrate by the laser beam 123 can be improved. However, the present disclosure is not limited thereto and the substrate processing can be performed while the respective transport line and the substrate(s) positioned thereon are moving.

[0024] Additionally or alternatively, the first transport line 112 is non-stationary, i.e., moving/transporting substrates in the transport direction 1, when the laser beam 123 is directed towards the second transport line 114 for substrate processing. Likewise, the second transport line 114 can be non-stationary, i.e., moving/transporting substrates in the transport direction 1, when the laser beam 123 is directed towards the first transport line 112 for substrate processing. A duty cycle of the laser device 122 can be increased. In particular, during a movement of a substrate on one transport line, the laser device 122 can process a substrate on the other transport line.

[0025] In some implementations, the apparatus 100 is configured to operate the first transport line 112 and the second transport line 114 independently from each other. As an example, as explained above, the first transport line 112 and the second transport line 114 can be operated asynchronously and/or alternately e.g. such that during a movement of a substrate on one transport line, the laser device 122 can process a substrate on the other (e.g. stationary) transport line.

[0026] According to some embodiments, which can be combined with other embodiments described herein, the laser device 122 is configured for laser scribing. Laser scribing can be used to structure a surface of the substrates 10. As an example, microchannels can be formed to increase an efficiency of the solar cells. Further, laser scribing can be used for local ablation of material provided on the substrate 10, such as a local ablation of a dielectric layer. In further embodiments, the laser device 122 can be configured to cut or divide a substrate into two or more pieces e.g. for the manufacture of shingled solar cells.

[0027] In some implementations, the laser device 122 can be configured to provide the laser beam 123 having wavelengths between 200 nm and 1500 nm, and specifically between 300 nm and 1100 nm. As an example, the laser device 122 can be configured to provide the laser beam 123 having a wavelength of about 355 nm, about 532 nm, and/or about 1064 nm. A width or diameter of the laser beam 123 can be in a range between 10 μm and 500 μm, specifically between 10 μm and 100 μm, and more specifically between 30 μm and 70 μm. A power provided by the laser device 122 can be in a range between 10 W and 500 W, and specifically in a range between 50 W and 200 W, such as about 50 W, about 100 W, or about 200 W.

[0028] FIGs. 2A and B show schematic views illustrating the first operational state and the second operational state of the apparatus for processing of substrates used in the manufacture of solar cells according to embodiments described herein.

[0029] According to some embodiments, which can be combined with other embodiments described herein, the deflection device 124 can be configured to switch between the first operational state and the second operational state. As an example, the apparatus, and particularly deflection device 124, can be configured to alternately direct the laser beam 123 towards the first transport line 112 and the second transport line 114 for substrate processing. According to some embodiments, the deflection device 124 can be configured to switch between the first operational state and the second operational state with a frequency between 0.1 Hz and 100 Hz, specifically with a frequency between 0.1 Hz and 10 Hz, and more specifically with a frequency between 1 Hz and 8 Hz. The frequency can be selected based on the time for substrate processing of an individual substrate and the time for switching the operational state. As an example, if the time for the processing of an individual substrate is 0.8 s and the time for switching the operational state (beam switching) is 0.2 s, the total time can be at least 1 s and the resulting frequency is at least 1 Hz.

[0030] In some implementations, the deflection device 124 can provide a pivot point 125 (or pivot axis) for the laser beam 123. The laser device (not shown) can be configured to direct the laser beam 123 onto the pivot point 125, wherein the laser beam 123 is deflected at the pivot point 125 towards the first transport line 112 in the first operational state and towards the second transport line 114 in the second operational state. The pivot point 125 can be provided between the first transport line 112 and the second transport line 114.

[0031] According to some embodiments, the laser beam 123 can be non-perpendicular with respect to the substrate, e.g., a substrate surface to be processed. As an example, an incident angle of the laser beam 123 with respect to a substrate normal or a surface normal 11 can be larger than 0°. In particular, the incident angle can be in a range between 1° and 60, and more specifically in a range between 10° and 45°.

