Application of GISAXS to the evaluation of polymer gratings fabricated by Nanoimprint Lithography

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1. Introduction

Nanostructures fabricated on the surface of thin polymer films present potential interest for a great variety of applications in nanotechnology. Different approaches involving lithographic [1] and alternative procedures [2] are currently being used to create such nanostructures. Particularly, Nanoimprint Lithography (NIL) is one of the most promising techniques for the nanostructuring of polymer materials [1]. We have used the potential of grazing incidence small angle X-ray scattering (GISAXS) in the investigation of gratings fabricated on silicon stamps and those defined by NIL on thin polymers films.

2. Experimental

Different polymers including poly (ethylene terephthalate) (PET), poly (trimethylene terephthalate) (PTT) and polycarbonate bisphenol A (PC) have been investigated. Polymer thin films were prepared by spin coating on silicon wafers (100). For NIL, mesa-type silicon stamps have been fabricated. The mesas have been obtained by optical lithography and wet etching, whereas the nanostructures were defined in the substrate by means of e-beam lithography, lift-off and reactive ion etching. Periodic superficial nanogratings have been produced by pressing the stamps over different polymer films at temperatures above their glass transitions.
Structured areas were analysed by GISAXS using the facilities of the BW4 beamline at HASYLAB (DESY, Hamburg). An X-ray wavelength of λ= 0.13808 nm, with a beam size of 40x20 μm^2 was used in our experiments. Scattered intensity was recorded by a Mar CCD detector of 2048x2048 pixels with a resolution of 79.1 μm per pixel, using a distance sample-to-detector of 2.211 m. An incidence angle α_i= 0.4º) was chosen, which is larger than the critical angle of polymer materials and then full penetration in the sample is ensured. Samples were positioned in such a way that the beam was parallel to the nanograting lines. Acquisition times between 1 and 100 s were used. GISAXS images were treated with the Fit2D software.

3. Results and Discussion

The structural information obtained by both Atomic Force Microscopy (AFM) and Grazing Incidence Small Angle X-ray Scattering (GISAXS) complements each other in a synergetic way (Figure 1). Aiming a deeper description of the nanogratings obtained on the spin coated polymer films, simulations of the GISAXS patterns were accomplished by using the software package IsGISAXS. Comparison of experimental and simulated GISAXS patterns suggests that polymer NIL gratings can be well described considering a one-dimensional crystalline lattice. Moreover, comparison between GISAXS patterns of the silicon stamp and that of the polymer NIL allows one to assess the transfer efficiency of the NIL process (Figure1).

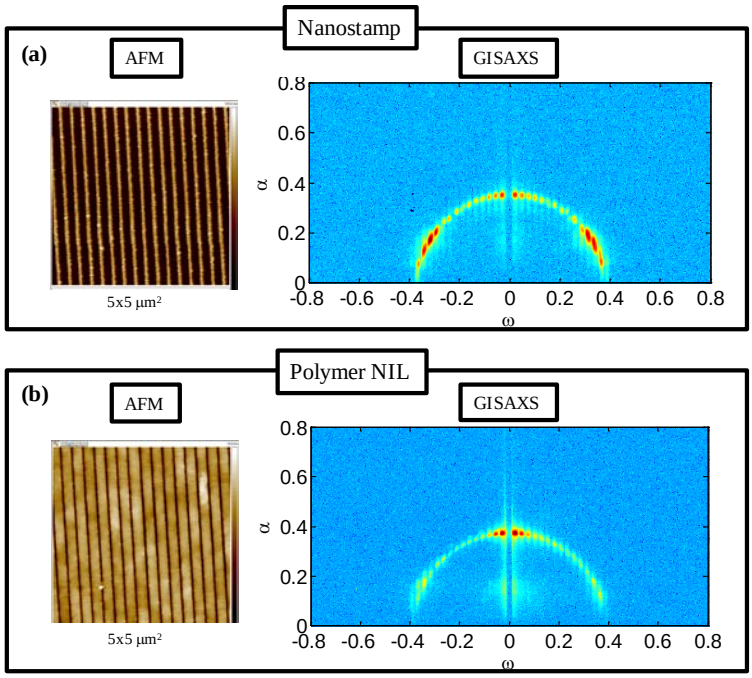

Figure 1: AFM images and GISAXS (BW4@HASYLAB DESY; Hamburg, Germany) patterns of a Silicon stamp **(a)** and its NIL on spin coated film of polycarbonate bisphenol A **(b)**.

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