LPVO Laboratory of Photovoltaics and Optoelectronics

Design and optimisation of TF Si PV modules with surface-textured glass by using a combined geometric optics / wave optics model

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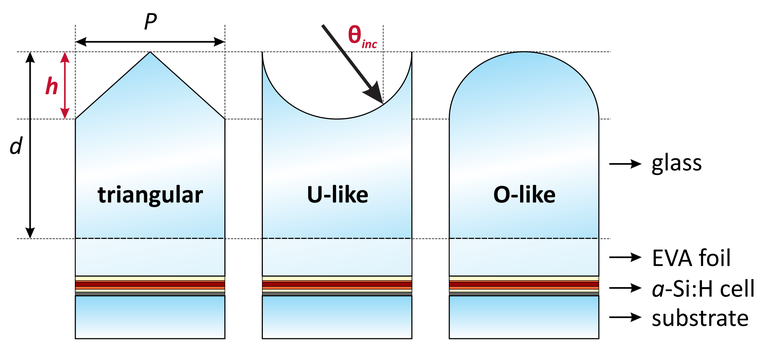
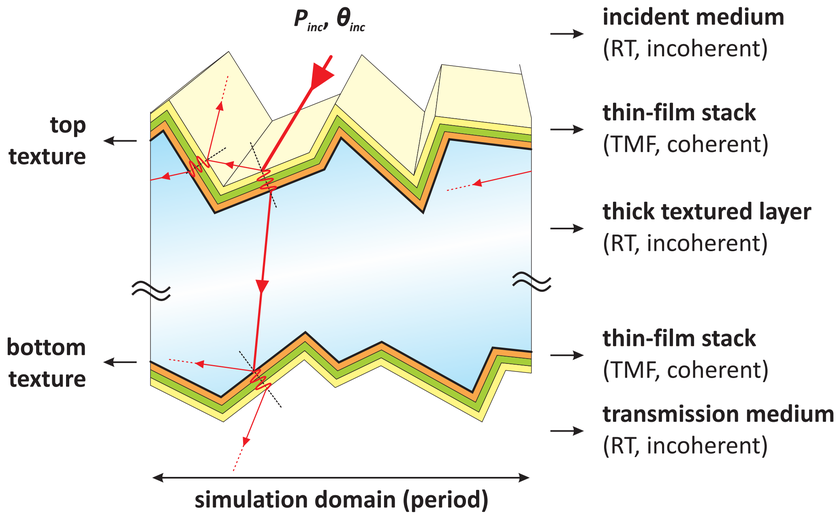
Objectives

- investigation of light-trapping potential of micro-scale textures applied on top of front glass in thin-film (TF) Si PV modules
- simulated device structure:
  front surface-textured glass (1 mm), encapsulating EVA foil (100 µm), ITO (70 nm), *p*-*a*-SiC:H (10 nm), *i*-*a*-Si:H (250 nm), *n*-*a*-Si:H (20 nm), sputtered ZnO:Al (80 nm), Ag (300 nm), rear glass substrate
- three types of one-dimensional periodic surface textures included in the analysis (period P = 100 µm, varied height h)

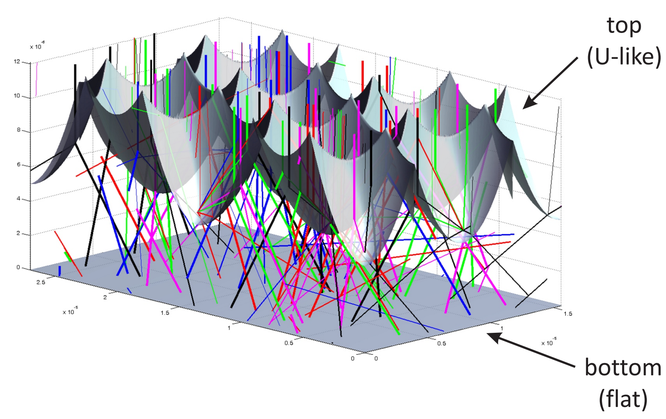


3D optical simulator CROWM

- micro- and milli-scale periodic 1D or 2D textures can be applied on either side of the thick substrate / superstrate layer of the investigated thin-film PV device
- combination of two simulation methods employed for different parts of the device:
  - thick textured layer → 3D ray tracing (RT, incoherent geometric optics)
  - thin-film solar cell → 1D transfer matrix formalism (TMF, coherent wave optics)
- primary simulation results:
  - total reflectance (R_{tot}), transmittance (T_{tot}), and absorptance (A) within each layer
  - quantum efficiency (QE), short-circuit current density (J_{sc}), and optical J_{sc} losses



[Lipovšek et al., Informacije MIDEM 41 (2012) 264-271]

