DESCRIPTION

TITLE OF THE INVENTION: METHOD AND DEVICE FOR DETECTING APPEARANCE DEFECT OF SOLAR CELL

FIELD OF THE INVENTION

[0001] This application relates to the field of solar cells, and more specifically, to a method and a device for detecting an appearance defect of a solar cell.

RELATED ART

[0002] Solar cells are new energy cells that can convert light energy into electric energy through a photoelectric effect. The energy conversion efficiency is greatly improved by developing from the primary first generation of single-crystal silicon or multi-crystal silicon solar cells to the third generation of solar cells. Typical third-generation solar cells include perovskites-type solar cells, in which perovskites-type organo-metal halide semiconductors are used as a light absorbing material, and when receiving sunlight, the semiconductors can convert received photon energy into a photoelectric current.

[0003] The application fields of the perovskites-type solar cells are quite wide, including photovoltaics, new energy automobiles, wearable devices, indoor electronic devices, the Internet of Things, remote control devices, and the like. Whether the appearance of a perovskites-type solar cell has a defect may affect the appearance level of a final product, and affect the photoelectric conversion performance of the product. In addition, because ordinary consumers also have access to perovskites-type solar cells, higher requirements are posed on the appearance of the perovskites-type solar cells. In a conventional method, the appearance of a product of a perovskites-type solar cell is determined mainly by means of manual visual inspection. This method has problems such as a relatively low efficiency and an inconsistent standard, being prone to false judgment and missing judgment, and secondary pollution.

[0004] Therefore, it is desirable to provide a method and a device for detecting an appearance defect of a solar cell, so as to overcome the defect of the foregoing manual visual inspection.

SUMMARY

[0005] An objective of this application is to provide a method and a device for detecting an appearance defect of a solar cell, which can implement rapid sorting on appearance levels of solar cells, reduce false judgment and missing detection caused by

manual visual inspection, ensure the consistency of inspection standards, and avoid secondary pollution on surface of the solar cells that may be caused by manual inspection.

[0006] According to a first aspect of this application, a method for detecting an appearance defect of a solar cell is provided. The method includes: receiving a first image of a solar cell captured by a first camera under a first light source; receiving a second image of the solar cell captured by the first camera under a second light source, where a first angle between the first light source and the solar cell is less than a second angle between the second light source and the solar cell; identifying a first defect of the solar cell in the first image and a second defect of the solar cell in the second image; and determining an appearance level of the solar cell based on the first defect and the second defect.

[0007] According to another aspect of this application, a device for detecting an appearance defect of a solar cell is further provided. The device includes a non-transitory computer storage medium, having one or more executable instructions stored therein, and the one or more executable instructions executed by a processor performing the following steps: receiving a first image of a solar cell captured by a first camera under a first light source; receiving a second image of the solar cell captured by the first camera under a second light source, where a first angle between the first light source and the solar cell is less than a second angle between the second light source and the solar cell; identifying a first defect of the solar cell in the first image and a second defect of the solar cell in the second image; and determining an appearance level of the solar cell based on the first defect and the second defect.

[0008] The foregoing is a brief description of this application, and there may be cases in which details are simplified, summarized, and omitted. Therefore, a person skilled in the art should recognize that this part is merely exemplary and is not intended to limit the scope of this application in any mode. This brief part is not intended to determine key features or necessary features of the claimed subject, nor is intended to be used as an auxiliary means for determining the scope of the subject claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0009] The foregoing and other features of the content of this application will be more fully clearly understood from the following specification and appended claims with reference to the accompanying drawings. It may be understood that these accompanying drawings only show several implementations of this application, and therefore should not be

considered as limiting the scope of this application. The content of this application will be described more clearly and in detail by using the accompanying drawings.

[0010] FIG. 1 and FIG. 2 respectively show a cross-sectional view and an exploded view of a solar cell 10 according to an embodiment of this application;

[0011] FIG. 3 is a top view of the solar cell 10 shown in FIG. 1 and FIG. 2;

[0012] FIG. 4 illustrates a device 100 for detecting an appearance defect of a solar cell 10 according to an embodiment of this application;

[0013] FIG. 5 illustrates a feeding module 1000 of the device 100 shown in FIG. 4;

[0014] FIG. 6 illustrates a tray 200 of the feeding module shown in FIG. 5;

[0015] FIG. 7 illustrates a first detection platform 2004 positioned on a first detection module 2000 of the device 100 shown in FIG. 4;

[0016] FIG. 8 illustrates a first camera module 2010 positioned on the first detection module 2000 of the device 100 shown in FIG. 4;

[0017] FIG. 9 is a side view of the first camera module 2010 shown in FIG. 8;

[0018] FIG. 10 is a schematic diagram of a detection optical path and a light source of the first camera module 2010 shown in FIG. 8 and FIG. 9;

