

Description

**DEVICE FOR THE LASER PROCESSING OF A WORKPIECE, USING
TWO LASER BEAMS**

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The invention relates to a device for the laser processing of a workpiece, in particular for processing a silicon wafer during the production of solar cells.

10 The rear-side opening process plays a crucial part during the production of solar cells composed of crystalline silicon. In this case, passivation layers situated on the rear side of the wafer are locally opened, i.e. locally removed, by means of laser
15 ablation. Said passivation layers serve for saturating unbound surface states which would lead to the recombination of charge carriers and thus to a reduced efficiency of the solar cell. A local opening of said passivation layers makes it possible, in a later
20 process step, to apply electrical contacts with the rest of the rear side passivated. For locally removing the passivation layer, it is known for the latter to be removed by means of a laser in the form of equidistant lines. In this case, finding an optimum ratio of
25 contact area and passivated area is crucial for the efficiency of the cell. One possibility for controlling said ratio is altering the distance between the lines and thus the number of lines per wafer.

30 Besides optimizing the efficiency and the requisite precision during the laser processing, the process speed is crucial for the economic viability of production. The most important influencing variables for a maximum process speed during laser ablation are

the pulse energy and the pulse frequency of the beam source and also the speed of the deflecting and focusing unit used.

5 In the prior art it is known, for the rear-side opening process, for a laser beam emitted by a fundamental mode laser to be guided over the wafer to be processed by means of a deflecting and focusing unit, generally a controllable mirror arrangement constructed from
10 galvanometer mirrors with an F-theta lens. Specific CAD software can be used to create layouts that are sent to the deflecting and focusing unit by means of corresponding hardware. Said unit is driven in such a way that the mirror arrangement guides the laser beam
15 in the form of the layout over the wafer. In this case, the process speed that can currently be realized technically is limited in particular by the speed at which the deflection mirrors arranged within the deflecting and focusing unit can be guided with the
20 requisite precision relative to the wafer.

The invention is based on the object, then, of specifying a laser processing device with which the process speed is increased during the laser processing
25 of a workpiece, in particular during the removal of the passivation layers on the rear side of a silicon wafer.

The stated object is achieved according to the invention by means of a laser processing device
30 comprising the features of patent claim 1. In accordance with these features, the device contains an apparatus for generating two laser beams, which propagate obliquely, i.e. not parallel with respect to one another at an angle, and a deflecting and focusing

unit for guiding and focusing the laser beams over or onto the workpiece, wherein the laser beams are linearly polarized in mutually perpendicular directions.

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Simultaneously processing the workpiece using two laser beams results in a doubling of the process speed compared with conventional methods. Moreover, since the laser beams are linearly polarized in mutually perpendicular directions, the laser beams can be guided closely alongside one another and in a partly overlapping or intersecting manner, such that closely adjacent regions of the workpiece surface can be processed simultaneously by means of one and the same deflecting and focusing unit.

If the apparatus for generating the laser beams comprises a beam guiding apparatus disposed upstream of the deflecting and focusing unit and containing an adjustable mirror arrangement for altering the direction of propagation of at least one of the laser beams, the distance between the laser beams focused on the workpiece can be set in a flexible manner.

Particularly uniform and reproducible processing results are achieved if the mirror arrangement comprises a plurality of deflection mirrors, which are adjustable in such a way that the laser beams always intersect at the same point of intersection independently of the angle, which point of intersection preferably lies at the midpoint of an aperture of the deflecting and focusing unit.

In one particularly advantageous configuration of the invention, the beam guiding apparatus comprises a partly transmissive end mirror disposed upstream of the deflecting and focusing unit, which end mirror
5 respectively deflects one portion of the laser beams to the deflecting and focusing unit and respectively transmits the other portion, wherein the transmitted partial beams are fed to a polarization beam splitter, which splits the transmitted partial beams, and wherein
10 at least one of the partial beams emerging from the polarization beam splitter is fed to a beam position detector. In this way, positioning errors of the adjustably mounted deflection mirrors and a thermally caused drift of the stationary deflection mirrors can
15 be identified and automatically compensated for if the measurement signals recorded by the beam position detector or detectors are forwarded to a control apparatus, which controls the adjustable mirror arrangement depending on said measurement signals in
20 such a way that the first partial beams always intersect at the same point of intersection.