[0032] According to some embodiments, which can be combined with other embodiments described herein, the deflection device 124 is configured to be moveable at least between a first orientation providing the first operational state and a second orientation providing the second operational state. The deflection device 124 can be configured to direct the laser beam 123 towards the first transport line 112 in the first orientation and towards the second transport line 114 in the second orientation. In some implementations, the deflection device 124 is rotatable around a rotational axis at least between the first orientation and the second orientation. As an example, the rotational axis can be substantially parallel to, or coincide with, the pivot axis. In particular, the rotational axis can pass through the pivot point 125. The rotational axis can be a substantially horizontal axis.

[0033] According to some embodiments, which can be combined with further embodiments described herein, the deflection device 124 includes one or more mirrors, such as rotatable mirrors. As an example, the one or more rotatable mirrors can be rotatable around the rotational axis at least between the first orientation and the second orientation to deflect the laser beam 123 towards the first transport line 112 and the second transport line 114, respectively.

[0034] Although a deflection device is described that is movable in order to change the operational state, the present disclosure is not limited thereto and other deflection devices suitable for redirecting the laser beam can be used, such as devices switchable between a reflecting state and a transmitting state.

[0035] According to some embodiments, which can be combined with other embodiments described herein, the deflection device 124 is configured to keep the laser beam essentially stationary during at least a part the substrate processing of an individual substrate, and particularly during essentially the entire substrate processing of the individual substrate. In some implementations, the deflection device 124 can be configured to move the laser beam during at least a part of the substrate processing of the individual substrate, such as during essentially the entire substrate processing of the individual substrate, e.g. by a rotation around the pivot axis and/or the rotational axis.

[0036] The term “operational state” is to be understood in the sense that the laser beam 123 is directed towards the first transport line 112 or the second transport line 114, irrespective of whether or not the laser beam 123 is stationary or moving during the processing of an individual substrate. As an example, the deflection device 124, such as the rotatable mirror, can rotate around the rotational axis in the respective operational states during processing of an individual substrate e.g. to form scribing lines on the substrate.

[0037] In some implementations, the apparatus of the present disclosure, and particularly the deflection device 124, can be configured for spot processing, line processing, and a combination thereof. For spot processing, the deflection device 124 can keep the laser beam 123 essentially stationary during the substrate processing in order to locally process the substrate. As an example, local regions of a material can be removed or ablated from the substrate. For line processing, the deflection device 124 can move the laser beam 123, e.g., by a rotation around the pivot axis and/or the rotational axis, over the substrate surface. As an example, line structures can be created on the substrate surface. In a combined spot and line processing, a plurality of local spots can be provided along a line on the substrate. In some implementations, a plurality of lines can be provided, such as a plurality of lines that extend substantially parallel to each other.

[0038] FIG. 3 shows a schematic top view of a system 300 for the manufacture of solar cells according to embodiments described herein.

[0039] The system 300 includes one or more process stations and the apparatus for the processing of substrates used in the manufacture of solar cells according to the embodiments described herein. At least one process station of the one or more process stations, such as a laser scribing station, includes the substrate processing arrangement of the apparatus.

[0040] In some implementations, the one or more process stations are selected from the group consisting of a loading station, an inspection station such as an optical inspection station, an alignment station, the laser scribing station, a printing station, a drying station, a buffer station, an electrical testing station, the sorting station, an unloading station, and any combination thereof.

[0041] As an example, the system 300 can include a first process station 302, a second process station 304, and a third process station 306 at the first transport line. The first process station 302, the second process station 304, and the third process station 306 can be sequentially arranged along the first transport line in the transport direction, such as the first transport direction. As an example, the first transport line can at least partially extend through the first process station 302, the second process station 304, and/or the third process station 306.

[0042] The system 300 can further include another first process station 302', another second process station 304', and another third process station 306' at the second transport line. The other first process station 302', the other second process station 304', and the other third process station 306' can be sequentially arranged along the second transport line in the transport direction, such as the second transport direction. The second transport line can at least partially extend through the other first process station 302', the other second process station 304', and/or the other third process station 306'.

