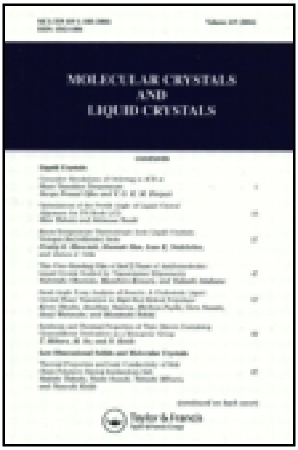

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Evaluation of Surface Roughness of Metal Thin Films and Langmuir-Blodgett Ultrathin Films from Scattered Light Due to Surface Plasmon Polariton

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Scattered light properties from Ag thin films and arachidic acid (C20) Langmuir-Blodgett (LB) films on the Ag thin films were investigated to evaluate the surface roughnesses of these films utilizing the surface plasmon polariton (SPP) excited in the attenuated total reflection (ATR) configuration. The surface roughness of the films was estimated from the angular distribution of the scattered lights. This result was qualitatively corresponding to the evaluation by the atomic force microscope (AFM) measurements.

Keywords: LB film; surface roughness; surface plasmon polariton; scattered light

INTRODUCTION

The evaluation of structures in LB ultrathin films is very important and has been carried out by many workers. The ATR measurement is one of the surface analyses and has been used to evaluate for various LB films. The surface roughness of the LB films on metal thin films can be evaluated from the scattered light due to the surface plasmon polariton (SPP) excited at the interface in the ATR configuration. In this paper, the surface roughness of arachidic acid (C20) LB films on Ag thin films were evaluated by the scattered light measurements. It was also evaluated by the AFM measurements.

EXPERIMENTAL DETAILS

The Kretschmann configuration [1] used for scattered light measurements is shown in Fig. 1. The prism and the cover glass were made of BK-7 glass with a reflective index of 1.515 at a wavelength of 632.8 nm. Ag thin films with a thickness of about 50 nm were evaporated on the cover glasses, and then C20 LB ultrathin films were deposited on the Ag thin films. The condition of the LB deposition was reported elsewhere[2]. The scattered light intensities $dI_s/(I_i d\Omega)$ were observed as a function of the scattering angle θ_s from -90° to 90°. The scattered lights from C20 LB films on the Ag films were calculated using the complex dielectric constants and thicknesses obtained from the ATR measurements[3], assuming a Gaussian distribution as an autocorrelation function with the transverse correlation length σ and the surface corrugation depth δ. In the evaluation, the light was considered to be scattered from the Ag/LB and LB/air interfaces. At first, the surface roughness of the Ag thin films was evaluated before the LB film deposition. Next, the surface roughness of C20 LB films on the Ag films was evaluated by subtracting the scattered light from the Ag/LB interface, that is, the Ag surface.

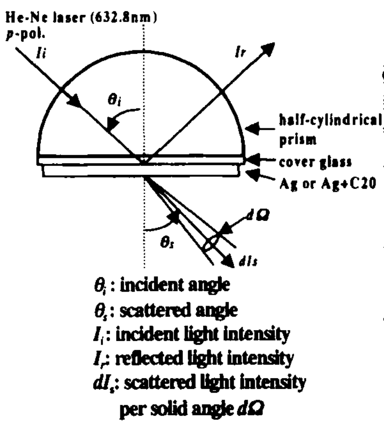

FIGURE 1 Kretchmann configuration used for the scattered light measurements.

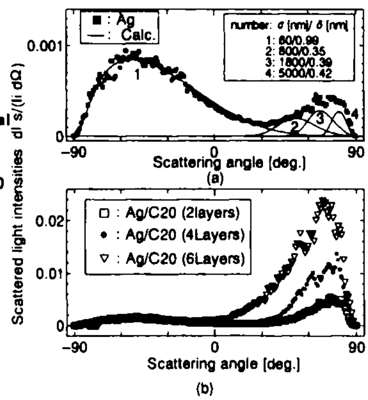

FIGURE 2 Scattered lights from the Ag film (a) and the C20 LB films on the Ag films (b).

