The Release of Thick SU-8 Films from Silicon Substrates

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Primary Source(s) of Research Funding: Staff Funding/NSF
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Primary CNF Tools Used: ABM contact aligner, hot plates

Abstract:

For over three decades, SU-8 photoresist has been a vital tool for the fabrication of three-dimensional, high aspect ratio geometries. The resist's mechanical and chemical attributes have enabled its use throughout the many disciplines of MEMS and microfluidic research. Still, SU-8 does have a few drawbacks that have hindered its use, one being its difficulty to be removed from a substrate. There are currently many unique methods from the MEMS and electrodeposition industries for removing SU-8 off metal and silicon, but they all involve either hazardous chemicals or specialized equipment. It was discovered that thick SU-8 features could be lifted off or released from a silicon substrate after a few weeks submerged in a simple detergent bath. With proper cleaning and an overnight dehydration, a new layer of SU-8 could be reapplied on these stripped wafers. Applying different forms of mechanical force and increasing the bath temperature greatly reduced the time required to remove SU-8 and repeatedly release full SU-8 structures. This low-cost and environmentally friendly process may open new pathways for rescuing wafers, producing three-dimensional parts or devices independent of a substrate, flexible electronics and other applications.

Summary of Research:

A solution of room temperature Dawn Detergent™ and deionized water (DI) can slowly undercut the interface between thick SU-8 features and the silicon substrate wafer. Depending on the surface area, the removal of microfluidic-sized SU-8 features may require two to six weeks of soaking. The use of running water or a nitrogen/compressed air gun at an incident angle could assist with the removal of the soaked SU-8 features before they completely detach in the solution.

It was later found that increasing the temperature of the detergent solution to 95°C along with thermal cycling hastened the release process. Thermal cycling could also release SU-8 without the use of detergents.

Currently, 38 µm of SU-8 has been the thinnest SU-8 film removed using this method. It may be safe to assume that the film stress of the SU-8 combined with the surfactant undercutting action may instigate the delamination. Research is currently being done on how film stress and thickness affects this process.

In order to spin SU-8 on stripped wafers again, any traces of the detergent or residual SU-8 should be removed. Wafers were first soaked overnight in DI water and then rinsed three more times. A piranha etch was done afterwards to strip away any remaining organic residues off the substrate. The wafers were dehydrated overnight in an oven at 90°C before spinning a new layer of SU-8 on the wafer again. Some outlines of the detached SU-8 features may remain on the surface of the wafer. Repeated piranha etches may eventually remove these features, but these outlines have not affected SU-8 applications or PDMS molding.

This method was used to release large 3-D shapes from a silicon wafer. The first example was a release a complete 160 µm microfluidic device from a silicon substrate using a 200 ml DI bath with 1 ml of Triton-X at 95°C for three hours (Figure 1).

Next, an 89 µm thick, two-inch diameter spiral was fabricated with SU-8 100. Twenty-four hours after the

post exposure bake, this wafer was placed in a room temperature DI water bath and was slowly heated 1.3°C a minute to 98°C. After one hour at the desired temperature, the wafer was removed from the bath and the SU-8 spiral was released from the wafer (Figure 2). This same wafer was again rinsed, piranha etched and dehydrated before repeating the experiment.

SU-8 was spun again, but at 1500 RPM with hopes of producing a 200 µm thick spiral (actual thickness was 178 µm). Again, the SU-8 structure was successfully removed after two total hours in the DI water bath.

In the short term, this method may be used to remove and reapply SU-8 after design changes, fabrication errors or replace essential features that are lost or broken by PDMS molding. SU-8 may be used as a quick way for fabricating prototype parts. Many ideas are currently being explored such as detachable SU-8 filters, gears and group of parts that could be released from a wafer and assembled later. Future work will focus on simulating a known UV-LIGA process of patterning SU-8 as electroplating molds and later removing the resist after depositing thick metallic films.

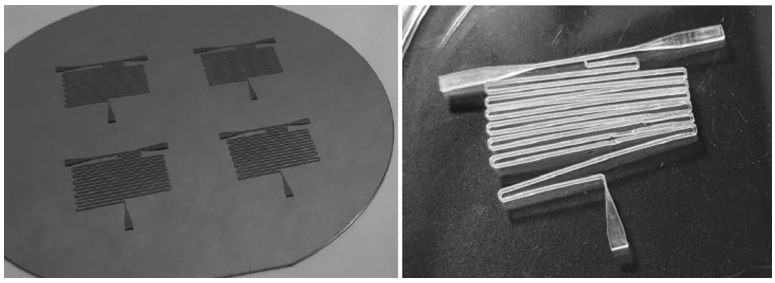

Figure 1: A complete SU-8 microfluidic device mold released from a silicon wafer. Left: Four 160 µm thick SU-8 devices patterned on a four-inch wafer. Right: Released device after submerged in heated Triton X-100 detergent solution for three hours.

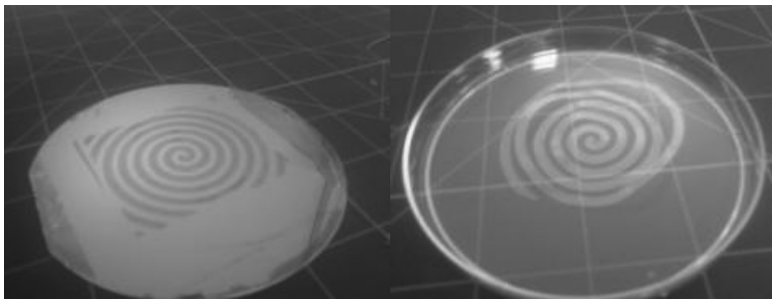

Figure 2: A complete 89 µm thick SU-8 spiral released from a silicon wafer after two hours in a DI water bath at 98°C.