Polyhedral Oligomeric Silsesquioxane (POSS) Functional Patterns Directly Fabricated by Nanoimprint Lithography

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Nanoimprint lithography (NIL) is an exciting next-generation lithography that combines the potential of a sub-10 nm patterning resolution with the high throughput, low cost and inherent simplicity of a stamping process.[1,2,3] However, one of the biggest impediments to the wide spread implementation of NIL is the availability of high quality molds. The fabrication of high resolution, 1× molds still requires costly, in terms of both time and money, high resolution serial patterning techniques such as electron beam lithography. In many applications these barriers alone are too formidable to enable penetration of NIL into different technology sectors. Here we present the direct patterning of POSS-based organosilicate materials via NIL. While these materials were originally intended for the direct patterning of interlayer dielectric insulator structures for semiconductor interconnect applications,[3] we have been able to optimize the microstructure of the organosilicate and obtain high modulus patterns that can be used to directly replicate imprint mold itself, and then used as a daughter mold for subsequent thermal or UV forms of NIL. Several recent studies have focused on developing PDMS-type mold replication materials for soft lithography, but these can not be used at high temperatures or pressures. The mold replication materials developed here are much harder and can be used for high temperature and pressure imprints. Spin-cast films of our optimized POSS-based oligomers are patterned by NIL at 170 ^{o}C and 3.4 MPa to replicate the patterns in the mold with high fidelity. The imprinted patterns are vitrified at 400 ^{o}C into a hard organosilicate with very little loss of the pattern fidelity. The resulting material shows a high modulus (E ~ 6.7 GPa), low surface energy (water contact angle greater than 95°), UV transmittance higher than 90 %, and excellent thermal and chemical stability. Because of these properties, the imprinted POSS-based patterns can be used *directly* as daughter imprint molds. Examples of high fidelity imprinting in polystyrene (PS) films, without the use of mold release coatings, at high temperatures and pressures illustrates the utility of these materials for NIL mold replication.

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[1] J. L. Guo, *J. Phys. D: Appl. Phys.* **37**, R123 (2004).
[2] S. Y. Chou, P. R. Krauss, P. J. Renstrom, *Science* **272**, 85 (1996)
[3] M. D. Stewart, C. G. Wilson, *MRS Bulletin* **30**, 947 (2005)

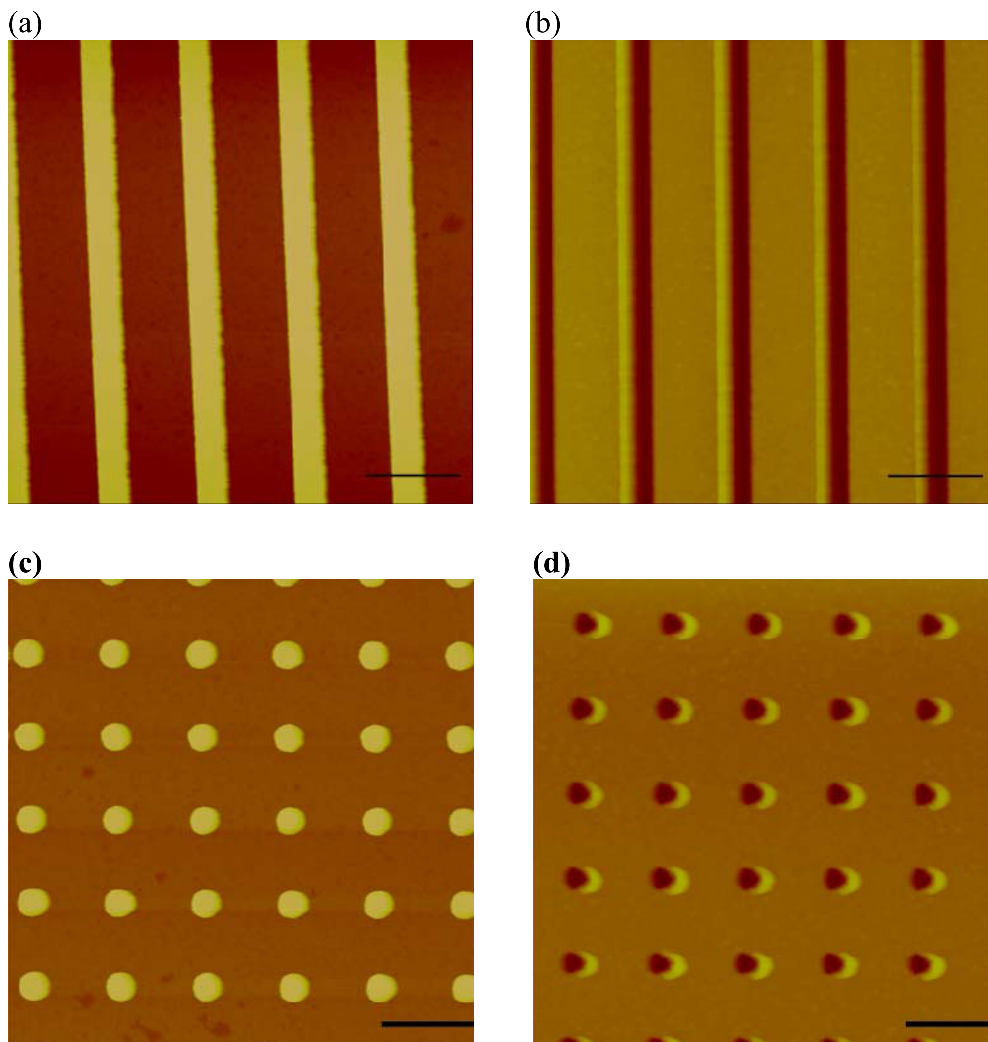

Figure 1. AFM height images are shown for fully vitrified imprints made into the POSS-based materials ((a) and (c), the daughter molds) and then polystyrene replicas ((b) and (d)) made directly from POSS-based patterns in part (a) and (c). The top part of the figure shows line and space patterns while the lower part demonstrates post and via structures. The scale bars correspond to 1 micron. The quality of the PS patterns is the same as the quality of the original silicon oxide master (not shown).