The supervisory board of the Kestcells Project announces the Seminar AMU-04:

# "*Black Silicon Photovoltaics*"

***Dates***: 24th of July, 2014.
***Place***: AMU, CINaM – Campus de Luminy - Salle Raymond Kern, Marseille, France

### *Program*

| Time | Subject | Speaker |
|---|---|---|
| 16:00 – 17:30 | Black Silicon Photovoltaics. | Prof. Ralf B. Wehrspohn |
| Fraunhofer-Institute for Mechanics of materials IWM Halle and Institute of Physics, Martin-Luther-University Halle-Wittenberg | | |

### *Summary*

A promising way to boost efficiencies in most known solar cell concepts is to improve light trapping in the absorber layer of the cell. The current state of the art light trapping in silicon solar cells is achieved by front side modifications like random- or inverted-pyramids with optimized anti-reflection coatings (ARC). They combine two important features: a very good enhancement in light-trapping for thick silicon absorbers (100 – 250 µm) and the capability to suppress electronic surface recombination. Such integrated ARC and passivation coatings consist of PECVD deposited dielectric layers (e.g. silicon-nitride, silicon-oxide, amorphous silicon). However, towards further cost reduction of silicon solar cells thinner absorber layers are required, which in turn demands much stronger improvement of high quality light-trapping features and the feasibility to effective passivation of the same.

A nanotexture consisting of needle like structures -often called black silicon- shows excellent ARC and light trapping properties. Reflection losses are minimized to less than 1.6 % between a light wavelength of 300 – 1100 nm. Our black silicon light-trapping scheme enables an absorption enhancement factor of ~10 at the band edge of silicon (1150 nm) as compared to a simulated perfect ARC, where the Yablonovitch limit corresponds to a factor of 15. Towards the integration of our nanostructures into a solar cell device, the passivation performance of atomic layer deposited thin $Al_2O_3$ films is investigated on a variety of black etched structures. The coatings lead to measured surface recombination velocities of less than 13 cm/s on bifacially black structured and 12 cm/s on polished 1–5 cm p-type Si CZ wafers. These results demonstrate that this technology provides the important features described abvove: a very high light trapping efficiency and simultaneously very low surface recombination velocities, which are needed to reach high efficiencies with solar cell concepts based on thin c-Si absorbers [1,2,3]. A comparison of

different black silicon textures from several groups world-wide is presented and discussed in the framework of light trapping efficiency, carrier lifetime and surface recombination velocities [4]

Finally a novel route to prepare black silicon by metallurgical silicon including upgrading the quality of black silicon [5].

1. M. Otto, M. Kroll, T. Käsebier, S.-M. Lee, M. Putkonen, R. Salzer, P. T. Miclea, and R. B. Wehrspohn, “Conformal Transparent Conducting Oxides on Black Silicon”, Adv. Mater. 22 (2010) 5035–5038.

2. M. Otto, M.Kroll, T. Käsebier, R. Salzer, A. Tünnermann, and R. B. Wehrspohn, “Extremely low surface recombination velocities in black silicon passivated by atomic layer deposition” Appl. Phys. Lett. 100 (2012) 191603.

3. K. Füchsel, M. Kroll, T. Käsebier, M. Otto, T. Pertsch, E.-B. Kley, R. B. Wehrspohn, N. Kaiser, A. Tünnermann, “Black silicon photovoltaics”, Proc. Of SPIE 8438 (2012) 84380M

4. Martin Otto, Michael Algasinger, Howard Branz, Benjamin Gesemann, Thomas Gimpel ,Kevin Füchsel, Thomas Käsebier, Stefan Kontermann, Svetoslav Koynov, Xiaopeng Li,Volker Naumann, Jihun Oh, Alexander N. Sprafke, Johannes Ziegler, Matthias Zilk, and Ralf B. Wehrspohn, Adv. Opt. Mater. Submitted.

5. X. Li , Y. Xiao , J. H. Bang , D. Lausch , S. Meyer, P.-T. Miclea, J.-Y. Jung , S. L. Schweizer, J.-H. Lee, and R. B. Wehrspohn” Upgraded Silicon Nanowires by Metal-Assisted Etching of Metallurgical Silicon: A New Route to Nanostructured Solar-Grade Silicon” Adv. Mater. 25 (2013) 3187-91.