Optical characterization and modelling of a perovskite solar cell

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Management of light propagation and absorption in a photovoltaic cell requires modelling its optical properties based on a precise knowledge of the optical index and thickness of each layer. Ellipsometry provides a powerful means of characterization of both the thicknesses and optical indices of stacked thin films. We have considered a typical perovskite cell consisting in a glass-FTO substrate (Pilkington, TEC7) onto which a compact TiO_2 layer was sprayed, and then covered by a mesoporous TiO_2 layer (spin-coated solution of 30-nm TiO_2 nanoparticles), a $CH_3NH_3PbI_2$ layer, a spiro-OMeTAD layer and finally a gold layer electrode. Each of these layers, when deposited individually on a glass substrate, was well characterized by ellipsometry with indices in agreement with literature values. However, the ellipsometric data for the stacked layers (fig. 1(a,b)) could only be described by assuming a complex structure involving various effective-index layers and many free parameters (fig. 1(c)), with limited physical significance. The reason is that the large roughness (RMS 40 nm) of the FTO layer creates a strong scattering which can neither be characterized by ellipsometry nor modelled by a stack of planar layers. Further experimental and numerical work is underway in order to properly describe the optical properties of such a cell and determine whether the effect of the FTO roughness is positive or detrimental to light management.

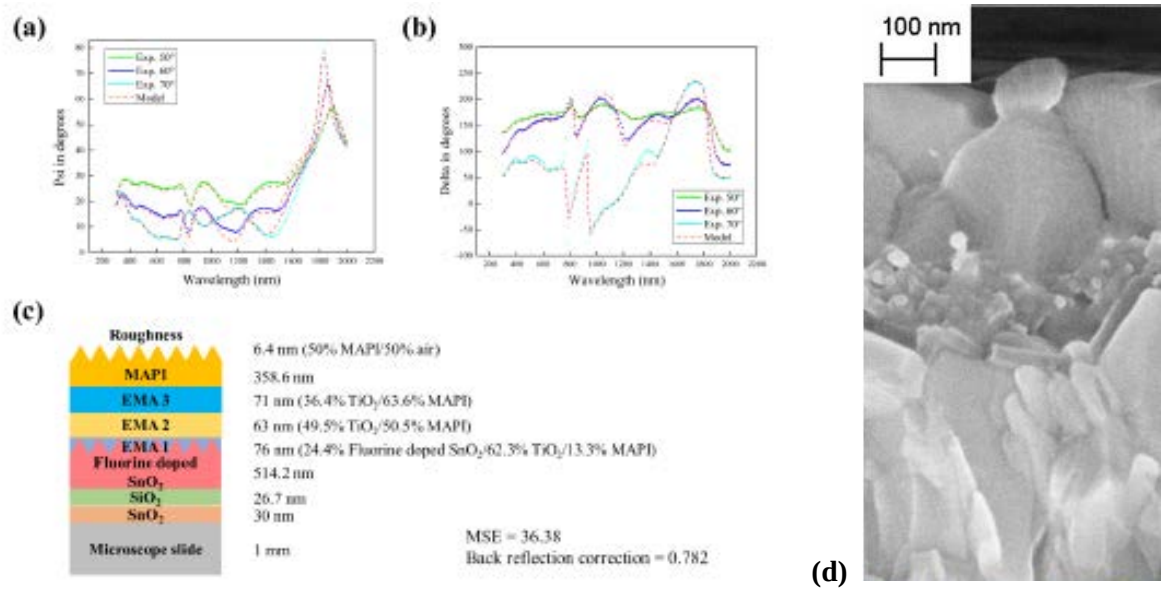

Figure 1 : Analysis of a stack of FTO + TiO_2 + mesoporous TiO_2 + $CH_3NH_3PbI_2$. (a) and (b) : Δ and Ψ ellipsometric functions measured at three different angles (full lines) and their theoretical fit (dotted lines) corresponding to the model stack described in (c). (d) : SEM image of the stack.