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## S E M I N A R

## aus

## Halbleiterphysik und Nanotechnologie

**Do, 19.4.2012, 9:15 Uhr**
**Hörsaal Allgem. Maschinenbau**

## "Classification and Investigation of Recombination Active Defects in Multicrystalline Silicon Thin Film Solar Cells "


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All multicrystalline silicon (mc-Si) solar cells suffer from recombination active defect structures. Recombination active defect structures in silicon solar cells made from pure- as well as from upgraded metallurgical grade (umg) Si feedstock are limiting (i) the solar efficiency and (ii) the electrical breakdown behavior. Therefore it is of utmost importance to understand the cause and the physical mechanism of recombination and prebreakdown processes at these defect structures. Since a mc-Si solar cell has a large number of defects it is mandatory to classify the different defect types before investigation.

Based on their electro-optical and structural properties [1] recombination active defects in mc-Si solar cells may be classified for defect diagnostics and quality control in the PV industry. Two types of recombination active defects can be clearly distinguished already on a macroscopic scale using voltage-depend Electroluminescence (EL) and Lock-in Thermography (LIT). For a more detailed understanding of the structural causes the classification was also performed on microscopic scale. Here, high resolution EL Microscopy, LIT and Scanning Electron Microscopy (SEM) with Electron Beam-induced Current Measurement (EBIC) is applied. It is shown that defect types on a macroscopic scale can be directly identified with structures observed on a microscopic scale. Structural and chemical properties of individual defect types are investigated on an atomic scale using Focused Ion Beam techniques for target preparation and subsequent Transmission Electron Microscopy (TEM). One defect type could be clearly correlated to metal precipitates located at defect structures of the underlying wafer explaining additionally the observed prebreakdown behavior at these defect structures [2]. Furthermore, we could show that this defect type is strongly influenced by the solar cell process [3]. Based on their specific structural and electronic properties, various other electrical defects may be understood in terms of charge carrier recombination acivity, prebreakdown by tunnelling and avalanche processes.


[1] K. Bothe et al., Luminescence emission from forward- and reverse-biased multicrystalline silicon solar cells, J. Appl. Phys. 106, 104510 (2009)
[2] A. Hähnel et al., TEM investigations on an iron particle inducing type-2 breakdown in mc-Si solar cells, 27th PCSEC Frankfurt (2012), to be published
[3] R. Bakowskie et al., Comparison of Recombination Active Defects in mc-Si by means of PL Imaging and Reverse Biased Electroluminescence, 26th PVSEC Hamburg (2011)



Research has been performed in collaboration with D. Lausch[1], M. Werner[1], J. Bauer[2], R. Bakowskie[3], R. Lantzsch[3], M. Mergner[1], K. Petter[3], O Breitenstein[2] ( [1] Fraunhofer Center for Silicon Photovoltaics, Walter-Hülse-Str. 1, 06120 Halle, Germany ,[2] Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany , [3] Q-Cells SE, Germany )