X-ray imaging of silicon solar cells

At a glance

X-ray diffraction imaging provides unique insights into the structure and behaviour of silicon solar cells, allowing the efficiency of devices to be improved.

Context

Key to the widespread adoption of photovoltaic (PV) cells is to increase the efficiency and reduce the cost of silicon devices. The best performing commercial PV cells, with an efficiency of around 21%, employ the same high-purity, single-crystal silicon used in the microelectronics industry. The majority of devices exploit cheaper multicrystalline silicon, however, which offers efficiencies in the region of 15%.

"Mono-like" silicon is quicker to grow and cheaper than electronics-grade silicon, and the latest prototype devices achieve similar performance. By increasing the efficiency of mono-like silicon PV cells, the cost per Watt will be reduced even further.

The challenge

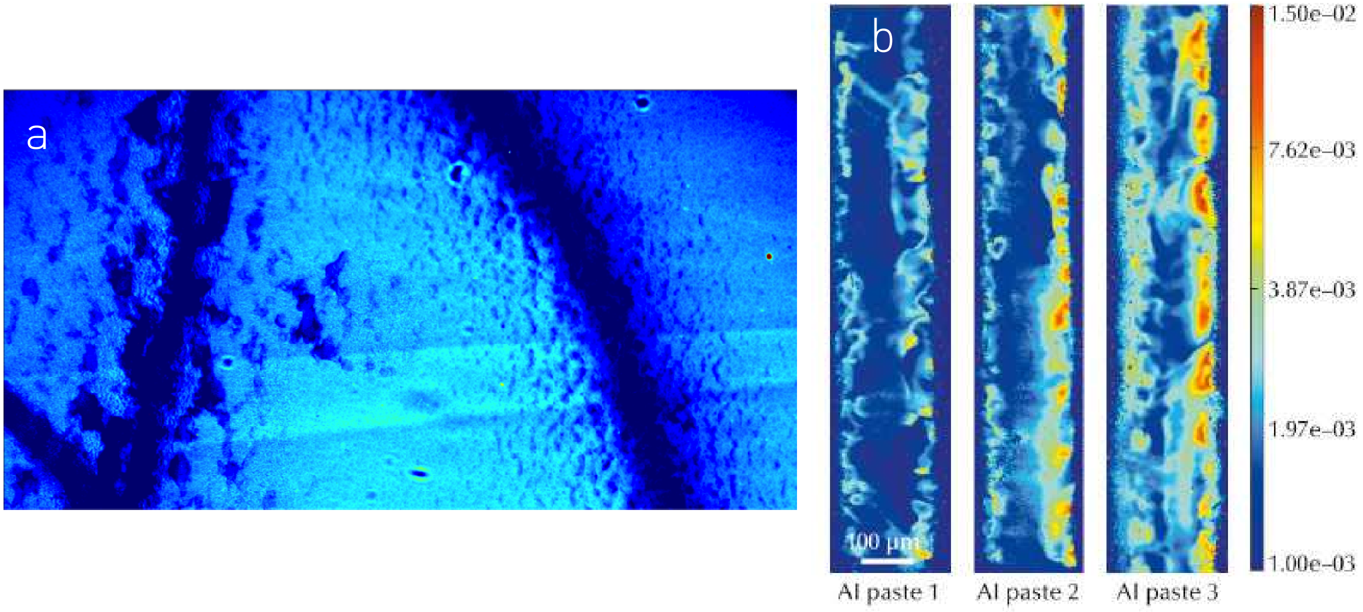
Dislocations and other electrically active defects in silicon can degrade device performance, so it is important to understand how and why they form to improve crystal growth. When optimizing the performance of silicon PV cells, it is vital to characterize the interaction between silicon and its metallic back plane, which is commonly fabricated by printing and annealing an aluminium paste.

Commercially available aluminium pastes are known to give rise to different PV performances. To find out why, researchers at ESRF beamline BM05, in collaboration with the CEA-INES, exploited advanced synchrotron X-ray imaging techniques to quantify the role of lattice distortions in PV cells with and without an aluminium backplane and when fabricated with different aluminium pastes.

The results

X-ray diffraction topography revealed significant distortion induced in the silicon when the aluminium backplane is present (figure a). In regions where the backplane was removed by etching, however, the sample shows much less distortion. These and other measurements demonstrated that the eutectic layer next to the aluminium back contact is directly responsible for the distortion and strain of the silicon.

The degree of distortion was measured using a technique called X-ray section topography rocking curve imaging (figure b). When compared with photovoltaic measurements, the results strongly suggest a correlation between photovoltaic efficiency and the lattice distortion of the silicon in contact with the eutectic and aluminium layers.



(a) Integrated diffracted intensity of a solar cell based on mono-like silicon, in which the left part of the sample has the full cell structure and the right part has the aluminium back plane removed. (b) Section topography rocking curve imaging of cells with back planes made from three different aluminium pastes: "paste 1", in a cell associated with high photovoltaic efficiency, causes less distortion of the Si wafer, while "paste 3" (corresponding to a less efficient cell) induced misorientations up to 8 x 10–3 degrees.
[T Thi et al. 2015 Solar Energy Materials and Solar Cells 135 17--21]

Conclusion

The results demonstrate that synchrotron methodologies are valuable techniques for studying not only the structure and crystalline perfection of silicon, but also features associated with the electrical efficiency in PV cells.

The ESRF/CEA-INES experiments revealed that the efficiency of mono-like silicon PV cell depends strongly on the amount, grain size and precise composition of aluminium paste used to fabricate the PV cell backplane.

The eutectic layer is directly responsible for the distortion and strain at the Si back surface, with a higher homogeneity producing less distortion and thus the highest efficiencies. The appropriate choice of paste is therefore crucial for producing high performance solar cells.

The technique

➢Defects in near-perfect crystals, such as dislocations, voids and grain boundaries, result in misorientation of the crystal lattice via long-range distortion and strain fields.

➢X-rays pass through a sample and are diffracted, with the distribution of diffracted intensity recorded by a 2D detector to reveal any departures from crystal perfection.

➢The non-destructive technique is applicable from ingot growth through to functional solar cells.

➢Users may run their own experiments or send in samples to be measured by ESRF scientists.

➢BM05 is ideal for white beam topography, monochromatic beam topography and rocking curve imaging in both projection and section geometries.

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