[0043] The first transport line and the second transport line can have similar or identical process stations. As an example, the first process station 302 and the other first process station 302' can be configured similarly or identically. Likewise, the second process station 304 and the other second process station 304' can be configured similarly or identically, and the third process station 306 and the other third process station 306' can be configured similarly or identically.

[0044] According to some embodiments, the substrate processing arrangement 320 having the laser device 322 and the deflection device 324 can be allocated to two process stations, such as the second process station 304 and the other second process station 304' at the first transport line and the second transport line, respectively. In particular, the substrate processing arrangement 320 can be configured for processing, such as laser scribing, of substrates in each of the two process stations. The two process stations can be provided as separate process stations, or can be integrated into one single process station extending across the first transport line and the second transport line.

[0045] In some embodiments, the substrate processing arrangement 320 can be configured for guiding or deflecting the laser beam 323 towards the second process station 304 for the processing of substrates on the first transport line and for guiding or deflecting the laser beam 323 to the other second process station 304' for the processing of substrates on the second transport line. For switching between the processing of substrates on the first transport line and the processing of substrates on the second transport line of the deflection device 324, such as a rotatable mirror, can be rotated around the rotational axis 325. The first process station 302 and the other first process station 302' can be alignment stations for aligning the substrates before the substrate processing. A precision of the laser processing, such as the laser scribing, can be improved. As an example, patterns formed by the laser beam 323 can be aligned with respect to the substrate.

[0046] According to some embodiments, which can be combined with other embodiments described herein, the substrate processing arrangement 320 can include a first optical path configured for guiding the laser beam 323 from the deflection device 324 to the first transport line for substrate processing and a second optical path configured for guiding the laser beam 323 from the deflection device 324 to the second transport line for substrate processing. The first optical path can include one or more first auxiliary deflection devices 326 for deflecting and guiding the laser beam 323 towards the first transport line. Likewise, the second optical path can include one or more second auxiliary deflection devices 326' for deflecting and guiding the laser beam 323 towards the second transport line.

[0047] In some implementations, the system 300 includes one or more process stations upstream of the substrate processing arrangement 320, such as the first process station 302 and the other first process station 302', and one or more process stations downstream of the substrate processing arrangement 320, such as the third process station 306 and the other third process station 306'. The terms "upstream" and "downstream" can be defined with respect to the transport direction provided by the first transport line and the second transport line.

[0048] As an example, the one or more process stations upstream of the substrate processing arrangement 320 can include a loading station and an inspection station, such as an optical inspection station or automated optical inspection (AOI) station. In some implementations, the optical inspection station can be the AOI station configured to perform an optical inspection of the substrates. For example, the inspection station can include one or more cameras, such as high-resolution cameras, configured to obtain images of the solar cells for optical inspection. The inspection station can be configured for inspecting at least one of a positioning of conductive lines of the solar cells, a printing quality of the conductive lines, a geometry of the conductive lines, a structural condition of the substrates including, but not limited to, cracks or micro cracks of the substrates, and a color of the substrates. According to some embodiments, the inspection station can be configured to detect an electroluminescence and/or photoluminescence for optical inspection of the substrates to be processed by the substrate processing arrangement 320.

[0049] The one or more process stations downstream of the substrate processing arrangement 320 can include a printing station. The printing station can be configured for printing, such as screen printing, of conductive patterns on the substrates used in the manufacture of the solar cells. The conductive patterns can be selected from the group consisting of fingers, busbars, and any combinations thereof. As an example, the printing station can be configured for double-printing.

[0050] A drying station can be provided after the printing station. A drying station can be configured for drying material deposited on the solar cell substrate in the printing station. As an example, the drying station can be an oven. A sorting station configured for sorting processed substrates, such as solar cells, based on testing results obtained through, for example, an electrical testing station and/or the inspection station, can optionally be provided, e.g. at the back end of the line.

