Vapor-phase infiltration synthesis of hybrid nanocomposite resist for next generation lithography

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Lithography-based patterning has been instrumental in achieving higher computing performance among integrated circuits by increasing the device areal density. However, in recent years, the trend has slowed down due to several technological challenges, with cost-effective patterning at sub-30 nm dimensions remaining one of the crucial ones. The patterning linewidth and throughput essentially depends on resist materials. Until now, the semiconductor process has been heavily depended on chemically amplified resists (CARs) to obtain necessary nanopatterns. However, for smaller nodes, these traditional carbon-based resist materials typically show poor etch resistance and are thus insufficient for allowing etching-based pattern transfer of high-aspect-ratio structures onto the substrate. Recently, vapor-phase infiltration of metal oxides into the nanopatterned polymeric resists has evolved as an effective way to enhance the etch resistance of these resists, using atomic layer deposition (ALD) tools.[1,2]

Here we have developed organic-inorganic hybrid resists by utilizing infiltration synthesis of AlO_x into spin-coated, commonly used resist, poly(methyl methacrylate) (PMMA) thin films. A typical infiltration process is depicted in Figure 1; wherein ALD precursor trimethylaluminum (TMA) is infiltrated into PMMA film followed by oxidation of TMA into AlO_x via exposure to H_2O vapor, generating a hybrid nanocomposite thin film. For different number of infiltration cycles, the patterning characteristics of the synthesized hybrid resist are investigated with the use of electron beam lithography (EBL). Marked improvement in the resist contrast (γ) is seen as number of infiltration cycles are increased, with a minor loss of sensitivity (Figure 2(a)). The evolution of resist etching rate for typical etch recipes, as illustrated in Figure 2(b), show a prominent enhancement in the etch resistance for chemical etch with increased infiltration compared to physical etch. With the use of 4 cycle infiltrated hybrid resist, we were able to pattern lines and elbow patterns down to 50 nm linewidth, which can be seen in Figure 3.

The insights gained from the presented study contribute to developing novel hybrid nanocomposite resist platform for next generation lithography without the need for complex synthesis chemistry. Both PMMA and ALD are widely used in the laboratories around the world. Thus, our results demonstrate easy access and cost-effective development route to new high-performance resists. With industry rapidly moving towards extreme-ultraviolet (EUV) lithography, such metal containing hybrid resists are poised to display added advantages such as increased throughput via enhanced sensitivity.

[1] Y.-C. Tseng, et al., *Adv. Mater.* **24**, 2608 (2012)
[2] Y.-C. Tseng, et al., *J. Mater. Chem.* **21**, 11722 (2011)

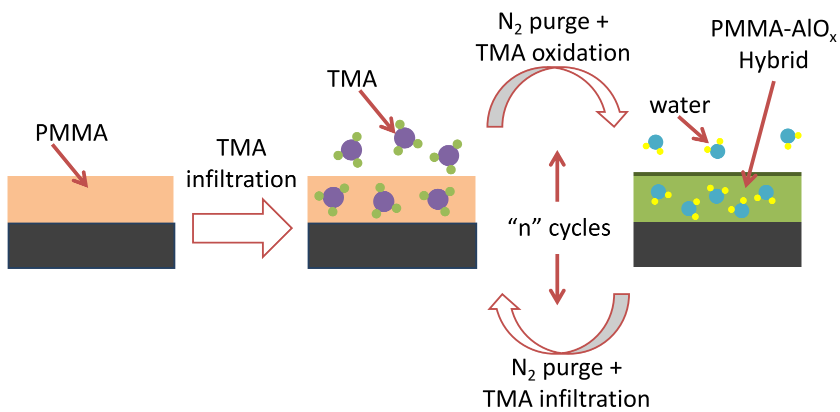

Figure 1: Schematic representation of a typical infiltration synthesis process.

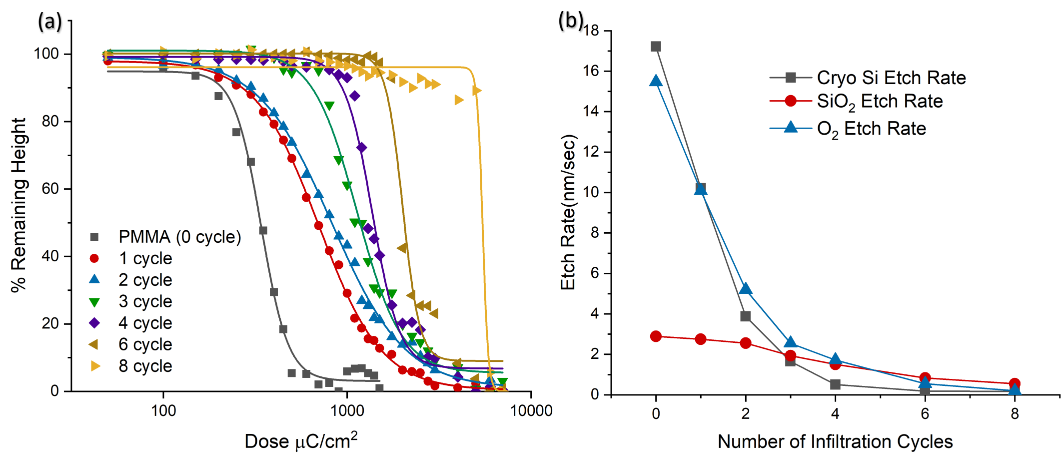

Figure 2: Evolution of resist characteristics of the hybrid nanocomposite resist with increasing number of infiltration cycles (a) dose response curve (b) resist etch rate for commonly used etch recipes.

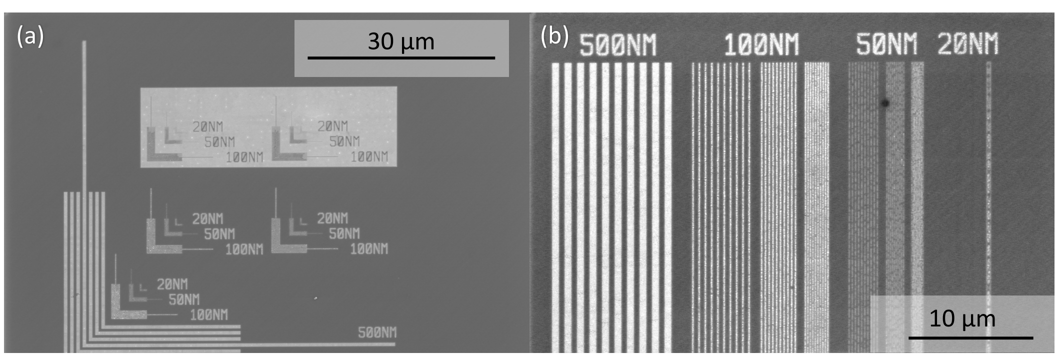

Figure 3: Scanning electron micrographs of as developed sub-micron features patterned into 4 cycle infiltrated hybrid resist using EBL.