DETERMINATION OF THE REFRACTIVE INDEX OF THE SE1211 RESIN USING AN SPR SPECTROSCOPY

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1. INTRODUCTION

This article presents the measurement of the refractive index of the polyimide resin SE1211 thin films by means of the surface plasmon resonance spectroscopy. The SE1211 is produced by the Nissan Coatings Co. and according to achieved description is a polyamic acid consisting long alkyl side chains. It is mainly used for aligning liquid crystal layers homeotropically. In the case of the planar waveguide evanescent wave spectroscopy the effective penetration depth is a function of the refractive index and the thickness of the layer that covers the waveguide. Therefore measurements of the refractive index of the aligning layer is important when the planar waveguide is covered with an aligned liquid crystal layer which interacts with an evanescent field.

2. PRINCIPLE OF THE MEASUREMENT METHOD

Surface plasmon resonance (SPR) reflectivity measurement are surface-sensitive spectroscopic methods that can be used to characterize a thickness and an index of refraction of the ultra thin films covering a surface of the noble metal (Au, Ag). SPR spectroscopy has been applied in the field of chemistry and biochemistry to characterize biological surfaces and to monitor binding events [1,2] as well as in the development of gas sensors [3,4].

Plasmon is a strongly attenuated electromagnetic wave propagating along the boundary between the thin metal layer and the dielectric one above it. The schematic view of this interaction can be seen at the Fig.1. The energy of the incident wave coupled with the surface plasmon is irrevocably dissipated in the system, so it cannot appear in the wave reflected from the metal/dielectric interface. The fundamental concept of the plasmon resonance in the prism configuration proposed by the by Kretschmann and Raether [5] states that an SPR excitation by the incident light wave at the base of the prism occurs when the wave vector of the plasmon k_{SPR} and the projection of the incident wave vector k in the direction of propagation of the plasmon are equal. Both the angle at which the surface plasmons are excited, and the angle, at which the attenuation of the incident wave is strongest, are related to the refractive index of the measured layer through the equations (1) and (2). The eq. (2) is an expansion of the eq. (1). and shows the refractive indices of metal and dielectric films openly.

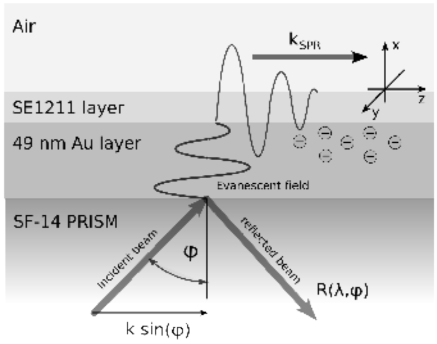

Fig.1. The schematic of the layered configuration of the SPR measurement set-up.

$$k \sin \varphi = k_{SPR} \quad (1)$$

$$k_o n_{prism} \sin \varphi_i = k_0 \sqrt{\frac{\varepsilon_{Au} n_s^2}{\varepsilon_{Au} + n_s^2}} \quad (2)$$

where: k_0 – a length of the wave vector of light in a vacuum, k_{SPR} - length of the wave vector of the surface plasmon, n_s – a refraction index of the dielectric medium above the metal layer, ε_{Au} – a real part of the dielectric complex constant of the active plasmon layer (e.g. Au), n_{prism}– a refraction index of the prism; θ_i – an incident angle of light against the normal to the prism base.

When conditions (1,2) are fulfilled the surface plasmons are created at an interface of the thin gold film and the SE1211 dielectric layer above. The formation of SPPs can be observed as a minimum in the plot of the reflectivity vs the incident angle of illumination and the wavelength of light, see. Fig. 3. As can be seen from Fig. 4. the length of the real part of the wave vector of the surface plasmons k_{SPR} besides the dependence on the refractive index of the metal layer and the refraction indices of the dielectric film depends on the wavelength of light. Therefore the SPR method is very useful for dispersion measurements.

3. EXPERIMENT

The SE1211 films were spin-coated at a speed 2000 rpm. onto the SF-14 glass plates that matched the prism used in SPR measurements. The SE1211 was dissolved in the NMP. The concentration was approx. 3%. After deposition the samples were cured for 1h. at a temperature of 80 deg. Celsius and then for a next 1h baked at a temperature of 180 deg. Celsius. A schematic view of the experimental set-up is shown on Fig. 2.

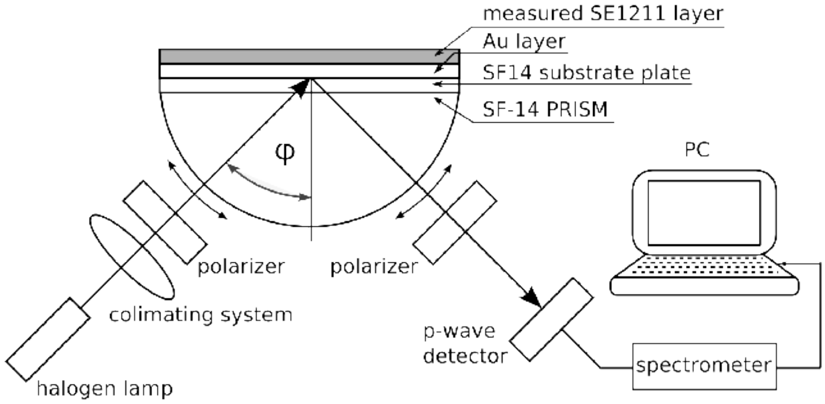

Fig.2. Experimental set-up and configuration of the layered structure for refractive index measurements

The substrates with deposited layers were coupled on immersion oil with a prism coupler, made of SF14 glass (Schott). This prism ensured the mechanical stability of the optical system and guaranteed the desired range of light-wave vectors.

