Extended Abstracts of the 2003 International Conference on Solid State Devices and Materials, Tokyo, 2003, pp. 774-775

C-8-2

Conversion between Three and Two Dimensional Optical Waves in Attenuated Total Reflection Kretschmann Configuration with Nanostructured Langmuir-Blodgett Films

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1. Introduction

Surface plasmons (SPs), two dimensional optical waves that are a coupling mode of free electrons and light, can be resonantly excited on metal surfaces in the Kretschmann and the Otto configurations by electromagnetic waves due to the total reflection of a p-polarized laser beam [1, 2]. SPs propagate along the surfaces with strong electromagnetic waves, evanescent waves, that decay exponentially away from the surfaces. The attenuated total reflection (ATR) method accompanied with SPs is used for evaluations of ultrathin films and sensing [1, 2]. SPs are also utilized in near field optics (NFO) where electromagnetic waves with light frequency are localized in structures smaller than the light wavelength [2]. It is thought that SPs are very useful as a method to connect NFO with three dimensional optical waves, far field optics, and conversions between three and two dimensional optical waves are also important for the future applications [2].

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 molecular thin films on metal films were directly irradiated from air by a laser beam, that is, reverse irradiation [2-5]. The emission properties corresponded to the resonant conditions of SPs in the Kretschmann configuration, and it is considered that multiple SPs were induced by means of excitation of dye molecules in the reverse irradiation [6-8].

In this study, emission light properties due to multiple SP excitations have been investigated for various nanostructured Langmuir-Blodgett (LB) thin films by means of the reverse irradiation in the Kretschmann configuration. Conversion properties between three and two dimensional optical waves were also measured for dye LB films with some nano-distances between the LB film and the metal thin film in the configuration.

2. Experimental Details

Rhodamine-B (RB) [6, 8] and arachidic acid (C20) LB films were deposited on microscopic cover glasses covered with vacuum evaporated silver (Ag) thin films. RB is one of photosensitizing organic dyes, showing photoluminescence (PL). RB (NKX736) was purchased from Hayashibara biochemical Lab., Inc. RB LB films mixed with C20 were deposited for good depositions and the molar ratio of the mixture was [RB]: [C20] =1:5. C20 has no optical absorption and is one of dielectric materials, and the thickness of the C20 monolayer was 2.76 nm [5]. Ag films were used as the SP active layers and the thickness of the evaporated Ag films was about 40 nm. C20 LB films were also used to maintain some nano-distances between the RB LB film and the Ag thin film.

Figure 1 shows the Kretschmann configuration and a system for detecting emission light through the prism when the RB LB films were excited by reverse irradiation using p- or s-polarized Ar^+ laser beams at 488nm [7, 9]. The LB films were put on the back surface of a half-cylindrical prism (BK-7, n=1.512 at λ= 488 nm). The emission light was measured with a sharp cut filter below about 520 nm as a function of emission angle, θe, where the light was observed.

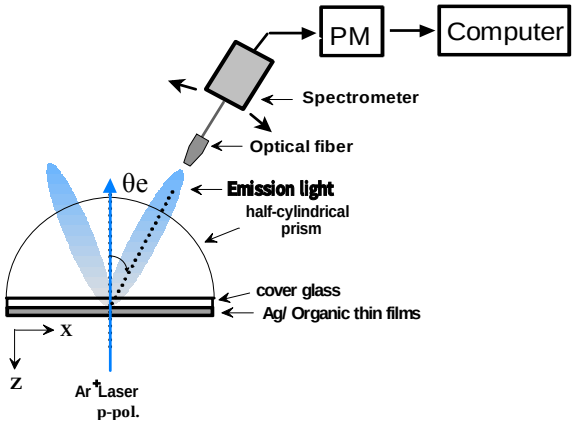

Fig.1 Kretschmann configuration and a system for detecting emission light in the reverse irradiation.

3. Results and Discussion

Figure 2 shows emission light properties as a function of emission angle from prism/Ag/RB LB samples with various numbers of the RB LB layers, from 4 to 16 layers, in the reverse irradiation of a p-polarized Ar^+ laser at 488.0 nm.