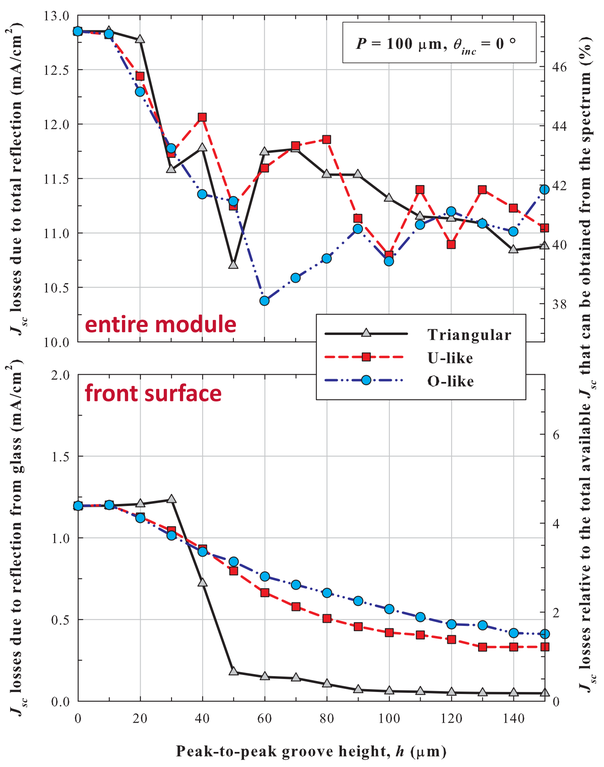


Example CROWM 3D simulation of light rays propagating through a surface-textured layer (U-like top texture, flat bottom).

Optimisation of 1D surface textures in *a*-Si:H PV modules

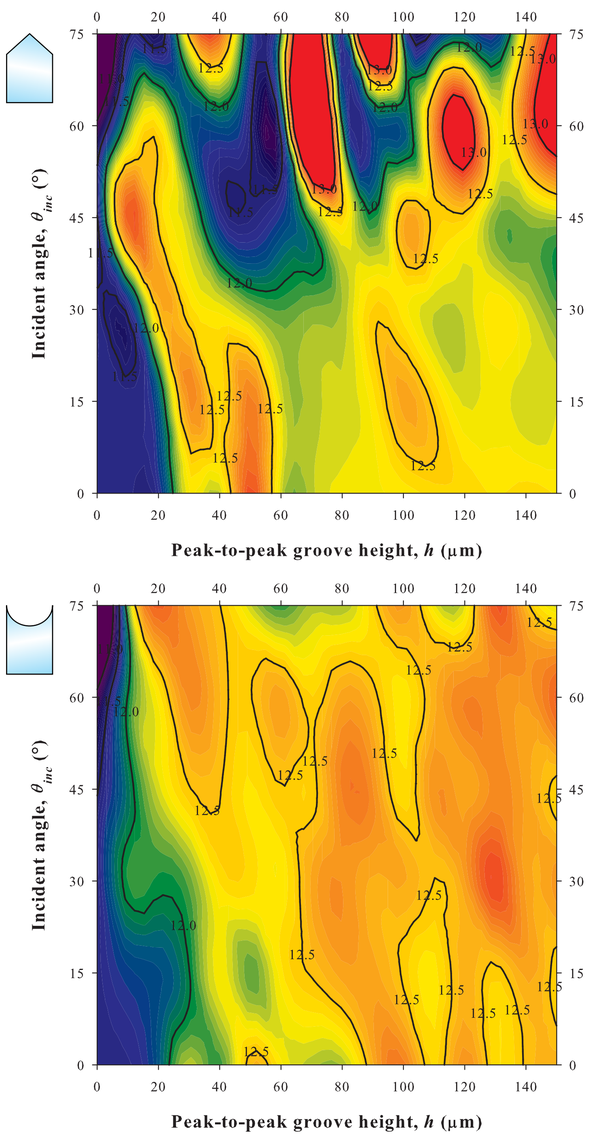
Reflectance losses

- important distinction between R of the front surface and R_{tot} of the entire module
- sufficiently high h values (h > 100 µm) enable reduced R_{tot} losses by 15 % on the average for all three types of textures
- pronounced R_{tot} minima observed at optimal h values → combination of slope angles and light ray propagation angles results in total internal reflection at the textured front glass / air interface



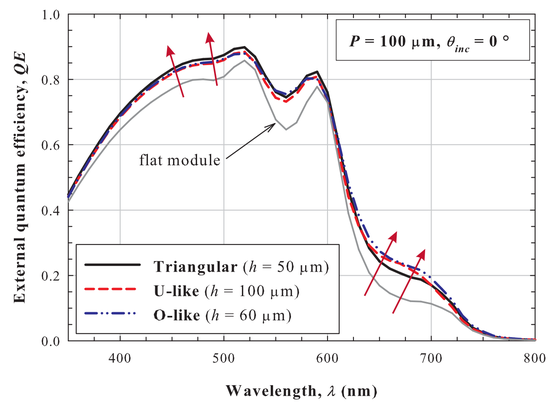
Current density mapping

- triangular textures result in high J_{sc} at specific incident angles (> 20 % J_{sc} boost)
- U-like textures are the least dependent on the angular illumination conditions



Quantum efficiency

- significant enhancement of QE as a result of front glass surface textures
- optimal triangular texture is beneficial for short-wavelength region
- optimal parabolic textures are more advantageous at longer wavelengths



Conclusions

- optimised micro-scale glass surface textures can significantly contribute to the performance of TF Si PV modules
- optimal U-like textures are especially beneficial for PV modules operating in variable angular illumination conditions (more than 10 % J_{sc} boost for a wide variety of incident angles)

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