Imprint and pattern transfer of silica sol-gel resist:

a powerful nanofabrication approach

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Key words: nanoimprint, sol-gel chemistry, 3 Dimensional patterning

The combination of sol-gel chemistry (bottom-up approach) and nanoimprint technology (top-down) is very promising for numerous applications such as semiconductor and optical devices or biomimetic structures. For instance, recent works show the opportunity to use directly patterned silica resists as low-k dielectric materials[1] or as a new route to 3-D patterning[2]. The versatility of sol-gel chemistry allows for tuning mechanical, chemical, electronic and optical properties and building of functional materials. Furthermore, these materials have attractive properties such as chemical and thermal stability (relatively high etching resistance, no shrinking until 450°C). Until now, the imprint patterning of inorganically crosslinked sol-gel (ICSG) materials has only been demonstrated in a few works[1-6] with resolution down to 50 nm[2]. Unlike typical materials used for thermal imprint, the beauty of these ICSG materials is that working with a sol, little or no imprint pressure is required even at low temperatures. In this work, we discuss single and sequential imprinting of ICSG resists followed by pattern transfer for complex structure formation on both rigid and soft substrates.

Soft thermal nanoimprinting of silicon alkoxyde sol-gel films are performed at low temperatures (Timp<140°C), for a few minutes (timp<10min), and at low pressures (<0.2MPa) followed by high aspect ratio pattern transfer. Bilayer elastomer stamps are prepared by casting liquid hard Polydimethylsiloxane (PDMS) and then soft PDMS on a silicon master mold[6]. ICSG resists are prepared from a methytriethoxysilane (MTEOS) sol mixed with aqueous solution under acidic conditions. MTEOS films are deposited by spin-coating and are imprinted with elastomer stamps. Initial film thicknesses are between 200 and 800 nm. This method is very versatile (for instance, one can pattern on curved surfaces) and low-cost, with the potential for high throughput. Furthermore, contrary to typical thermal imprint polymers, the silicon dioxide type chemistry of ICSG offers the potential for very high etching resistance.

Figure 1a shows an ICSG imprinted pattern (Figure 1a). After imprinting, ICSG resist is used as the etching mask to transfer patterns to silicon by Inductively Coupled Plasma (ICP) etching (see Figure 1b). The process uses alternating steps of etching (SF6/Ar chemistry) and passivation (CH4/CHF3) and is demonstrated suitable for etching high aspect ratio features down to 10 nm with similar masks[7]. Overall etching selectivity of this ISCG resist over silicon is 2.5:1 and could be improved with process changes. Figure 2 shows fabrication of structures by sequential imprinting of two different patterns to produce structures of higher complexity than in our previous work[2].

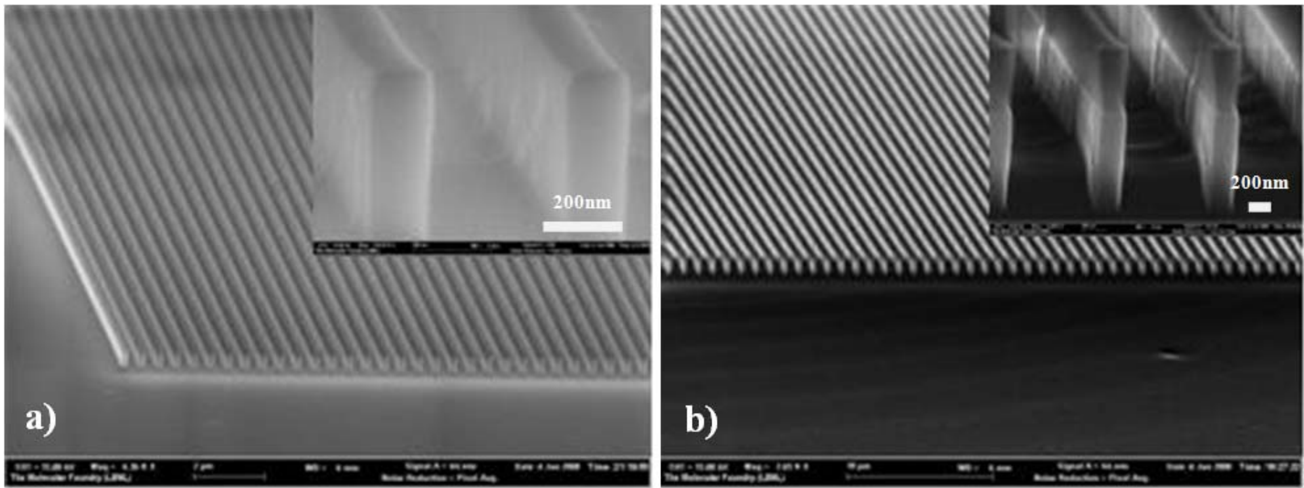

Figure 1: Scanning Electron Microscopy: a) direct imprinted ICGS patterns b) after etching into silicon (linewidth= 250nm, pitch = 1µm, height = 1µm)

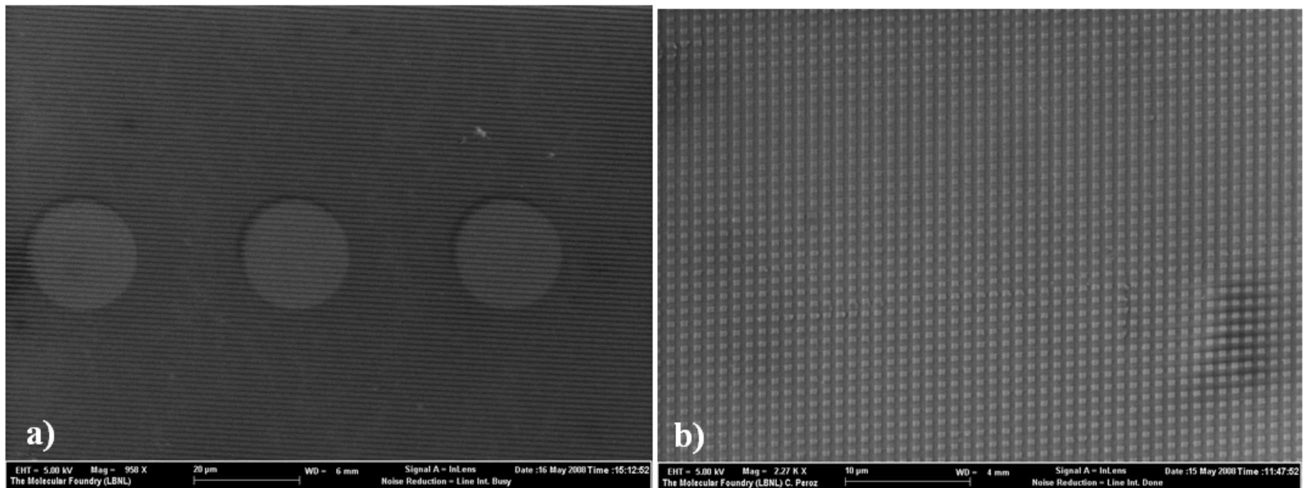

Figure 2: Example of double imprintings of the same ICSG film: a) SEM pictures of gratings (pitch 1µm) + 20 µm diameter circles features. b) gratings + gratings at 90°

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