Energy dependence of self-organized nanostructures on photoresist surfaces by ion bombardment at normal incidence

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Ion bombardment is a promising maskless method of generating self-organized nanostructures. The later critical dimension of ion-induced nanostructures is less than those produced by holographic lithography. However, the aspect ratio of such nanostructures is low. A possible route is to employ ion-induced nanostructures on photoresist. Subsequently, the aspect ratio of substrates under photoresist is enhanced. Although a lot of semiconductors, metals, and oxides have been studied on their ion bombardment. To the best of our knowledge, the investigation of ion-induced nanostructures on photoresist is still missing.

In this study, the ion bombardment of inorganic materials is extended to an organic surface of photoresist. The photoresist surfaces were bombarded by Ar^+ with ion energies ranging from 200 eV to 800 eV at normal incidence. The energy dependence of self-organized nanostructures on photoresist surfaces was investigated using atomic force microscopy. Similar as inorganic materials, nanostructures on photoresist is also strongly dependent on ion energy. As shown in figure 1, different morphologies were observed, including nanodots with nanoholes (@ 200 eV and 300 eV), nanoholes, and smooth (@ 600 V and 800 eV). Especially, nanoholes were achieved at ion energies from 350 eV to 550 eV. Furthermore, as shown in figure 2(a), the rms roughness of the photoresist increases, saturates and reduce with increasing ion energies. While etching rates almost linearly increase with ion energies. The average diameters and depth of nanoholes tends to be stable and saturate at energies from 400 eV to 500 eV (Figure 2(b)). We assume that the dominant destabilizing mechanisms could be the combination of curvature-dependent sputtering and mass redistribution.

Further chemical characterization, such as secondary ion mass spectrometers measurement, of the bombarded photoresist is to be performed to see whether the ion bombardment varied the chemical bonds among surface layer of photoresist or not. This work may stimulate the investigations of new ion-induced nanostructures of other organic or polymer materials applied in lithography. The work may also be helpful for models or simulation of ion bombardment for organic materials.

We acknowledge support from the National Natural Science Foundation of China under Grant No. 11675169 (NSFC).

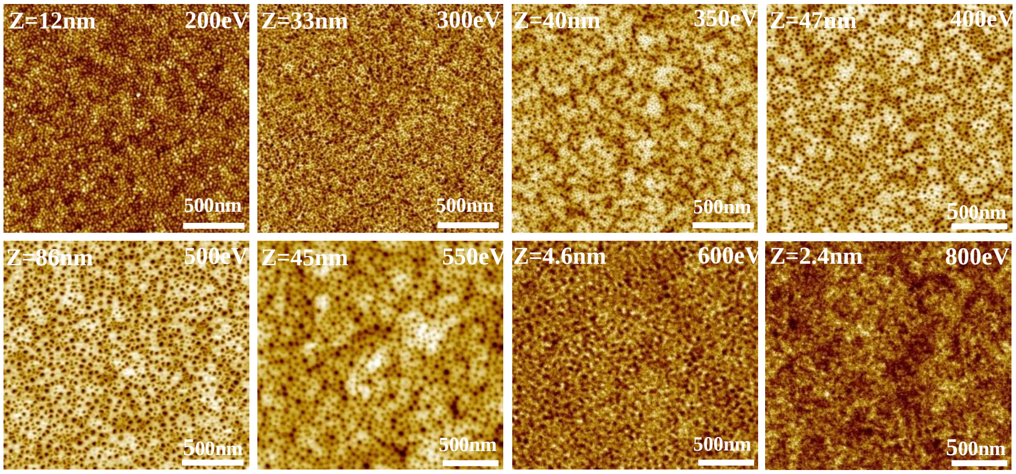

Figure 1: AFM images of photoresist surfaces at different ion energies and normal incidence. The current density j of ion beam is 250 μA·cm^{-2}, and ion fluences Φ is 1.87×10^{18} cm^{-2}. The different height scales z of the images are specified in each image. The image size is 2×2 μm^2.

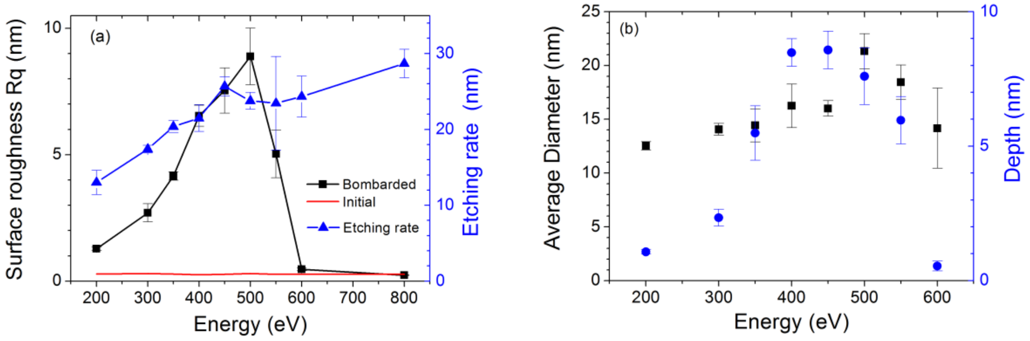

Figure 2: (a) Roughness Rq and etching rate, (b) Average diameter and depth obtained from AFM topographs as a function of the ion energy.