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

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Introduction

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. 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 190-2100 nm.

Experimental Conditions

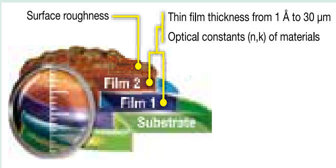
UVISEL

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 % In2O3 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 N2 (1 bar).

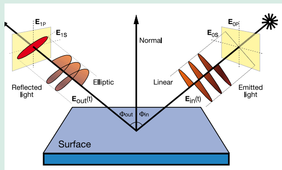
We thank the Department of Electrical and Electronic Engineering, Public University of Navarra in Pamplona (Spain) for providing these samples.

The optical constants and thicknesses of ITO were determined by Spectroscopic Ellipsometry (SE) using a UVISEL Phase Modulated Spectroscopic Ellipsometer.
SE is an optical technique that measures the change in the polarization state of light reflected from the surface of a sample.



Main properties determined by Spectroscopic Ellipsometry

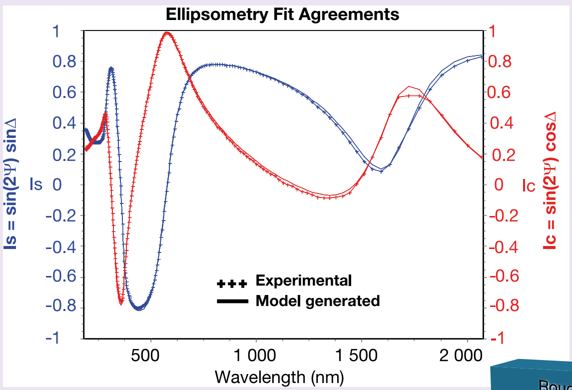
This powerful optical technique is used to measure thin film thickness from 1Å to tens of microns, optical constants, bandgap energy, surface and interface roughness, etc. It can be applied in situ or ex situ and it is ideally suited for the control of thin film Photovoltaic structures.

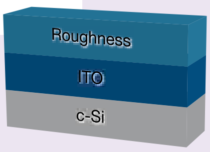


Change the polarization state of the light reflected from the surface of a sample

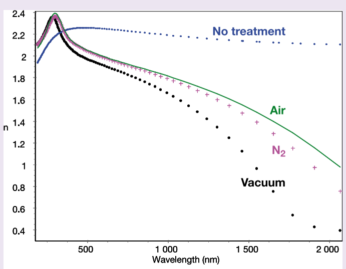
Results

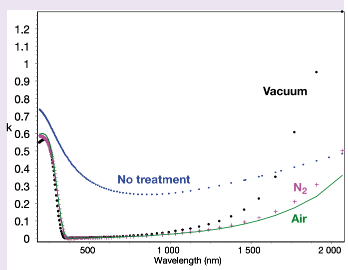
Measurements were performed using the HORIBA UVISEL Phase Modulated Spectroscopic Ellipsometer over the spectral range 190-2100 nm (0.6-6.5 eV).
The ITO samples were modelled using a two-layer model, with a rough overlayer on the top of the main layer. The rough layer is described using the Effective Medium Approximation Theory with a mixture of 50 % void and 50 % ITO.





Sample Name	ITO Thickness (nm)	Roughness (nm)	Annealing Treatment	Atmosphere
A	84.9	2.9	4 hrs at 500°C	Vacuum
B	77.1	3.0	4 hrs at 500°C	Nitrogen
C	78.9	1.0	4 hrs at 500°C	Air
D	78.7	2.0	None	None





The optical constants show that all of the heat treatments improve the ITO transparency and lower 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. In addition to thickness and refractive index, roughness, gradient profile and conductivity can also been determined.