Machine Vision System for Surface Defect Inspection of Printed Silicon Solar Cells

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***Abstract*—Solar power has become more and more important due to the decrease of the energy sources. The solar cell is the main device to transform solar power to electric power. Since the power efficiency of solar cell is decreased with defects generated in manufacturing process, defect inspection is crucial to ensure the reliability of solar cells. This paper presents a cost-effective machine vision system for surface defect inspection of printed polycrystalline silicon solar cells. The defects of printed busbars and fingers are effectively inspected by using auto-thresholding and projection techniques sequentially in the inspection process. Experimental results have demonstrated that the defect inspection of printed polycrystalline silicon solar cells is very effective with the proposed system.**

Keywords- Printed polycrystalline solar cell, Surface defect, Machine vision.

I. INTRODUCTION

The continuing decrease in the oil energy has made solar energy technology one of the fastest developing techniques today. The solar energy is generally used by the solar cells, which can produce the electric power directly from sunlight. In the final printing process of solar cells, however, it may induce some defects. These defects would worse the reliability, and even decrease the power efficiency of solar cells. To monitor the product quality, defect inspection of solar cells should be implemented in the production line.

Defect inspection was inspected manually in former days. However, manual inspection is not only time-consuming, but also has the disadvantages of non-consistence and low precision. Many applications of defect inspection, such as in the area of print circuit boards (PCBs)[1-3], thin film transistor liquid crystal display (TFT-LCD)[4,5], and solar cells[6], by machine vision are proposed. Not like the inspection techniques developed for PCBs, the methods for defect inspection of solar cells seem to be rarely proposed.

The printed type of polycrystalline silicon solar cells is shown as Fig.1. In this paper, we propose a cost-effective machine vision system for the surface defect inspection of printed polycrystalline silicon solar cells. The following sections will illustrate the defect inspection processes and results by using the proposed system based on image processing techniques.

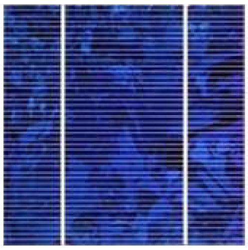

Figure 1. Printed polycrystalline silicon solar cells.

II. DEFECT INSPECTION PROCESSES AND RESULTS

A. Defect types and system implementation

After screen printing process, two types of metallic top contacts, i.e., busbars and fingers are marked on the surface of solar cells to form the printed solar cells. Busbars are connected directly to the external leads, while fingers are finer areas of metallization which collect current for delivery to the busbars. Defects exist on busbars and fingers, as shown in Fig.2, will worse the current delivery efficiency.

Figure 2. Defects on busbars and fingers of the printed solar cells.

With an aim to detect the above-mentioned defects, the inspection system for surface defects of printed polycrystalline silicon solar cells is implemented as shown as Fig. 3. In the system, the adjustable ring-type light emission diode (LED) light source can provide different color light on the inspected solar cells. Charge couple device (CCD) camera equipped with a telecentric lens captures the image and transfers to the personal computer (PC). The captured images are analyzed by the developed image processing methods to find out the surface defects of solar cells. Furthermore, the inspection process is designed to detect the surface defects of the printed type polycrystalline silicon solar cells, as shown as Fig. 4.

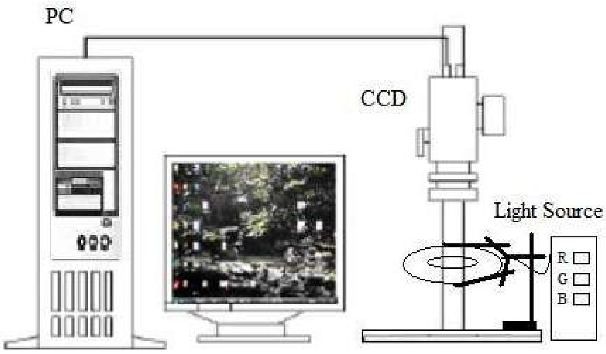

Figure 3. The inspection system scheme for surface defects of printed polycrystalline silicon solar cells.