[0051] According to some embodiments, which can be combined with other embodiments described herein, the system 300 is configured for manufacture of shingled solar cells, which can also be referred to as “hypercells” or “supercells”. The shingled solar cells can be used in solar cell modules. The shingled solar cells can be made of a plurality of partially overlapping solar cell pieces (also referred to as “solar cell elements”). Adjacent solar cell pieces are electrically connected to each other in the overlapping region. The solar cell pieces are connected in series such that current generated by the individual solar cell pieces flows along the series of solar cell pieces to be collected, for example, at an end portion of the solar cell arrangement. The overlapping configuration can provide high-efficiency solar cell arrangements. In particular, the shingled solar cells allow to increase a module power by increasing a used or active area. Typically, the overlapping configuration can increase the module power by, for example, 20 to 40 Watts. The used or active area can correspond to an area that is irradiated by solar light and that participates in the generation of power. As an example, the used or active area can correspond to an area of the solar cells that is not covered by, for example, conductive line patterns, such as fingers and/or busbars.

[0052] According to some embodiments, which can be combined with other embodiments described herein, the laser device 322 can be configured to cut or divide a substrate into two or more pieces. As an example, the substrate can be a solar cell used for the manufacture of the shingled solar cell. The laser device 322 can be configured to cut the solar cell into the solar cell pieces.

[0053] FIG. 4 shows a flow chart of a method 400 for the processing of substrates used in the manufacture of solar cells according to embodiments described herein. The method 400 can utilize the apparatuses and systems according to the present disclosure.

[0054] The method 400 includes in block 410 a directing of a laser beam towards a first transport line for substrate processing using a deflection device having a first operational state, and in block 420 a changing of the first operational state of the deflection device into a second operational state to direct the laser beam towards a second transport line for substrate processing. Changing the first operational state into the second operational state can include rotating one or more mirrors of the deflection device e.g. around a rotational axis to redirect the laser beam.

[0055] According to some embodiments, the method 400 further includes repeatedly switching between the first operational state and the second operational state to alternately process substrates on the first transport line and the second transport line. By alternately processing substrates on the first transport line and the second transport line, only one single laser device can be provided and a complexity of the setup can be reduced while a duty cycle of the laser device can be increased.

[0056] In some implementations, the method 400 further includes operating the first transport line for transporting the substrates along a first transport direction when the laser beam is directed towards the second transport line for substrate processing and/or operating the second transport line for transporting the substrates along a second transport direction when the laser beam is directed towards the first transport line for substrate processing. The first transport direction and the second transport direction can be essentially parallel to each other. In some implementations, the first transport direction and the second transport direction can be identical. The operating scheme described above can optimize a throughput of the system for the manufacture of solar cells.

[0057] In some embodiments, the method 400 includes a stopping of the first transport line when the laser beam is directed towards the first transport line for substrate processing and/or a stopping of the second transport line when the laser beam is directed towards the second transport line for substrate processing. Stopping the respective transport line allows substrate processing, such as laser scribing, while the substrates are stationary, i.e., not moving. A precision of the substrate processing, such as an alignment of the processing structures generated by the laser device on the substrate, can be improved. However, the present disclosure is not limited thereto and the first transport line and/or the second transport line, i.e., the substrates, can be moving during the substrate processing.

[0058] According to embodiments described herein, the method 400 for processing of substrates used in the manufacture of solar cells can be conducted using computer programs, software, computer software products and the interrelated controllers, which can have a CPU, a memory, a user interface, and input and output devices being in communication with the corresponding components of the apparatus for processing, such as testing, of solar cells.

[0059] FIG. 5 shows a schematic view of a process sequence according to embodiments described herein. “A” denotes the first transport line and “B” denotes the second transport line.

[0060] As shown for the first transport line, a first substrate can be loaded e.g. into the process station configured for substrate processing at the first transport line using the substrate processing arrangement (510). The first substrate can then be processed (520) and unloaded e.g. from the process station (530). A second substrate can be loaded into the process station (540) and the second substrate can be processed (550). As an example, the unloading of the first substrate (530) and the loading of the second substrate (540) can take about 1.25 s.

