

Influence of Laser Cutting on P-N Junction Behavior of Solar Cell

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Abstract:

We present the results of far-field nanoscopic investigation on the sub-micrometer localization and characterization of defects in optoelectronic devices (e.g. monocrystalline silicon solar cell structure) due to the material processing. Solar cells are generally prepared from Si-ingots sawed into thin round wafers by metallic wire. Hence, first defects appear on the sites of metallic precipitates, which reduce quantum efficiency of cells. Second type of defects then originates from further fitting of the round wafer into square cells. The latter can be dimensioning by mechanical sawing or breaking, laser opening or water jet stream cutting. Laser opening, as one of new processing techniques which could diminish the losses in the cells, is a promising tool but not yet well developed. Therefore this paper brings first results of preliminary study concerning the influence of laser cutting on the behavior of semiconductor p-n junction.

Introduction

Solar cells are large *p-n* junction semiconductor devices. Their quality, efficiency, reliability and lifetime critically depends on bulk, surface and edge imperfections [1]. Irregularities resulting from structural inhomogeneities or chemical impurities are the origins of non-ideal behavior, resulting in undesired loss of converted solar energy. Conventional optical solar cell inspection systems are able to detect and determine visibly-large defects that appear on the solar cell surface only [2], but hidden and small irregularities inside the cell or on its borders, e.g. almost invisible microcracks and tiny inhomogeneities, which occur during the fabrication of the cells [3] also affect overall efficiency and lifetime of the solar cell.

Defects can be present in different localized regions in solar cells and so arising electric shunts diminish the cell conversion efficiency by decreasing short circuit current and fill factor. With the extensive application of solar power produced by monocrystalline silicon solar cell modules, there is an increasing number of badly shunted cells. Consequently, it is indispensable to deal with the shunts [4]. Traditionally, the poor quality cells are discarded, which is a wasteful way, or disposed of in chemical solutions, then re-undergo the fabrication

process during which metal contamination is hard to get rid off [5]. Until some years ago, the standard process for the edge isolation of solar cells was the plasma edge isolation. But in the last few years, this technique has been widely replaced by wet chemical isolation and by laser isolation [6].

When a solar cell is reverse-biased with low voltage, weak emission from imperfections (pre-breakdown sites) usually appear when the reverse voltage is higher than 3V. This breakdown is due to irregularities in the solar cell structure. If the current density is high enough, the sample degradation could occur. To avoid this degradation, it is necessary to measure with as low as possible bias, because after partial breakdown a current is gathered in the defect regions [7]. We report on study of local measurement using Scanning near-field optical microscope (SNOM) with cooled photomultiplier in the photon counting regime, and, due to weak signals, a high sensitivity light detection. This technique allows non-destructive detection, localization and high spatial resolution of light-emitting centers originating from different imperfections in the cell.

Experimental

The experiments were done on small area of the monocrystalline silicon solar cell surface with pyramidal topography obtained by classical chemical processing, all deposited on a copper support plate.

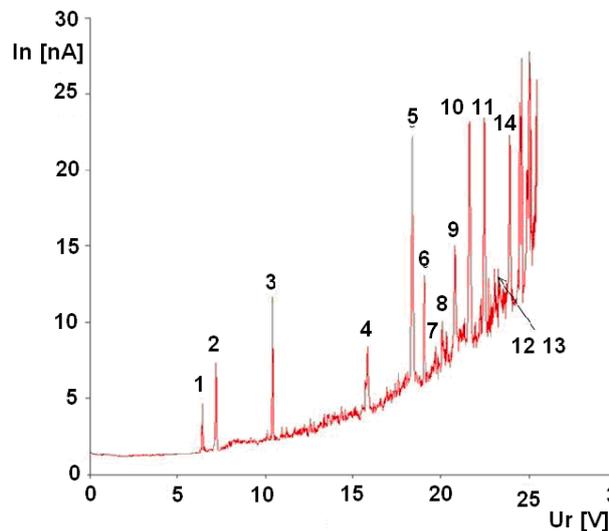


Fig. 1: Noise current vs reverse-bias voltage of the solar cell defects [8].