[0019] FIG. 11a and FIG. 11b respectively show a photo 300 of the solar cell 10 captured by a first line scanning and a photo 400 of the solar cell 10 captured by a second line scanning according to an embodiment of this application;

[0020] FIG. 12 illustrates a second detection module 3000 of the device 100 shown in FIG. 4;

[0021] FIG. 13 is an exemplary photo 500 of the solar cell 10 captured by an area scanning according to an embodiment of this application;

[0022] FIG. 14 exemplarily illustrates threshold settings and corresponding appearance levels of impurity spots, bubbles, linear scratches, chipped edges, chipped corners, and edge burr defects;

[0023] FIG. 15 illustrates a code spraying assembly 4010 in a code spraying module 4000 of the device 100 shown in FIG. 4; and

[0024] FIG. 16 illustrates a material receiving module 5000 of the device 100 shown in FIG. 4.

[0025] Before any embodiment of the present invention is explained in detail, it should be understood that the application of the present invention is not limited to the details of construction and the arrangements of the components described in the following description or shown in the following accompanying drawings. The present invention can

have other embodiments and can be implemented or performed in various modes. In addition, it should be understood that the phraseology and terms used herein are for the purpose of description and should not be considered as limiting.

DETAILED DESCRIPTION

[0026] In the following detailed description, reference is made to the accompanying drawings that form a part thereof. In the accompanying drawings, similar references usually represent similar components, unless otherwise indicated in the context. The illustrative implementations described in the detailed description, the accompanying drawings, and the claims are not intended to be limiting. Other implementations may be used and other variations may be made without departing from the spirit and scope of the subject of this application. It may be understood that various compositional configurations, replacements, combinations, and designs may be performed on various aspects of content of this application that are generally described in this application and that are illustrated in the accompanying drawings, and all of these definitely constitute a part of the content of this application.

[0027] FIG. 1 and FIG. 2 respectively show a cross-sectional view and an exploded view of a solar cell 10 according to an embodiment of this application. As shown in FIG. 1 and FIG. 2, the solar cell 10 includes: an absorbing layer 12, which may be, for example, a perovskites-type light absorbing material layer, and is configured to absorb illumination and generate a current carrier pair; and a first electrically conductive layer 14a and a second electrically conductive layer 14b positioned on two sides of the absorbing layer 12. The first electrically conductive layer 14a extracts electrons from the absorbing layer 12 by using an electronic transport layer (not shown) positioned between the first electrically conductive layer 14a and the absorbing layer 12, and the second electrically conductive layer 14b extracts voids from the absorbing layer 12 by using a void transport layer (not shown) positioned between the second electrically conductive layer 14b and the absorbing layer 12. The first electrically conductive layer 14b and the second electrically conductive layer 14b are respectively connected to an external circuit, to externally transfer a current formed by means of photoelectric conversion. In an embodiment, the solar cell 10 further includes a transparent glass substrate 18a. The first electrically conductive layer 14a, the electronic transport layer, the absorbing layer 12, the void transport layer, and the second electrically conductive layer 14b are all formed on the glass substrate 18a by means of, for example, coating, depositing, or another suitable means.

[0028] Further referring to FIG. 1 and FIG. 2, the solar cell 10 further includes a transparent glass cover 18b, on which packaging glue 16 may be applied, to allow the glass cover 18b and the first electrically conductive layer 14a to be adhered together. The glass substrate 18a and the glass cover 18b package the absorbing layer 12 and the like therein.

[0029] FIG. 3 is a top view of the solar cell 10 shown in FIG. 1 and FIG. 2. As shown in FIG. 3, the solar cell 10 has a substantially rectangular shape. Although a substantially rectangular shape is shown in FIG. 3 as an example, it may be understood by a person skilled in the art that another shape, such as a square, an oval, or a runway-like shape, may be selected as required for the solar cell 10.

[0030] Still referring to FIG. 3, the glass substrate (as shown in the figure, the substrate is positioned on the side closest to an observer in FIG. 3, and a specific structure of the substrate may refer to FIG. 1 and FIG. 2) forms an overall outer contour of the solar cell 10, and has a length A5 and a width B3. Preferably, the absorbing layer 12 is located right in the middle of the glass substrate, and is preferably arranged substantially symmetrically. Respective long sides of the absorbing layer 12 and corresponding long sides of the glass substrate have distances A2 and (A5-A3), and respective short sides of the absorbing layer 12 and short sides of the substrate have distances B1 and (B3-B2).

