Electroluminescence Characterization of Crystalline Silicon Solar Cells

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Abstract
Crystalline Si solar cells emit infra-red light under the forward bias as so called “Electroluminescence, EL”. The photographic imaging of EL intensity gives spatial information of solar cell performance with high resolution, which yields improved performance and reliability of solar cells.

Keyword: crystalline silicon solar cell, electroluminescence, crystal defect,

1. INTRODUCTION

An electroluminescence (EL) imaging technique has caught much attention as a powerful photographic diagnosis tool to provide spatially resolved information about the electronic material properties of solar cells [1-4]. In addition mechanical deficiencies such as substrate breakage and/or electrode breakdown can be easily detected in a short time. The intensity of EL is proportional to the total excess minority carrier density [3]. All the intrinsic defects and extrinsic deficiencies which reduce the minority carrier density will induce the spatial variation of EL intensity, and be displayed as dark parts (spots, lines or clouds) in EL images. In this report, the overview of EL imaging technique is introduced.

2. EXPERIMENTAL

The experimental set up is explained in elsewhere [1]. The system is simply composed a cooled Si CCD and/or InGaAs cameras used to capture EL images. The exposure time was 0.5 – 1 sec depending on the EL intensity. IR filters matched with the detection wavelength (e.g., around 1150 and 1500 nm in the cases of bandgap and deep level emissions in crystalline Si cells [4], respectively) were attached in front of the camera lens. Forward bias voltage was applied to the sample to flow the current of around 30 - 40mA/cm2. It should be noted that this forward current was almost the same as photo-generated current under 1 sun irradiation, and so the EL measurement was considered to reflect the working state of solar cells.

3. RESULTS

The emission spectrum of a crystalline Si cell taken by an infrared sensitive Ge detector was shown in Fig.1 by a dashed line. The dominant peak was at 1150nm, which was the band-to-band radiative recombination assisted by phonons. The sensitivity of Si-CCD was shown by a dotted line in Fig.1. The limited portion of the EL emission (shown by a bold line) could be detected.

Fig.1. Emission spectrum and sensitivity of Si-CCD.

Fig.2. Typical EL image for single crystalline Si cell.
The specific EL image in the case of defective single crystalline Si cell was shown in Fig.2. Generally speaking, uniform emission was expected due to the homogeneous material properties as seen in a major part of the cell surface. But, straight dark lines and scattered dark spots were observed, and they were caused by the breakdown of finger electrodes and process induced faults (dust, etc.). The long winding line was due to the wafer breakage which could not be detected by the conventional optical image as shown in the inset. These mechanical faults will reduce the production yield and affect the long term reliability of the cell. The EL method is an easy and quick way to detect these “extrinsic deficiencies”.

Fig.3. Typical EL image for a module composed of polycrystalline Si cells.

Typical EL images in the case of polycrystalline Si cells were shown in Fig.3. In contrast to the single crystalline case, crystallographic defects such as grain boundaries, dislocations and aggregation of point defects were observed as dark lines and clouds other than the cracks by substrate breakage or hidden cracks. The EL intensity is proportional to the total number of minority carriers in Si substrates. Not only the intrinsic defects but also extrinsic deficiencies induce the reduction of minority carrier number in polycrystalline Si cells. Especially, the extrinsic deficiencies cause serious problem in the reliability by the thermal heat cycles and mechanical distortions under actual installation conditions. So, the distinction of extrinsic deficiencies with intrinsic defects becomes very important in mass production of Si cells and modules.

5. CONCLUSIONS

Photographic diagnosis method of Si solar cells using electroluminescence was reviewed. The electroluminescence imaging technique was a versatile method to reveal the defective parts in solar cells visually in a short time. Extrinsic deficiencies such as substrate breakage and hidden cracks could be detected discriminating with the intrinsic defects by the temperature subtraction method, which is suitable for the quality control in the cell production process.

REFERENCES