Development of Laser Scattering System and Inspection of Micro Defects in Crytalline Silicon Wafer of Solar Cell

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Abstract

Solar cell is considered as powerful renewable green energy. The inspection of micro defects in silicon wafer is of importance. In this paper, a laser scattering system is newly developed for inspection of silicon wafer. Effective system parameters of laser scattering are experimentally determined using maximum connected area of scattering (MCAS), which is a distinct and important feature for detection of micro defects. The performance of system parameters and MCAS are verified through several experiments in normal and defective wafer

1 Introduction

Recently, concerns on green energy become rising due to exhaustion of fossil energy and environmental contamination problems. The inspection of micro defects for silicon wafer is of importance according to wafer slimming. The inspection device for solar cell is mostly focused on macro defects, which include surface and topology defects. These defects are relatively visible and so it is enough to inspect them using image processing. However, micro defects such as scratch, pinhole, dent and inclusion, are not easy to detect because they are in a very shallow and wide region. Researches for these micro defects have not been studied well.

In this paper, a laser scattering system is newly developed for their detection. Using the developed system, the performance of extracted parameters and detection features are verified through several experiments in normal and defective wafers

2 Development of laser scattering system

Scattered light depends on micro surface topology, in case physical properties such as reflectance, color, and texture, etc, are constant. Here, laser scattering pattern is affected by geometric micro topology of reflective surface, and laser scattering intensity is changed by both incident angle and viewing one of laser. Based on scattering properties of silicon wafer, laser scattering mechanism in Fig. 1 is newly

development to detect micro defects. Vision system is applied in the detection part to catch hold of the inclination of scattering light. Spot-shaped laser with wavelength 636.6nm is used as light source. Laser scattering patterns are investigated according to change of incident laser angle and viewing camera one. Also, the azimuth angle of camera is considered to identify the optical deflection of laser scattering. The pitch stage makes an inspection table slope slant and the inspection table is equipped to rotate by 360°.

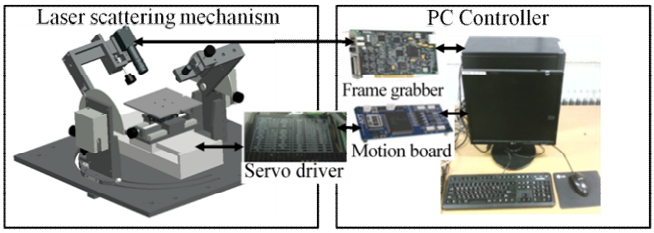


Figure 1: Laser scattering inspection system

3 Selection of effetive parameters and detection of mirco defects

Through a detailed investigation of scattering patterns, useful system parameters have been obtained: an incident angle of 75° for the laser and a viewing angle of 70° for the camera. The machined micro defects are described in Fig. 2. In this experiment, a micro defect with length 64㎛, width 32㎛, and depth 4㎛ is selected to reflect and simulate actual defects. Laser scattering patterns of micro defects are described in Fig. 3. Several pattern features are extracted; thus, their usefulness for detecting micro defects is examined in detail.

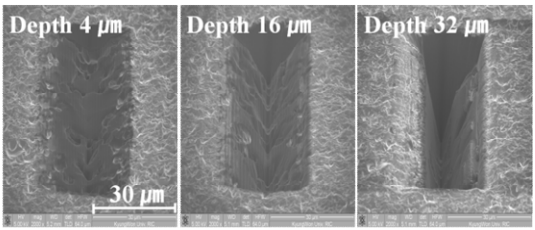
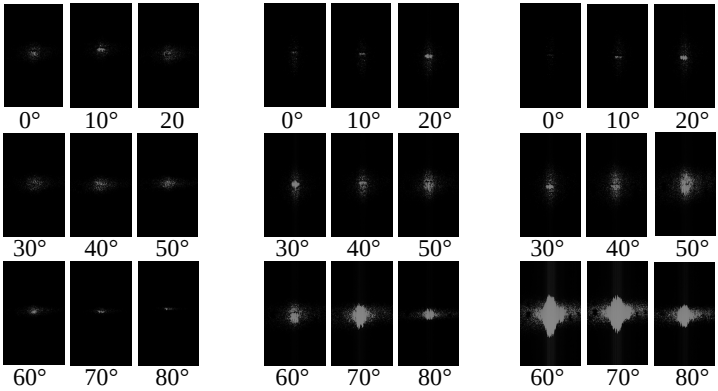