[0061] With regards to the second transport line, during the processing of the first substrate at the first transport line, another first substrate can be loaded e.g. into the process station configured for substrate processing and the second transport line using the substrate processing arrangement (510’). During the unloading of the first substrate and the loading of the second substrate at the first transport line, the other first substrate can be processed (520’). The other first substrate can be unloaded (530’) and another second substrate can be loaded (540’) at the second transport line while the processing of the second substrate at the first transport line is performed. As shown in the exemplary process sequence in FIG. 5, a duty cycle of the laser device can be increased because the laser device is in operation even during e.g. the loading and/or unloading procedures.

[0062] The present disclosure uses a laser device for substrate processing, such as laser scribing, together with a deflection device that can deflect a laser beam provided by the laser device. The deflection device can direct the laser beam to either the first transport line or the second transport line, depending on the operational state of the deflection device. Switching the operational state can redirect the laser beam from the first transport line to the second transport line, or vice versa. The same laser device can be used for the processing of substrates positioned on both the first transport line and the second transport line. A complexity and/or a footprint of the apparatus can be reduced. A duty cycle of the laser device can be increased.

[0063] While the foregoing is directed to embodiments of the disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

CLAIMS

1. An apparatus for processing of substrates used in the manufacture of solar cells, comprising:

a transport arrangement having at least a first transport line and a second transport line configured for transportation of the substrates; and

a substrate processing arrangement at the transport arrangement, wherein the substrate processing arrangement includes:

a laser device configured to provide a laser beam for processing of the substrates; and

a deflection device having a first operational state and a second operational state, wherein the deflection device is configured to direct the laser beam towards the first transport line in the first operational state and towards the second transport line in the second operational state.

2. The apparatus of claim 1, wherein the deflection device is configured to be moveable at least between a first orientation providing the first operational state and a second orientation providing the second operational state, wherein the deflection device is configured to direct the laser beam towards the first transport line in the first orientation and towards the second transport line in the second orientation.

3. The apparatus of claim 1 or 2, wherein the deflection device includes one or more mirrors.

4. The apparatus of claim 3, wherein the one or more mirrors are rotatable mirrors.

5. The apparatus of any one of claims 1 to 4, wherein the apparatus is configured to alternately direct the laser beam towards the first transport line and the second transport line for substrate processing.

6. The apparatus of any one of claims 1 to 5, wherein the laser device is configured for laser scribing.

7. The apparatus of any one of claims 1 to 6, wherein the first transport line is stationary when the laser beam is directed towards the first transport line for substrate processing, and wherein the second transport line is stationary when the laser beam is directed towards the second transport line for substrate processing.

8. The apparatus of any one of claims 1 to 7, wherein the first transport line is non-stationary when the laser beam is directed towards the second transport line for substrate processing, and wherein the second transport line is non-stationary when the laser beam is directed towards the first transport line for substrate processing.

9. System for the manufacture of solar cells, comprising:

one or more process stations;

the apparatus of any one of claims 1 to 8, wherein at least one process station of the one or more process stations includes the substrate processing arrangement.

10. The system of claim 9, wherein the one or more process stations are selected from the group consisting of a loading station, an inspection station, an alignment station, a laser

scribing station, a printing station, a drying station, a buffer station, an electrical testing station, a sorting station, an unloading station, and any combination thereof.

11. The system of claim 9 or 10, wherein the system is configured for manufacture of shingled solar cells.

12. A method for processing of substrates used in the manufacture of solar cells, comprising:

directing a laser beam towards a first transport line for substrate processing using a deflection device having a first operational state;

changing the first operational state of the deflection device into a second operational state to direct the laser beam towards a second transport line for substrate processing.

13. The method of claim 12, further including:

repeatedly switching between the first operational state and the second operational state to alternately process the substrates on the first transport line and the second transport line.

14. The method of claim 12 or 13, wherein changing the first operational state into the second operational state includes rotating one or more mirrors of the deflection device.

