# Nano-patterning of PMMA on insulating surfaces with various anti-charging schemes using 30 keV electron beam lithography

M. Muhammad,[1,2], S. Buswell[1,3], S. K. Dew[1], M. Stepanova[1,2]

[1]*Department of Electrical and Computer Engineering, University of Alberta T6G 2V4*
[2]*National Institute for Nanotechnology NRC, Edmonton, Alberta, Canada T6G 2M9*
[3]*Applied Nanotools Inc., Edmonton, Alberta, Canada T6E 5B6*

As a low cost and high throughput method for nanoscale pattern replication employing UV transparent masters, the step and flash imprint lithography (SFIL) is gaining prominence for its potential in photonics and integrated-circuit fabrication [1]. However, dielectric materials appropriate for fabricating nanostructured SFIL masters present a challenge when employing electron beam lithography (EBL) as polymeric resists such as PMMA on top of insulators accumulate charge during EBL exposures, thereby degrading the process. In this work, we explore the performance of four different anti-charging schemes when employing EBL for nanofabrication of dense arrays of dots with diameters 16nm to 30nm in PMMA on UV transparent fused silica (FS) substrates. In scheme 1 (Fig. 1), an FS substrate was spin-coated with 950K molecular weight PMMA to provide a nominally 90nm thick layer. On top of PMMA, a 10nm thick Al layer was sputtered as an anti-charge coating. In scheme 2, PMMA on an FS substrate was coated with a 70nm thick layer of water soluble charge conducting polymer (aquaSAVE, Mitsubishi Rayon Co.), and scheme 3 uses a 30nm thick Cr layer sandwiched between FS and PMMA. A similar method was used earlier for template fabrication for SFIL[2]. Scheme 4 has a 30nm thick film of Al in between the FS and PMMA. The PMMA thickness was kept at 90nm for all four systems. Dense dots arrays with a 50nm × 50nm pitch were exposed with EBL (Raith 150) using 30 keV electrons. Nanopatterns in PMMA were realized by carrying out room temperature development in IPA: water 7:3; the anti-charge overlayers of Al and aquaSAVE being removed with MF CD-26 and water, respectively, prior to the development process in schemes 1 and 2. Fig. 2 shows the applicable dose windows [3] for the four schemes, determined by SEM (Hitachi S-4800) inspection of the regions of under- and over-exposure of the dots arrays exposed with various doses. Almost similar applicable dose windows were observed for schemes 2, 3 and 4, whereas for scheme 1 the window was significantly narrower. The reason is a relatively stronger increase in electron forward scattering [3,4] by the Al anti-charging layer in scheme 1 in comparison to the others. Also noticeable in Fig. 2 is a similar sensitivity for the EBL process for all four schemes. Dots with diameters as small as 16nm were realized with doses close to the lower boundary in the dose windows of Fig. 2. Fig. 3 shows SEM images of dot arrays in PMMA, coated with a 5nm chrome anti-charge layer for visualization purposes. Qualitatively, the distribution of dots' size is less uniform in scheme 1 than the other schemes.

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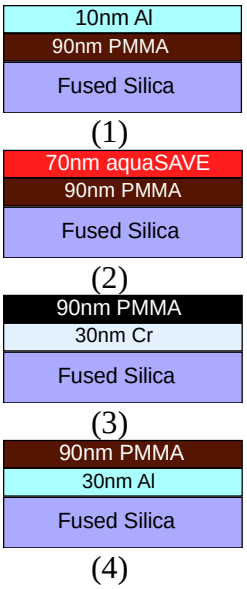


Fig. 1. Outlines of the four anti-charging schemes employed for pattern generation.

