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Photovoltaic Device Characterization Using the UVISEL Spectroscopic Ellipsometer

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Photovoltaic devices are multi-layer structures in which different materials such as transparent conductive oxides (TCO), light-absorbing materials, and antireflection coatings are combined to convert light energy into electric energy. The efficiency of the photovoltaic device depends on the optical interference occurring in the multi-layer structure. Therefore, optical constants such as refractive index, absorption coefficient, and film thickness of each layer are important parameters to measure. Spectroscopic ellipsometry can be the most accurate optical and nondestructive technique to measure, quickly and simultaneously, optical constants as well as film thickness of a multi-layer structure.

Experimental Description

In an effort to characterize with the best accuracy the individual layers constituting the photovoltaic device, three separate samples with step-wise layer constructions were measured: (1) Glass/SnO_2, (2) Glass/SnO_2/µc-Silicon, (3) Glass/SnO_2/µc-Silicon/ZnO.

The UVISEL, a highly accurate and sensitive Phase Modulated Spectroscopic Ellipsometer (PMSE), manufactured by HORIBA Jobin Yvon, was used for this study. Details on this system have been elaborated elsewhere (1). Briefly, after passing through the first polarizer which establishes a linear polarization, the probing beam reflects at an oblique angle from the sample surface. The output head comprises a photoelastic modulator (PEM) oscillated at 50 kHz and an analyzer that resolves the polarization state of the reflected beam. A high-resolution grating monochromator directs sequentially the light for each wavelength onto the detector. For each wavelength, two traditional ellipsometric angles, Ψ and Δ, respectively the ratios of the amplitude and phase changes of the polarized light, are collected. As ellipsometry is an indirect technique, a modeling-based analysis procedure done by our DeltaPsi2™ software is performed to extract film thickness, optical constants, as well as composition, anisotropy, crystallinity, roughness and more. In this work, ellipsometric data were collected at an angle of incidence of 70° using the UVISEL ER which covers a spectral range from 190 nm to 2100 nm.

Results and Discussion

Figure 1 shows the optical properties for each material for sample (3). The left axis represents the refractive index (n) whereas the right axis represents the extinction coefficient (k). The µc-Si layer has graded optical properties with values different at each interface. For the ZnO, we found that an inhomogeneous layer made of 82.2% of ZnO and 17.8% of void is first deposited before having pure ZnO material. Optical properties for both ZnO layers are also depicted in figure 1. Figure 2 shows film thickness of each individual layers found by the UVISEL including a top roughness layer of 27Å.

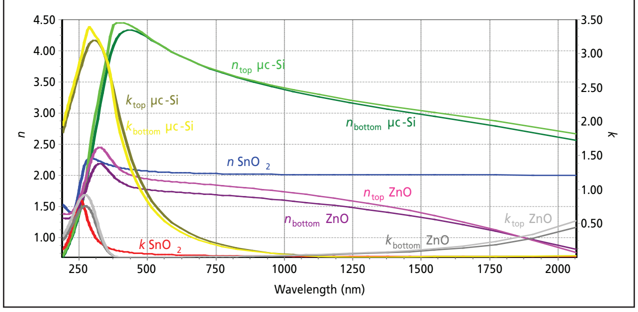

Figure 1: Optical constants of SnO_2, µc-Si and ZnO measured by the UVISEL. Left hand side represents to refractive index whereas right hand side is the extinction coefficient.

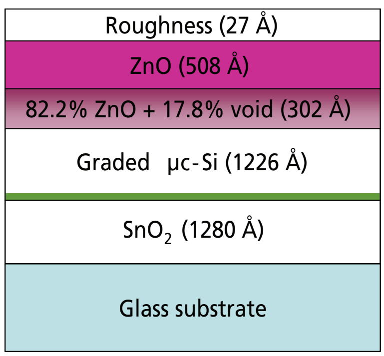

Figure 2: Ellipsometric model and film thickness of each layer measured by the UVISEL.

Conclusion

Spectroscopic ellipsometry is an accurate and sensitive technique for the characterization of film thickness and optical properties of multi-layer structure. By utilizing phase modulation, the UVISEL provides the highest level of accuracy, sensitivity and signal to noise ratio required to measure multiple ultra thin layers with poor optical contrast.

Reference

(1) B. Drevillon, J.Y. Parey, M. Stchakovsky, R. Benferhat, Y. Josserand, and B. Schlayen, *SPIE Proc.*, **1188**, 174 (1990).

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