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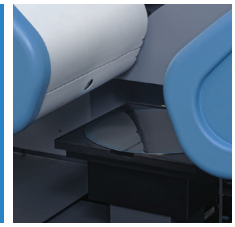
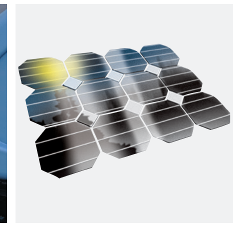
Spectroscopic Ellipsometry

Optical Characterization of ITO Films Prepared in Different Atmospheres using Spectroscopic Ellipsometry





Application Note

Photovoltaic SE30

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Indium tin oxide (ITO) is one of the most widely used transparent conducting oxides because of its two chief properties, its electrical conductivity and optical transparency, as well as the ease with which it can be deposited as a thin film. As with all transparent conducting films, a compromise must be made between conductivity and transparency, since increasing the thickness and increasing the concentration of charge carriers will increase the material's conductivity, but decrease its transparency.
ITO is often used to make transparent conductive coatings for displays such as liquid crystal displays, flat panel displays, plasma displays, touch panels, and electronic ink applications. Thin films of ITO are also used in organic light-emitting diodes, solar cells, antistatic coatings and EMI shieldings. In organic light-emitting diodes, ITO is used as the anode (hole injection layer). ITO is also used for various optical coatings, most notably infrared-reflecting coatings for automotive, and sodium vapor lamp glasses. Other uses include gas sensors, antireflection coatings and electrowetting on dielectrics.

The aim of this study was to see the effect of the heat treatment conditions in various atmospheres on optical properties of ITO films, by spectroscopic ellipsometry over the spectral range 190-2100nm.

Sample preparation

These ITO films were made on a silicon substrate, by DC sputtering (Quorum K675XD) in a $7x10^{-3}$ bar partial pressure of argon and a current of 150 mA. The ITO target is made up of 90 % In_2O_3 and 10 % SnO_2 of 99.99 % purity.

After the deposition, the films were annealed at 500° C for 4 hours and then slowly cooled in various atmospheres, such as air, vacuum (0.6 bar) and N_2 (1 bar).

Experimental

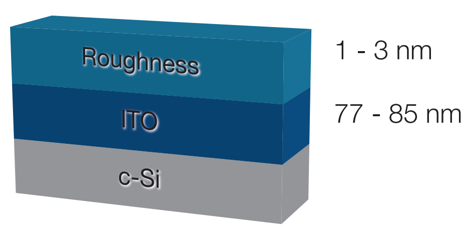
The measurements were performed using the HORIBA UVISEL Phase Modulated Spectroscopic Ellipsometer over the spectral range 190-2100nm (or 0.6-6.5eV) at an angle of incidence of 70°.

SE (Spectroscopic Ellipsometry) is an optical technique that measures the change in the polarization state of light reflected from the surface of a sample.

Results

Each ITO samples were represented using a two-layer model, with a rough overlayer on the top of the main layer.

This rough layer is described using the Bruggeman Effective Medium Approximation with a mixture of 50% void and 50% ITO.



Two-layer structure used for the ellipsometric modeling

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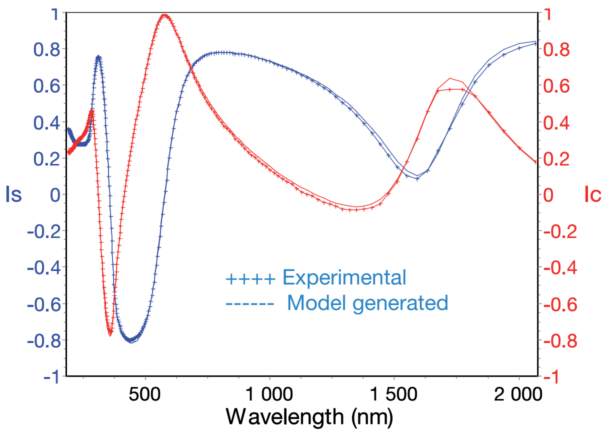
The next graph represents the good agreement between the generated and the experimental (Is, Ic) ellipsometric data.



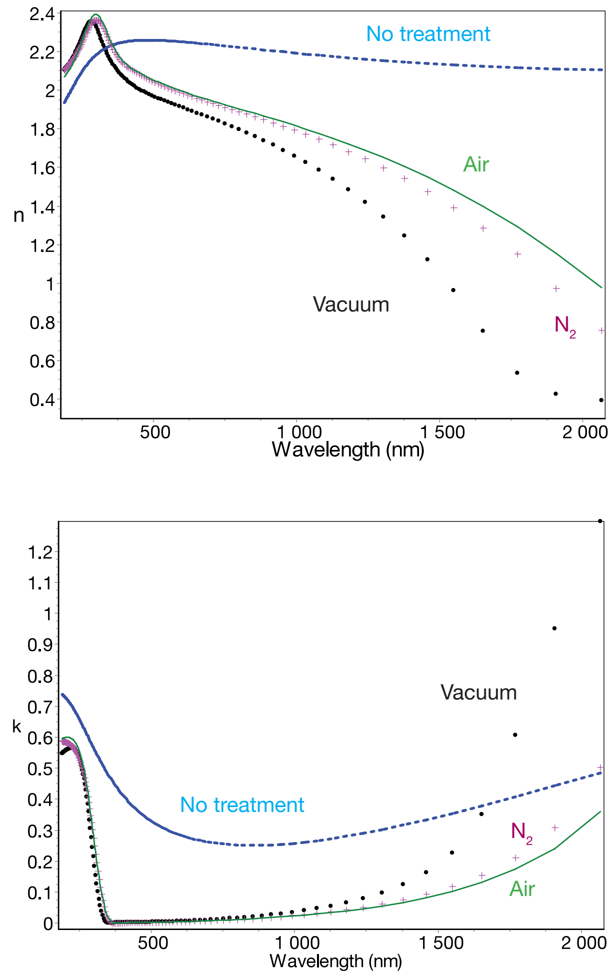
Ellipsometry fit agreements

The ITO optical constants were determined using a combination of a Drude oscillator (to model the absorption in the NIR range) and a double New Amorphous Formula (to model the absorption in the UV range). This combination was easily done using “User Defined Formula” feature.

The optical constants (n,k) show that all of the heat treatments improve the ITO transparency and decrease absorption in the NIR range.

Conclusion

The solar industry uses a wide range of materials to manufacture solar cells. In most cases these materials are deposited as thin films in the nanometer or micrometer range. The UVISEL Spectroscopic Ellipsometer is well suited for the characterization of these materials and the influenced of the atmospheres on the optical properties. In addition to thickness and refractive index, roughness, gradient profile and conductivity can also been determined.



Optical constants (n,k) of ITO
with different heat treatment conditions

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