High-temperature development of thick hydrogen silsesquioxane resist for fabricating dense and high aspect ratio nanostructures

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The negative-tone resist of hydrogen silsesquioxane (HSQ) has proven to be an excellent candidate for fabricating ultrahigh resolution dense lines and high aspect ratio nanostructures. [1] Technical challenges in patterning dense nanostructures still remain for applications of HSQ. In HSQ developers, the dissolution of resist is driven by hydroxide ions (OH−) and enhanced by high temperatures. Salty developers containing 4% wt NaCl can significantly improve the contrast of HSQ. [2] However, OH− and Na^+ ions also lead to Si substrate etching when 1-2 nm natural oxidation layer is etched at high temperatures. We found that, at 35℃, the etching resistance of natural oxidation layer on Si wafer in the salty tetramethyl ammonium (TMAH) developer with wetting agent (AZ726 MIF/ NaCl) was better than that in salty developers without wetting agent, indicating that longer development time can be used to remove footing/bridges between patterns. One may argue that the presence of wetting agent in AZ726 MIF developer promotes the interaction of ions (OH−) with the resist molecules, nor does it enhance the natural oxidation layer etching. The contrast curves show that the sensitivity of HSQ at 35 ℃ is 2 time larger than that at room temperature and the contrast values at 35 ℃ and room temperature are same. Based on above analysis, the TMAH (AZ726 MIF) / NaCl developer at 35 ℃ was used to develop 486 nm HSQ resist exposed by the Joel 9500 electron beam writer. The developing time was 3.5 minutes. After CO_2 supercritical point drying, 20-nm-wide dense lines with high aspect ratio up to 20 were patterned on both the Si wafers and the substrates coated with Ti/Au/Cr seedlayers (see Figure 1). The single-crystalline Au nanostructures were formed through the gaps of resist patterns by utilizing pulse reversal Au electroplating (see Figure 2). Our resultes suggest that the high-temperature development of HSQ is suited to patterning high aspect ratio nanostructures due to the enhancement of the interaction of hydroxide ions with resist molecules.

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[1] J. Vila-Comamala, S. Gorelick, V. A. Guzenko, E. Färm, M. Ritala, and C. David, Nanotechnology 21, 285305 (2010).

[2] J. K. W. Yang, B. Cord, H. Duan, K. K. Berggren, J. Klingfus, S. W. Nam, K. Kim, and M. J. Rooks J. Vac. Sci. Technol. B 27, 2622 (2009).

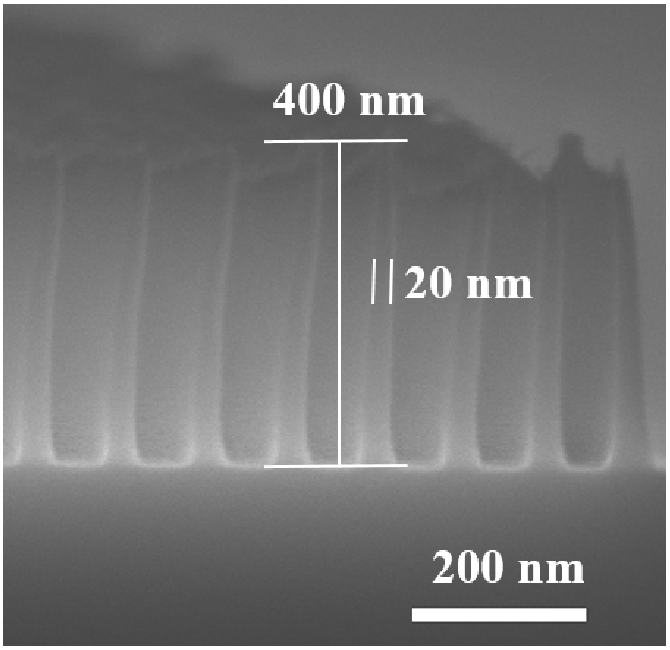

Figure 1: High aspect ratio HSQ nanostructures achieved by the high-temperature development: The height and width of dense lines are 400 nm and 20 nm, respectively. The aspect ratio is up to 20. The period is 100 nm.

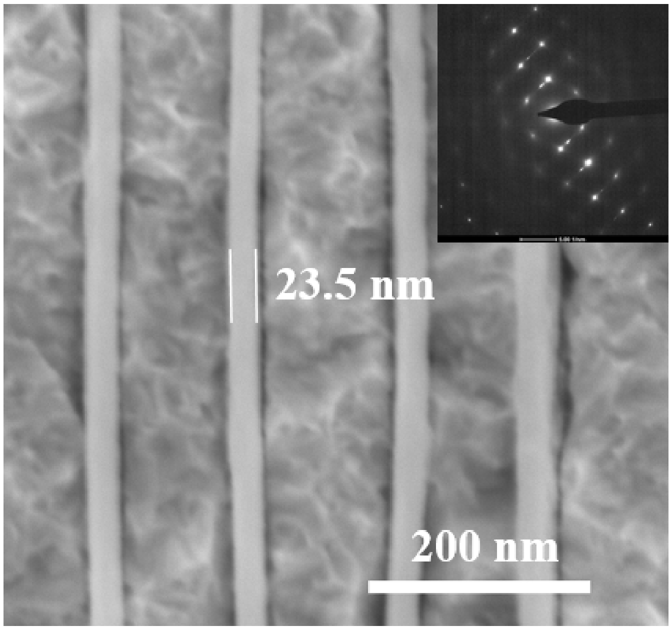

Figure 2: Single-crystalline Au filled in gaps between HSQ nanostructures: The height and width of HSQ dense lines are 400 nm and 23.5 nm, respectively. The period is 120 nm. The inserted top-right image shows that the filled Au is single-crystalline.