Extended Abstracts of the 2001 International Conference on Solid State Devices and Materials, Tokyo, 2001, pp. 670–671

P-3-2

Light Emission Property from Organic Dye Thin Films due to Excitation of Multiple Surface Plasmons

Takayuki Nakano, Mitsuru Terakado, Kazunari Shinbo[1], Keizo Kato,
Futao Kaneko[1], Takahiro Kawakami[1] and Takashi Wakamatsu[2]

Graduate School of Science and Technology, Niigata University, Niigata, 950-2181 JAPAN;
[1]Dept. of Electrical and Electronic Engineering, Niigata University, Niigata, 950-2181 JAPAN;
Phone/Fax: +81-25-262-6741, E-mail: fkaneko@eng.niigata-u.ac.jp
[2]Department of Electrical Engineering, Ibaraki National College of Technology, Hitachinaka, 312-8508 JAPAN

1. INTRODUCTION

Surface plasmon resonance (SPR), that is, attenuated total reflection (ATR) has attracted much attention for measurements and sensing, since surface plasmons (SPs) resonantly excited at ultrathin metal surfaces are strongly influenced by conditions of the surfaces [1]. The ATR measurements utilizing SP excitations have been used to evaluate structure and optical properties of organic ultrathin films on metal ultrathin films, to estimate orientations of liquid crystal molecules [2-5] and as one of sensing methods [6,7]. The ATR methods have been also investigated for device applications, because of strong optical absorption and strong electric fields due to SP excitations [8, 9]. Recently, emission light at a resonant angle region of SP excitations was observed through the prism in the ATR Kretschmann configuration, when metal ultrathin films on the prism or organic ultrathin films on metal ultrathin films were directly irradiated from air by a laser beam[10,11]. The emission light depended upon resonant conditions of SPs in the Kretschmann configuration, and it is thought that multiple SPs were excited by means of the direct excitation of organic dye films by a laser beam, that is, reverse irradiation [11-13].

In this study, the emission light properties have been investigated in details for merocyanine (MC) and crystal violet LB films on silver (Ag) films using the conventional ATR method and the reverse irradiation in the Kretschmann configuration.

2. EXPERIMENTS

2.1 Sample preparation

Merocyanine (MC) and crystal violet (CV) were used as organic dye molecules and these Langmuir-Blodgett (LB) films were prepared by the LB method. MC is one of cyanine dyes and shows photoelectric properties [9] and p-type conduction. CV is one of triphenylmethyl groups and shows n-type conduction. The MC or CV molecules were mixed with arachidic acid (C20) for good depositions and the molar ratios of these mixtures were [MC or CV]: [C20] =1:2.

In this study, two types of LB films were prepared. One was the MC LB film with 16 monolayers. Another was an alternate LB film with 16 monolayers of MC and CV LB monolayers (MC/CV LB film). The both LB thin films were deposited on the C20 LB films with 2 monolayers on Ag thin film. The Ag thin film of which thickness was about 50 nm was used as SP active layer. The Ag thin film was deposited on a microscopic cover glass by a vacuum evaporation method.

2.2 A measuring system of emission light by the reverse irradiation in the Kretschmann configuration

Figure 1 shows a system to detect emission light through the prism when the sample was excited by the reverse irradiation in the Kretschmann configuration. The sample was located on the bottom of a half-cylindrical prism (BK-7, n=1.512 at λ = 488 nm) as shown in Fig.1. The sample was irradiated at the vertical incident angle, θ_i=0°, by a p-polarized Ar^+ laser beam at 488nm. The emission light was observed through the prism in the Kretschmann configuration [11-13]. The spectra of the emission light were measured at various emission angles where the light was observed. The emission light was detected with a photo-multiplier (PM) through an optical fiber and a spectrometer, and a photo-counting unit mounted on the computer.