RESULTS AND DISCUSSION

Figures 2 (a) and (b) show the angular distributions of scattered lights from the Ag film and the C20 LB films on Ag films, respectively. Four pairs of σ/δ for the Ag thin film were used as the parameters of the Ag/LB interface. The values of δ after the LB film deposition were modified by fitting the theoretical curves to the experimental ones in the range of $-90 < \theta s < 0$, since the scattered lights in the range were mostly caused by the roughness of Ag film surfaces and the increase in δ might be caused by the immersion of the substrates into the subphase[2]. Figure 3 (a) shows the measured and calculated scattered lights of the C20 LB films with 4 monolayers on the Ag film. The scattered light from the LB surface is shown in Fig. 3(b), which was obtained by subtracting the calculated curves (B) from the experimental data (A) in Fig. 3(a). By fitting the calculated spectra to the subtracted data, two pairs of roughness parameters were obtained for the surface of the C20 LB film with 4 monolayers. The roughness parameters of C20 LB films with different numbers of monolayers obtained in similar ways were shown in Fig. 4. The δ increased with the number of monolayers. The large δ with small σ in the surface roughness was observed prominently for the LB film with 6 monolayers.

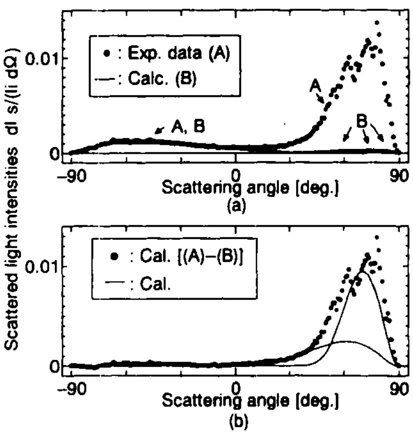

FIGURE 3 Scattered lights from Ag/LB (a) and LB/air (b) interfaces of the C20 LB film with the 4 monolayers.

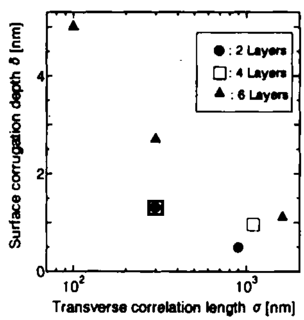

FIGURE 4 Calculated roughness parameters of the C20 LB films with different numbers of the monolayers.

The AFM images of the C20 LB films with 2 and 6 monolayers are shown in Figs. 5 (a) and (b), respectively. In Fig. 5(a), the surface roughness with large σ is observed corresponding to the roughness at the interfaces of the cover glass/Ag and/or Ag/LB films. With increasing the number of monolayers, the very large objects with 200-400 nm in diameter were observed on the surface. The roughness with σ smaller than 100 nm appeared in the LB film with 6 monolayers. The roughness averaged in the measured region increased with the number of monolayers from 2 to 6. This result was qualitatively corresponding to the evaluation by the scattered light measurements.

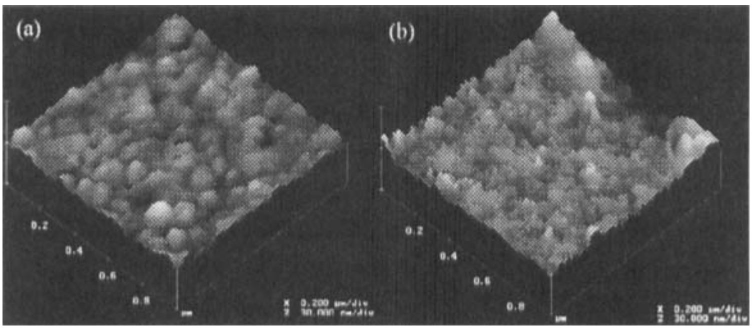

FIGURE 5 AFM images of the C20 LB films on the Ag films: (a) with the 2 monolayers; (b) with the 6 monolayers.

CONCLUSIONS

The surface roughness of C20 LB films with the different numbers of monolayers was evaluated from the scattered light measurements utilizing SPP. The roughness parameters of C20 LB films on the Ag film were changed with the number of the monolayers. The surface roughnesses were also investigated by the AFM measurements. The roughness parameters obtained from scattered light measurements were qualitatively corresponding to the results observed by the AFM measurements.

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