Electronic Supplementary Material (ESI) for Journal of Materials Chemistry C
This journal is © The Royal Society of Chemistry 2013

Electronic Supplementary Information (ESI): [Additional Development and Post-development Processes]

Various Development Methods

Process techniques including hot development and sonic agitation have been used in the development process of IM-MFPT12-8 resist. 50 nm dense lines were patterned using 30 kV electron beam. Using cyclohexanone as developer, immersion development and ultra-sonic assisted development at room temperature (20°C) and hot development at 40°C were applied to compare the effects of the three development methods to the line patterns. The development duration was 30s for all the three methods.

The comparison of hot development and room temperature development is shown in Fig. S1. There was no significant improvement of the line patterns with the two development methods (Fig. S1 (a) and S1 (b)). Moreover, considerable amount of residues after development were observed on the silicon substrate (Fig. S1 (c)).

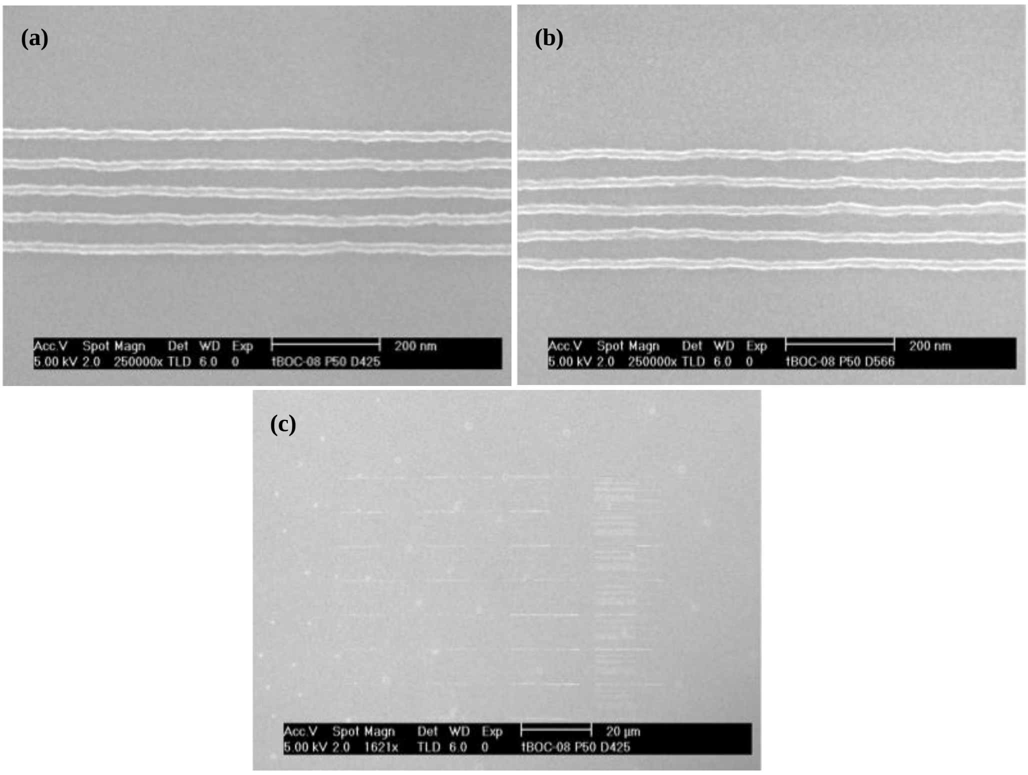


Fig. S1 SEM images of (a) 50 nm dense lines developed in cyclohexnone at room temperature (20°C) and (b) at 40°C; (c) Residues observed on silicon substrate after 40°C hot development.

The comparison of immersion development and ultra-sonic assisted development is shown in Fig. S2. There was no significant improvement of the line patterns with the two development methods.

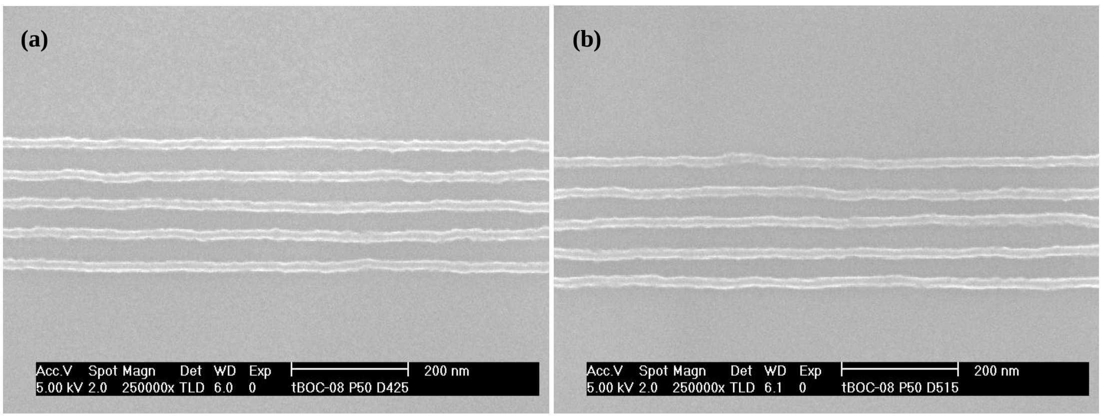


Fig. S2 SEM images of 50 nm dense lines developed in cyclohexnone by (a) immersion development and (b) ultra-sonic assisted development.

Post-development Processes

Hard bake after development has been applied to evaluate the swelling of the line patterns. Again the 50 nm pitch dense line patterns were used in the test.