15. The method of any one of claims 12 to 14, further including at least one of:

operating the first transport line for transporting substrates along a first transport direction when the laser beam is directed towards the second transport line for substrate processing;

operating the second transport line for transporting substrates along a second transport direction when the laser beam is directed towards the first transport line for substrate processing;

stopping the first transport line when the laser beam is directed towards the first transport line for substrate processing; and

stopping the second transport line when the laser beam is directed towards the second transport line for substrate processing.

Fig. 1

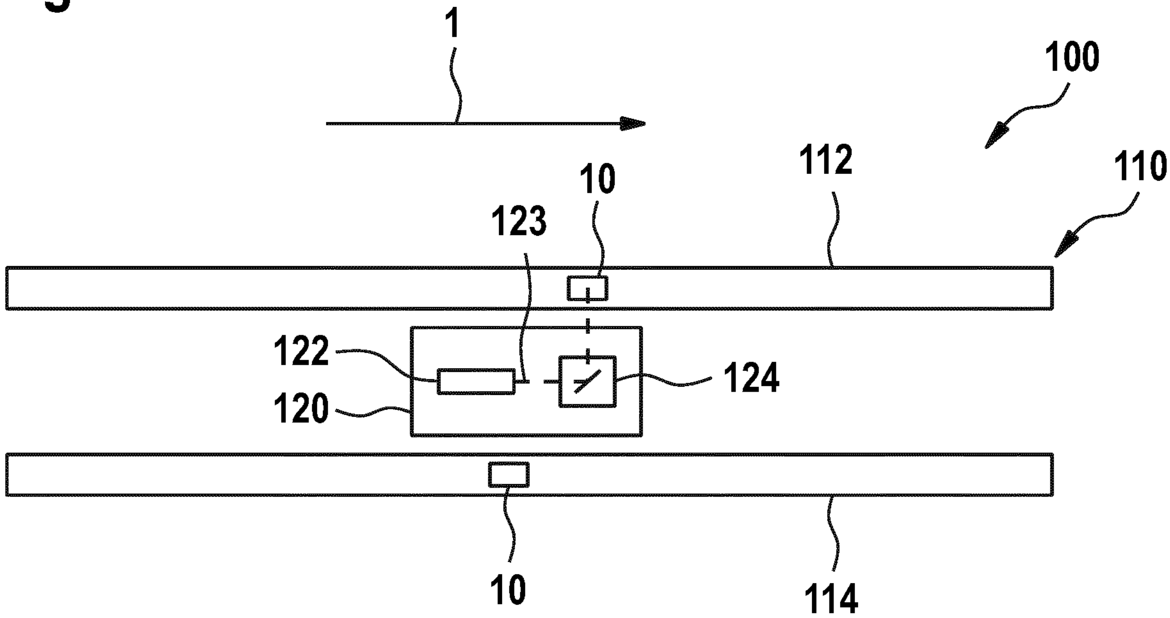
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Fig. 2A

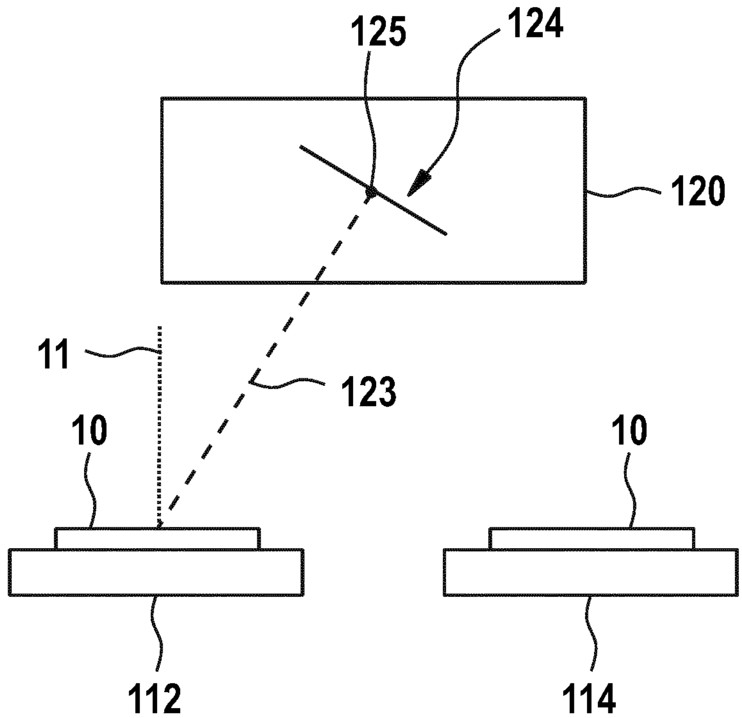
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Fig. 2B

