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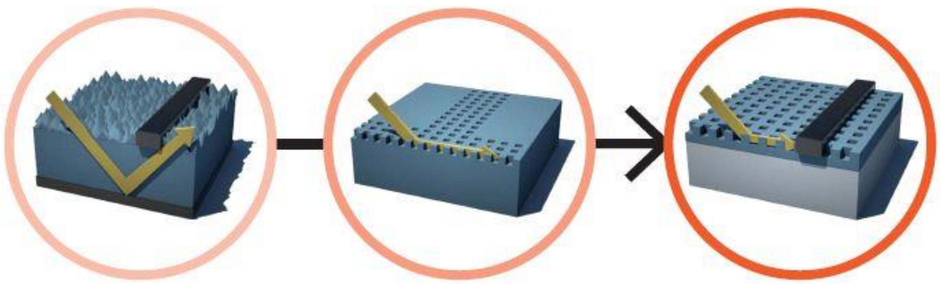

photoNvoltaics

nanophotonics for ultra-thin crystalline silicon photovoltaics

Crystalline silicon is the most widespread and preferred material for photovoltaics. Earth-abundant, non-toxic and stable, it presents many assets for a large-scale deployment of solar electricity. It has however an intrinsic drawback, its rather weak absorption of light, particularly of lower-energy photons in the infrared spectrum. This requires the usage of rather thick wafers of silicon, that contribute to a significant share of the final module cost and especially of energy consumption for their production. An efficient way of trapping these low-energy photons would enable making thinner silicon cells as "thick" optically as standard wafers, hence reaching high energy-conversion efficiencies with thinner/lower-cost solar cells.

Texturing of silicon at the sunlight-wavelength scale is known to have such potential of boosting the light absorption of thin crystalline silicon films beyond what can be achieved with standard larger-scale textures. The aim of PhotoNVoltaics was to learn which nanotexture geometries are optically optimal and how to integrate them into thin films of crystalline silicon without damaging their electrical performance. The project brought together 7 partners from 3 different fields – photovoltaics, photonics and nanolithography – and from 3 different worlds – R&D, academia and industry – to study and achieve in 3 years the conditions for a successful integration of photonic nanotextures into solar cells.

The consortium investigated, in tight interaction loops of modelling and experiments, which photonic nanotextures (with which dimensions, shapes, pattern) work best as front-side textures of thin-film crystalline-silicon solar cells.

The nanotextures were evaluated not only optically but also electrically, to assess and understand their impact on the solar cell functioning and to find how to mitigate their negative impacts when necessary. Furthermore, periodic, pseudo-periodic and random textures were compared. The results confirm that for light-trapping purposes, periodic structures outperform random textures, but that the controlled disruption of periodicity is beneficial for the optical performance. Interestingly, this means that some tolerance on nanopattern defects is allowed during fabrication. Eventually the project has led to the development of a set of powerful tools for modelling realistic solar cells with a very broad range of patterns, and it defined guidelines for efficient integration of nanophotonic textures into thin-film crystalline silicon solar cells.

This understanding was demonstrated by the achievement of ultra-thin cells with boosted short-circuit current densities, without any losses in their electrical properties, resulting in more than a doubling of their energy-conversion efficiency. Furthermore, our results also show that if boosting light absorption beyond the Lambertian limit may be possible in optimised optical demonstrators, it is far more challenging in functional solar cells, where a significant part of the highly-absorbed light is lost in non-active parts of the device, that are however indispensable for the cell functioning.

Finally, not only the technical aspects but also economical aspects were studied, to identify the current bottlenecks for deployment into industry of 3 different nanolithography techniques.

www.photonvoltaics.org