Further advantageous configurations of the invention are specified in the further dependent claims.

25 For further explanation of the invention, reference is made to the exemplary embodiment in the figure, which shows a device according to the invention in a basic illustration.

30 In accordance with this figure, the device comprises an apparatus 6 containing two laser beam sources 2, 4, which apparatus generates two laser beams L1, L2 linearly polarized in mutually perpendicular

directions. The apparatus 6 contains a beam guiding apparatus 8, by means of which the two laser beams L1, L2 emerging from the laser beam sources 2, 4 are oriented in such a way that, upon entering a deflecting and focusing unit 10 disposed downstream of the apparatus 6, they propagate closely alongside one another and obliquely at a small acute angle α with respect to one another. In the deflecting and focusing unit 10, the laser beams L1, L2 are deflected by adjustable deflection mirrors (not illustrated in the mirror) and are focused onto a workpiece 14 by an F-theta lens 12 at adjacent foci F1, F2 in a processing plane. The workpiece 14 is a silicon wafer, the rear side of which is provided with a passivation layer 16 and the rear side of which faces the deflecting and focusing unit 10.

The beam guiding apparatus 8 comprises two motor-adjustable deflection mirrors 18, 20, by means of which the direction of propagation of the laser beam L2 emerging from the laser beam source 4 can be controlled. The laser beam L1 emerging from the laser beam source 2 is guided exclusively via stationary deflection mirrors 22, 24 and a stationary end mirror 26, to which the laser beam L1 is also deflected, wherein the deflection mirror 24 is a polarization beam splitter, which transmits the laser beam L1 and reflects the laser beam L2, such that both laser beams L1, L2 propagate toward the end mirror 26. In this case, the motor-adjustable deflection mirrors 18 and 20 are positioned in such a way that the laser beams L1 and L2 intersect or overlap at the midpoint A of an aperture of the deflecting and focusing unit 10. By means of the deflection mirrors 18, 20, the angle α and

thus the distance a between the foci F_1 , F_2 on the workpiece 14 can be set in a flexible manner.

5 Since two laser beams L_1 and L_2 are guided by the deflecting and focusing unit 10, their foci F_1 , F_2 are guided by movement of the deflection mirrors, situated in the deflecting and focusing unit 10, on the workpiece along two parallel lines along which, in the example, the passivation layer 16 is removed. For the
10 processing of the wafer with n lines, accordingly, the foci F_1 , F_2 have to be guided only $n/2$ times over the wafer. As a result, the process time is also reduced by half.

15 The end mirror 26 is partly transmissive and respectively transmits a small portion of the laser beams L_1 , L_2 . The partial beams TL_1 , TL_2 transmitted by the end mirror 26 are separated from one another in a polarization beam splitter and respectively fed to a
20 beam position detector 30-1, 30-2. The latter respectively measure the beam position, i.e. both angle and position of the respective partial beams TL_1 , TL_2 . The measurement signals M_1 , M_2 detected by the beam position detectors 30-1, 30-2 are fed to a control
25 apparatus 32, which controls the deflection mirrors 18 and 20 and thus the beam position of the laser beam L_2 within the beam guiding apparatus 8 and thus the angle α between the laser beams L_1 and L_2 propagating between the beam guiding apparatus 8 and the deflecting and
30 focusing unit 10. In this case, the two deflection mirrors 18, 20 are moved in such a way that the point of intersection of the laser beams L_1 , L_2 coupled into the deflecting and focusing unit 10 and thus the apex of the tilting movement always lies at the midpoint A

of the aperture of the deflecting and focusing unit 10.
The distance a between the foci $F1$, $F2$ in the
processing plane is set by the variation of said angle
 α . It is thus possible, within a physically expedient
5 scope, to realize any desired distances between the
ablation lines on the wafer.

