Electroluminescence Imaging and Light-Beam Induced Current as characterization techniques of Multi-Crystalline Si Solar Cells

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ELi/PLi and LBIC characterization of Upgrade Metallurgical-Grade (UMG) Si solar cells

UMG silicon

It's produced at lower cost using metallurgical purification processes.

- **↑↑ Impurity concentration.**
- **↓↓ Minority carrier diffusion lengths.**

We present herein a study of upgrade metallurgical-grade (UMG) Si solar cells using ELi and LBIC characterization

Electroluminiscense imaging (Eli)

- Allow to capture full cells scale pictures. ✓
- Fast and sensitive. ✓
- Low spatial resolution. ✗

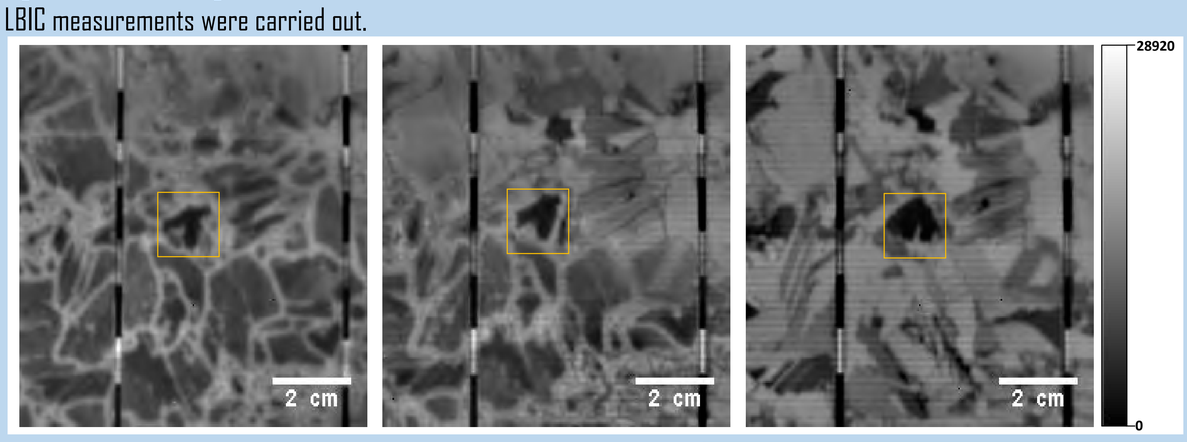
One lost details of the defect distribution, leading to misinterpretations Of the minority carrier diffusion length and quantum efficiencies.

Light beam induced current (LBIC)

Study the electrical activity of the defects at a micrometric scale provides additional understanding of the role played by the defects in the cell properties.

Eli Measurements

Figure 1. (a–c) EL images of three solar cells with different efficiencies. The marked areas indicate the zones where LBIC measurements were carried out.



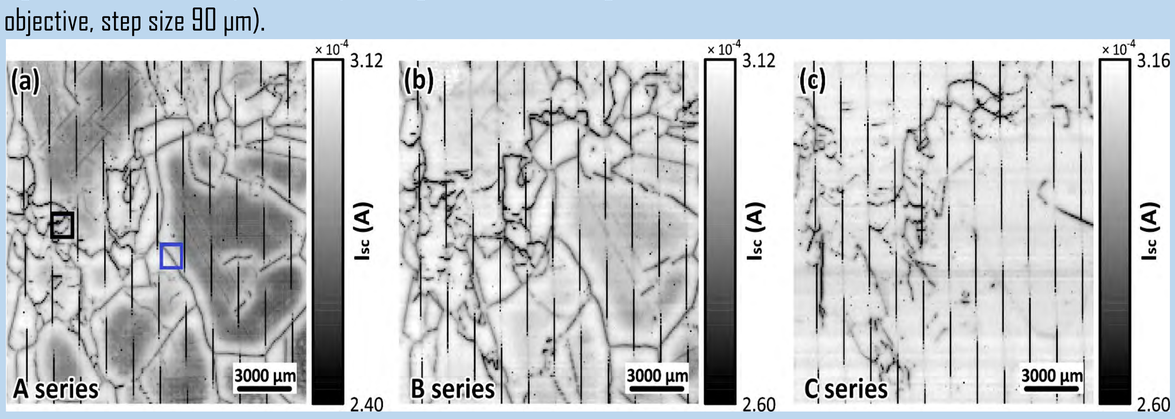
Areas with a high trapping carrier activity appear as dark contrasted.

Thes regions can be asociated with:

- **Grain boundaries (GBs)**
- **Dislocations**
- **Micro-cracks**
- **Defective contacts**

LBIC Measurements

Figure 2. (a–c) LBIC maps of the square regions indicated in Fig. 1a–c, obtained with an 853 nm laser (1.8 x 1.8 cm², 20x objective, step size 90 µm).



