Projection of solar cell back side contact to the LBIC image

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Abstract: - This work presents a detailed analysis of the LBIC images with visible back side contact. The LBIC measurement for a solar cell local characterization has been developed and tested on mono-crystalline silicon solar cells. The solar cells were locally illuminated by a focused light source of different wavelengths. The response (current or potential) of the solar cell was measured at stationary conditions during the scanning process. A large number of independent data with high spatial resolution were obtained. Applying an advanced fitting procedure on these data yields a set of local parameters for each point on the solar cell, giving information on the distribution of the photo current, series, shunt resistance and lateral diffusion of minority carriers. The theoretical approach to this technique will be discussed and the applicability of this characterization tool will be demonstrated and compared.
We have studied a group of silicon solar cells with good and wrong standard parameters. In this part we describe our study of the comparison between LBIC images with different wavelengths of the light source and explain the projection of back side contact of LBIC image by the theory of secondary emission of infrared light.

Key-Words: - LBIC, wavelength, silicon solar cell, back side contacts, front side contacts, luminescence

1 Introduction

The absorption of light in a semiconductor is indicated by the absorption coefficient. Not only does it determine whether light can be absorbed for photoexcitation, but it also indicates where light is absorbed – in which depth. A high value of absorption coefficient indicates that light is absorbed near the surface where the light enters semiconductor. A low value indicates that absorption is low and light can penetrate deeper into the semiconductors (Table 1). In the extreme, light can be transparent for long wavelengths without photoexcitation.

Table 1 Penetration depth of photon to silicon Si [5]

Wavelength (nm)	400	500	550	600	700	750
Penetration depth (μm)	0.19	2.3	3.3	5.0	8.5	16
Wavelength (nm)	800	850	900	950	1000	1100
Penetration depth (μm)	23	46	62	150	470	7600

2 Experiment

Light Beam Induced Current (LBIC) works on the principle of exposure of a very small area of a solar cell, usually by laser beam focused directly on the solar cell surface. This point light source moves over the measured solar cell in the direction of both the X and the Y axes. Thanks to local current response the XY current distribution in the investigated solar cell can be measured. Acquired data are then arranged in the form of a current map and the behaviour of each individual part of the solar cell is thus visible.

Light sources with wavelengths of various colours were used for scanning samples of solar cells. The various wavelengths of light were used to show the different defects in different depths under the surface of silicon solar cells. High illuminating LED diodes installed in a special tube were used. The tube was a capsule for smooth installation of the LED diode instead of standard lasers. Owing to this solution, easy regulation of illumination is enabled.

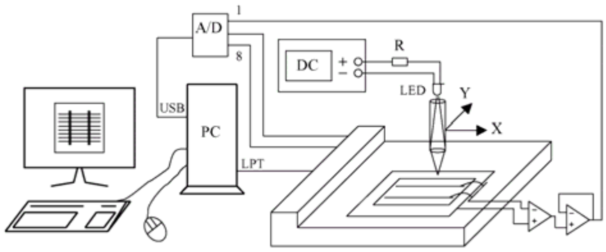

Fig. 1 LBIC method workplace.

The LBIC method is implemented by the movement of the light source (focused LED diode or laser) fixed on the grid of the pen XY plotter near the solar cell surface. Thanks to the local response of the solar cell to incident light we get the scan of local current differences (using the measurement PC card). From the obtained data we can get the whole picture of the solar cell current response to light. From this picture we can read the most local type of defect.

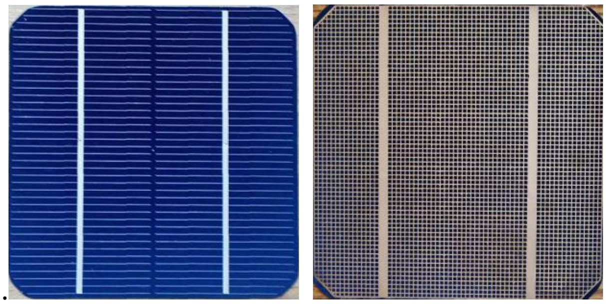

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Fig. 2 Front and back side of tested monocrystalline silicon solar cell.

In such a current map it is therefore possible to determine the majority of local defects. Sometimes there it is necessary (automatically or by hand or manually) to extend the steps of grey on displayed areas to obtain a good picture of particular defects.

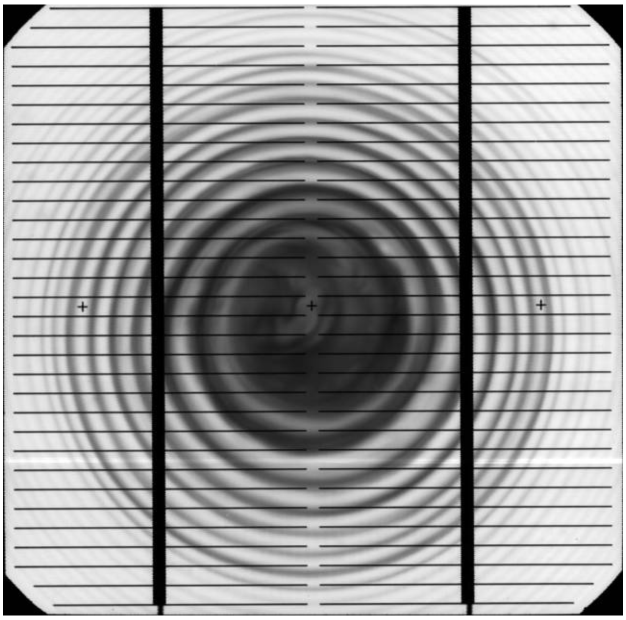

Fig. 3 LBIC picture of solar cell containing swirl defects. Visible front side contacts and material defects (swirl defect made by oxide in substrate). Sample 57A3, IR LED light source

