solutions for science

COMPENDIUM

Indium-Tin-Oxide (ITO)

INTRODUCTION

Tin-doped indium oxide is a solid solution of indium(III) oxide (In_2O_3) and tin(IV) oxide (SnO_2), typically 90% In_2O_3, 10% SnO_2 by weight. It is a degenerate n-type semiconductor with high transparency and nearly metallic conductivity. In the infrared region of the spectrum it acts as a metal-like mirror. Thin films of ITO find applications as transparent electrodes in optoelectronics like organic light emitting devices (OLEDs), photovoltaic, and in the liquid crystal display industry. 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. Imaging spectroscopic ellipsometry is the analytical tool of choice to identify the best compromise even on the microscopic scale.

In literature, a number of papers report results from non imaging ellipsometry like changes in thickness and optical properties. Ellipsometry is used for the detection of changes of the ITO layer properties base on process parameters during preparation or coursed by annealing. Mostly, thickness of the ITO – layer and optical properties of the ITO film are of interest. Imaging ellipsometry offers not only the value of the parameter but also the microscopic distribution. An impressive example from literature will be descript later.

An issue for conventional ellipsometry is that ITO films are normally coated on transparent substrates and especially for characterization of thin flexible substrates back reflections are disturb the results. For these type of An Imaging ellipsometer can be equipped with a beam cutter to underpress the influence of backside reflection beam cutter (figure 2). This tool is essential to measure on thin transparent substrates like polymer foils (figure 1)

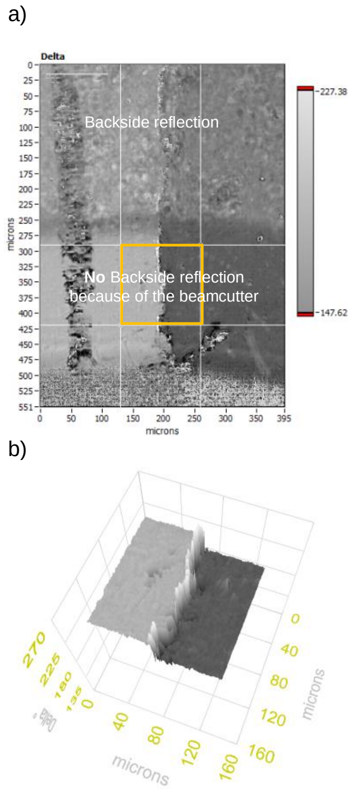

Figure 1. Delta map of polymere foil coated on the righ half with ITO, measured with a beam cutter.
A) Delta values for the complete viel of view. The clear area is free of backside reflection because of use of beam cutter. B) image section inbetween the green lines of A, displayed in 3d-view.

VIEW ON LITERATURE

- Local Influence on Optical Properties and Thickness of ITO-Films by Means of Plasma Flow

The main feature of tin-doped-indium oxide In_2O_3:Sn is the combination of electrical conductivity and optical transparency. ITO is mainly used to make transparent conductive coatings for liquid crystal displays, flat panel displays, plasma displays, touch panels, electronic ink applications, organic light-emitting diodes, solar cells, and antistatic coatings. Different deposition processes can be used to produce ITO layer. The lateral distribution of thickness and optical properties of films locally grown out of plasma flow on a base from magnetron sputtering was detected with the nanofilm_ep3se. Spectra of Delta and Psi were measured for regions of interest for a general inspection and a large scale investigation. The high resolution investigation on a smaler scale was based on a spectra of Delta maps at different wave length.

Experimental:

Vaupel et al. performed the measurements using an single wave imaging ellipsometer (EP3SW) with a wavelength of 532 nm, angle of incidence of 60°. Delta maps were recorded with a polarizer range of 4º, with 10 image scans per sample for both ellipsometric delta and psi. The spatial distribution of the

Δ and Ψ, have been measured with a nulling Imaging Spectroscopic Ellipsometer EP³ SE, equipped with 2x, 10x objectives, and automatic sample alignment stage. The measurements were carried out within the wavelength range 360-1000 nm at 70° angle of light incidence. The data were acquired and evaluated by EP3View Software. Inhomogeneity of the film thickness and optical properties was studied in three steps. As the first step, Δ and Ψ spectra of 10 regions of interest (ROIs) were acquired simultaneously in the high plasma flow area (edge of the wafer) and spectrum of one ROI in the low plasma flow area (centre of the sample). Each ROI was corresponding with 0.3 mm x 0.3 mm sample surface area, over which Δ and Ψ was averaged. Notice, that ROI-size and lateral resolution (here 4 µm) can be much smaller than beam size (here 2 mm diameter) in imaging ellipsometry. The spectra were averaged over four measuring zones. Spectra of one ROI in the high plasma flow area are given in Fig. 1. The ellipsometric data were fitted to a 4-layer model including air, ITO film, SiO2 film and Si substrate, providing thickness of the films. The model does not include surface roughness because AFM measurements show root-mean square roughness of the film below 1 nm that is less than the accuracy of the film thickness determination.

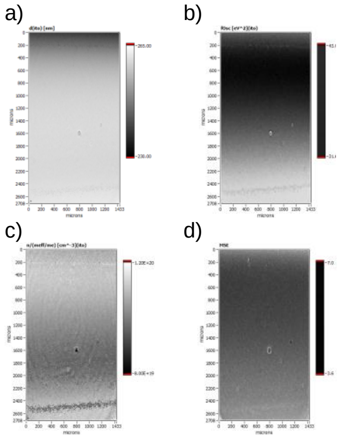

Figure 2. Local-scale maps of ITO film thickness, Lorentz oscillator force, free electron density, and mean square error (MSE).

References:

Vaupel M., Vinnichenko M. (2008) Plasma flow induced local variation of dispersion constants of ITO-films observed with spectroscopic imaging ellipsometry. physica status solidi 5, 1137–1140

Optical modeling:

A frequently used way to parameterized the optical properties of an ITO-layer is a Drude-Lorentz approach. Depending on the substrate surface and ITO surface, respectively, a roughness layer or a mix interlayer is required for a proper modeling.

CONCLUSION

Imaging ellipsometry is the method of choice for thin film methrology of patterned self assembled thiol monolayers on gold surfaces. The technique has been used for pattern with changing packing density, with different chemical endgroups, changing chainlength and substrate selective patterning. In the most cases the authors have used a single wave imaging ellipsometer, performing maps and angle of incident spectra.