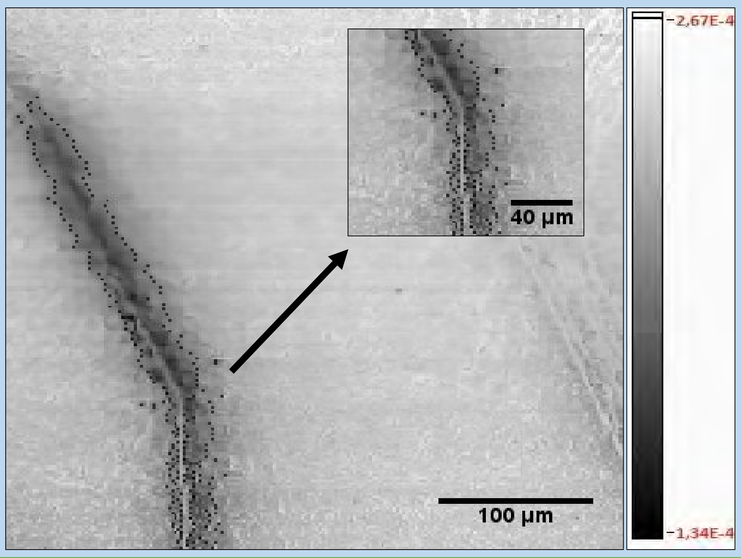
The impurities are gettered by the strain field of the grain boundaries and dislocations during the solidification leaving the surrounding areas depleted of impurities.

This effect is more marked for cells with lower efficiency (A series).

High resolution LBIC map

Fig. 3. High resolution LBIC map obtained with an excitation wavelength of 853 nm (600x600 µm2, 100x objective, step size 3 µm) showing an intragrain defect decorated with tiny dark spots.

Tiny dark spots can be associated with metallic clusters without optical and electrical activity.



This effect was observed in intragrain defects, but not in GBs.

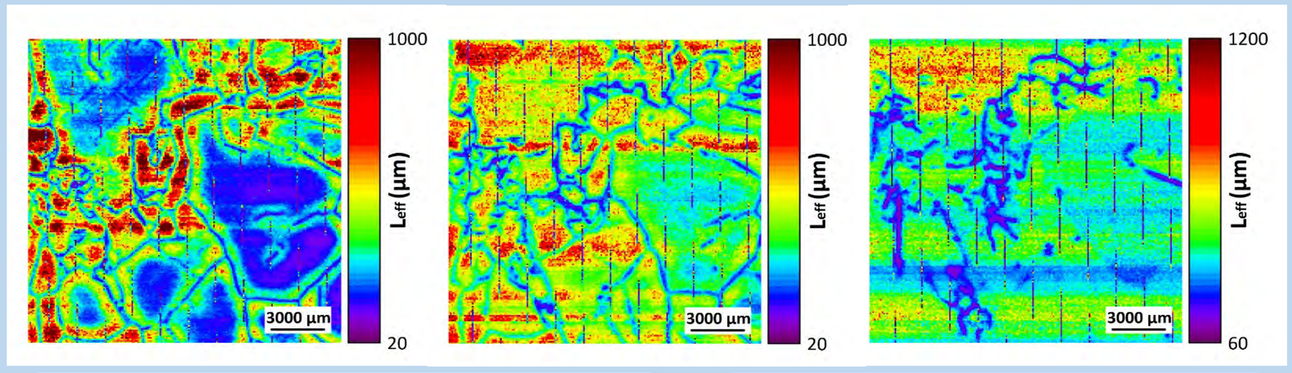
These defects are characteristic of feedstock with low purification as UMG Si.

IQE and L_{eff} maps

Fig. 4. (a–c) Leff maps of the A, B and C-series solar cell obtained with 853 nm and 975 nm lasers,

The effective diffusion lengths (Leff) are calculated from:

$$\frac{1}{IQE(\lambda)} \approx 1 + \frac{1}{\alpha(\lambda) L_{eff}}$$



L_{eff} increases from A to C. In sample A the diffusion length is severely reduced inside the grains, while it increases around the defects because of the impurity depletion around them.

This is the opposite to sample C, where the diffusion length is higher inside the grains, and appears limited at the intragrain defects formed by clusters of dislocations.

Conclusions

Full cell ELi images reveal dark contrasted areas corresponding to electrically active impurities inside the grains. Decreasing the impurity concentration changes the contrast of the Eli images.

High spatial resolution LBIC maps reveal the true defect activity patterns. The interpretation of the full wafer Eli images must take account of the patterns observed at high spatial resolution. A simple scaling from full wafer Eli to high resolution LBIC must be taken with care because of the different spatial scales

Defective studied areas revealed the presence of tiny dark spots, related to impurity clusters precipitated in impurity rich regions around intragrain defects. These defects are characteristic of low feedstock purification.

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