Novel hybrid resist platform for nanolithography: Ex-situ vapor-phase infiltration into conventional organic resists

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As the semiconductor industry is rapidly integrating extreme-ultraviolet lithography (EUVL) into high-volume manufacturing, the lack of suitable EUV resists is one of the critical challenges. In particular, resists capable of high-resolution patterning with high EUV absorption and robust etch resistance are urgently needed. Organic-inorganic hybrid resists are being pursued as an effective way of addressing these rigorous process requirements. [1] However, they still fall short in meeting the performance criteria (e.g. resolution, feature roughness), while their complex chemical syntheses poses significant hurdle in controlling the resist composition and performance.

We have developed an organic-inorganic hybrid resist platform featuring versatile ex-situ control of resist performance by incorporating inorganic elements, exhibiting high-absorption for extreme ultraviolet (EUV) radiation, using vapor-phase infiltration into standard organic resist.[2,3] With poly(methyl methacrylate) (PMMA)-AlO_x hybrid as a model composition we unveiled controllability of the critical exposure dose, contrast (as high as ~30) for electron beam lithography (EBL), along with etch resistance enhancement; estimated Si etch selectivity over ~300, demonstrating high aspect ratio ~17 with ~30 nm resolution Si fin-structures.

We expand our organic resist matrix portfolio to inherently high sensitivity organic resists, that also exhibit higher reactivity to vapor-phase infiltration precursors. We are exploring compositional variants and evolution of their resist sensitivity, contrast with solvent-base combinational formulation of developer chemistry. Furthermore, we also investigate the effect of alloyed (mixed) infiltration on the etch resistance for various plasma based etch recipes.
Along with studying these hybrid resists for EBL, we also report preliminary results outlining their use for EUVL, which could potentially pave the way for higher sensitivity hybrid resists.

References - [1] L. Li *et al.*, Chem. Soc. Rev. **46**, 4855 (2017).
[2] N. Tiwale *et al.*, J. Mater. Chem. C **7**, 8803 (2019).
[3] N. Tiwale *et al.*, in *Proc. SPIE 11326, Adv. Patterning Mater. Process. XXXVII*, edited by R. Gronheid and D. P. Sanders (SPIE, 2020), p. 113260J.

Figures –

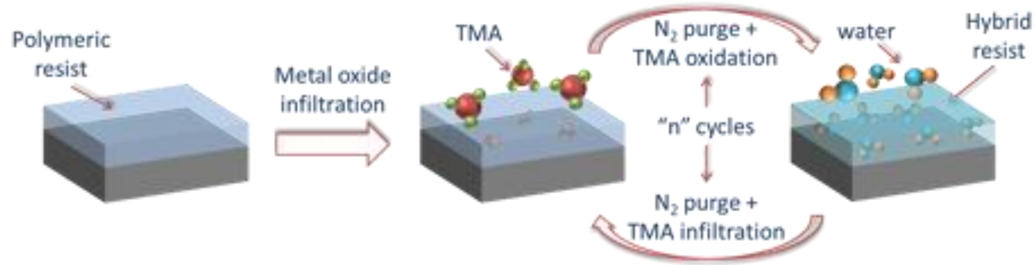

Figure 1: Schematic process flow of the vapor phase infiltration synthesis.

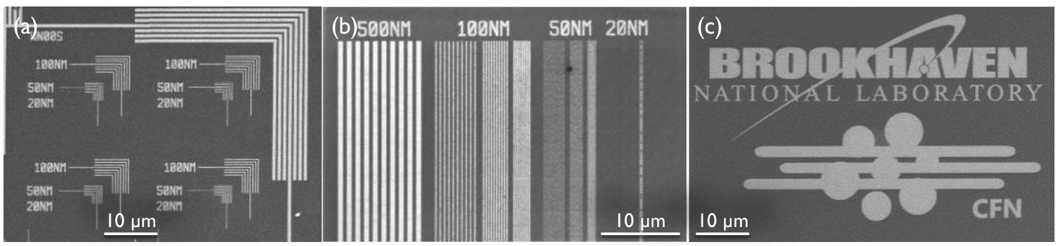

Figure 2: Scanning electron micrographs of features down to 50 nm resolution patterned using PMMA-AlO_x hybrid resist.

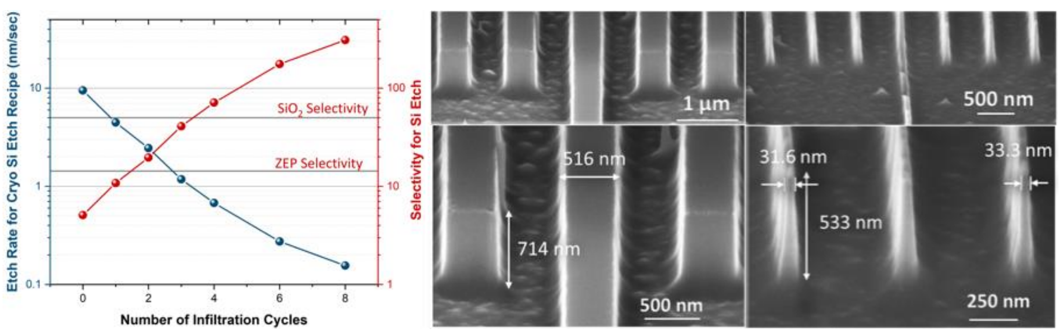

Figure 3: On left, etch rate and etch selectivity evolution for Cryogenic Si process for PMMA-AlO_x hybrid resist with different number of infiltration cycles. On right, high aspect ratio patterns transferred int Si substrate using 4-cycle hybrid.

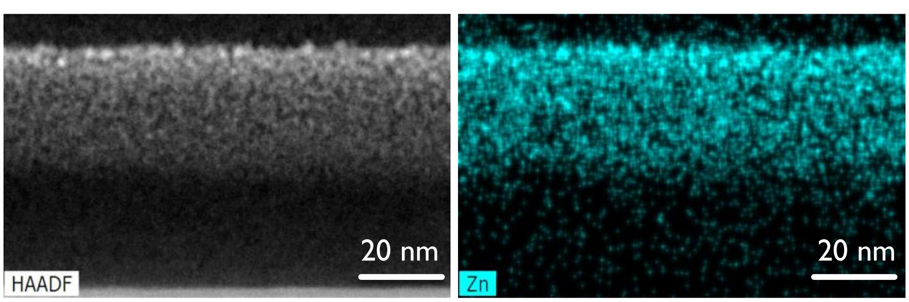

Figure 4: Example of ZnO_x infiltration into high sensitivity resist.