Extended Abstracts of the 2002 International Conference on Solid State Devices and Materials, Nagoya, 2002, pp. 222-223

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Fabrication and Surface Plasmon Excitation Properties of Polystyrene Submicron Sphere Thin Films

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1. Introduction

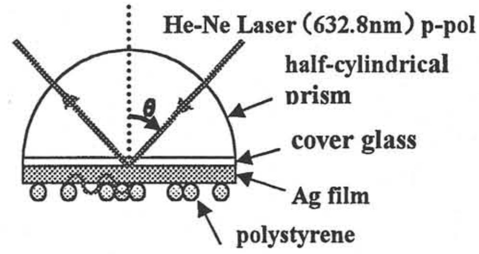
Micro-spheres of dielectric materials attract much interest for new characteristics such as optical localization, photonic band and so on [1-3]. Polystyrene (PS) micro-spheres also show some unique optical modes and there are some reports using near-field optics [4]. For developing devices using such micro-spheres, it is very important to fabricate 2-dimentional mono-sphere films with ordered structure and to evaluate structure and optical properties of the films. The attenuated total reflection (ATR), that is, the surface plasmon resonance (SPR) method is one of quite useful techniques to evaluate thickness, dielectric constants and /or optical properties of ulrathin films.

In this study, films of PS submicron spheres with 0.1 in diameter were fabricated, and surface morphologies of the films were observed using an atomic force microscopy. ATR properties [5, 6] and emission light were also investigated for the PS submicron sphere films on silver films utilizing SP excitations due to the reverse irradiation in the ATR Kretschmann configuration [7, 8].

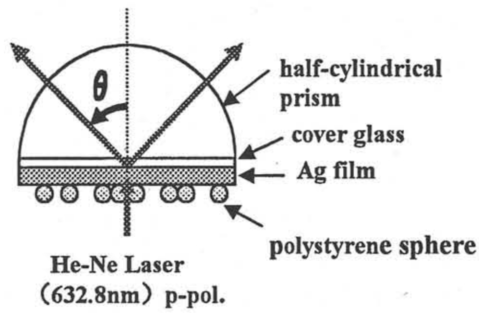
2. Experimental detail

The PS films were fabricated by a self-assembly method. Slide glass or Ag evaporated slide glass (50 nm in thickness) were used for the substrates. The substrates were immersed in 3-aminopropyltriethoxysilane solution (10mM in acetone) for 60 min and in acetone for 1 min. The sample surfaces were positively charged after this treatment. The substrates were then immersed to the PS spheres dispersed in distilled water (4 wt% of PS spheres with 0.1 μm in diameter were contained in the solution). The PS spheres were adsorbed to the surface and the immersing time was 10, 30, 60 min.

The sample surface was observed using atomic force microscopy (AFM, Digital Instrument, Nanoscope III-a). ATR (SPR) and emission measurements were carried out for the films. Figures 1 (a) and (b) show the sample configurations of the measurements. The ATR curves were observed using He-Ne laser with wavelength at 632.8 nm. Emissions from the prism were observed around dip angles of ATR curves with the laser beam irradiated normal to the direction of the prism. The emissions are due to surface plasmon (SP) excitations which were induced by the modulation of excitation condition due to surface roughness and/or energy transfer from polarizations of excited molecules on the metal surface [7, 8].



(a) ATR



(b) Emission light

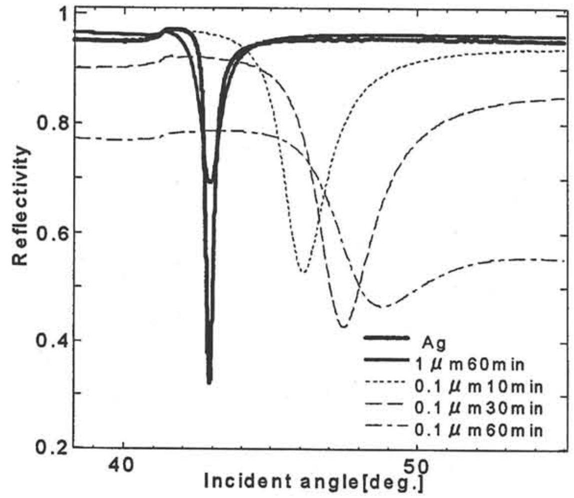
Fig.1 Sample configurations of (a) ATR and (b) emission light measurements.

3. Results and discussion

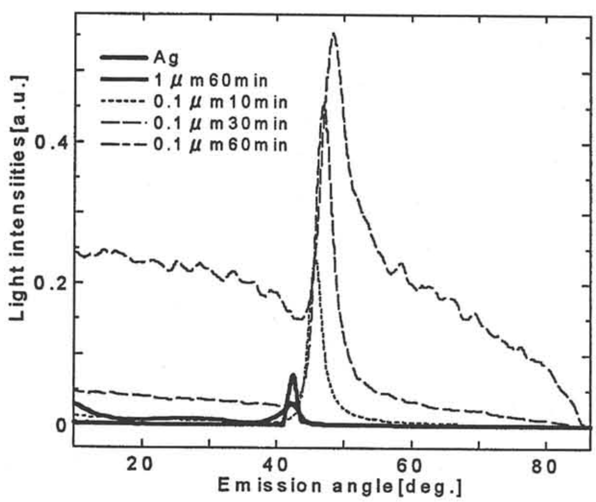
Morphology of the PS films on glass substrates was investigated using AFM images. The sphere coverage on the substrates gradually increased with deposition time. Morphology of the films depended on the sphere diameter.

The spheres with 0.1 μm diameter tended to cover the surface uniformly.

Figures 2 (a) and (b) show the ATR curves and the emission light for the PS films with 0.1 μm diameter on Ag. Large dips due to surface plasmon excitations can be seen in the ATR curves. The ATR properties depended on the deposition time, that is, coverage of the PS spheres on the Ag films. Emission light was observed for the same sample and also depended on the deposition time. The emission angles in Fig.2 (b) almost corresponded to the dip angles of the ATR curves in Fig.2 (b). The results showed that the emissions were caused by the SP excitations. The intensities were much larger than that of bare Ag film. Moreover, the intensities increased with the adsorption of the spheres.



(a) ATR curves.



(b) Emission light.

Fig.2 ATR curves (a) and emission light (b) of the PS micro-sphere films on Ag film.

It is considered that the large emissions are induced by strong excitations of SP due to large roughness of the PS spheres [7].

ATR and emission light properties were also investigated for the 1.0 μm sphere films. An example of ATR and emission light properties is shown for the film of 1.0 μm spheres deposited for 60 min in Fig.2. The properties were different from ones of the 0.1 μm sphere films and were caused by the diameter larger than the penetration depth of the evanescent wave on Ag film that is about 0.19 μm [9]. It is thought that ATR and emission light measurements are very useful for evaluation of micro-sphere films.

4. Conclusions

Fabrication of PS submicron spheres with 0.1 μm in diameter was investigated using the ATR (SPR) method and emission light in the ATR Kretschmann configuration. The ATR and the emission light properties strongly depended upon the diameters of the spheres and the deposition time. It was estimated that these properties were caused by the SP evanescent fields, the diameters of the spheres and/or the coverage on Ag.

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