SMOOTH SUB-30 NM STAMPS FOR NANOIMPRINT LITHOGRAPHY FABRICATED BY STANDARD UV-LITHOGRAPHY AND OXIDATION

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We present a process sequence for fabrication of smooth stamps for thermal nanoimprint lithography (NIL) [1] having a protrusion tip less than 30 nm wide (Fig.1). The stamps are fabricated by standard micrometer resolution cleanroom processes, viz. UV-lithography, reactive ion etching (RIE), and oxidation. As a demonstrator hydrophilic, sealed nm-sized channels for DNA analysis are fabricated. The stamps are imprinted into 50k poly-methylmethacrylate (PMMA) on a silicon substrate and the imprinted polymer pattern is used as a direct etch mask to fabricate nm-sized grooves in the silicon. The silicon grooves are oxidized to make the sidewalls hydrophilic. This oxidation step also offers an enhanced size control of the grooves. Finally, the grooves are sealed with a pyrex wafer by anodic bonding, resulting in nm-sized channels which can be used for DNA analysis [2,3].

The nm-sized knife edge stamps are fabricated from silicon wafers. A 270 nm thermal oxide is grown by wet oxidation on the silicon and 7 μm wide and 1 mm long lines are patterned in AZ5214E (Shipley) photoresist by UV-lithography. The oxide is etched by a buffered hydrofluoric acid, which undercuts the photoresist. The silicon is isotropically etched by RIE followed by a photoresist removal by acetone and the resulting protrusions are oxidized to sharpen the profile. Finally, the oxide is removed by buffered hydroflouric acid, resulting in 3.2 μm high knife edge protrusion with a tip width less than 30 nm. Prior to imprinting the stamps are coated with an anti-sticking coating deposited from a C_4F_8 plasma [4].

Silicon substrates are prepared by spin casting 50k PMMA (20 wt% in anisole) (MicroChem). A polymer film height of 3.6 μm is achieved by a double spin process. In both spin steps 3 mL of PMMA solution is spun on at 1000 rpm. After each spin step the solvent is baked out on a hotplate at 150°C for 10 min. The imprint is performed in a home built nanoimprint machine. The imprint takes place at 170°C with an imprint force of 2000 N on a 4-inch wafer. The imprint force is kept for 5 minutes at the imprint temperature while cooling to 70°C. An electron micrograph of the imprinted PMMA is shown in the figures (Fig.2).

The imprinted PMMA film is used as an etch mask in a pattern transfer step by anisotropic RIE. The RIE process is based on a SF_6/O_2 plasma which transfers the polymer profile into the silicon substrate. The PMMA is removed by acetone using ultrasonic aggregation. After inspection the etched grooves are made hydrophilic by thermal wet oxidation, which also offers an additional groove size control (Fig.3). Finally, the grooves are sealed by a pyrex wafer by anodic bonding.

The fabricated nm-sized hydrophilic channels can for example be used as a passive DNA stretching device in a lab-on-a-chip system [2,3]. Such a device can be used to determine the length distribution of DNA fragments in a sample. An advantage is that this method is not restricted to DNA fragments shorter than approximately 40,000 base pairs like conventional gel based techniques.

References:

[1] S. Chou *et al.*, Appl. Phys. Lett. **67** (1995) 3314.
[2] H. Cao *et al.*, Appl. Phys. Lett. **81** (2002) 174.
[3] J. O. Tegenfeldt *et al.*, Anal. Bioanal. Chem **378** (2004) 1678.
[3] A. A. Ayón *et al.*, Mat. Res. Coc. Symp. Proc. **605** (2002) 141.

Figures:

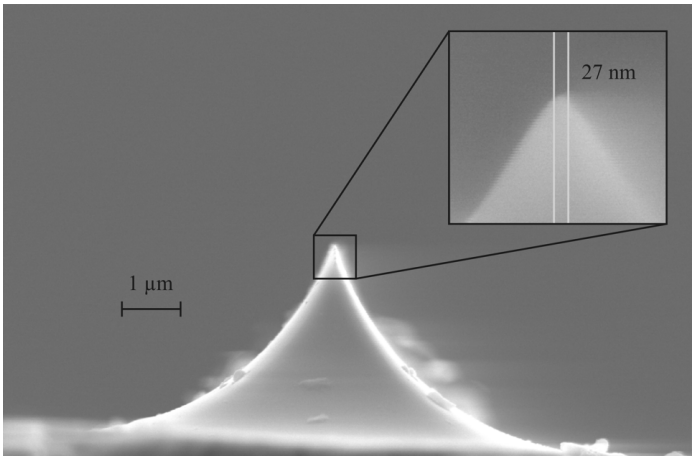

Fig 1. Scanning electron micrograph of knife edge NIL stamps for imprinting of DNA stretching channels. The stamps are made by standard cleanroom processing, i.e. UV-lithography, reactive ion etching (RIE), and oxidation. The inset shows a close up of the knife edge protrusion, having a width of 27 nm.

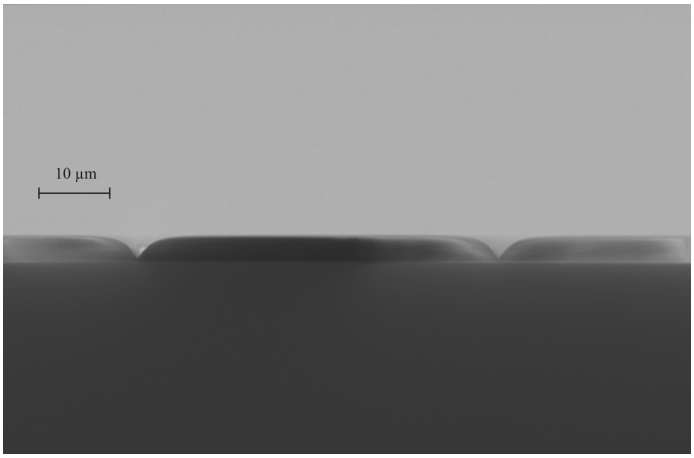

Fig 2. Scanning electron micrograph of imprinted 50k PMMA on a silicon substrate. The initial polymer thickness is 3.6 µm and the stamp protrusion height is 3.2 µm, resulting in a residual polymer layer thickness of approximately 400 nm.

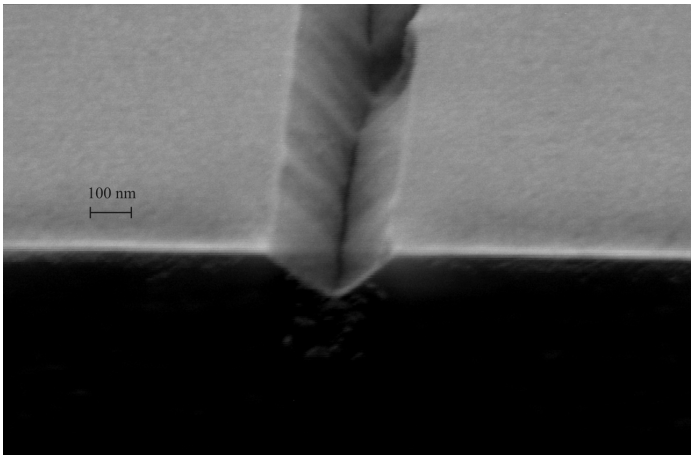

Fig 3. Scanning electron micrograph of a groove etched into the silicon substrate by RIE. The sidewalls are made hydrophilic by oxidation. The sample was metalized prior to inspection.