3. RESULTS AND DISCUSSIONS

Figure 2 shows the emission light spectra from the prism/Ag/LB films, ((a): MC LB film , (b): MC/CV LB film) at various emission angles in the reverse irradiation measurements. The spectra of the emission light strongly depended on the emission angle. The peak wavelengths of the emission light became shorter as the emission angles increased. The relation between the wavelength and the emission angle agreed with the resonant condition of excitations of SPs in the Kretschmann configuration of the ATR method. It was thought that multiple SPs were simultaneously excited and the light was emitted through

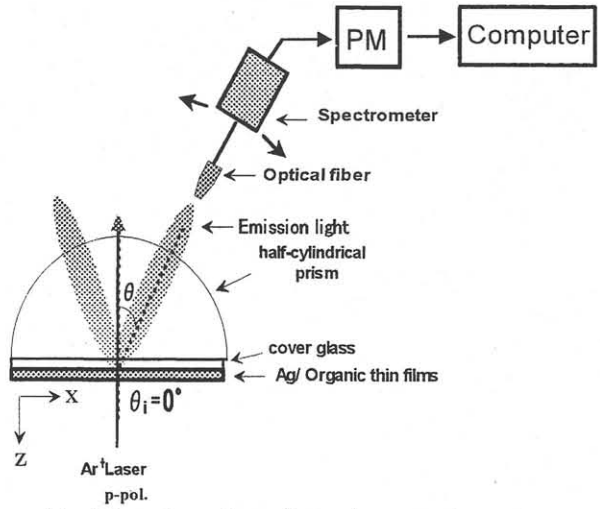

Fig. 1 Sample configuration and a measuring system.

the prism. The spectra in Figs. 2 (a) and (b) distributed around about 600nm and 700nm, respectively. These peaks almost corresponded with the PL peaks of MC and CV, respectively. Especially in Fig.2 (b), the emission light from MC was not observed. It was thought that these

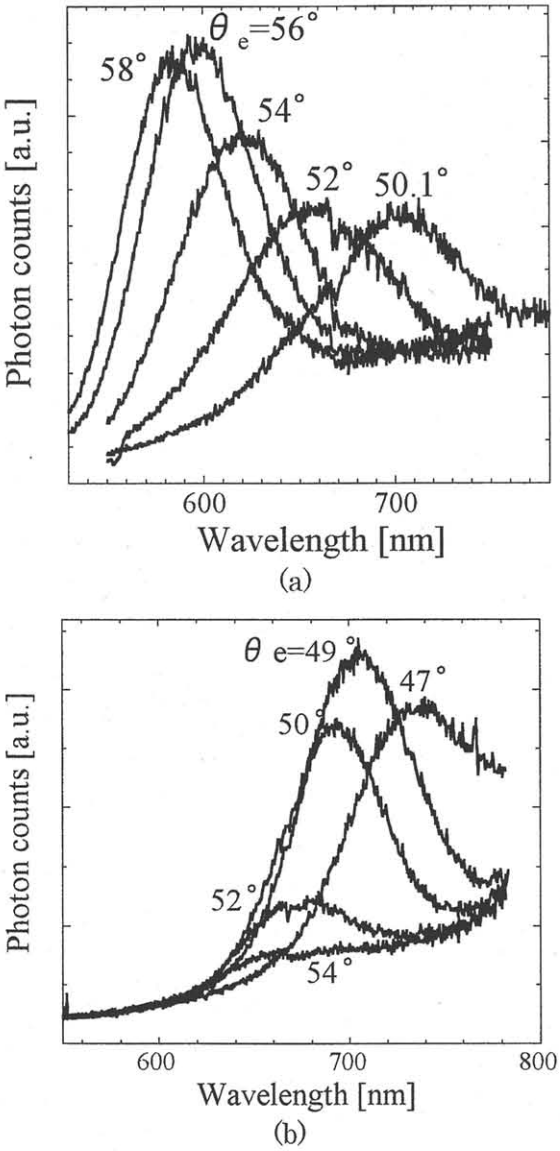

Fig.2. Emission light spectra at various emission angles due to the reverse irradiation. (a); MC LB films, (b); MC/CV LB films.

phenomena were caused by the energy transfer from MC to CV. It is thought that these properties may be used as a device with light emission of selectable colors and new sensing techniques.