[0031] An exposed electrode region 14 (indicated by oblique lines in FIG. 3) between the substrate and the cover is configured to connect to an external circuit. FIG. 3 exemplarily illustrates that two sides of the solar cell 10 each has an electrode region 14. The electrode region 14 has a length equal to the width B3 of the substrate, and has a width of A1 and (A5-A4). It may be understood that, in the solar cell 10, there are distances (A2-A1) and A6 (i.e., A4-A3) between the absorbing layer 12 and the electrode region 14 in the length direction. It may be understood that, for a piece of a solar cell 10 having an excellent appearance level, the sizes A1-A6 and B1-B3 mentioned above should be consistent with corresponding sizes of a standard sample, to ensure the consistency of appearances and sizes of products. If the sizes are inconsistent, the cell output characteristics of the solar cell may be affected, a connection between the solar cell and the external circuit may be affected, and the like.

[0032] In addition to the consistency of the sizes, some defects, such as a color difference between the color of the absorbing layer and a standard color, color non-uniformities, and bubbles, scratches, chipped corners, dirt, and shattering on the substrate 18a and/or the cover 18b, generated due to a problem in a manufacturing process thereof may further exist in the solar cell 10. The foregoing defects are specifically described below with reference to examples. It may be understood that these defects also affect the performance of

the solar cells, and therefore need to be detected and identified, and more preferably, identified by using an automatic detection device, so that the inspection efficiency can be significantly improved.

[0033] Usually, that the size of the foregoing solar cell does not meet a requirement (appearance defects related to the size) and other process defects can all be identified by inspecting the appearance of the solar cell, and complex circuit detection is not needed. Therefore, the inventors of this application have conceived of an automatic detection device for detecting an appearance defect of a solar cell, to implement inspection of the solar cell.

[0034] FIG. 4 illustrates a device 100 for detecting an appearance defect of a solar cell 10 according to an embodiment of this application. The detection device 100 can inspect, for example, the solar cell shown in FIG. 1 to FIG. 3, and preferably, can inspect a plurality of solar cells in batches.

[0035] As shown in FIG. 4, the device 100 includes five modules from upstream to downstream, that is, a feeding module 1000, a first detection module 2000, a second detection module 3000, a code spraying module 4000, and a material receiving module 5000. Although the foregoing five modules exemplarily shown in FIG. 4 are divided into five modules, it may be understood by a person skilled in the art that two or more of the foregoing five modules may be combined into one module, and each module may be divided into a plurality of submodules. In addition, according to different embodiments, the order of the first detection module 2000 and the second detection module 3000 may alternatively be replaced.

[0036] FIG. 5 illustrates a feeding module 1000 of the device 100 shown in FIG. 4. The feeding module 1000 includes a material feeding bin 1002 configured to store one or more trays 200. FIG. 6 illustrates a tray 200 of the device 100 shown in FIG. 4, on which one or more recesses 202 are provided, to carry one or more solar cells 10 to be inspected. Still referring to FIG. 5, the material feeding bin 1002 further includes a rack 1004 and a drive mechanism 1006 mounted on an upper surface of the rack 1004. A tray slide frame 1008 is mounted on the drive mechanism 1006. Under the driving of the drive mechanism 1006, the tray slide frame 1008 can move the standard tray 200 from a position located at the material feeding bin 1002 to a position to be transferred. The feeding module 1000 further includes a first carrying mechanism 1010, which can carry the solar cell 10 located on the tray 200 from the feeding module 1000 to the first detection module 2000. The first carrying mechanism 1010 includes a first gripper 1012. The first gripper 1012 can be driven to move in a horizontal direction, to align a solar cell 10 to be gripped in the tray 200. After the alignment,

the first gripper 1012 is driven to move in a vertical direction, to grip a corresponding solar cell 10 in the tray 200.

[0037] FIG. 7 illustrates a first detection platform 2004 located on a first detection module 2000 of the device 100 shown in FIG. 4. As described above, after the first gripper 1012 grips the solar cell 10, the solar cell 10 is transferred to the first detection platform 2004 of the first detection module 2000, for the inspection on the first detection module 2000.

[0038] FIG. 8 illustrates a first camera module 2010 located on the first detection module 2000 of the device 100 shown in FIG. 4. As shown in FIG. 8, the first camera module 2010 is located right above the first detection platform 2004, and is configured to move backward and forward by a camera slide frame 2012. The first camera module 2010 includes a first camera 2020, and when the first camera module 2010 moves through the first detection platform 2004, the first camera 2020 can take a photo of the solar cell 10 located on the first detection platform 2004. In an embodiment, the first camera 2020 may be a line scan camera having a 0.02 mm/pixel precision and 8K color. It may be understood by a person skilled in the art that the first camera 2020 may be a line scan camera of other specifications.

