Extended Abstracts of the 2004 International Conference on Solid State Devices and Materials, Tokyo, 2004, pp. 576-577

P7-11

Fabrication and Surface Plasmon Excitation in Thin Films of Fluorescent Microspheres with Polyvinyl alcohol

Kazunari Shinbo[1,2], Aya Ikarashi[1], Masayuki Yamamoto[1], Yasuo Ohdaira[1,2], Keizo Kato[1,2] and Futao Kaneko[1,2]

[1]Niigata University, Department of Electrical and Electronic Engineering
2-8050 Ikarashi, Niigata 950-2181, Japan
Phone/Fax: +81-25-262-7543 E-mail: kshinbo@eng.niigata-u.ac.jp
[2] Niigata University, Center for Transdisciplinary Research
2-8050 Ikarashi, Niigata 950-2181, Japan

1. Introduction

Dielectric micron and submicron spheres have attracted much interest for phenomena that cannot be observed in bulk states, such as optical localization, photonic bandgap and so on [1-3]. For applications of these spheres in optical devices, it is very important to fabricate thin films and to evaluate structure and optical properties of the films. The attenuated total reflection (ATR) utilizing surface plasmon (SP) resonance is one of the most useful techniques to evaluate thickness and/or optical properties of ultrathin films [4, 5]. Furthermore, emission lights through the prism can be observed due to reverse irradiation in the ATR Kretschmann configuration [6, 7]. The emission lights are induced by surface plasmon excitation, i.e., the part of the energy of the surface plasmon emitted through the prism as far-field light. The SP emission lights are promising for developing new sensors, optical devices and so on [7].

In this study, films of 100 nm fluorescent spheres with polyvinyl alcohol (PVA) were fabricated, and surface morphologies of the films were observed using atomic force microscopy (AFM). Such films of spheres with polymers can be useful for controlling optical properties and film structures. The ATR and SP emission light properties due to the reverse irradiation [6, 7] were also investigated in the prism/silver/ sphere film Kretschmann configurations.

2. Experimental Detail

The 100 nm PS spheres containing fluorescent dye were used in this study. Thin films of the PS spheres with PVA were fabricated by spin-casting of suspension of PS sphere in water with PVA. The concentrations of PVA were 2.5, 5.0 and 7.5 mg/ml, while the number of the PS sphere in the suspension was fixed to about 9.5×10^{12} /ml.

The sample surface was observed using atomic force microscopy (AFM, Digital Instruments, Nanoscope III-a). The ATR and emitted light measurements were carried out for prism/Ag film/sphere film system. Emission lights through the prism were observed around dip angles of ATR curves when the laser beam was irradiated normal to the film from the air. Such emission lights are due to surface plasmon excitations that are induced by the modulation of the excitation condition due to surface roughness and near-fields of excited fluorescent dyes [8].

3. Results and Discussion

Figure 1 shows an AFM image of the film of fluorescent sphere with PVA. The concentration of PVA was 2.5 mg/ml. The spheres exist randomly in the film. With the PVA concentration in the solution, the thickness of PVA increased and spheres tend to be buried in PVA.

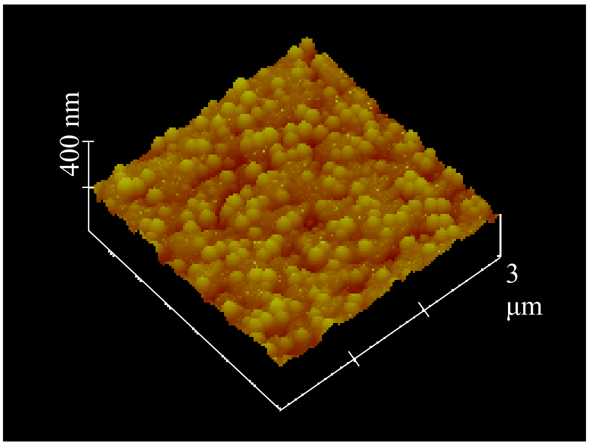

Fig. 1. An AFM image for a thin film of fluorescent microspheres with polyvinyl alcohol.

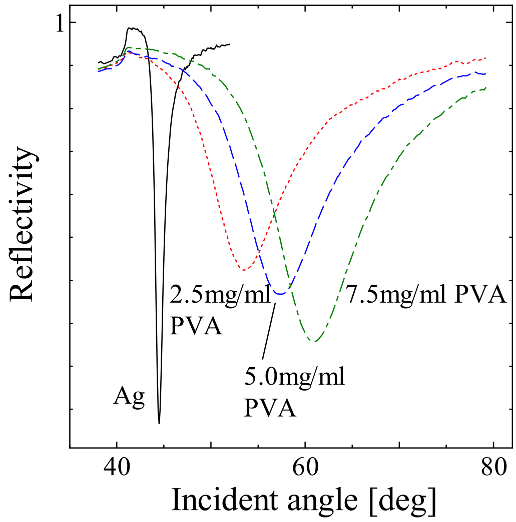

Fig. 2. The ATR curves for the thin films of fluorescent microspheres with polyvinyl alcohol. (λ=488.0 nm)

