3C/2008G569

Real-time observation of film structure using x-ray waveguide phenomenon

Kouichi HAYASHI*[1], Wen HU[1], Hisataka TAKENAKA[2], Kosuke SUZUKI[3], Masahisa ITO[3]
[1]Tohoku University, Aoba-ku, Sendai 980-8577, Japan
[2] NTT-AT Nanofabrication Co. Atsugi, Kanagawa 243-0124, Japan
[3] Gunma University, Kiryu, Gunma 376-8515, Japan

Introduction

We have observed this waveguide phenomenon for n-$C_{33}H_{68}$ and copper phthalocyanine thin films, and pointed out that the energy spectra of the guided x rays through the films using white x-ray beams provide information on the film thicknesses and densities similarly to x-ray reflectivity. In the present study, we used synchrotron radiation white x rays and measured the time dependence of the guided x-rays from the organic thin film.

Experimental procedure

Figure 1 (a) shows the experimental geometry for the observation of the guided x rays and reflected x rays using white x rays. The sample used here was Si/PMMA(polymethyl methacrylate)/Si, which has been studied as a typical planar x-ray waveguide. The PMMA and Si layers were grown by spin-coating and sputtering, respectively. The thicknesses of the Si (2.23 g/cm^3) and PMMA (1.19 g/cm^3) layers were estimated to be 99.8 nm and 7.2 nm, respectively, using a standard laboratory x-ray reflectivity apparatus. White x-rays were irradiated on the sample surface under the grazing incidence condition. The energy spectra of the guided x rays were observed by a solid state detector connected with a digital signal processor. The grazing incidence angle ϕ_1 was fixed at 0.177 ˚. The size of the incident beam was 20 × 20 μm^2.

Results and discussion

Before the time-resolved measurement, we measured the guided x rays at the x-ray exit angles of . ϕ_2 = -0.05˚, 0.00 ˚ and 0.05˚. These three spectra are plotted in Fig. 1 (b). Three resonant TE (transverse electric) modes of the guided X-rays were observed and are indicated as TE_0, TE_1 and TE_2. The energies of the guided x rays of TE_0, TE_1 and TE_2 were 7.76, 8.40 and 9.23 keV, respectively, and these energies agreed well with the energies calculated using the above mentioned structure parameters of the present sample obtained by the standard x-ray reflectivity. The angular dependence of ϕ_2 on the guided x-ray intensity differed by the TE mode, as shown in Fig.1 (a). Therefore, the peak of the TE_0 mode was observed in the spectrum only at ϕ_2 = 0.00 º, and the peak of the TE_1 mode was observed at ϕ_2 = -0.05 º and 0.05 º. The peak of the TE_2 mode is observed at all spectra in Fig. 1 (b). In addition to the guided x-ray peaks, peaks due to x-ray refraction through Si substrate are exhibited in the spectra, and are indicated by the dashed circle in Fig. 1 (b). The energy of the refraction varies with the change of the ϕ_2 according to Snell's law, unlike the guided x rays whose energies are constant with the ϕ_2.

After the angular dependence measurements mentioned above, we fixed the detector position at ϕ_2 = 0.00 º to obtain the time dependence of the spectra of the guided x rays. Soon after starting the x-ray irradiation on the sample, we recorded the x-ray spectra every 10 sec up to 1400 sec. Figure 1 (c) shows the time dependence of the spectrum of the guided x-rays until 400 sec. The position of the peak of the TE_2 mode gradually varied toward higher energy for first 200 sec, while the position of the peak of the TE_0 mode was mostly unchanged. This indicates that the structure of the PMMA layer changed rapidly just after the x-ray irradiation was started. This structural change was caused by strong synchrotron radiation white x rays.

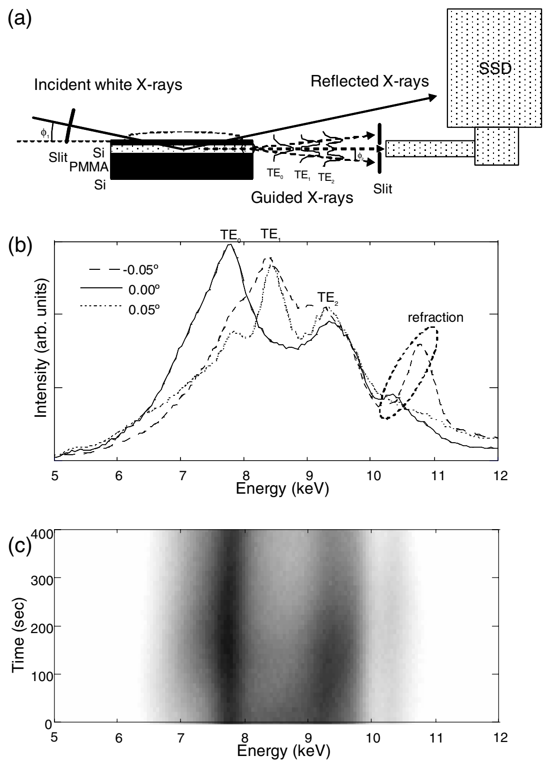

Fig. 1. (a) Geometry of experimental setup for observation of guided x rays. (b) Spectra of the guided x-rays from Si/PMMA/Si multilayer at ϕ_2 = -0.05º, 0.00º, 0.05º. (c) Time dependence of the guided x-rays at ϕ_2 = 0.00º.