[0039] FIG. 9 is a side view of the first camera module 2010 shown in FIG. 8. As shown in FIG. 8 and FIG. 9, the first camera module 2010 further includes a pair of first light sources 2022 arranged at two sides of a vertical detection light path 2021 of the first camera 2020, and a second light source 2024 located at a side of the vertical detection light path 2021. In the process in which the first camera module 2010 moves backward and forward by the camera slide frame 2012, the first light sources 2022 and the second light source 2024 move together with the first camera 2020, to provide additional light for photographing of the camera 2020, thereby improving the imaging effect. In an embodiment, the first light sources 2022 and the second light source 2024 are strip-shaped LED light sources.

[0040] FIG. 10 is a schematic diagram of a detection optical path and a light source of the first camera module 2010 shown in FIG. 8 and FIG. 9. As shown in FIG. 10, when observed in a direction perpendicular to a moving direction of the first camera module 2010, the pair of first light sources 2022 has a first angle α with the plane of the solar cell 10, and the second light source 2024 has a second angle β with the plane of the solar cell 10. In an embodiment, the first angle α may range from 40° to 50°, which is a relatively small reflection angle, and the second angle β may range from 75° to 85°, which is a relatively larger reflection angle comparing with the first angle.

[0041] In an embodiment, the first camera module 2010 performs twice line scanning on the solar cell 10 on the first detection platform 2004, to obtain two photos of the solar cell

10. In the first line scanning process, the first light sources 2022 are turned on and the second light source 2024 is turned off; and in the second line scanning process, the second light source 2024 is turned on and the first light source 2022 are turned off. It may be understood that, when the solar cell 10 is irradiated by using different light sources, appearance details (including defects) of the solar cell 10 are presented differently.

[0042] FIG. 11a and FIG. 11b respectively are an exemplary photo 300 of the solar cell 10 captured by first line scanning and an exemplary photo 400 of the solar cell 10 captured by second line scanning according to an embodiment of this application. As shown in FIG. 11a, in the first line scanning process, the pair of first light sources 2022 illuminate the surface of the solar cell 10 at opposite angles, and therefore the photo 300 captured by the camera 10 has few shadows and a higher brightness, so that details of the solar cell 10 can be presented more clearly. It may be understood by a person skilled in the art that when light is illuminated on a shiny object, reflected light appears in two forms: specular reflection and diffuse reflection, and a camera can be enabled to photograph a more realistic color by avoiding specularly reflected light and detecting diffused reflected light. The first light sources 2022 are designed to have angles ranging from 40° to 50°, to improve the color accuracy. Correspondingly, photo 300 may be used for detection of color uniformity and a color difference of the absorbing layer 12 of the solar cell 10, detection of bubbles or foreign objects in the solar cell 10, or the like.

[0043] As shown in FIG. 11b, in the second line scanning process, the second light source 2024 illuminates the surface of the solar cell 10 at a relatively high angle, and therefore the photo 400 captured by the camera 2020 can better represent a surface defect of the solar cell 10. It may be understood by a person skilled in the art that when a high-angle light source illuminates a surface of an object, an even region can smoothly reflect light, so that an image looks bright and clear; and a portion of an uneven surface (such as a scratch) has a poor light reflection performance and therefore is more easily detected than an even part. Correspondingly, the photo 400 can be better used for detection of scratches and foreign objects (such as dirt, fingerprints, and oil spots) on the surface of the solar cell 10. Therefore, the device 100 may implement multi-level appearance defect detections on a solar cell based on twice light source illumination from different angles, thereby improving the detection accuracy. It should be noted that, in this embodiment, the first light source and the second light source are two separate light sources, but in some other embodiments, the two light sources may alternatively be integrated into one light source. Illumination and detection at a

plurality of angles may be implemented by rotating the integrated light source, or rotating the solar cell 10 (e.g., by the tray thereof).

[0044] FIG. 12 illustrates a second detection module 3000 of the device 100 shown in FIG. 4. As shown in FIG. 12, the second detection module 3000 includes a second camera 3002 and a second detection platform 3004 located below the second camera 3002. After the solar cell 10 undergoes twice line scanning at the first detection module 2000, a second carrying mechanism 3050 (referring to FIG. 4) carries the solar cell 10 located on the first detection platform 2004 to the second detection platform 3002. In an embodiment, the second camera 3002 is an area array camera, for example, a black-and-white area array camera having a 0.017 mm/pixel precision and 150 million pixels. It may be understood by a person skilled in the art that a black-and-white area array camera has the advantages of a high speed and a high resolution, and has a great advantage in high-precision edge identification. However, an area array camera having a suitable resolution may alternatively serve as the second camera 3002.