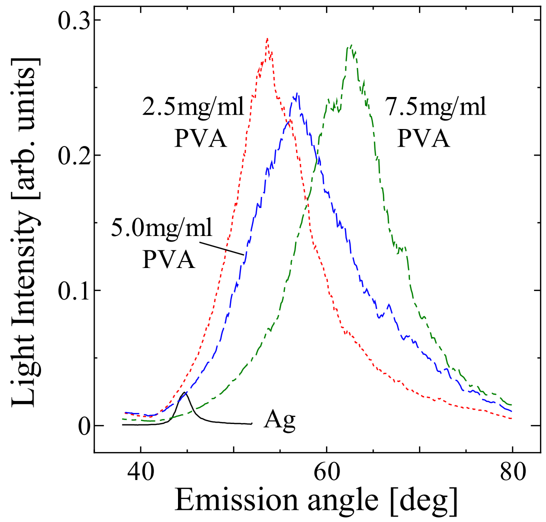

Fig. 3. The emission light intensity curves for the thin films of fluorescent microspheres with polyvinyl alcohol. (λ=488.0 nm)

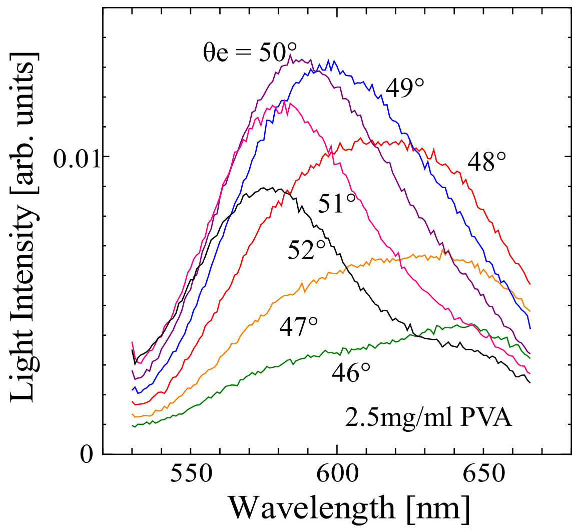

Fig. 4. The SP emission light spectra for the thin film of fluorescent microspheres with polyvinyl alcohol.

Figure 2 shows the ATR curves for the sphere films. Large reflectivity dips due to SP excitations were observed and shifted to higher angle with PVA concentration because of the large film thickness. The intensity curves of SP emission lights due to reverse irradiation (Ar^+ laser, λ=488.0 nm) as a function of emission angle are shown in Fig.3. The peak angles almost correspond to the ATR dip angles in Fig. 2, which indicates the lights are due to SP excitations. The emission light spectra were also observed at various emission angles and strongly depended on the emission angle, as shown in Fig. 4. The dispersion relations of SPs were calculated from the ATR and the emission light properties in Fig.4 [6, 7] and the relations corresponded with each other as shown in Fig. 5. Moreover, each spectrum in Fig.4 almost corresponded to a part of the broad PL spectrum of the sphere film. These results also support that the emission lights are due to multiple SP excitations induced by near-fields of excited fluorescent dyes and are observed due to prism coupling. The SP emission property also depends on the PVA contained in the films.

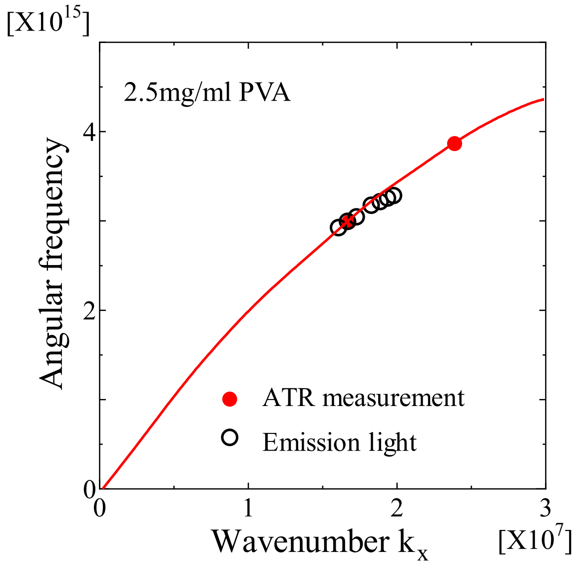

Fig. 5. The dispersion relations for the thin film of fluorescent microspheres with polyvinyl alcohol.

3. Conclusions

Thin films of fluorescent dyes with PVA were fabricated and the structure and the SP excitation properties were observed. The films were very easy to fabricate and useful for controlling optical properties and developing new optical devices using surface plasmons.

Acknowledgement

This work was partly supported by a Grant for Promotion of Niigata University Research Projects and by a Grant-in-Aid for Scientific Research from the Japan Society for the Promotion of Science.

References

[1] K. Ohtaka, H. Miyazaki and T. Ueta, Materials Science & Engineering B, 48, (1997) 153-161.

[2] A. Ashkin and A. Dziedric: Phys. Rev. Lett., **38** (1977) 1351-1354.

[3] F. Meseguer, A. Blanco, H. Miguez, F.G. Santamaria, M. Ibisate, C. Lopez, Colloid. Surf. 202 (2002) 281-290.

[4] *Surface Polaritons*, V.M. Agranovich and D.L. Mills (eds.) (North-Holland, Amsterdam, 1982).

[5] A. Baba, F. Kaneko, K. Shinbo, K. Kato, S. Kobayashi and T. Wakamatsu: Jpn. J. Appl. Phys., **37** (1998) 2581-2586.

[6] T. Nakano, M. Terakado, K. Shinbo, K. Kato, F. Kaneko, T. Kawakami and T. Wakamatsu: Jpn. J. Appl. Phys., **41** (2002) 2774-2278.

[7] F. Kaneko, K. Wakui, H. Hatakeyama, S. Toyoshima, K. Shinbo, K. Kato, T. Kawakami, Y. Ohdaira and T. Wakamatsu, Jpn. J. Appl. Phys., **43**, (2004) 2335-2340.