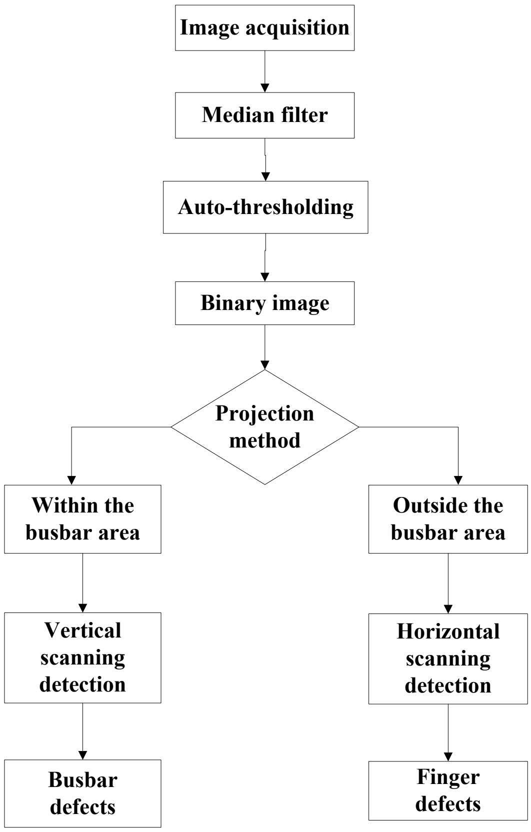

Figure 4. Surface defect inspection process of printed silicon solar cells

B. *Inspection steps and results of printed type solar cells*

In the printed type defect inspection process, the defects on busbars and fingers are the main inspection task. The detected sample is first located precisely according to a positioning accessory equipped on the inspection stage. Then, we adjust different color light to eliminate the background texture and to enhance the inspected area, i.e., busbars and fingers. We found that the red light projection can achieve this purpose. Then the image is acquired with the gray-level CCD camera and a 0.35x lens. The captured images are processed with median filtering to remove unwanted noise and transformed to binary image with the auto-thresholding process, as shown as Fig.5.

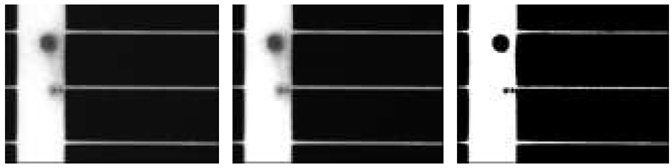

Figure 5. The printed solar-cell image. (a) the captured image; (b) the filtering image; (c) the binary image.

Since the busbars and the fingers are in vertical relation in the printed type solar cell images, projection method [7] was used to identify these two printed-line images in this study. Furthermore, the image area of busbar in Fig.5 could be presented alone by processing the data of vertical and horizontal projection. Once the busbar area image is determined, vertical scanning detection is then used to inspect defects within the busbar area. The vertical scanning is sequentially performed a one-dimensional scanning from the left margin to the right margin of busbar area pixel by pixel. If the gray-level value of a scanned pixel is zero, the pixel location is recorded. After the vertical scanning process is finished, all scanning pixels whose gray-level value are zero are marked green in the original image to present the busbar defects, as shown in Fig. 6.

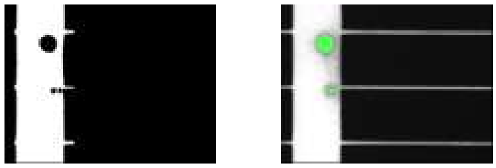

Figure 6. Defect inspection within the busbar using vertical scanning detection.

After the busbar defects have inspected, the finger defects are detected by applying horizontal scanning detection to the binary image outside the busbar area. The tiny inspected finger defects, for example, is marked yellow in the original image, and is also specially labeled with a red circle for clear display, as shown in Fig. 7.

Figure 7. Finger defect inspection using horizontal scanning detection.

III. CONCLUSIONS

In this paper, a cost-effective machine vision system is developed to perform the surface defect detection of the printed type polycrystalline silicon solar cells. All captured images are processed with median filtering to remove unwanted noise. In the other way of inspecting printed type defects, the busbars and fingers are first identified with the projection method. And then the defects of busbars and fingers are inspected and labeled by using the one-dimensional vertical and horizontal scanning detection. The surface defect inspection correctness of using the proposed machine vision system has been verified by the experiment results.

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