Optical measurements were carried out at a temperature 21 deg. Celsius for the p-polarized light at a wavelength ranging from 450 nm up to 780 nm. It can be seen that the p-polarized light illuminating the sensing structure passes through the optical system composed of collimating system and the Glann polariser. The reflected light was recorded on the CCD line built in the spectrometer. The D.C. voltage signal on the output of the spectrometer was read-out by the 14-bit Advantech data acquisition PC card.

4. RESULTS AND DISCUSSION

The optical SPR characteristics of the SE1211 films are shown on the Fig. 3-5. On the basis of the measured reflectivity of the p-polarised light the refractive index of the SE1211 was calculated by means of non-linear fit using a Levenberg – Marquardt algorithm. The film thickness ***d*** that must be provided for fitting procedure. The following results were achieved using the ellipsometer: $\boldsymbol{d_E=15\ nm}$ and $\boldsymbol{n=1.5300}$ (λ=633 nm). The thickness of the SE1211 layer obtained on the basis of the fitting procudure is $\boldsymbol{d_{SPR}=19nm}$. The fitting procedure brought the additional error of the thickness of the layer estimated at $\boldsymbol{\Delta d=\pm 5nm}$.

The refractive index was calculated for ten different wavelengths chosen from the 537 to 780 nm wavelength bracket, see the dots on the Fig.5. Below the 537 nm a determination of the plasmon dip was vague and a fitting error was too high for effective calculations. The dispersion curve shown on the Fig.5 is a fit obtained on the basis of the Cauchy formula:

$$n(\lambda)=A+\frac{B}{\lambda^2} \tag{3}$$

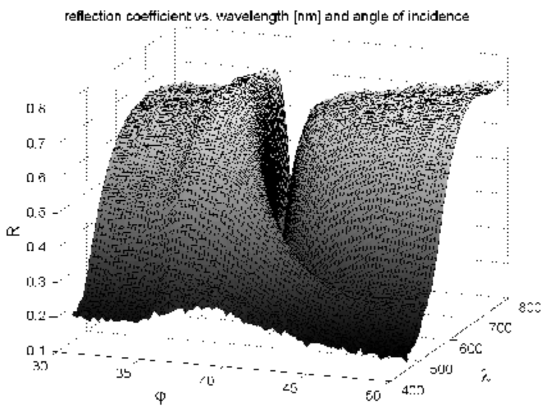

Fig.3. The reflection coefficient R vs a wavelength of the incident light an angle of the incidence for SE1211 layer.

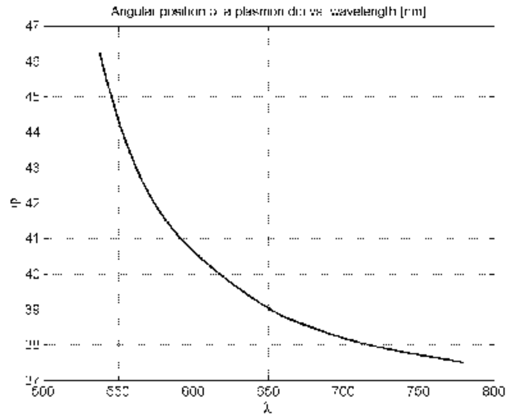

Fig.4. The angular position of the plasmon dip vs a wavelength of the incident light.

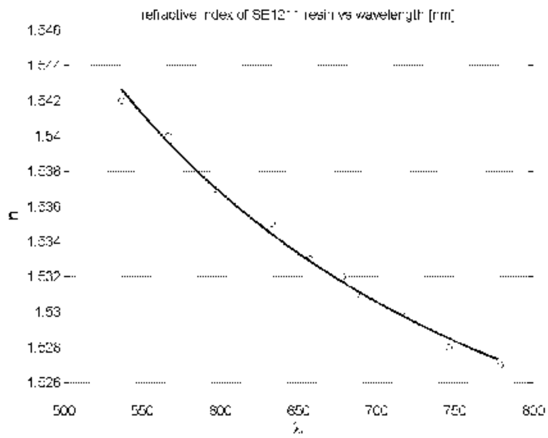

Fig. 5. The refractive index of the SE1211 resin vs wavelength. The dots marks the values calculated on the basis of SPR measurements. The line represents the fit using Cauchy formula (3).

5. CONCLUSIONS

In this paper, the aligning polymeric SE1211 layer have been investigated by means of the SPR resonance. The results obtained on the basis of ellipsometric and SPR measurements for 633 nm are slightly different. This difference is caused by the indeterminacy of the layer thickness. The results obtained for the wavelengths less then 537 nm are inadequate due to computational errors which arose form the high indeterminacy of the plasmon dip. Namely the plasmon dip for those wavelengths is much wider.

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