Surface roughness and resist thickness issues in patterning of ultra-dense lines in hydrogen silsesquioxane

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Hydrogen silsesquioxane (HSQ) has become a highly investigated negative-tone resist for realizing ultra-dense line patterning. Sub-10 nm grating pitch has been achieved using novel salty developers; these developers have been critical in pushing new limits in patterning [1]. Resist thickness effects on patterning of isolated HSQ lines have been investigated [2]. It has also been reported that after development, the surface roughness of HSQ, which affects linewidth fluctuations, drops rapidly with increased electron beam dose [3]. The broad array of parameters such as resist thickness and roughness, developer types and temperature, and other exposure issues need to be further investigated in order to realize the ultimate potential of HSQ.

In this work, we present studies on the effects of the developer conditions such as developer temperature on the surface roughness of HSQ and how these parameters affect the resolution of HSQ as defined by the pitch of ultra-dense lines. The utility of the exposed resist patterns for metal fabrication is also investigated. HSQ (Fox-14) resist with a thickness of 100 nm spun on silicon wafers were used for the determination of contrast and roughness parameters. Exposures were conducted by utilizing a JEOL JBX-6000FS electron beam nanowriter at 50 kV. Both pre-baked and non-baked resists were utilized. Developments were performed using 25% TMAH, NaOH/NaCl 0.25/0.7 N [1], and TMAH/NaCl 0.25/0.7N [4] for comparison. Developer temperatures were varied from 20 °C to 50 °C. Both normalized contrast curves and the corresponding roughness curves of HSQ were measured by AFM; preliminary results are shown in Fig. 1. The rms surface roughness of HSQ increased with developer temperature. High contrast and the higher roughness values were both achieved for salty developers, especially for TMAH/NaCl 0.25/0.7 N [4]. Contrast constants up to 20 were obtained for the TMAH/NaCl 0.25/0.7 N developer. The roughness curves of non-baked HSQ decreased slowly around the bottom of the resist, which differed from those obtained for pre-baked (200 ºC) HSQ.

Figure 2 (a) shows the surface roughness of HSQ at different thicknesses. Values for pre-baked and non-baked samples were similar. Dense lines with 15-nm-pitch have been achieved with a salty developer in 8-nm-thick HSQ as shown in Fig. 2 (b). Detailed experimental results on the effects of temperature on the resolution and repeatability of the ultra dense lines in various HSQ resist thicknesses will be presented. Pattern transfer at these ultra-high resolutions into Cr/Au and Cr/Ag thin films for surface-enhanced Raman scattering applications will also be presented.

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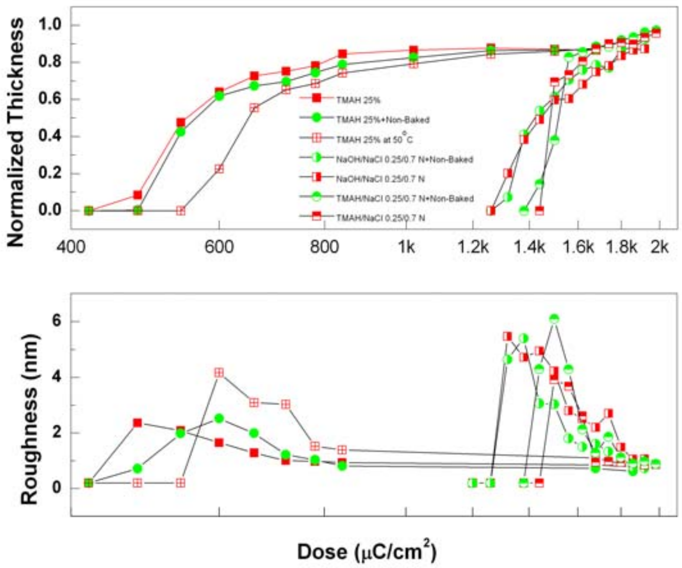
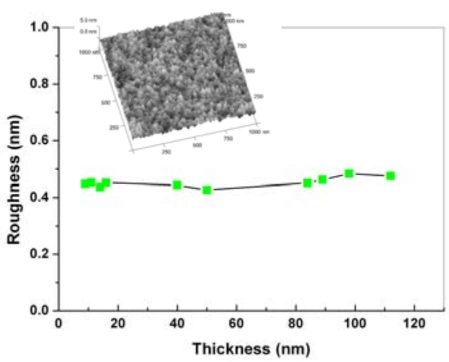
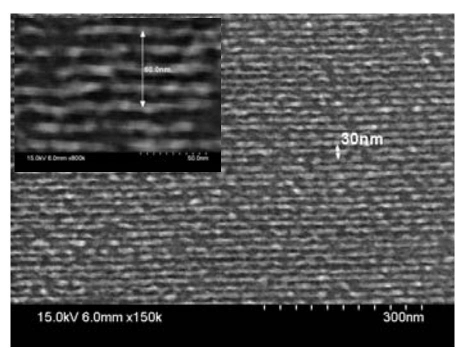


FIG. 1. Contrast curves and corresponding roughness curves (lower section) for HSQ developed with 25% TMAH, 25% TMAH at 50 ^{o}C, NaOH/NaCl 0.25/0.7 N, and TMAH/NaCl 0.25/0.7N, respectively (developed at 20 ^{o}C if not specified).



(a)



(b)

FIG. 2. (a) Surface roughness of non-baked HSQ at different thicknesses with the inset showing the surface roughness map of 8-nm-thick, non-baked HSQ; (b) 15-nm-pitch HSQ gratings achieved with 8-nm-thick non-baked HSQ and a salty developer at 20 ^{o}C with the inset showing the enlarged view.