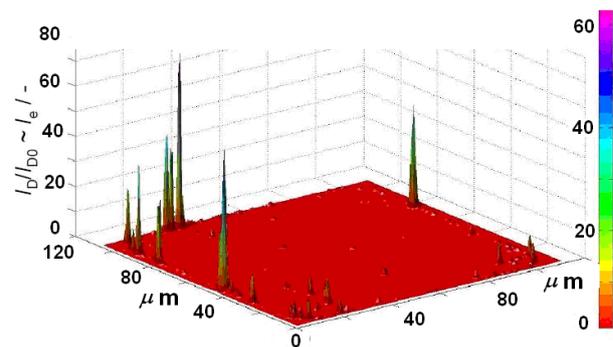


Fig.2: Localization of defects in wafer using reverse-bias light emission ($U_r = -5.9$ V).

Electrical measurement of noise current vs. voltage on silicon p-n junction allows detect and localize the pre-breakdown sites originated from defects, which originate from metallic precipitates due to the mechanical sawing (Figs.1 and 2).

Results

The decisive factor for solar cell performance is a minimization of recombination possibilities. In order to obtain high efficiency, front and rear side must be electrically isolated on the edges.

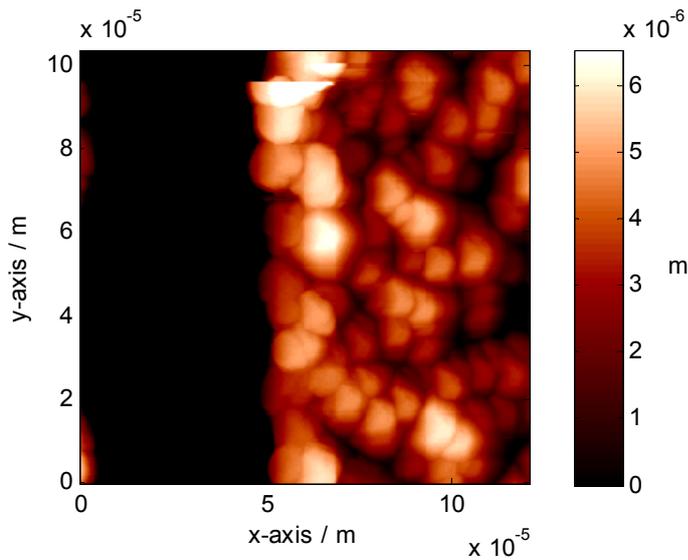


Fig. 3: 2-D Near-field topography of the solar cell edge

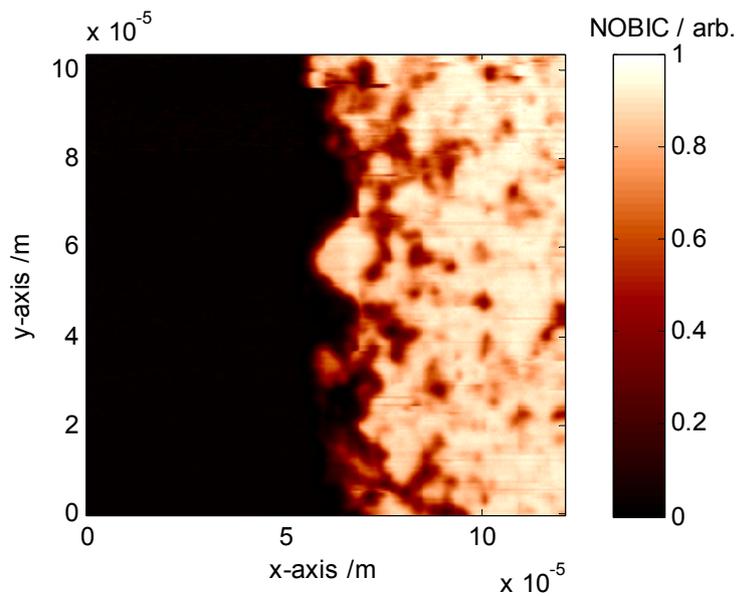


Fig. 4: 2-D NOBIC map of the same part of Fig.3.

