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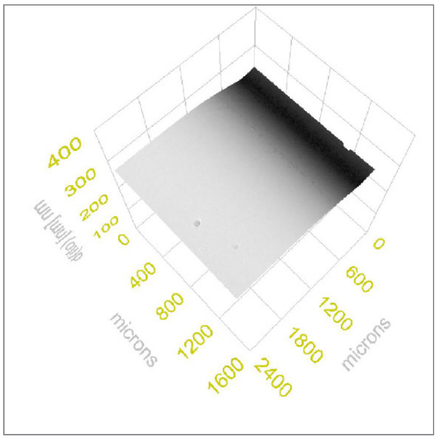
APPLICATION NOTE

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

ABSTRACT

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. In the optical model the dispersion function of the ITO layer was describt by a constant background refractive index and and a Lorenz oscillator. The calculated optical properties were the frequency of the UV absorption line, the refractive index, the extinction and the thickness of the ITO layer.



Thickness map of an ITO layer

Introduction

Tin-doped-indium oxide In2O3:Sn (ITO) is an n-type semiconductor with high transparency and nearly metallic conductivity. Thin films of ITO find applications in optoelectronics, solar cells, and in the liquid crystal display industry. Liquid crystal cells of LCD and TFT displays are made of it. Organic light emitting devices (OLEDs) also use ITO-films on glass. In order to control the quality of the films, it is important to measure film thickness and chemical composition, i.e. concentration of the metals tin and indium.

Sample

ITO layer (appr. 198 nm with 5 nm roughness layer) on 259 nm SiO2 layer on Si-wafer. The ITO-film was produced in two steps. First the whole wafer was coated by an ITO-film with almost constant thickness grown out of plasma flow from magnetron sputtering. Second the ITO-film is further grown out of plasma flow localised in two areas.

Instrumentation

Spectroscopic Imaging Ellipsometer EP^3-SE incl. EP^3 View Software, 2 x and 10 x objectives

Task

Measure the lateral distribution of thickness and optical properties of the ITO-film.

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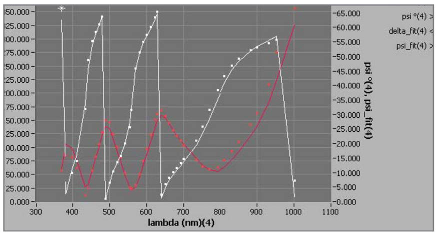

Fig. 1: Spectra of Delta/Psi as a function of wavelength lambda recorded in the low plasma flow area of the sample.

Steps of Evaluation

- For first and general inspection measure spectra of Delta/Psi in several ROIs of one field of view simultaneously and fit by appropriate optical model for ITO film thickness and for frequency and damping of the ITO oscillator function
- For large scale inspection record spectra of Delta/Psi along a line scan across the sample and fit again
- For high resolution small scale inspection record a spectrum of Delta maps and obtain one resulting map for each of the fit

Measurements

Spectra of Delta and Psi (fig. 1) have been recorded as 4-zone mean at 70° angle of incidence in different sites of the sample. Spectra of 10 ROIs have been measured simultaneously in the high plasma flow area and one spectrum in the centre of the sample low flow. Data are fitted with the following optical model, which includes the definition definitions of the dispersions, of the layer stack, and of the fit parameters. We make the approach, that the dispersion of ITO consists of a constant background refractive index n = 1.949 and extinction k = 0.006, and of an oscillator with frequency f, amplitude a = 25 eV^2, and damping g, and of a free electron gas (with plasmon excitation) with electron density 9.5 10^{19} cm^{-3} and damping 0.1 eV. The oscillator frequency is in the UV and the plasmon excitation is dominant in the IR part of the spectrum. The roughness of the ITO layer is described by a 5 nm thin effective medium consisting with 50 % of ITO and 50 % of air. Data fitting is provided for the thickness of the ITO-film and oscillator frequency f and damping g. Instead of these parameters, all other parameters have been fitted for.

It has been turned out, that some of those other parameters are not independent from these ones, and that the spectrum is not sensitive on some of those parameters. Therefore the fitting parameters have been restricted only to thickness, frequency, and damping.

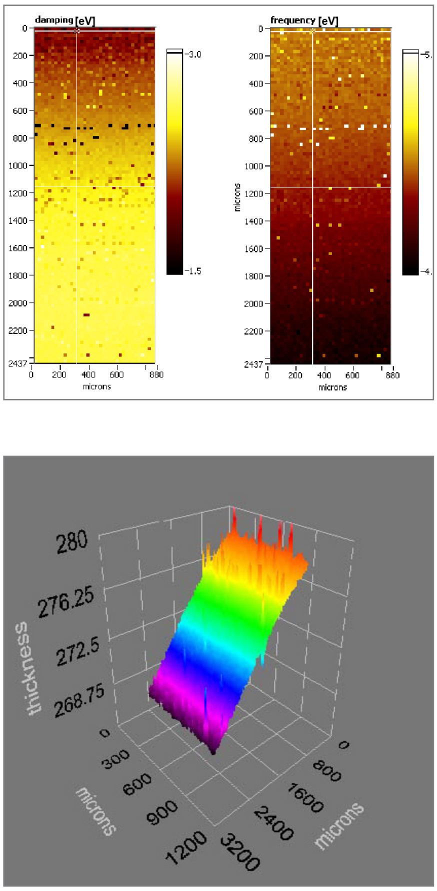

Fig. 2: Damping and Frequency of the oscillator and 3D-Thickness-map of ITO in the low plasma flow area with 20 µm lateral resolution

Results

In order to investigate the lateral variation of the ITO properties in the localized high plasma flow area, a Spectrum of Delta-maps was measured. It has been confirmed, that fitting only the Delta spectrum, instead of Delta and Psi, was sufficient to obtain the fit results correctly. This enables us to record high resolution maps of the fit results damping, frequency, and thickness (fig. 2). To this end Delta-maps were recorded at the six different wavelengths 421, 479, 555, 581, 661, 832 nm. The optical model is used to calculate the set of fit parameters pixel by pixel. In that way the maps of the fit results (fig. 2) are generated. By means of the fit results the dispersion functions of refractive index and extinction can be reconstructed for each pixel of the map.

Conclusion

Optical properties, i.e. the frequency of the UV absorption line, the refractive index, and the extinction, and the thickness of one ITO-film are investigated by means of imaging ellipsometer EP3SE. The frequency of the absorption line of ITO increases with the ITO-thickness in the microscopic field of view of the localized high plasma flow area. By contrast the frequency decreases with increasing ITO-thickness along the macroscopic length scale of a 60 mm cross section. Frequency, damping, and thickness of ITO are mapped with 20 µm lateral resolution by a fit on a spectrum of Deltamaps

Acknowledgement

Samples were kindly provided by Dr. Mykola Vinnichenko from Z Rossendorf, Germany