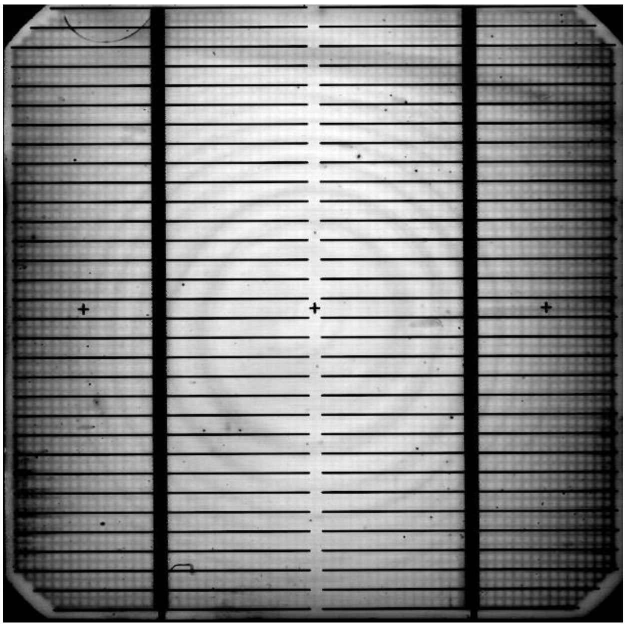

Fig. 4 The same method and sample with different light source wavelength. Visible front side contacts, material defects and part of back side contacts. Sample 57A3, green LED light source

3 Problem Solution

Thanks to different wavelengths of used light illumination we can detect different defects and structures depending on the penetration depth of light photon. However, the experiments have shown that we can detect structures behind the expected depth such as the contact bar on the back side of solar cells. These contacts we did not detect using a long wavelength (IR-980 nm or red-630 nm LED) but they were clearly visible at a short wavelength (green-525 nm, blue-430 nm or UV-400 nm LED). Nevertheless, using a long wavelength we can clearly detect deep material defects such as swirls, which are not clearly detectable by UV or blue wavelength, but this wavelength enables us to detect surface defects.

Projection of back side contact bar to short wavelength LBIC picture can be explained by the theory of secondary emission of long wavelength light (~1100 nm) which has penetration depth (~7300μm) much more higher then solar cells depth.. The incident light is absorbed in the surface of the solar cell and generates an electron-hole pair. Part of this carrier charges are separated and generate photocurrent, but owing to the high recombination rate on the surface a big amount of these carrier charges recombine and emit IR light. The IR light incidents on metal contact are absorbed without generation electron-hole pair. Light incident to back surface without metallic contact is reflected back and is absorbed inside substrate volume. This theory was verified by scanning of a solar cell illuminated by UV light (Fig. 5) in the IR region (Fig. 6).

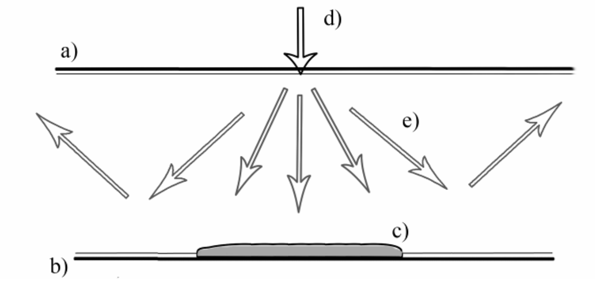

Fig. 4 Theory of projection back side contact during secondary emission of long wavelength light. a) front side surface, b) back side surface, c) metallic contact on back side, d) short wavelength light e) emitted long wavelength light.

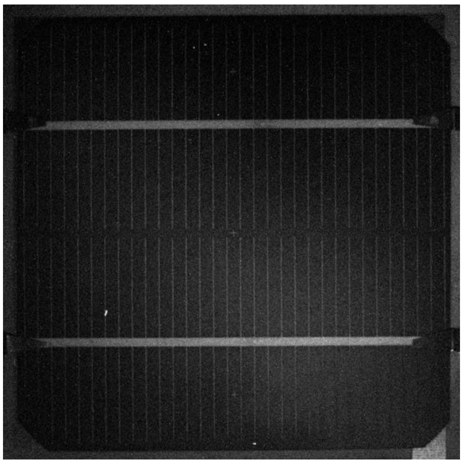

Fig. 5 Photoluminescence of solar cell 24B3 illuminated by UV-400 nm light, scan through blue filter (380- 460nm)

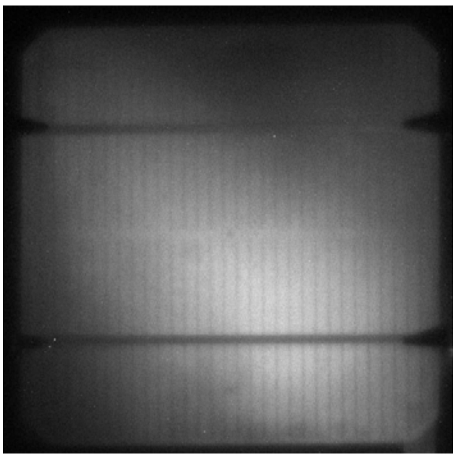

Fig. 6 Photoluminescence of solar cell 24B3 illuminated by UV-400 nm light, scanned through IR filter (742 nm and more)

4 Conclusion

The measurement of solar cells using the LBIC method makes possible defect detection. Various wavelengths of light were used to show different defects in different depths under the surface of silicon solar cells. This article presents an LBIC analysis of set silicon solar cells which were prepared using the up-to date technique. The measurements have demonstrated a strong dependence existing between the used wavelength of the light source and the LBIC characteristics, and the possibility of projecting the back side by selecting a suitable wavelength of light source.

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