To confirm our hypothesis that the laser opening could eliminate a majority of edge defects, the left part of the cell (Fig.2) was completely ablated with CO₂ laser. Topography of resulting edge structure was mapped with Scanning near-field optical microscope (SNOM) (Fig.3). Consequently Near-field optically induced photocurrent (NOBIC) map of this region (Fig.4) has also been obtained.

Figure 5, which is 3-D representation of Fig.4, gives us more precise information about thermal degradation due to the laser cutting of proceeded monocrystalline silicon layer.

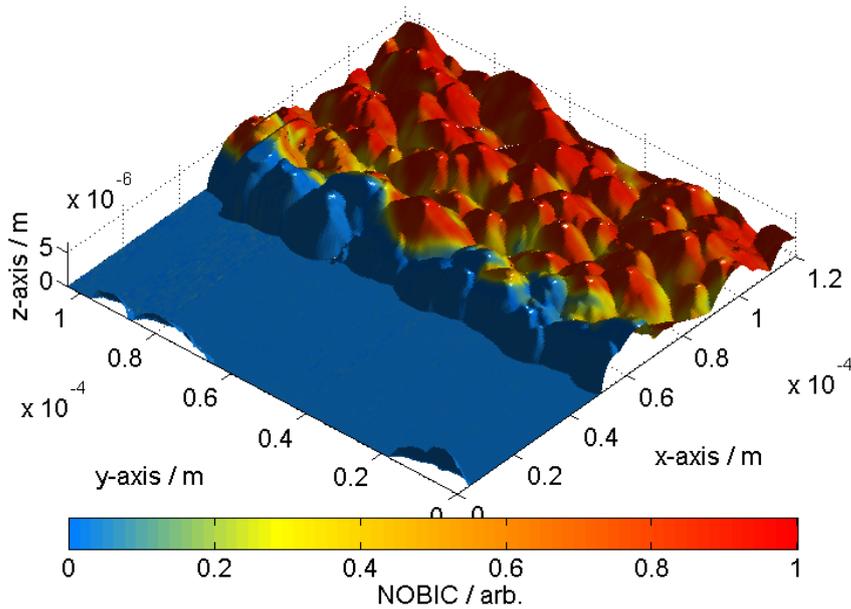


Fig. 5: 3-D map of locally induced photocurrent in p-n junction

In respect of water jet stream cutting, the main problem is connected with a diffusion of OH⁻ ions into a lattice of Si and SiO₂. Due to their absorption in SiO₂ near the first communication window, most of useful wavelengths are absorbed [9], the cell edge begins to be non-conducting. This processing diminishes the overall efficiency of the cell.

Conclusions

A calibrated SNOM and NOBIC technique combined with electrical measurement of noise current vs. reverse bias-voltage was used to investigate regions of p-n recombination in three different types of solar cells processing. The results show that due to the laser ablation it is possible to reduce the influence of some defects introduced by mechanical processing in the material. On the other hand, laser ablation could modify, due to the high energy and

temperature of a laser beam, a composition of the solar cell edge structure. A water jet stream seemed to be very effective tool, but the diffusion of OH⁻ ions also represents a serious problem and considerably limits the efficiency of light-energy conversion. The investigations show that this material is extremely enriched with SiO₂-preprecipitates, which partly decorate extended defects and may act as recombination centers. SiO₂-preprecipitates also act as gettering centers for metallic impurities.

These preliminary results show that a use of laser ablation or cutting is one of the way how to avoid imperfections in the edge area and improve solar cell efficiency. Although a laser is able to cut smooth edges (Fig.3) of the cell, it also thermally influences a behavior of p-n junction in the material (Fig.5) and degrade its overall efficiency. The further study concerning evaluation of advantages and disadvantages of this method is challenged.

Acknowledgments

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