The emission properties depended upon the PL properties of the dye LB films and corresponded to the resonant conditions of SPs in the Kretschmann configuration [6, 7]. It is thought that the emission phenomenon involves the following processes: (1) multiple SP are induced by polarizations of excited dye molecules on metal thin films, (2) propagating on the metal surface, and (3) light that is converted from propagating multiple SPs is emitted at the resonant SP conditions in the configuration due to film properties and/or roughness of the films [7-10].

The emission intensity was very small for the RB LB film with 4 layers as shown in Fig.2, but the intensities increased in proportion to the thickness for the LB films having above 8 layers. It is tentatively estimated that non-radiative energy transfer or charge transfer from the excited RB to the metal film occurs in the thinner RB LB film and the first process (1) is weaker than that in the thicker RB LB films [10].

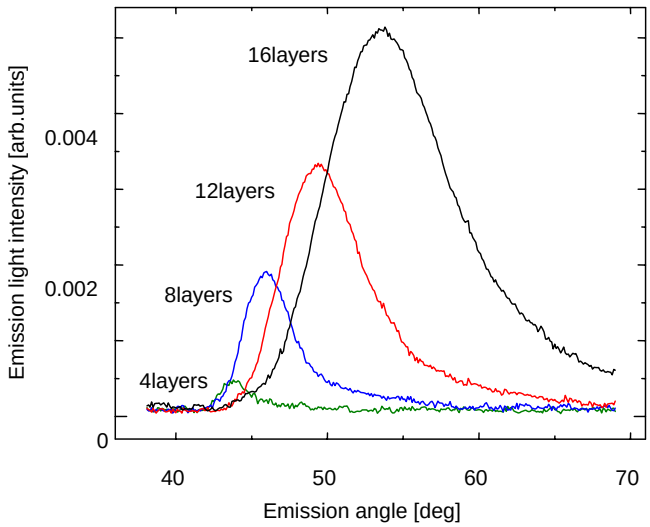

Fig.2 Emission light properties as a function of emission angle from prism/Ag/RB LB samples with various numbers of the RB LB layers (4-16 layers) in the reverse irradiation of a p-polarized Ar^+ laser at 488.0 nm.

When the RB LB films were directly excited by an Ar^+ laser at 488.0 nm, PL properties at the opposite side were observed for the cover glass/Ag/ C20 (0-12 layers) /RB (8 layers) LB films with various separations between the Ag and the RB LB film. The PL properties were shown in Fig.3. Although the thicknesses of the RB LB film (8 layers) and the Ag film (about 40 nm) were constant, the PL intensities strongly depended upon the separation and were smaller as the RB was closer to the Ag film. The intensity was almost saturated for the separation of C20 LB film with 12 layers. It is also estimated that the phenomenon in the smaller separations was due to non-radiative energy transfer or charge transfer from the excited RB to the metal film [10].

The emission properties in Fig.2 contain conversions from three to two dimensional optical waves and from two to three ones. It is thought that the emission properties depending upon the position of the RB from the Ag are very useful for conversion between three and two dimensional optical waves.

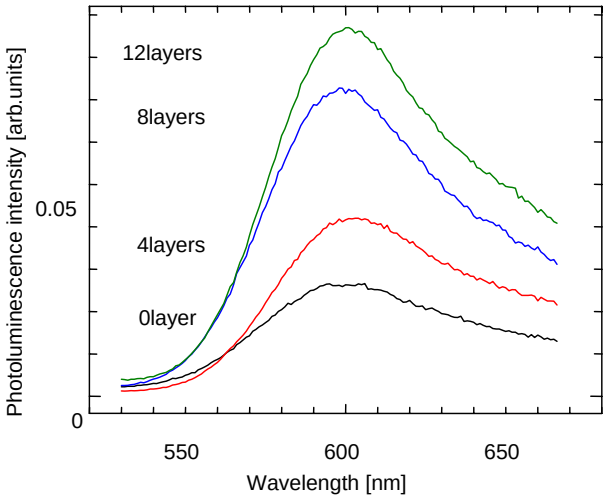

Fig.3 Photoluminescence for the cover glass/Ag/ C20 (0-12 layers) /RB (8 layers) LB films with various separations between the RB LB film and the Ag film, excited by an Ar^+ laser at 488.0 nm and measured at the opposite side.

4. Conclusions

The emission light properties from Ag/RB LB films were investigated using the reverse irradiation. The emission light strongly depended upon the position of the RB from the Ag. It is thought that the phenomenon is very useful for conversion between three and two dimensional optical waves.

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