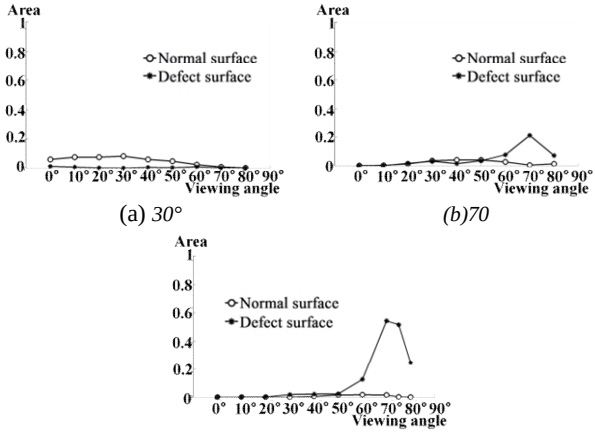
Figure 2: Images of micro-defects

As shown in Fig. 4, an useful feature, maximum connected area of scattering(MCAS) in scattered patterns depends on the system parameters and it is compared in both normal and defective surfaces.



(a)30° (b)70° (c)75°

Figure 3: Scattered images of a defect for change of incident angle



(a) *30°* *(b)70*

(c) 75°

Figure 4: MCAS comparisons for change of incident angle

When both an incident angle that exceeds thereference angle from the Rayleigh criterion and a dark-field viewing angle are applied to a defective wafer surface, a lot of diffuse scattering from micro defects can be anticipated. Therefore, MCAS is selected as the useful feature for defect detection. Regarding ten arbitrary points in a normal wafer surface, each MCAS is extracted by image thresholding and labeling processes. The respective sizes are averaged and normalized according to changes of parameters. Very large size differences in MCAS are noticeable between normal and defective wafer surfaces, when the incident angle is 75° and the viewing angle is 70°, as shown in Fig. 4(c). This is judged as very important information for the detection of micro defects. An incident angle 75° fully satisfies the Rayleigh criterion, as does

a viewing angle 70° in the dark-field region, wherein a lot of diffuse scattering results from micro defects. Fig. 5 shows the performance comparison regarding MCAS between normal and defective wafer surfaces. Here, there are 15 points near the micro defect for scattering experiment. Regarding normal wafer surfaces, 100 experiment points are selected. There are big differences between the two surfaces. Accordingly, the extracted feature, MCAS, is very applicable for the detection of micro defects. Also, the condition of the applicable system parameters is the same.

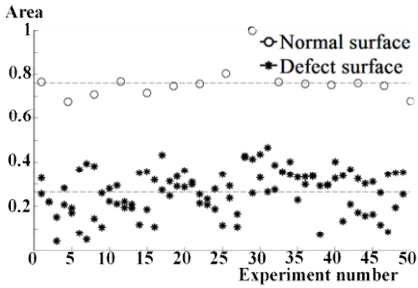


Figure 5: *Performance evaluation of MCAS for detecting micro defects.*

Through experimental analysis of scattering patterns, essential system parameters and useful features are acquired to detect micro defects in the crystalline silicon wafers of solar cells.

4 Conclusions

A laser scattering system is newly developed for inspection of micro defects in solar cell wafer. Extracted scattering parameters and MCAS are regarded as important information for detecting micro defects. Their usefulness and applicability have been verified through many experimental results.

Acknowledgement

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