Macroporous silicon as absorber for thin heterojunction solar cells

Marco Ernst[1], Rolf Brendel[1,2], Rafel Ferré[1], and Nils-Peter Harder[1,3]

[1]Institute for Solar Energy Research Hamelin (ISFH), Am Ohrberg 1, D-31860 Emmerthal, Germany
[2]Institute of Solid-State Physics, Leibniz Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany
[3]Institute of Electronic Materials and Devices, Leibniz Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany

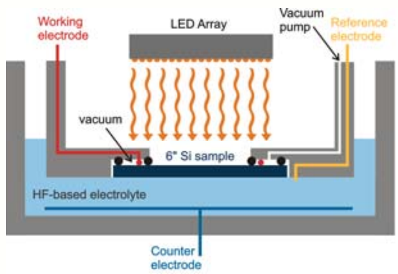
Objectives

- Reducing the Si material consumption per solar cell
- Maintaining the high efficiency potential of monocrystalline Si
- Formation and separation of thin macroporous silicon (MacPSi) layers from a wafer for using this layer as absorber for thin-film solar cells

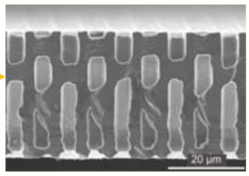
(V. Lehmann et al., German patent DE 42 02 455 C1, filed 1992)

Illustration of formation and separation of a macroporous Si layer from a substrate wafer. Finally, the substrate is cleaned for re-use.

Formation of macropores in n-type Si



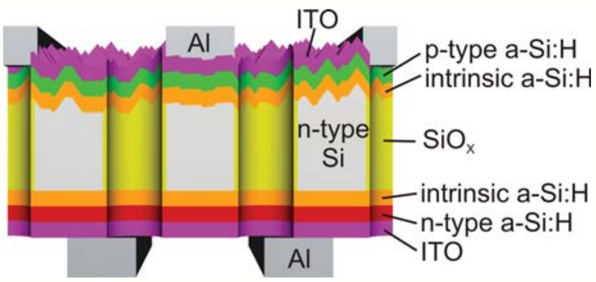
Schematic of the electrochemical etching setup with rear-side illumination



Cross section of a detached and free-standing (33 ± 2) µm thick macroporous Si absorber layer.

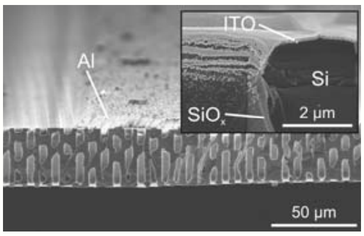
- Rear-side illumination generates electron-hole pairs
- Holes (minority carriers in n-type Si) are required for the electrochemical dissolution of silicon in hydrofluoric acid (HF)-based electrolytes
- Pore diameter (and thus the porosity) controlled by current density which is a function of the light intensity
- Pore diameter (4.7 ± 0.2) µm; pore distance 8.3 µm
- The porosity is (29.1 ± 2.5) %
- Detachment of 85 × 85 mm²-sized MacPSi-films that are separated into 25 × 25 mm²-sized pieces

Heterojunction solar cell processing



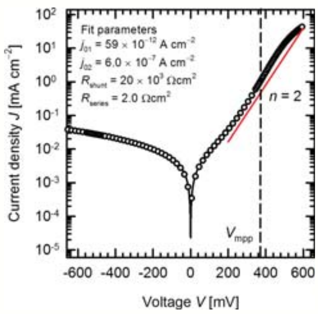
Schematics of the macroporous silicon solar cell *(not to scale)*.

- Heterojunction cell process:
  - Intrinsic amorphous Si (a-Si)/p⁺-type a-Si/indium tin oxide (ITO) layer stack on the front side
  - Intrinsic a-Si/n⁺-type a-Si/ITO layer stack on the rear side
- Pore walls passivated with a thermally grown oxide layer
- Pores are open when depositing the layers onto the 3.92 cm²-sized and (33 ± 2) µm-thick cell
- Oblique evaporating of Al fingers through a shadow mask to avoid shunting
- Rear-side grid is at interdigitated positions relative to the front-side grid to further reduce the risk for shunting

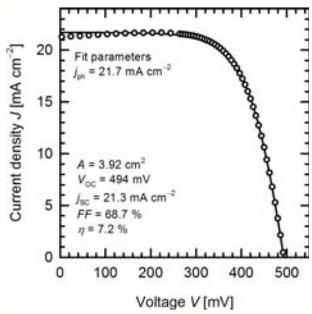


Cross section of an identically processed MacPSi cell with an Al finger. The inset shows the oxide layer on the pore walls as well as the ITO layer at the surface.

Solar cell results



In-house measured dark (circles) and fitted (line) *J-V* curve of the MacPSi cell. The red line is a plot for *n* = 2.



In-house measured (circles) and fitted (line) *J-V* curve of the MacPSi cell under one sun illumination.

- First working MacPSi solar cell with an energy-conversion efficiency of 7.2 %
- Lumped shunt resistance of 20 × 10³ Ωcm²
  → No shunting through pores
- Reference cells: Open-circuit voltage of 659 mV, short-circuit current density of 28.9 mA cm⁻², fill factor of 74.2 %
  → Heterojunction cell process itself is not limiting the performance of the MacPSi cell
- Cell performance is likely to be limited due to poorly passivated pore surfaces. Average surface recombination velocity at the pore walls is 300 cm s⁻¹ determined from quantum efficiency analysis

Conclusion – First solar cell results using macroporous Si as absorber are very promising. Future work will have to optimize surface passivation of the pore walls to improve cell efficiency.

Institute for Solar Energy Research Hamelin (ISFH)
Am Ohrberg 1, D-31860 Emmerthal, Germany, Mail: ernst@isfh.de, Tel.: +49 (0) 5151 999-644, Fax: +49 (0) 5151 999-400