What is essential for the efficiency of the solar cells
is the spatial precision with which the wafers are
10 processed during the laser ablation. However, thermally
induced drifts of the optical elements by which the
laser beams are guided can have the effect that the
distance a between the foci $F1$, $F2$ and thus the lines
changes, which could adversely affect the efficiency of
15 the cell. The active beam regulation ensures that a
drift of the laser beam $L1$ emitted by the beam source 2
and guided in the beam guiding apparatus is compensated
for by the tracking of the laser beam $L2$ emitted by the
beam source 4, such that the angular position of the
20 laser beams $L1$, $L2$ reflected by the end mirror 28 with
respect to one another and their point of intersection
and thus the line distance a on the silicon wafer
remain constant.

25 The operator of the installation can, by means of
software, predefine the desired distance between the
foci $F1$, $F2$ in the process plane and the control
apparatus 32 realizes said distance by means of the
appropriate movement of the motorized deflection
30 mirrors 18, 20. In combination with the choice of the
appropriate layout, the workpiece 14, the silicon wafer
in the example, can then be processed with equidistant
ablation lines at the desired distance.

Two laser beam sources 2, 4 are provided in the exemplary embodiment. In principle, however, two laser beams linearly polarized perpendicularly to one another can also be generated by means of a single laser beam source with corresponding polarization beam splitters.

Claims

1. A device for the laser processing of a workpiece (14), comprising an apparatus (6) for generating a first and a second laser beam (L1, L2), which propagate obliquely with respect to one another at an angle (α), a deflecting and focusing unit (10) for guiding and focusing the laser beams (L1, L2) over or onto the workpiece (14), wherein the laser beams (L1, L2) are linearly polarized in mutually perpendicular directions.

2. The device as claimed in claim 1, wherein the apparatus (6) for generating the laser beams (L1, L2) comprises a beam guiding apparatus (8) disposed upstream of the deflecting and focusing unit and containing an adjustable mirror arrangement for altering the direction of propagation of at least one of the laser beams (L2).

3. The device as claimed in claim 2, wherein the mirror arrangement comprises a plurality of deflection mirrors (18, 20), which are adjustable in such a way that the laser beams (L1, L2) always intersect at the same point of intersection independently of the angle (α).

4. The device as claimed in claim 3, wherein the point of intersection lies at the midpoint (A) of an aperture of the deflecting and focusing unit (10).

5. The device as claimed in any of claims 2 to 4, wherein the beam guiding apparatus (8) comprises a partly transmissive end mirror (26) disposed upstream

of the deflecting and focusing unit (10), which end mirror respectively deflects one portion of the laser beams to the deflecting and focusing unit (10) and respectively transmits the other portion, wherein the
5 transmitted partial beams (TL1, TL2) are fed to a polarization beam splitter (28), which splits the transmitted partial beams (TL1, TL2), and wherein at least one of the partial beams (TL1, TL2) emerging from the polarization beam splitter (28) is fed to a beam
10 position detector (30-1, 30-2).

6. The device as claimed in claim 5, comprising a control apparatus (32) for controlling the adjustable mirror arrangement depending on a measurement signal
15 (M1, M2), forwarded from the beam position detector or detectors (30-1, 30-2) to the control apparatus, in such a way that the laser beams always intersect at the same point of intersection independent of the angle (α).

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7. The device as claimed in claim 6, wherein the point of intersection lies at the midpoint (A) of an aperture of the deflecting and focusing unit (10).

25 8. The device as claimed in any of the preceding claims, wherein the apparatus (6) comprises two laser beam sources (2, 4).

9. The use of the device for locally removing a
30 passivation layer (16) on the rear side of a silicon wafer during the production of solar cells.