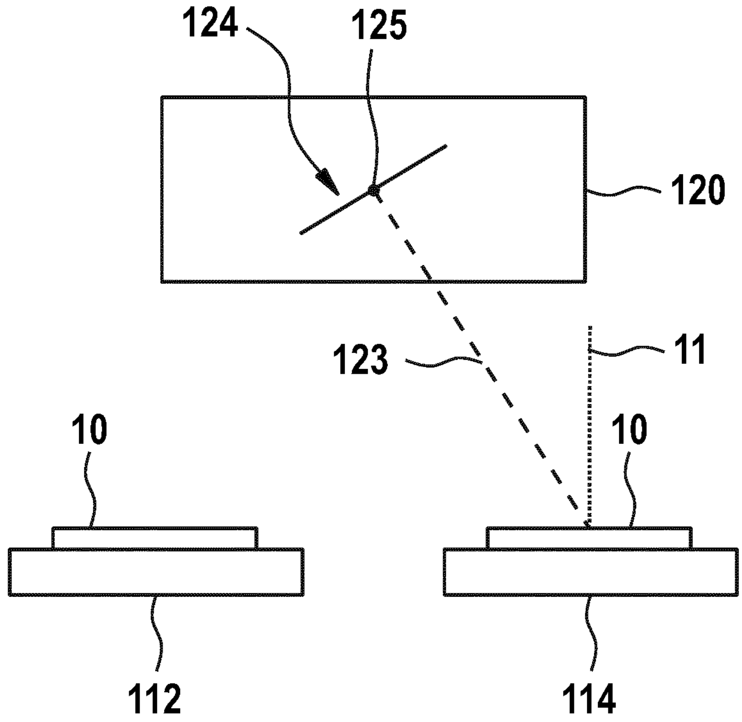
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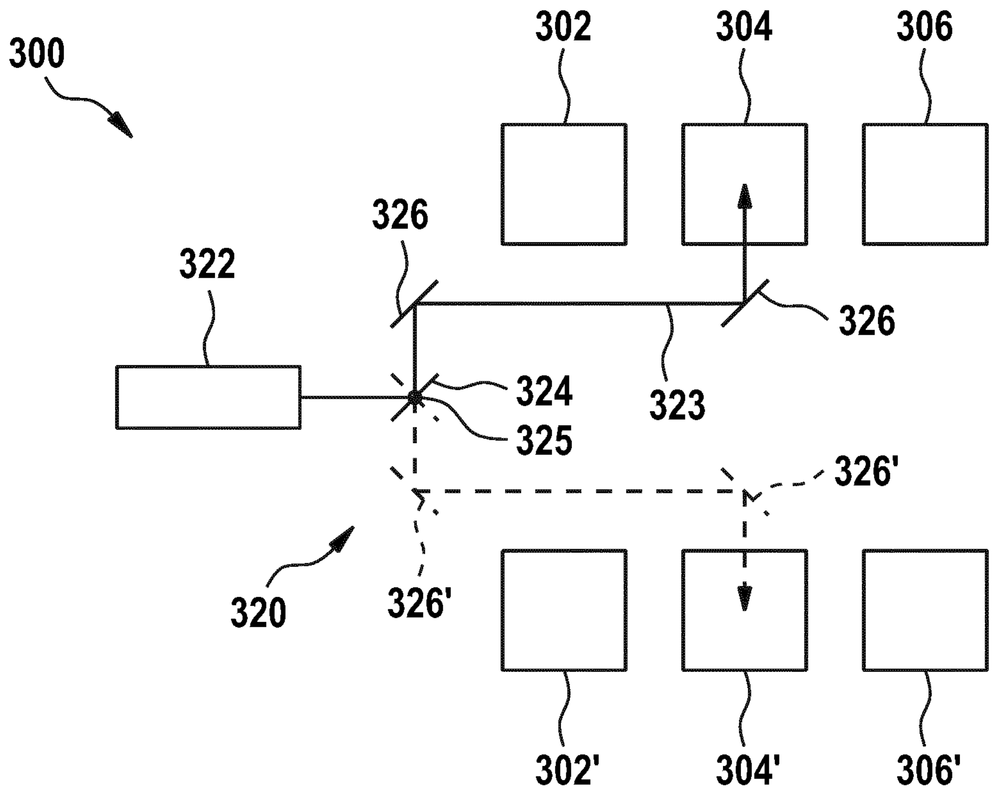
Fig. 3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324
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326'
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326'
302'
304'
306'