5 min hard bake at temperatures of 90°C (which is the post-exposure bake temperature) and 120°C have been tested to compare with the sample without hard bake. As shown in Fig. S3, there is a significant improvement of line quality on the sample with the 90°C/5 min hard bake (Fig S3 (b)). However, hard bake at a high temperature of 120°C damaged the lines (Fig. S3 (c)). The line width and line edge roughness (LER) (in brackets) of the samples without hard bake and with 90°C/5 min hard bake were 19.9 nm (6.2 nm) and 18.6 nm (5.0 nm), respectively. This result indicates that the hard bake process at appropriate temperatures might promote further evaporation of the organic developing solvent penetrated into the crosslinked network, thus reducing the swelling effect during the development process.

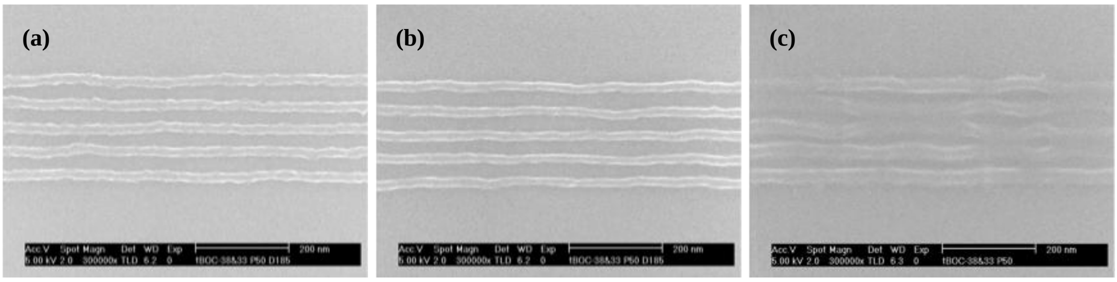
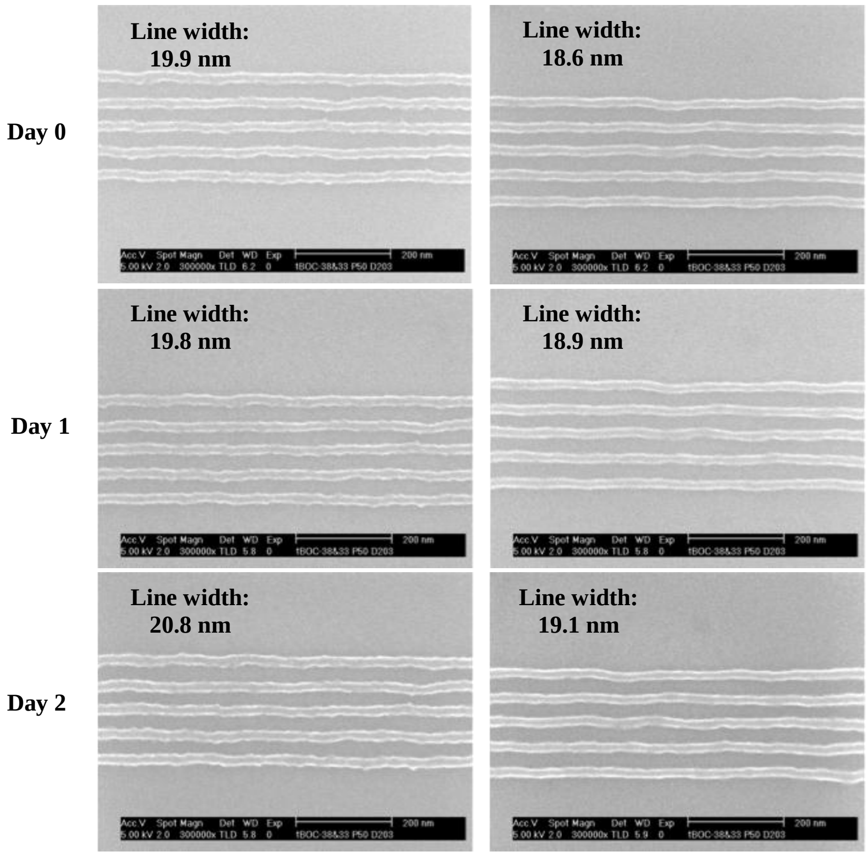


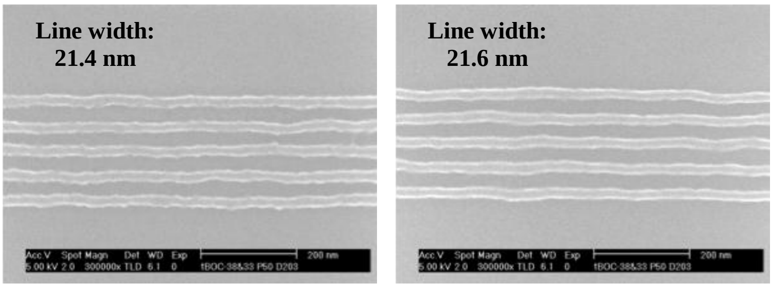
Fig. S3 SEM images of 50 nm dense lines (a) without hard bake, (b) with 90°C/5 min hard bake and (c) with 120°C/5 min hard bake.

The above-mentioned samples without hard bake and with 90°C/5 min hard bake were stored in air and imaged every 24 hours for another 3 days. Fig S4 shows the SEM images and the line widths accordingly. The increasing line width values for both samples with and without hard bake indicate that the swelling effect is not only introduced from the development process but might also be attributed to the environment, e.g. the air humidity.



This journal is © The Royal Society of Chemistry 2013

Day 3



(a) **(b)**

Fig. S4 SEM images of 50 nm dense lines (a) without hard bake and (b) with 90°C/5 min hard bake. Images were taken every 24 hours for 3 days.