[0045] Still referring to FIG. 12, the second detection module 3000 further includes a third light source 3006 located on the side of the second detection platform 3002 close to the second camera 3002 and a fourth light source 3008 located on the side of the second detection platform 3002 far away from the second camera 3002. In an embodiment, the third light source 3006 may be formed by four strip-shaped light sources, and the angle of each strip-shaped light source is adjustable. Similar to the foregoing first light source, the angle of the third light source 3006 relative to the second detection platform 3002 may range from 40° to 50°. In an embodiment, the fourth light source 3008 is a white backlight source and the second detection platform 3004 is transparent. The fourth light source 3008 illuminates a back surface of the solar cell 10 located on the second detection platform 3002. Therefore, the second camera 3002 can clearly photograph an edge of each main structural region of the solar cell 10 in coordination with the third light source 3006 and the fourth light source 3008.

[0046] FIG. 13 is an exemplary photo 500 of the solar cell 10 captured by area scanning according to an embodiment of this application. Due to the transparency of the substrate and the translucency of the packaging glue, a boundary of the substrate, a boundary between the absorbing layer and the packaging glue, a boundary between the absorbing layers, and a boundary between the electrode region and the packaging glue of the solar cell 10 can be clearly identified from the photo 500 in FIG. 13. Referring to FIG. 2, the boundary identified from the photo 500 in FIG. 13 basically corresponds to a boundary depicted in each part in FIG. 2. Therefore, the captured photo 500 may be used to detect whether values of

A1~A6 and B1~B3 corresponding to the solar cell 10 are the same as values of A1~A6 and B1~B3 of the standard sample, to determine the accuracy of the size of the solar cell 10. The accuracy of the size referred to in this application includes accuracies of the sizes of different parts of the solar cell and accuracies of positions relative to other parts. It may be understood that, in some embodiments, an alignment mark or a standard size may alternatively be disposed on the tray on which the solar cells are positioned, and the alignment mark or the standard size may be located in a peripheral region of the solar cell, so that the alignment mark and the standard size can be synchronously imaged when the solar cell is imaged, to facilitate measurement of values of A1~A6 and B1~B3.

[0047] In an embodiment, due to the fact that edges of the solar cell 10 are clearly photographed in the photo 500, it can be determined, by comparing the photo 500 with a standard sample, whether the solar cell 10 has any chipped corner, chipped edge, edge burrs, or the like can be determined. In an embodiment, the foregoing photos 300 and 400 taken by the first camera may alternatively be used to determine whether the solar cell 10 has any chipped corner, chipped edge, edge burrs, or the like.

[0048] After the first detection module 2000 and the second detection module 3000 take the three photos 300, 400, and 500 of the solar cell 10, visual detection processing software running on the device 100 or visual detection processing software (not shown) running on a computer device coupled to the device 100 can identify various defects of the solar cell 10 based on the photos 300, 400, and 500, and further determine which different appearance levels the solar cell 10 belongs to.

[0049] In an embodiment, a user may first identify and classify various defects of the solar cell 10, and construct a defect classification data set. Further, the user may train a neural network model based on a constructed data set by using a deep learning tool, to obtain a trained visual detection processing software. In an embodiment, for example, 100, 1000, or 5000 samples may be provided for each defect. It may be understood by a person skilled in the art that the more samples provided, the more accurate the detection result of the trained model will be. Finally, a user can use a trained visual detection processing software to identify various defects of the solar cell 10 on the acquired photos, and determine the appearance level of the solar cell 10.

[0050] In an embodiment, for detecting a color difference of the absorbing layer 12 of the solar cell 10, the visual detection processing software first converts the photo 300 from an RGB color channel into a Lab color channel. Wherein, L represents a lightness of the color; $a>0$ indicates a red shift, while $a<0$ indicates a green shift; $b>0$ indicates a yellow shift, while

b<0 indicates a blue shift. The visual detection processing software can identify an effective region (e.g., the absorbing layer 12), and calculate a corresponding Lab parameter value of the effective region. In an embodiment, the user may provide a standard sample, and the visual detection processing software can detect a current color difference ΔE (referring to the following equation 1) between the solar cell 10 and the standard sample.

[0051] $\Delta E=\mathrm{sqrt}((L-L_{standard})^2+(a-a_{standard})^2+(b-b_{standard})^2)$ (equation 1)

[0052] In an embodiment, for detecting a color uniformity of the absorbing layer 12 of the solar cell 10, the visual detection processing software first converts the photo 300 from an RGB color channel into an HSV channel. Wherein, H represents a hue; S represents a saturation; and V represents a brightness value. The visual detection processing software can identify an effective region (e.g., the absorbing layer 12), and calculate an overall average variance ΔH (referring to the following equation 2) of an H channel of the effective region.

[0053] $\Delta H=\sum(x_i-\bar{x})^2/n$ (equation 2)

[0054] Wherein, n represents a number of effective pixels, x_i represents a grayscale value of pixels in the H channel, and $\bar{x}$ represents an average grayscale of the H channel. A lower ΔH indicates a more uniform color, and a higher ΔH indicates a more non-uniform color.

