Two-step development method of hydrogen silsesquioxane resist for high-density electron beam nanopatterning

Hyo-Sung Lee, Jung-Sub Wi, Sung-Wook Nam, Hyun-Mi Kim, and Ki-Bum Kim
Dept. of Materials Sci. and Eng., Seoul National Univ., Seoul 151-742 Korea

For a successful definition of nanometer scale features in high-density using electron beam lithography, the usage of the resist with high contrast value is essential. For hydrogen silsesquioxane (HSQ) resist reported as a high resolution negative tone resist, the higher contrast value has been reported to be obtained by the extension of development time.

In this work, we study on the development characteristics with the extension of development time of HSQ resist. We newly found the development stopping phenomena and we propose the two-step development method. After e-beam exposure, HSQ resist was developed for various development times in the range of from 10 sec to 5 min at 21^{o}C in 25 % tetramethylammonium hydroxide (TMAH) aqueous solution. As shown in Fig. 1(a), it is observed that the HSQ development rate gradually reduces as development time within 1 min and that, at 1 min the development process stops. By X-ray photoelectron spectroscopy (XPS) analysis, we identified that this development halt results from passivation of TMAH-insoluble, siloxane layer on the HSQ surface during development process. To continue the development process, we used the two-step development method which follows three processes: the first TMAH development process, the siloxane layer removal process using dilute hydrofluoric acid (HF) solution, and the second TMAH development process. By using this method, HSQ surface after development process is converted into that before development, and that the halted development progresses after 1 min as shown in Fig. 1(b). The two-step method more effectively generated the isolated dot array patterns than the typical one-step method in highly dense dot array features with 25 nm pitch. Furthermore, the resist scum was cleanly eliminated in dense array features (Fig. 2). Our method could be applied as a very useful tool for trimming HSQ resist in a high-density e-beam nanopatterning.

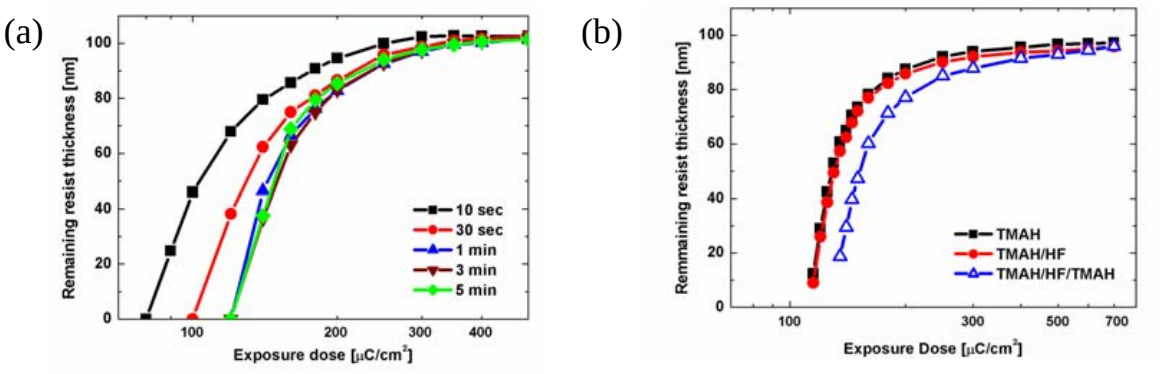

Fig. 1. (a) HSQ resist contrast curves at various development times (10 s, 30 s, 1 min, 3 min, 5 min) using 25 % TMAH developer in 19 kV e-beam exposure. (b) HSQ resist contrast curves for TMAH (1 min), TMAH/HF, and TMAH/HF/TMAH development.

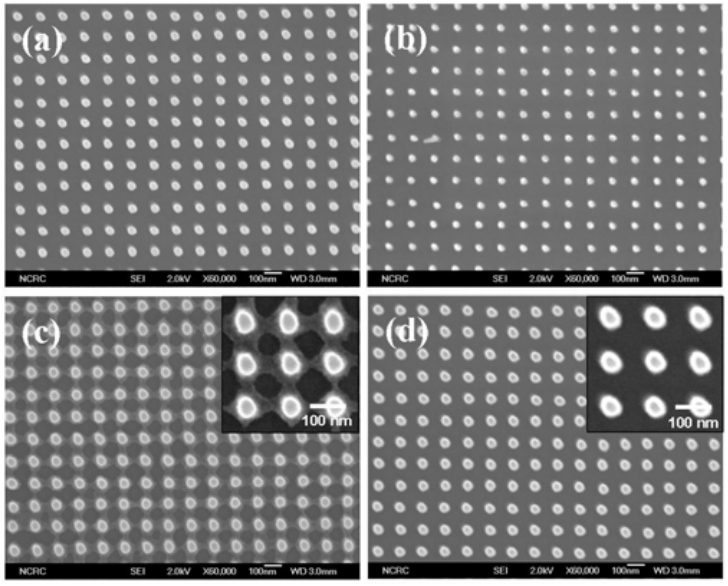

Fig. 2. Plan-view SEM images of e-beam patterning results for dot array. (a) One- and (b) two-step development after 37 fC exposure with 120 nm pitch, (c) one- and (d) two-step development after 28 fC exposure with 120 nm pitch,