Investigation of surface roughness of poly(methylmethacrylate) at reduced temperatures

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Poly(methylmethacrylate) (PMMA) is a popular electron beam resist for high resolution nanolithography. The line edge roughness of PMMA line gratings [1] and the association of surface roughness of PMMA with its line edge roughness [2] have been investigated at room temperature. Recent activities on low temperature development of PMMA have demonstrated significant improvements in contrast and line edge roughness [3-6]. However, the surface roughness of PMMA at low temperatures has not been reported.

To this end, we present a study on the surface roughness of PMMA developed at various temperatures. PMMA of different number-average molecular weights ranging from 200 K to 2.2 M were electron-beam exposed and developed at temperatures ranging from 20 °C to 0 °C. Electron-beam writing was performed in a JEOL JBX-6000FS nanowriter at 50 kV. Development was carried out in 1:3 MIBK/IPA. Both normalized contrast curves and the associated roughness curves are shown in Fig. 1 and appear steeper with the decrease of the temperature. A noticeable feature is the sharp drop of the roughness at the bottom of the resist, i.e., at the resist/substrate interface. It is observed that with decreasing temperature, the maximum roughness increases as shown in Fig. 2. At each temperature, the higher molecular weight PMMA exhibited higher maximum roughness. However, before the peak of the roughness, the higher molecular weight PMMA demonstrated less roughness. Also, at the same exposure dose, the roughness is lower with decreasing temperature, which means that the roughness is related to the dissolution rate of the exposed PMMA. The origin of the roughness derives from both the electron-resist interactions and the mechanism of the dissolution of irradiated resist.

These results along with grain size distribution of PMMA fragments will be presented. The properties of the surface at lower temperatures well below 0 °C will be further investigated. The effects of molecular weight, temperature, and different developers on the surface roughness will be presented and discussed.

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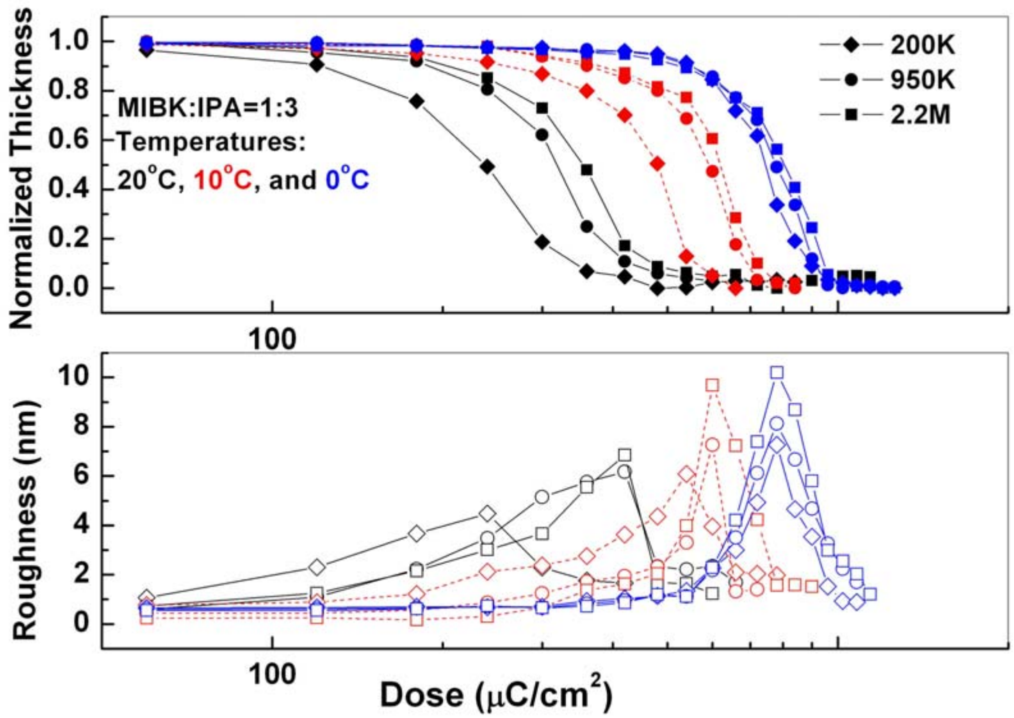

FIG. 1. Contrast curves and corresponding roughness curves (lower section) for PMMA of different molecular weights developed in 1:3 MIBK/IPA at various temperatures.

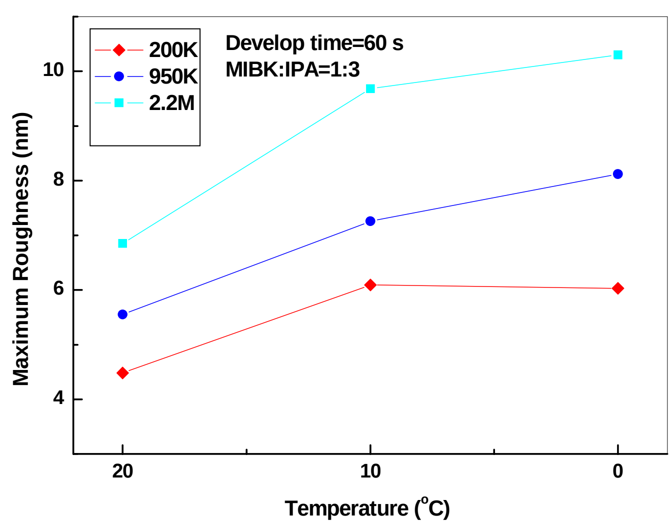

FIG. 2. Maximum roughness of different molecular weight PMMA at different temperatures