[0055] Therefore, through the thresholds of ΔE and ΔH set by a user in advance, the visual detection processing software can determine whether the color of the absorbing layer 12 of the solar cell 10 has a color difference (e.g., it is determined that there is a color difference when the calculated color difference ΔE is greater than the threshold), and whether the colors are uniform (e.g., it is determined that there is a color difference when the calculated overall average variance ΔH of the color is greater than the threshold), and further determine the appearance level of the solar cell 10. In an embodiment, the visual detection processing software may identify a color difference between different pieces within the absorbing layer 12 (e.g., exemplarily formed by five pieces of region) or a color difference between regions within one piece, and determine whether a color difference between a plurality of pieces is excessively large, or determine whether there is an excessively large quantity of pieces having excessive color differences. In an embodiment, the visual detection processing software may measure the area or size of a region having a color difference and non-uniform colors, and determine the appearance level of the solar cell based on a specification of the specific area or size set by a user.

[0056] In an embodiment, the visual detection processing software converts all of the photos 300, 400, and 500 from the RGB channel into the HSV channel, segments images

based on grayscale values of pixels in the H channel, and extracts suspected defect regions. In an embodiment, the trained neural network model in the visual detection processing software can screen the extracted suspected defect regions, to extract effective defects and remove ineffective defects. For example, a grayscale value of a suspected defect region may be compared with a grayscale value of the background, and when a difference between the grayscale values of the suspected defect region and the background is greater than 10, it is determined that the suspected defect region is a defect region. In an embodiment, the visual detection processing software can determine the size (e.g., the length, the width, or the height) and the area of a defect, and a form (e.g., roundness and straightness) of the defect. For example, a scratch usually has an elongated strip shape, a bubble usually has a round shape, and a chipped corner usually has an irregular form. Therefore, the visual detection processing software can classify the identified defect to an appropriate type through the neural network model trained by using the data set.

[0057] In an embodiment, the visual detection processing software can locate the positions of the solar cell 10 in the photos 300, 400, and 500, and construct contour coordinates of the solar cell 10. In an embodiment, the user may provide a standard sample, and the visual detection processing software can compare the contour of the solar cell 10 with the contour of the standard sample, to identify a chipped corner, a chipped edge, edge burrs, or the like of the solar cell 10.

[0058] In an embodiment, the user may alternatively set a determining standard of the appearance level of the solar cell in advance, and the determining standard may be integrated in the device 100. FIG. 14 exemplarily illustrates threshold settings and corresponding appearance levels of impurity spots, bubbles, linear scratches, chipped edges, chipped corners, and edge burrs defects. As shown in FIG. 14, for an impurity spot, a bubble, and a linear scratch, D represents a diameter, W represents a width, L represents a length, DS represents a spacing, and N represents a number; for a chipped edge, a chipped corner, and edge burrs, X and Y respectively represent sizes in the figure. When a corresponding value detected by the visual detection processing software falls within a corresponding threshold range, the visual detection processing software can determine the corresponding appearance level of the solar cell 10. For example, a highest appearance level may be a level S, a good appearance level may be a level A, and an unqualified appearance level may be a level NG. Although FIG. 14 exemplarily shows determining standards for appearance levels of different defect types, it is clear to a person skilled in the art that the user may set other defect types and other threshold standards according to requirements.

[0059] As described above, it is easier to extract defects such as bubbles inside the substrate through the photo 300, it is easier to extract defects such as scratch and dirt on the surface of the substrate through the photo 400, and it is easier to extract defects of contour edges through the photo 500 and extraction of defects such as bubbles inside the substrate can be assisted. Therefore, the visual detection processing software can comprehensively determine the appearance defect of the solar cell 10 using the information provided by the three photos.

[0060] In an embodiment, a user may photograph a standard sample in advance by the second detection module 3000 to obtain an image of the standard sample, and calibrate, for example, the sizes A1~A6 and B1~B3 of the standard sample as described above. In an embodiment, a user may set parameters of a measurement line (e.g., an edge detection strength and a width of the measurement line), and draw a preset measurement line. The visual identifying software can select a measurement point in the photo 500 based on the measurement line preset by the user, and perform measurement between two points on the corresponding measurement point of the solar cell 10 in the photo 500. Finally, the visual identifying software can compare the measurement line recorded in the solar cell 10 in the photo 500 with the measurement line of the standard sample to obtain a relative position and a relative direction of the two measurement lines, and compare the relative position and the relative direction with thresholds to determine whether a size of the solar cell 10 satisfies a requirement.

