Calculating the Haze Parameter of Textured Transparent Conductive Oxide

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Abstract

In thin-film solar cells (a-Si:H, µc-Si:H, CIGS, etc.) the scattering of light is very important to increase the absorption in active layers of solar cells and to minimize the absorption in supportive layers. With efficient scattering and absorption of light in active layer, the active layer can be thinned down, thus decreasing the production time and cost. Today the most efficient thin-film solar cells are designed or deposited on random texturized transparent conductive oxides (TCO), for instance on widely used Asahi-U TCO (Figure 1). Such random texture increases the light scattering in the broad range of wavelengths, while the regular textures such as gratings are efficient only at specific wavelengths. Design and optimization of surface texture is mainly regulated by solar spectrum and the absorption coefficient of material. It is important to achieve a good scattering in the wavelength region above 500 nm, where the part of the light is transmitted through the absorptive layer. By prolonging light path in the absorptive layer the quantum efficiency of solar cell increases and thus the solar cell efficiency. In order to study different random morphologies it is important to set up a good and efficient numerical model. The model was built using COMSOL Multiphysics 4.2a with RF Module. It will be shown how to import the AFM (atomic force microscopy) scan of TCO morphology, how to create good mesh of texture and how to create the studied domain to extract out the haze parameter (H). Haze parameter determines the portion of light that is scattered (diffused light (Idif)) at interface compared to total intensity (Itot) of light (specular (Ispec) and diffused light):

H=I_dif/I_tot =I_dif/(I_spec+I_dif)

Haze parameter is texture and wavelength dependent, thus the wavelength sweep in the wavelength region from 500 to 1000 nm is required to obtain the haze function in the region of interest. The haze parameter at specific wavelength is calculated from the far-field domain. Two different approaches and models how to obtain haze parameters will be shown. One model with air-perfect electric conductor (PEC) interface and the model with realistic interface between two custom materials. The trick how to minimize the boundary and numerical error will be shown and discussed. The simulations results of two different models will be compared to the haze measured by spectrophotometer. Very good agreement is obtained between measurement and simulation (Figure 2). The model advantages over measurements will be discussed and how to obtain additional light scattering information from the interfaces inside the solar cell.

Figures used in the abstract

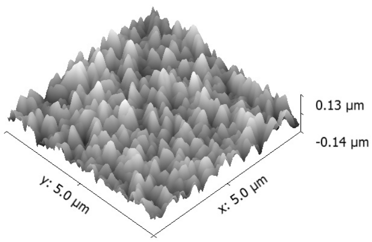

Figure 1: AFM scan of textured TCO.

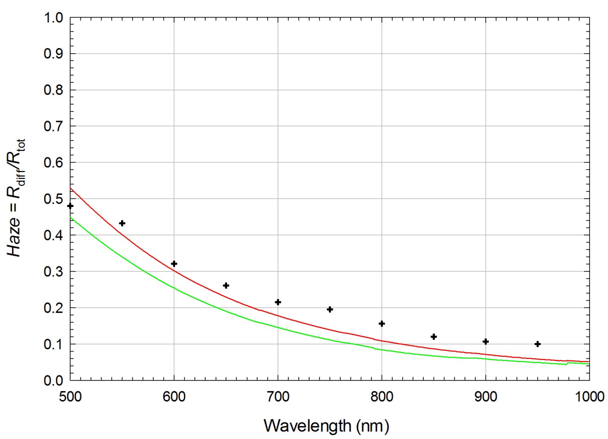

Figure 2: Simulated (symbols) haze for air-PEC interface and measured (lines) haze for air-Al and air-Ag textured interface.