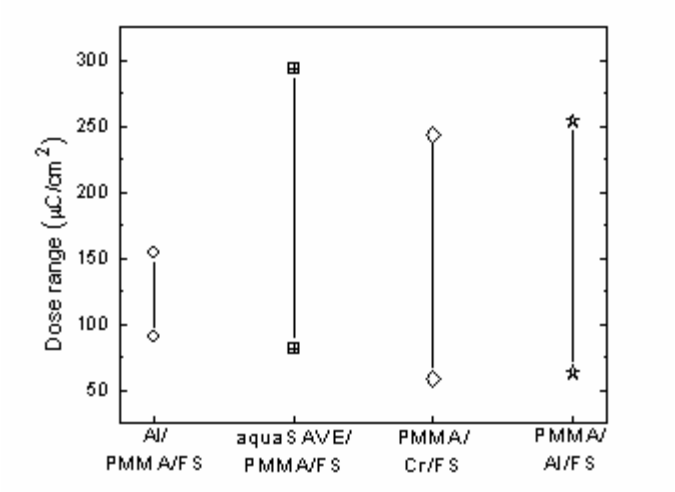


Fig. 2. Applicable dose windows for quality arrays of 50nm × 50nm pitch dots realized in PMMA on fused silica (FS) substrates via different anti-charging schemes (Fig. 1). The solid lines show the dose range for which quality patterns were observed.

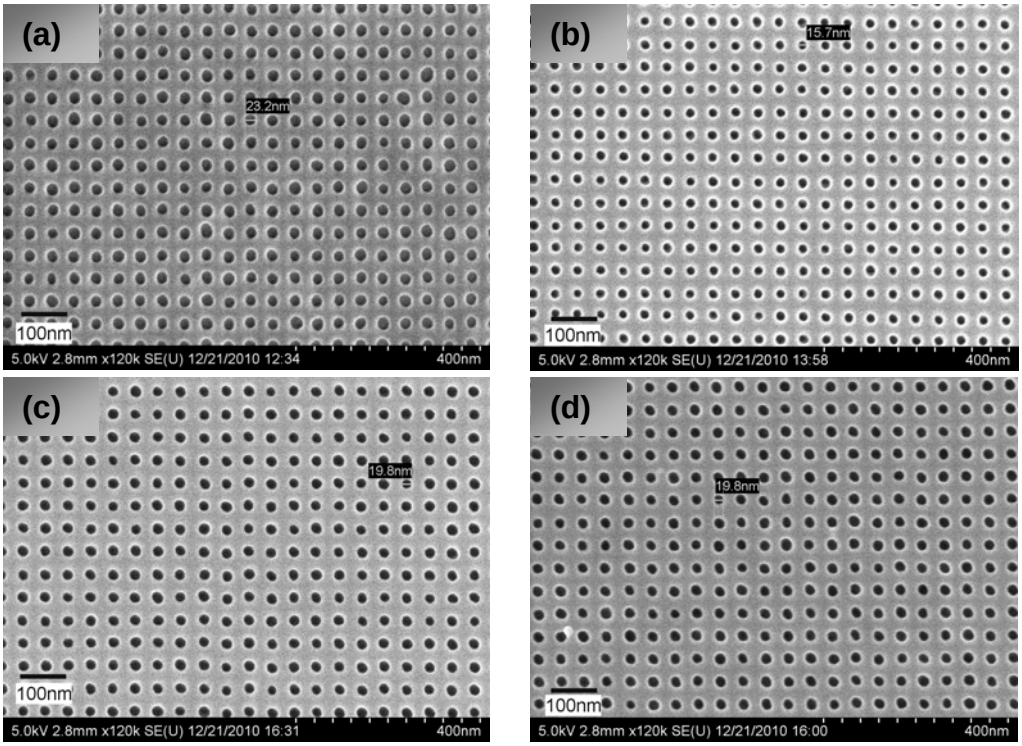


Fig. 3. SEM (Hitachi S-4800) images of 50nm × 50nm pitch dots fabricated in 90nm thick PMMA using 30 keV electrons at 125 μC/cm$^2$ (2.8 fC/dot) dose via (a) scheme 1, (b) scheme 2, (c) scheme 3, and (d) scheme 4. For visualization purposes, a 5 nm thick anti-charge layer of Cr was sputtered on the samples.