[0061] In an embodiment, the visual detection processing software can record a defect photo of the inspected solar cell 10 and record a defect type, a defect position, a defect size, and the like of the defect photo, to construct a historical data set. A historical data set can, on one hand, be looked up by a user, and on the other hand, can be processed by analysis software, to obtain a statistical analysis of the appearance of the batch of solar cells. The analysis software may be embedded in the visual detection processing software, or may be another piece of independent software. The analysis software may make statistics on a yield of the solar cells, a discovery ratio of different defect types, a discovery position, a deviation amount of the size, and the like. The data statistics provided by the analysis software can help a manufacturer of solar cells optimize a production process, quality control, and the like. In particular, due to the fact that the detection device of this application can perform automatic inspection on a solar cell, the detection device may be integrated in a production line of solar cells, and is configured to monitor, in real time, the solar cells produced in the production line online, and feeds back the statistical data of defects of the monitored solar cells (especially

defects of different types) to the production line. The production line may be provided with a main control device, which can determine, based on received defect feedback information, procedures or steps in the production line that may cause defects, and adjust or replace these procedures or steps accordingly. For example, some procedures or steps that are prone to generating defects may be equipped with a replacement module, configured for replacement when a currently running module needs to be repaired, so as to keep the entire production line to run continuously. It may be understood that the main control device may be integrated with a neural network model or a similar artificial intelligence engine, and the neural network model or the similar artificial intelligence engine may be trained to automatically determine a procedure or a step causing a defect or a type of defects.

[0062] Back to FIG. 4, after the solar cell 10 is photographed by the second detection module 3000, the third carrying mechanism 4050 carries the solar cell 10, after detection, to a code spraying table 4002 of the code spraying module 4000. It may be understood that, when the solar cell 10 is carried to the code spraying table 4002, the foregoing visual identifying software has completed identifying and determining of the color, the defect, and the size of the solar cell 10, and provides the appearance level of the solar cell 10 according to the standard preset by the user.

[0063] FIG. 15 illustrates a code spraying assembly 4010 in a code spraying module 4000 of the device 100 shown in FIG. 4. The code spraying assembly 4010 is configured to perform code spraying on the solar cell located on the code spraying table 4002. The code spraying assembly 4010 includes a support plate 4012, a sliding lead screw 4014 disposed on the support plate 4012, and a code spraying slide frame 4016 capable of sliding on the sliding lead screw 4014. The code spraying slide frame 4016 is provided with a code spraying head 4018 and a code reader 4020. As described above, after determining the appearance level of the solar cell 10, the trained module of the device 100 instructs the code spraying assembly 4100 to spray the solar cell 2010 with information including the level and code of the solar cell 10. In an embodiment, a two-dimensional code, a bar code, or another identifier including information may be sprayed. After the solar cell 10 is placed on the code spraying table 4002, the code spraying head 4018 is driven to a working position, to perform code spraying on the solar cell 10. After the code spraying is completed, the code reader 4020 is driven to the working position to read the code of the solar cell 10, so as to verify whether the code spraying of the solar cell 10 is completed and whether information about the code spraying is accurate.

[0064] FIG. 16 illustrates a material receiving module 5000 of the device 100 shown in FIG. 4. After the code reader 4020 completes code reading, the fourth carrying mechanism 5002 of the material receiving module 5000 carries the solar cell 10 to the corresponding tray 200 located on the material receiving module 5000 according to the appearance level of the solar cell 10. After the tray 200 is filled with solar cells 10, the tray 200 is moved to a material receiving bin corresponding to a corresponding appearance level. FIG. 16 exemplarily shows material receiving bins 5010, 5020, and 5030 of three appearance levels, to accommodate the solar cells 10 corresponding to the level S, the level A, and the level NG. In an embodiment, when a code sprayer 4020 fails in code reading, a fourth carrying mechanism 5002 transports the solar cells to a transient storage box (not shown in the figure) for products that are detected to be abnormal, for subsequent manual check.

[0065] Therefore, the detection device disclosed in this application can implement rapid sorting on appearance levels of solar cells, reduce false judgment and missing detection caused by manual visual inspection, ensure the consistency of inspection standards, and avoid secondary pollution on glass sheets that may be caused by manual inspection. In addition, according to the detection method disclosed in this application, not only defects such as bubbles, impurities, scratches, foreign objects, and chipped corners of the solar cell can be detected, but also a color difference, a color uniformity, and a size accuracy can be detected, so that the appearance level of the solar cell can be determined more comprehensively.

[0066] The embodiments of the present invention may be implemented by using hardware, software, or a combination of software and hardware. The hardware part may be implemented by using dedicated logic. The software part may be stored in a memory and executed by an appropriate instruction execution system, such as a microprocessor or dedicated design hardware. A person of ordinary skill in the art may understand that the foregoing device and method may be implemented by using a computer executable instruction and/or included in processor control code. For example, such code is provided on a carrier medium such as a disk, a CD, or a DVD-ROM, a programmable memory such as a read-only memory (firmware), or a data carrier such as an optical or electronic signal carrier. The device of the present invention and a module thereof may be implemented by a hardware circuit such as a super large scale integrated circuit or a gate array, a semiconductor such as a logic chip or a transistor, or a programmable hardware device such as a field programmable gate array or a programmable logic device, or may be implemented by software executed by various types of processors, or may be implemented by a combination of the foregoing hardware circuit and software, for example, firmware.

