Hard resist masks prepared with sequential infiltration synthesis process for high-resolution deep etch

Xianghai Meng[1] and Ming Lu[2]
1. Materials Science and Engineering Department, Stony Brook University, Stony Brook, NY 11794
2. Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, NY 11973
mlu@bnl.gov

Transferring high-resolution patterns with plasma etching is a critical process in the manufacture of semiconductor devices and MEMS (microelectronic mechanical system) devices. When the etching depth is much larger than the pattern critical dimension (CDs), it becomes even more challenging because the etch masks, which are typically patterned photo- or electron beam resists, do not offer high etch selectivity over the materials to be etched, while the maximal thickness of the resist patterns generally decreases with the reduction of pattern CDs during lithography processes. A traditional solution to this problem is to introduce an intermediate “hard” mask layer whose etch resistance is much higher than resist mask. However, hard mask materials must be compatible to the lithography chemicals, adhere to the substrate surface strongly enough at desired thickness, and have high-fidelity etching recipe with resist masks, which are not always available.

A new-invented sequential infiltration synthesis (SIS) technique, which hardens the e-beam resist PMMA and ZEP 520 by depositing alumina into the polymer matrix, greatly improves the etching resistance of these resists while keeping the pattern resolution intact, which is very promising[1]. In this article, we exam the etching rates of SIS process treated PMMA, ZEP 520 as well positive photo resist Shipley S1811 and negative photo resist Microresist MaN-1410 along the depth of infiltration under three different type of plasma etch recipes: oxygen plasma, cryogenic silicon and silicon oxide etch, which represent the plasma etch dominated by chemical reaction, week ion bombardment and modest ion bombardment. The experiments reveal the nonlinear relationship between the etching rate and the infiltrated alumina density, which indicates the etching resistance of SIS process treated resists can be further improved. Several approaches will be discussed and compared in detail.

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[1] Y., Peng Q., Ocola L. E., Czaplewski D. A., Elam J. W., and Darling S. B., "Etch Properties of Resists Modified by Sequential Infiltration Synthesis," J. Vac. Sci. Technol. B, 29, 06FG01-06FG04, 2011

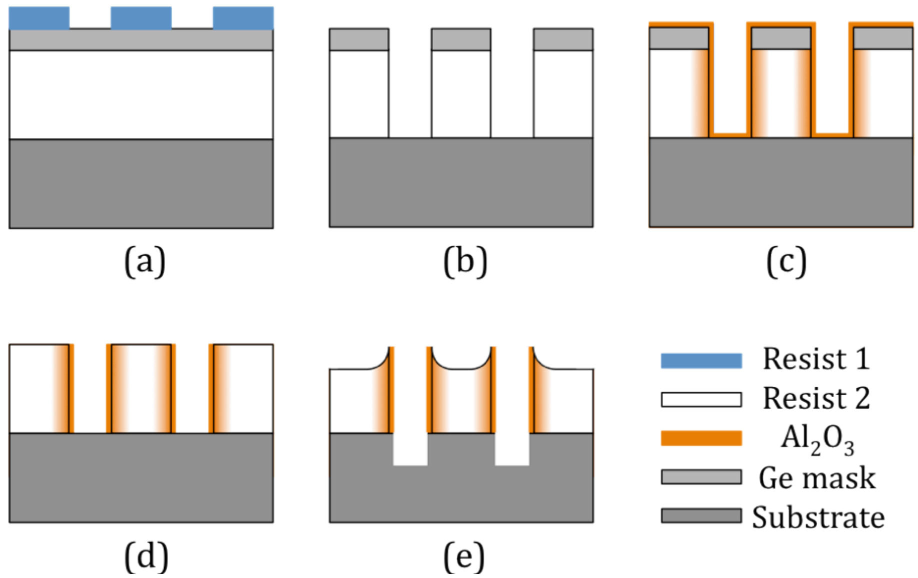

Figure 1: Process flow for sample preparation. (a) Pattern on resist 1; (b) Transfer pattern from resist 1 to Ge mask and resist 2 by reactive ion etch; (c) Alumina sequential infiltration synthesis in resist 2 layer; (d) Remove top alumina and germanium mask by reactive ion etch; (e) Dry etch test with certain recipe.

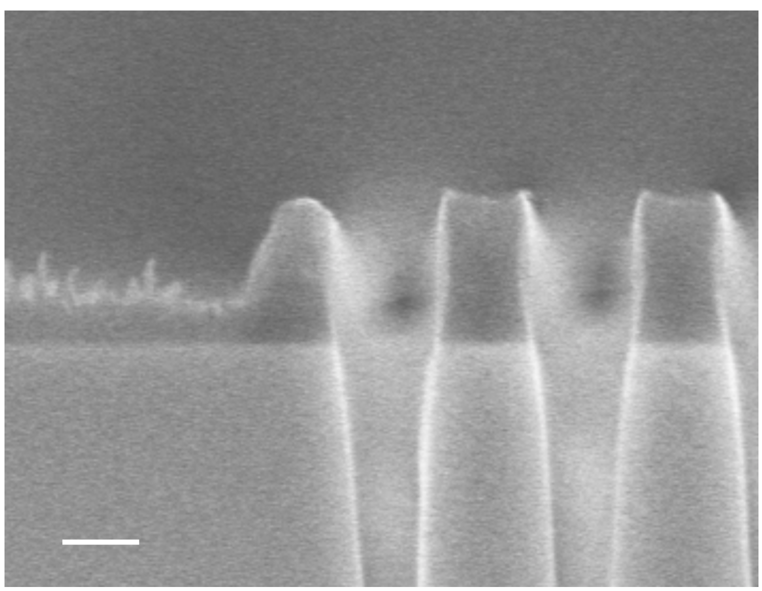

Figure 2: Cross-section SEM micrograph of an etched PMMA test sample pre-treated by alumina SIS process. The sample was etched by a cryogenic silicon etch process based on SF_6/O_2 chemicals at 32 V DC bias. The scale bar is 400 nm.