Metallic Organic Resists: Their Impact On Nano Pattern Transfer

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A new class of electron beam resist materials has been developed that is based on a family of heterometallic rings (Figure 1a). The negative tone resists produce a high resolution (7 nm on 18 nm pitch[1]) and extraordinarily high etch selectivity for silicon (130:1 has been demonstrated) when subjected to a pseudo-Bosch inductively coupled plasma–reactive-ion etch (ICP–RIE).[2] This presentation will describe how these materials can be incorporated into organic resists such as Poly(methyl methacrylate) (PMMA, Figure 1b) and Poly(poly(1-naphthyl methacrylate) (PNMA, Figure 1c) to create new *positive tone* nanocomposite resists that can enhance the host material's dry etch resistance.
The PMMA and PNMA nano composite resists were simulated and showed that a resolution of 50 nm half pitch could be achieved (Figure 2a and e). The PMMA nanocomposite resist was written with a resolution of 50 nm half-pitch (Figure 2b) where the simulation showed strong agreement with the experimental results. The etch rate of the resist was found to be 0.49 nm/second, while the silicon etch rate was 1.93 nm/second (Figure 2c), yielding a selectivity of 4:1. Figure 2d shows the successful pattern transfer after the resist has been removed. The PNMA nanocomposite resist was also written with a resolution of 50 nm half-pitch (Figure 2f). Figure 2g shows that the etch rate of the resist was 0.1 nm/second, while the silicon etch rate was 2 nm/second, yielding a selectivity of 20:1. Figure 2h shows the successful pattern transfer after the resist has been removed. These results are significant when compared directly compared with other resists at 50 nm half-pitch, where the etch selectivities to silicon are 1:1 for PMMA and 2.7:1 for ZEP520A, currently recognized as having the highest dry etch performance of any organic e-beam resist.[3]

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[1] S. M. Lewis et al., *Angew. Chem. Int. Ed.* 2017, **56**, 6749.
[2] S. M. Lewis, et al., *Nano Lett.,* 2019, **19**, 6043.
[3] Goodyear, et al., *Proc. SPIE* **9428**, 94280V, (2015).

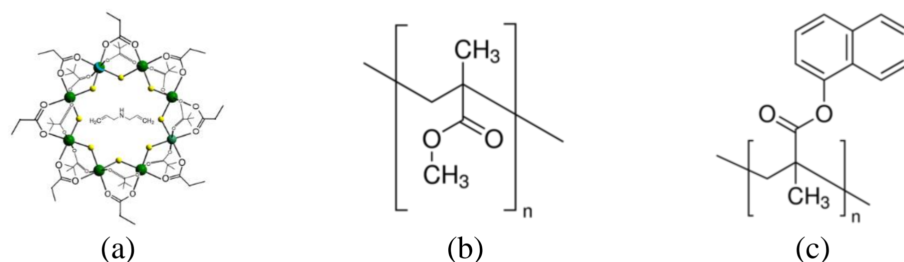

Figure 1: (a) $[Ally]_2Cr_7NiF_8(propionate)_{16}$: The structure of the molecules in a crystal, in ball-and-stick representation. Cr atoms are green, Ni atom is green with blue band and F atoms are yellow. H atoms are omitted for clarity. (b) The molecular structure of Poly(methyl methacrylate) (PMMA). (c) The molecular structure Poly(poly(1-naphthyl methacrylate) (PNMA).

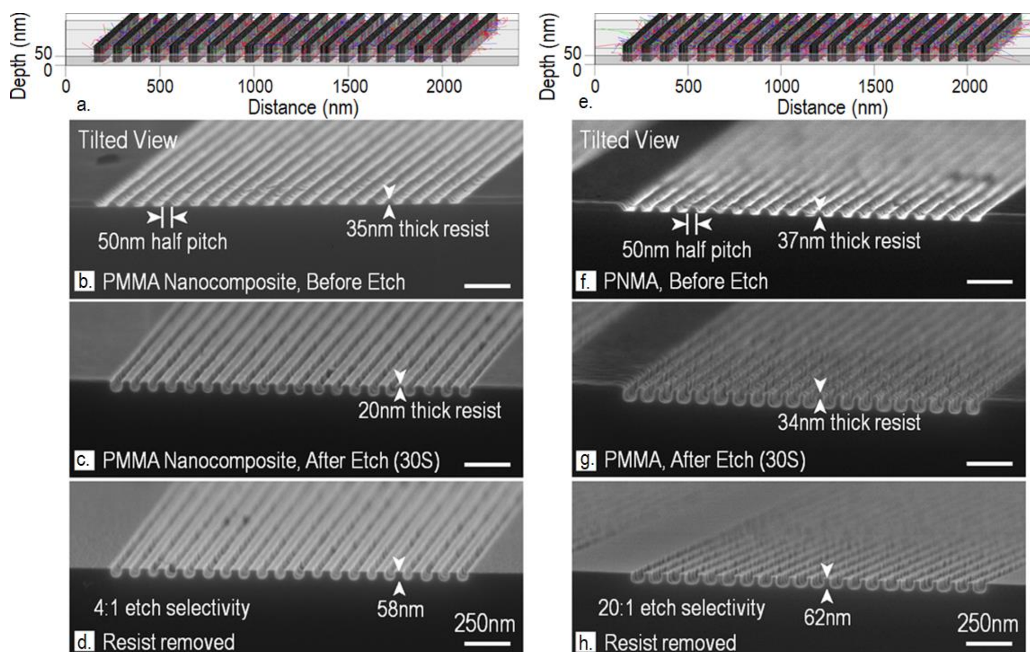

Figure 2: (a) Monte Carlo simulation of the performance of PMMA nanocomposite resist. (b) Patterned PMMA nanocomposite resist before the dry etching process; the exposure dose was 5300 $\mu C/cm^2$. (c) Resist after a 30 second pBosch dry etch process; (d) Fins with a 50 nm width after oxygen plasma removal of the resist. (e) Monte Carlo simulation of the performance of PNMA resist. (f) Patterned PNMA resist before the dry etching process; the exposure dose was 70000 $\mu C/cm^2$. (g) Resist after a 30 second pBosch dry etch process;. (h) Fins with a 50 nm width after oxygen plasma removal of the resist. The exposure parameters were 100 kV acceleration voltage, 1 nA beam current, and 5 nm step size. The parameters of the dry etch process were as follows: a mixture of SF_6 and C_4F_8 gases with flow rates of 22 and 35 sccm, respectively, was admitted to the chamber and controlled to a pressure of 10 mTorr; the substrate holder temperature was set to 15 °C; 4 Torr of Helium back side pressure was maintained to provide good thermal conductance between the substrate holder and the sample; the RIE forward power was 20 W, and the ICP forward power was 1200 W.