Fig. 4

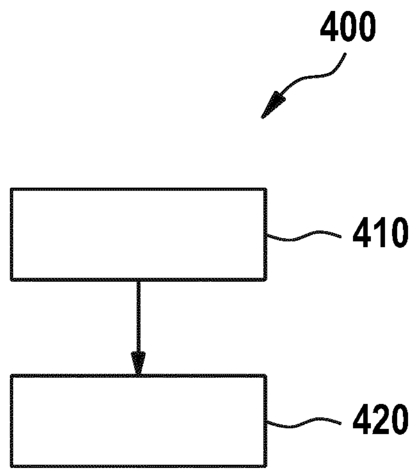
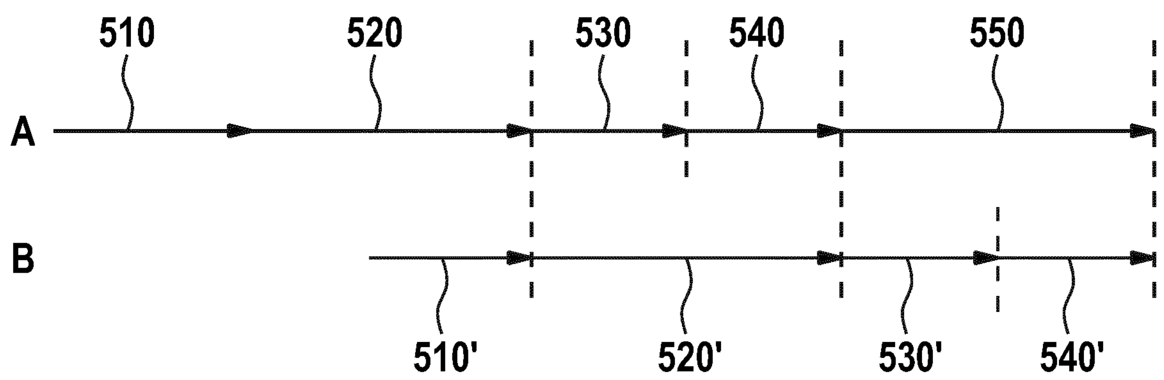


Fig. 5



INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/050336

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01L31/18 H01L31/0463 B23K26/082
ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L B23K

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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X	WO 2012/010924 A1 (DATACARD CORP [US]; MICHENET SEBASTIEN [FR]; BERTHE BENOIT [FR]; JASPE) 26 January 2012 (2012-01-26) abstract; claims 1-13; figures 2A-7 page 2, line 8 - page 6, line 6 page 9, line 5 - page 19, line 25 -----	1-10
Y	US 2009/077805 A1 (BACHRACH ROBERT Z [US] ET AL) 26 March 2009 (2009-03-26) abstract; claims 1-20; figures 1-2B paragraph [0062] paragraph [0078] paragraph [0096] - paragraph [0103] -----	1-15
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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
30 August 2017	06/09/2017

Name and mailing address of the ISA/	Authorized officer
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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