Insights into high-illumination properties of nanowire Si/a-Si:H solar cells

Tiphaine MATHIEU-PENNOBER[1], Martin FOLDYNA[2], Shan-Ting ZHANG[3,4], François H. JULIEN[1], Maria TCHERNYCHEVA[1]

1: C2N, UMR 9001, CNRS, Université Paris-Saclay, 91120 Palaiseau, France.
2: LPICM, UMR 7647, CNRS, Ecole Polytechnique, IP Paris, 91128 Palaiseau, France.
3: CNRS, UMR 9006, Institut Photovoltaïque d'Ile-de-France (IPVF), 91120, Palaiseau, France
4 : Institut Photovoltaïque d'Ile-de-France (IPVF), 91120, Palaiseau, France
tiphaine.mathieu-pennober@c2n.upsaclay.fr

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Nanowires (NWs) with radial junction geometry allow to decouple the light absorption and the carrier collection. This is particularly advantageous for lower-quality materials having short minority carrier diffusion lengths such as hydrogenated amorphous Si (a-Si:H). Solar cells made of Si/a-Si:H radial junction NWs can be highly cost-efficient since they can be grown on large areas at rather low temperatures (around 400 °C) with plasma enhanced chemical vapor deposition techniques and show promising energy conversion efficiency over 9%.[1] Compared to their bulk counterparts, NWs show less degradation under light irradiation (the Staebler-Wronski effect) than typical planar a-Si:H cells.[1] In this study, we provide an analysis of the NW and planar cell properties under high illumination.

The behavior of Si NWs/a-Si:H solar cells (with active area of 3.14 mm^2) under concentrated laser illumination (wavelength of 532 nm) is tested with different laser spot size as defined by a pinhole (nominally 400 µm – 1400 µm in diameter). When increasing the illumination power beyond a certain threshold, the open-circuit voltage (V_{oc}) and the short-circuit current (I_{sc}) decrease (Fig. 1). Such a decrease is not expected from literature, where a lower efficiency under high illumination is mostly attributed to a lower fill-factor. The same behavior is observed with a planar a-Si:H cell, which demonstrates that it is rather related to the material itself and not to the NW structure.

These effects scale with the total illumination power, which is surprising considering that similar integrated powers for different spots correspond to very different intensity profiles and local generation rates. Interestingly, when the V_{oc} values are plotted as a function of I_{sc}, they show a rather complex relationship, previously not described in the literature. Finally, the cell presents an irreversible degradation under high illumination (marked with colorful bars in Fig. 1) with a steep decrease of V_{oc} and I_{sc} as well as the power conversion efficiency. The observed behavior will be discussed for the NW, planar a-Si:H and planar c-Si solar cells.

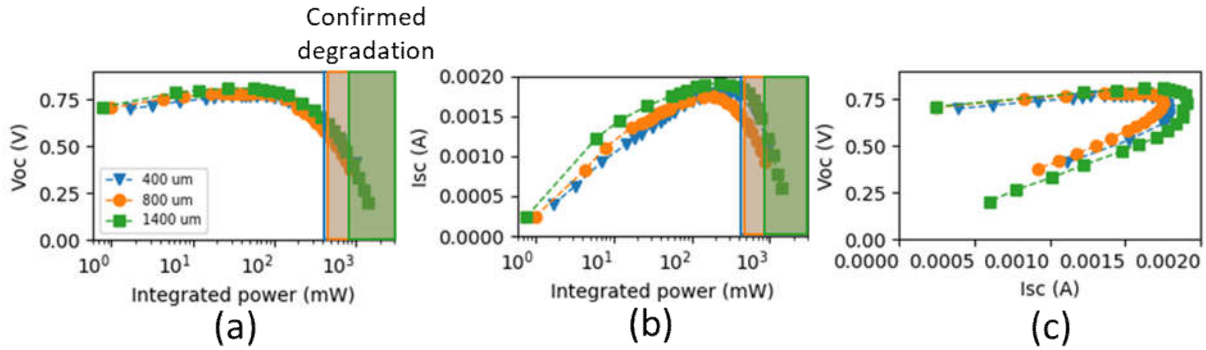

Figure 1: (a) V_{oc} and (b) I_{sc} under increasing illumination for different diameters of the laser spot for the Si/NW a-Si:H cell. The region of confirmed irreversible degradation is shown in shaded color for every set of measurements. (c) V_{oc} compared to I_{sc} for increasing illumination.

References :

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