Polycarbonate as a dual-tone resist for electron-beam lithography

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Electron-beam lithography (EBL) with high performance resist is of great significance for nanofabrication. Polycarbonate (PC) is an important and commonly used engineering plastic with high chemical stability, mechanical toughness and good biocompatibility. Such features make PC ideal for applications such as micro and nanofabricated biosensors. PC can be easily patterned by nanoimprint. However, the use of PC as EBL resist is not widely reported[1,2]. So far PC is reported to behave as a positive-tone EBL resist. In this work, we find that polycarbonate can also be used as a negative-tone resist at high exposure dosage. This feature opens new patterning routes for PC in applications such as dielectrics, microfluidics, and biosensors.

We fabricate 100 nm linewidth gratings in PC with EBL. To obtain the contrast curve, a 7 x 10 array of squares of 30 x 30 μm^2 was exposed with gradually increasing doses. The wide range of exposure dosages enables us to systematically study the impact of electron bombardment on PC resist. To start with, a solution of 4% w/v of PC in cyclopentanone was deposited by spin-coating on a silicon substrate. The spin-coating was performed at a speed of 1500 rpm, resulting in PC film with a thickness of 132 nm. The PC film was heated to 170℃ for 5 minutes to drive out the solvent. After exposure at 80 keV using Nanobeam nB5 EBL system, the resist was developed in pure cyclohexanone for 10 seconds at room temperature followed by IPA rinsing and nitrogen drying. The pattern depths were measured by atomic force microscope (AFM) and the data were plotted to generate the contrast curve.

Figure 1(a) shows the AFM image of 100 nm PC gratings and the curve of remaining PC thickness at different exposure dosages. The contrast is calculated as $\gamma = 0.75/\log(D_{0.75}/D_0)$ ~2.42, and the sensitivity is about 1.7 mC/cm^2. It should be noted that due to the proximity effect, those values may be modified for other pattern size and density.

PC structures patterned by EBL can be further modified by controlled dewetting. Due to strong chain entanglement in PC, the end point of PC thermal reflow can be precisely controlled by film thickness as reported in our previous studies, where sub-50 nm gap were formed from micron scale structures. We will report our effort to achieve sub-10 nm gap by controlled dewetting from PC nanostructures patterned by EBL. Furthermore, we study the bonding change of PC chains under low and high exposure dosages by Raman spectroscopy, and hence illustrate the molecular origin of both positive and negative tone behaviors of PC resist in EBL.

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[2] L. Moretto, M. Tormen, M. De Leo, A. Carpentiero and P. Ugo, Nanotechnology 22, (2011).

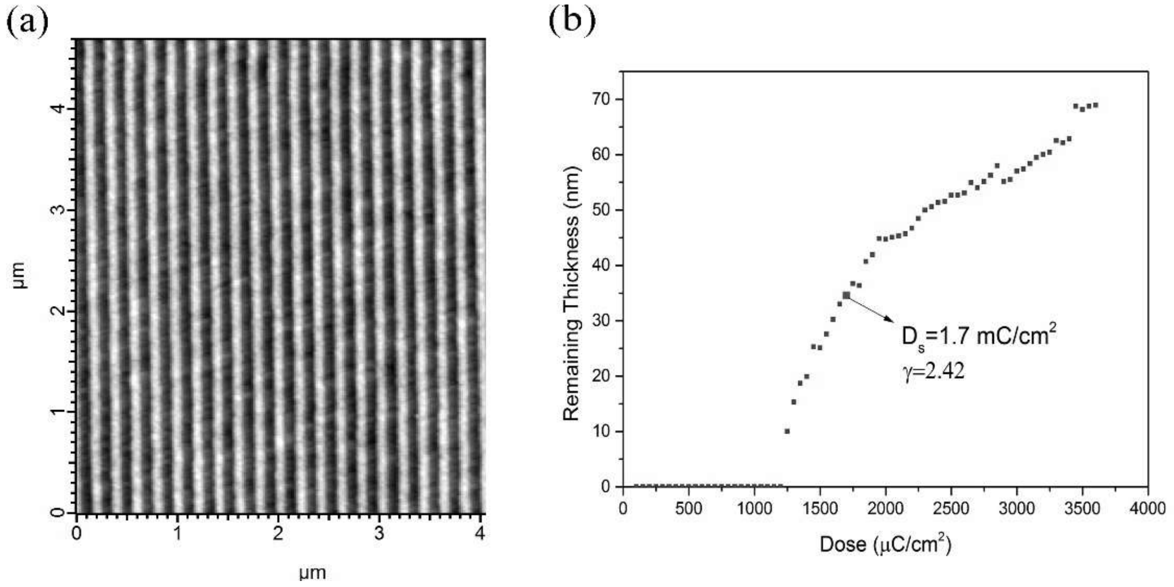

Fig. 1. (a) AFM image of 100 nm linewidth PC gratings fabricated by EBL using PC as a negative tone resist; (b) The thickness of remaining PC resist as a function of dosage after exposure and development with cyclohexanone. The contrast value γ and sensitivity D_s are 2.42 and 1.7 mC/cm^2, respectively.