Plasma Etched Micromachined Silicon Stampers for Plastic Biotechnology Applications

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The move to miniaturization of biochip devices offers tremendous potential for the improvement of health care, both in terms of reduced analysis time, and in significantly lowering the volume requirements of patient blood, or other bodily fluids. In this paper we present a method of fabricating very small features in plastic materials, such as polycarbonate, to create miniature devices containing channels and fluid reservoirs. The first step in creating such a device is the plasma etching of a Si master "stamper" to a depth of 40-50 microns. This Si master stamper can then used as a mold to form the channel pattern directly into plastic using hot embossing technology. Many plastic prototype devices can be rapidly embossed from just a single master Si stamper. However, one major area of concern is the release (demolding) of the Si stamper after hot embossing. The stamper wall profile must be positively tapered to avoid cracking of the relatively brittle silicon material.

The objective of this study was to develop a robust plasma etch process that would uniformly etch silicon to a depth of 40-50 microns with a positive wall taper. As shown by the equipment scale modeling results in Figure 1, high-density plasma etching using SF6+O2 chemistry will result in an isotropic undercut profile. Based on our experience, this type of profile is undesirable for hot embossing, as excessive breakage of the silicon stamper will occur during demolding, when attempting to release the silicon from deep narrow channels in plastic. Bosch etching, in which the plasma switches between SF6/O2 etch and C4F8 deposition chemistries, was found to offer the capability of altering the wall profile to achieve a positive taper but undesirable surface roughness ("grass") was observed in the large etched field areas[1].

An unswitched process, in which SF6, O2 and C4F8 are used simultaneously, was found to offer the best results in terms of achieving a positively tapered Si wall profile and smooth surface suitable for fabrication of silicon stampers (see Fig. 2). This work was carried out in a loadlocked STS Multiplex ICP system. A number of plasma etch input parameters were investigated for their effect on wall taper and surface morphology. Parameters investigated included gas flow ratios, pressure, RF powers, temperature, pattern density, and masking material. The predictive capabilities of our in-house modeling software were used to explore process parameter space and shorten cycles of learning. Complementary experimental data was created and analyzed using JMP® design of experiment software (SAS Institute Inc.).

Finally, using the optimized plasma etch process, Si stampers were etched and used to create channels by hot embossing, for use in plastic capillary electrophoresis devices, as shown in Fig. 3.

Ref.
1. W.J. Dauksher, et.al, Microelectron. Eng (to be published 2002).

Fig 1. Simulation result for unswitched process using 200 SF6, 20 O2 at 100W (ICP), 20W (bias), 60mT, 10deg C.

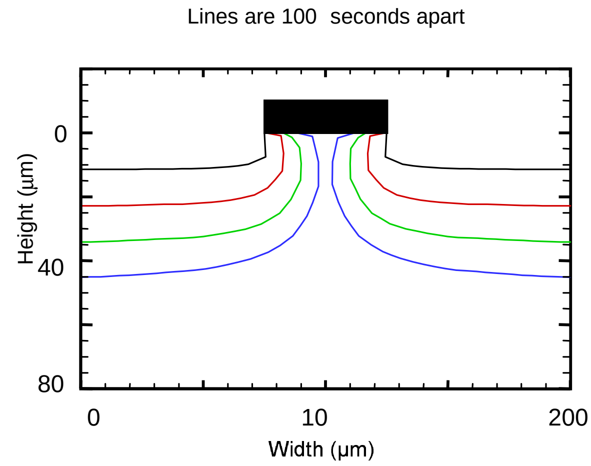

Fig. 2 Silicon stamper with positively tapered profile after plasma etch using optimized unswitched process (prior to removal of photoresist mask).

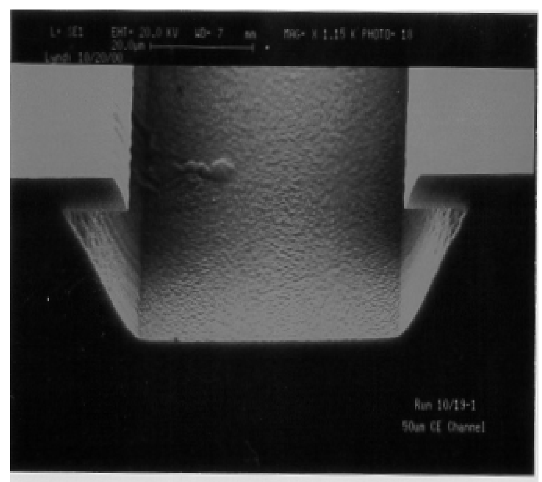

Fig. 3 Final microfluidic channels formed in plastic after hot embossing using plasma etched silicon stamper.