[0067] It should be noted that although several steps or modules of the method and the device for detecting an appearance defect of a solar cell are mentioned in the foregoing detailed description, this division is merely exemplary and is not mandatory. Actually, according to this embodiment of this application, features and functions of two or more modules described above may be embodied in one module. On the contrary, a feature and a function of one module described above may be further divided into multiple modules to be materialized.

[0068] A person of ordinary skill in the art may understand and implement other changes to the disclosed implementations by studying the specification, the disclosed content, the accompanying drawings, and the appended claims. In the claims, the word “include” does not exclude other elements and steps, and the words “a” and “an” do not exclude a plural. In an actual application of this application, one element may perform functions of a plurality of technical features cited in the claims. Any reference signs in the claims should not be construed as limiting the scope.

WHAT IS CLAIMED IS:

Claim 1: A method for detecting an appearance defect of a solar cell, the method comprising:

receiving a first image of the solar cell captured by a first camera under a first light source;

receiving a second image of the solar cell captured by the first camera under a second light source, wherein a first angle between the first light source and the solar cell is less than a second angle between the second light source and the solar cell;

identifying a first defect of the solar cell in the first image and a second defect of the solar cell in the second image; and

determining an appearance level of the solar cell based on the first defect and the second defect.

Claim 2: The method of claim 1, wherein the identifying step comprises:

determining grayscale values of respective pixels in the first image and the second image; and

determining the first defect and the second defect based on the grayscale values of respective pixels.

Claim 3: The method of claim 1 or 2, wherein the determining step comprises:

determining sizes of the first defect and the second defect;

receiving thresholds of the first defect and the second defect; and

determining the appearance level of the solar cell based on a comparison of the sizes of the first defect and the second defect with the thresholds.

Claim 4: The method of claim 3, wherein the first defect is selected from one or more of a group consisting of: an uneven color of an absorbing layer of the solar cell, bubbles in the solar cell, and impurities in the solar cell.

Claim 5: The method of claim 3, wherein the second defect is one or more selected from a group consisting of: scratches, foreign objects, and dirt on a surface of the solar cell.

Claim 6: The method of claim 1, wherein the first angle ranges from 40° to 50°, and the second angle ranges from 75° to 85°.

Claim 7: The method of claim 1, further comprising:

receiving a standard image of a standard sample related to the solar cell;

determining a standard color of an absorbing layer of the solar cell in the standard image; and

determining a color difference between a color of the absorbing layer of the solar cell in the first image and the standard color, wherein the first defect is the color difference.

Claim 8: The method of claim 1, further comprising:

receiving a third image of the solar cell captured by a second camera under a third light source and a fourth light source, wherein the fourth light source is a backlight source;

receiving a standard image of a standard sample related to the solar cell;

determining a third defect of the solar cell based on the third image and the standard image; and

determining the appearance level of the solar cell based on the third defect.

Claim 9: The method of claim 8, wherein the third defect is selected from one or more of a group consisting of: chipped corners, chipped edges, and edge burrs of the solar cell.

Claim 10: The method of claim 8, wherein the third defect is a size difference between the solar cell and the standard sample.

Claim 11: The method of claim 10, wherein the size difference comprises differences between a size and a position of the absorbing layer of the solar cell, and a size and a position of the absorbing layer of the standard sample.

Claim 12: The method of claim 8, further comprising:

identifying the first defect of the solar cell in the third image; and

determining the appearance level of the solar cell based on the first defect in the first image and the third image.

Claim 13: The method of claim 8, further comprising:

identifying the third defect of the solar cell in the first image and the second image; and

determining the appearance level of the solar cell based on the third defect in the first image, the second image and the third image.

Claim 14: The method of claim 1, wherein the first camera is a line scan camera.

Claim 15: The method of claim 8, wherein the second camera is an area array camera.

Claim 16: A device for detecting an appearance defect of a solar cell, the device comprising a non-transitory computer storage medium having one or more executable instructions stored therein, the one or more executable instructions being executed by a processor performing the following steps:

receiving a first image of a solar cell captured by a first camera under a first light source;

receiving a second image of the solar cell captured by the first camera under a second light source, wherein a first angle between the first light source and the solar cell is less than a second angle between the second light source and the solar cell;

identifying a first defect of the solar cell in the first image and a second defect of the solar cell in the second image; and

determining an appearance level of the solar cell based on the first defect and the second defect.