Resonance enhancement of X-rays and fluorescence yield from marker layers in thin films

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Marker layers are used in the study of polymer-polymer interdiffusion in thin films. For example, diffusion coefficients have been determined by placing a marker layer of Au between two polystyrene (PS) layers of different molecular weights and measuring the shift of the marker layer position due to polymer interdiffusion by Rutherford backscattering spectrometry (RBS)[1]. For determining a marker layer position in a thin film, while RBS has a typical depth resolution of $\sim$ 200 $\mathring{A}$, X-ray techniques can provide a depth resolution of $\sim$ 2 $\mathring{A}$.

X-ray resonance enhancement in thin films have been used to determine the depth distribution of components in a thin (350 $\mathring{A}$) PS-PBr$_x$S polymer blend layer [2]. If this technique is to be used to determine a marker position over the whole depth of the thin film, an important question has to be answered. Theoretical plots in refs. 2, 3 and 4 as well as in the inset of Fig.1 show that the X-ray field intensities at depths equidistant from the middle of the film are equal. It may appear that an element placed at either of these two equidistant positions would give rise to the same fluorescence yield, and consequently by fluorescence yield measurements their positions could not be distinguished. However, this is not true. The field intensities are equal only at specific angles. Here we demonstrate that fluorescence yield from atoms placed at such depths, equidistant from the middle of the film, detected over an angular range, has quite different profiles and there is no ambiguity in the detection of these positions. We demonstrate this by embedding thin Ti, Fe and W marker layers in a 500 $\mathring{A}$ thin Si layer on a Au-coated glass substrate. Approximately 10 $\mathring{A}$ thin Ti, Fe and W layers were embedded at approximate depths of 125, 250 and 375 $\mathring{A}$ respectively. Theoretical calculations and experimental results are shown in Fig.1 and Fig.2 respectively. From Fig.2 it is clear that Ti and W placed symmetricaly around Fe give rise to quite different fluorscence yield profiles as expected from theory (Fig. 1). Hence these positions can be easily distinguished from the measured fluorescence yield profile. The experimental data are raw data, which are to be properly corrected for fitting with the theory. The experiment has been performed at the ROEMO-I beamline.

It has been shown here that the marker position can be determined over the whole film thickness unambiguously and diffusion studies can be performed with high depth-resolution.

Acknowledgement

References

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[3] J. Wang, M. Bedzyk and M. Caffrey, Science **258**, 775 (1992).

[4] D. K. G. de Boer, Phys. Rev. **B 44**, 498 (1991).

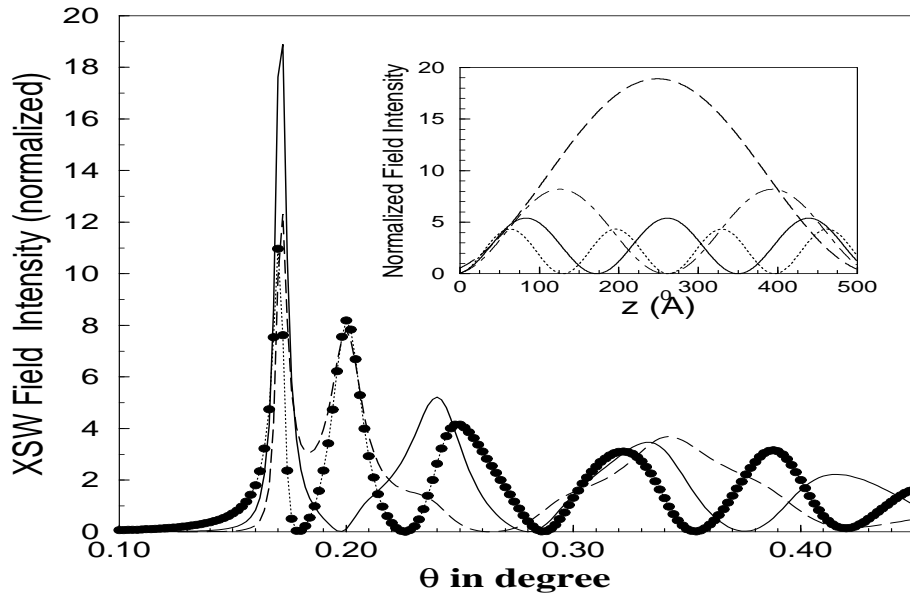Figure 1: Field Intensity variation with angle of incidence at different depth: 125 $\mathring{A}$ ($\bullet \bullet \bullet$), 250 $\mathring{A}$ (——), 375 $\mathring{A}$ ($- \cdot -$). Inset: Field variations at first (- - -, $\theta = 0.173^o$), second ($- \cdot -$, $\theta = 0.2^o$), third (——, $\theta = 0.241^o$) and fourth (......, $\theta = 0.289^o$) order resonance enhancement positions.
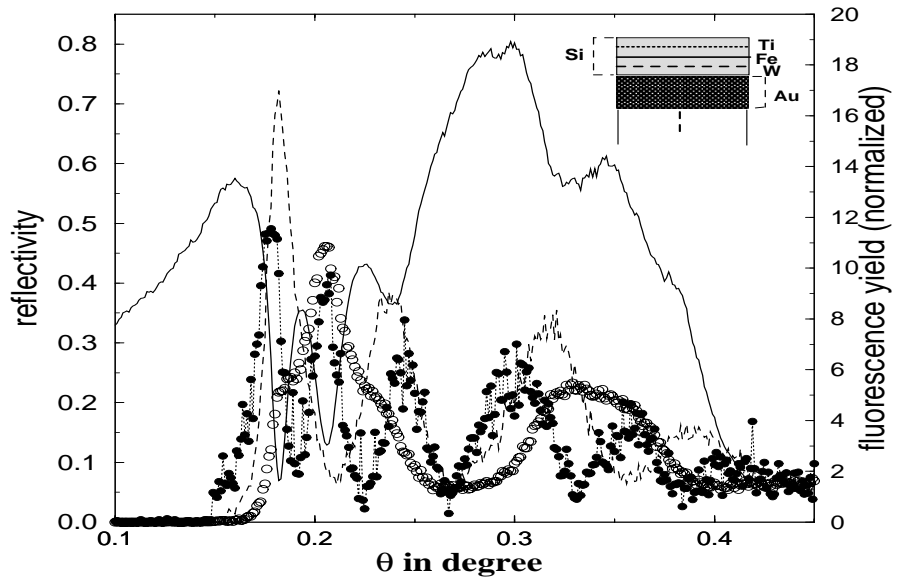

Figure 2: Reflectivity (——) and Ti ($\bullet \bullet \bullet$), Fe (- - -) and W (o o o) fluorescence yield (Raw data).