Direct measurement of optical losses in plasmon-enhanced thin silicon films

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Plasmon-enhanced absorption, often considered as a promising solution for efficient light trapping in thin film silicon solar cells, suffers from pronounced optical losses i.e. parasitic absorption, which do not contribute to the obtainable photocurrent. Direct measurements of such losses are therefore essential to optimize the design of plasmonic nanostructures and supporting layers. Importantly, contributions of useful and parasitic absorption cannot be measured separately with commonly used optical spectrophotometry.

In this study we apply a novel strategy consisting in a combination of photocurrent and photothermal spectroscopic techniques to experimentally quantify the trade-off between useful and parasitic absorption of light in thin hydrogenated microcrystalline silicon (μc-Si:H) films incorporating self-assembled silver nanoparticle arrays located at their rear side. The highly sensitive photothermal technique accounts for all absorption processes that result in a generation of heat i.e. total absorption while the photocurrent spectroscopy accounts only for the photons absorbed in the μc-Si:H layer which generate photocarriers i.e. useful absorption [1].

We demonstrate that for 0.9 μm thick μc-Si:H film the optical losses resulting from the plasmonic light trapping are insignificant below 730 nm, above which they increase rapidly with increasing illumination wavelength. For the films deposited on nanoparticle arrays coupled with a flat silver mirror (plasmonic back reflector), we achieved a significant broadband enhancement of the useful absorption resulting from both surface texturing and plasmonic scattering, and achieving 91% of the theoretical Lambertian limit of absorption.

[1] S. Morawiec et al. Experimental Quantification of Useful and Parasitic Absorption of Light in Plasmon-Enhanced Thin Silicon Films for Solar Cells Application. *Scientific Reports* **6** (2016)