4. CONCLUSION

The light emission property from Ag/organic dye thin films due to surface plasmon (SP) excitations was investigated using the reverse irradiation of the laser beam in the Kretschmann ATR configuration. By the reverse irradiation, emission light was observed through the prism, and the spectra remarkably changed with the emission angles. It was concluded that the emission light was caused by simultaneous excitations of multiple SPs at the Ag/organic dye thin film.

ACKNOWLEDGMENT

This work was partly supported by a Grant-in-Aid for Scientific Research from the Ministry of Education, Science, Sports and Culture in Japan and by the Research Project 2000 at Niigata University.

REFERENCES

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

[2] F. Kaneko, S. Honda, T. Fukami, K. Kato, T. Wakamatsu, K. Shinbo and S.Kobayashi: "Attenuated Total Reflection Properties and Structures in Squarylium LB Films", Thin Solid Films, 284 –285 (1996) pp.417-419.

[3] K. Kato, Y. Aoki, K. Ohashi, K. Shinbo and F. Kaneko: "Evaluation of C_{15}TCNQ Langmuir-Blodgett Ultrathin Films by Attenuated Total Reflection Measurements", Jpn. J. Appl. Phys., 35 (1996) pp.5466-5470.

[4] T. Fukami K. Kato, K. Shinbo, F. Kaneko, K. Satoshi and T. Wakamatsu: "Attenuated Total Reflection and Complex Dielectric Constants in Azobenzene LB Films Adosorbing Cyanine Dyes":Mol.Cryst.Liq.Cryst., 327(1999) pp.103-106.

[5] A.Baba, F. Kaneko, K. Shinbo, K.Kato, S. Kobayashi and T. Wakamatsu: "Evaluation of Tilt Angles of Nematic Liquid Crystal Molecules on Polyimide Langmuir-Blodgett Films using the Attenuated Total Reflection Measurement Method", Jpn. J. Appl. Phys. 37(1998) pp.2581-2586.

[6] R. Casalini, J.N. Wilde, J. Nagel, U. Oertel and M.C. Petty "Organic vapor sensing using thin films of a co-ordination polymer: comparison of electrical and optical techniques" Sensors and Actuators B, 57 (1999) pp.28-34.

[7] K.Kato, C.M. Dooling, K.Shinbo, T.H.Richardson, F.Kaneko, R.Tregganing, M.O.Vysotsky and Chris N.Hunter: "Surface Plasmon Resonance Properties and Gas Response in Porphyrin Langmuir-Blodgett Films" 9th Int. Conf. on Organized Molecular Films, Vol.I,T183, p.246

[8] T. Wakamatsu, K. Saito, Y. Sakakibara and H. Yokoyama: "Surface Plasmon- Enhanced Photocurrent in Organic Photoelectric Cell", Jpn.J.Appl.Phys., 36 (1997) pp.155-158.

[9] K. Shinbo, T. Ebe, F. Kaneko, K. Kato and T. Wakamatsu: "Photoelectric Property of Merocyanine LB Film Cell Utilizing Surface Plasmon Excitation", Trans. IEE Japan, 118-A (2000) pp.71-77.

[10] T. Kume, S. Hayashi and K. Yamamoto: "A new method of surface plasmon excitation using metallic fine particles", Materials Science & Engineering A217/218 (1996) pp.171-175.

[11] T. Nakano, T. Wakamatsu, H. Kobayashi, F. Kaneko, K. Shinbo, K. Kato and T. Kawakami: Mol. Cryst. Liq. Cryst., 349 (2000) pp.235-238.

[12] K. Shinbo, K. Honma, M. Terakado, F. Kaneko, K. Kato: "Emission and Scattered Light From Merocyanine Langmuir-Blodgett Film on Ag Thin Films Due to Surface Plasmon Polariton Excitation", Proc. of The 9th Int. Conf. on Organized Molecular Films. Vol. 1, p.185 (2000)

[13] T.Nakano, H.Kobayashi, K.Kato, F.Kaneko, K.Shinbo, T.Kawakami and T.Wakamatsu: "Emission light properties from Ag/Rhodamine-B LB films due to surface plasmons excitation Kretschmann and reverse configurations" MRS Fall Meeting, JJ8.35, p.678 (2000)