Single High Aspect Ratio Pillar Support Structures

Michael T. Northen
Dept. of Materials
Kimberly L. Turner
Dept. of Mechanical and Environmental Engr.
UC Santa Barbara
Santa Barbara, CA 93106
north@engineering.ucsb.edu

We present the realization of a novel processing technique for creating three dimensional structures in single crystal silicon. The structures consist of differently shaped silicon dioxide platforms supported by a **s**ingle **h**igh **a**spect **r**atio **p**illar **s**upport (SHARPS), Fig. 2. The SHARPS have controllable geometry and diameters down to half of a micron. We utilize the SHARPS to better understand the micromechanics at the micron size scale, as well as inspiration for new device architectures. We exploit the microscale conformance of the SHARPS structures to create an integrated multi-scale adhesive mimicking a common adhesive motif found in nature.

A new processing technique is used to create three dimensional structures consisting of a platform supported by a single support in the middle. The structure produced offers unique opportunities in testing refined geometries in the micron and sub-micron domain. These testing opportunities will increase the understanding of microscale phenomenon, essential for furthering design and fabrication of microdevices. To our knowledge, this is the first time such a geometry has been fabricated or studied, opening up a new scheme for directionality varied mechanical properties in low dimensional microstructures.

Figure 1 illustrates the general process flow for making SHARPS structures. A key attribute of this work is the ability to create 3-dimensional, half micron geometries, using a single lithography step. Furthermore, the submicron features are connected to tens to hundreds of micron features. This allows an interface from the half millimeter dimension to the half micrometer dimension. The variety of pillar and surface geometries allows us the opportunity to test microscale phenomenon never before realized. In addition the structures produced open up new avenues in device architecture.

Currently our research is focused on using the SHARPS structure in an integrated multiscale microadhesive system mimicking the micro and nano structure of the gecko's foot. The gecko foot is composed of nearly five hundred thousand hairs or setae which are approximately ten microns in diameter[1-3]. From the end of each of these setae are hundreds of projections called spatulae. Here we present our initial steps to fabricate a synthetic structure similar (in function) to the pad of the gecko foot. In our analog the setae of the gecko are the SHARPS structures, forming an array of flexible platforms conforming to meso- and micro-scale topography changes, while still providing a strong mechanical bridge to the substrate. The spatulae, fine terminal ends of the setae, are vertically aligned nanorods or nanotubes. Combining the two structures we produce a system mimicking the gecko's foot and able to accommodate multi-scale surface roughness. This technology can be used in chip-scale distributed sensor systems to meso-scale robotics in environments ranging from water to space.

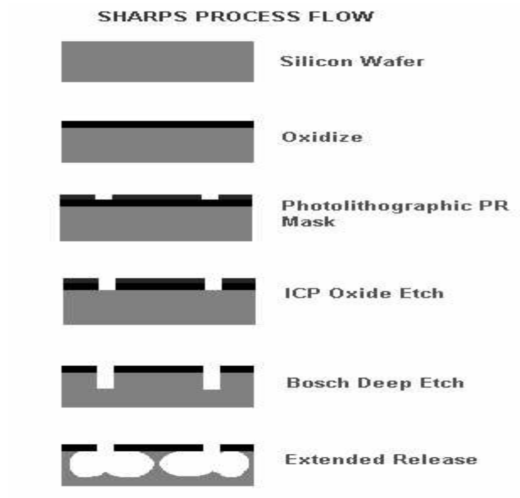

Figure 1. Process flow for creating the SHARPS structures.

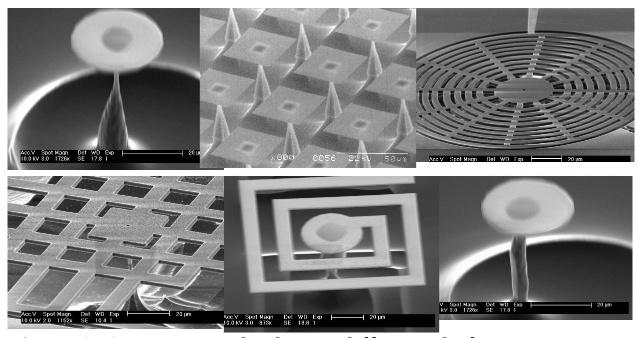

Figure 2. SEM images displaying different platform geometries. (From top and left to right) Round, square, slotted round, slotted square, serpentine and asymmetric platforms.

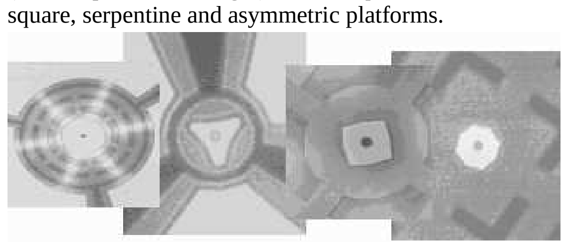

Figure 3. Optical Micrographs displaying multiple pillar geometries.

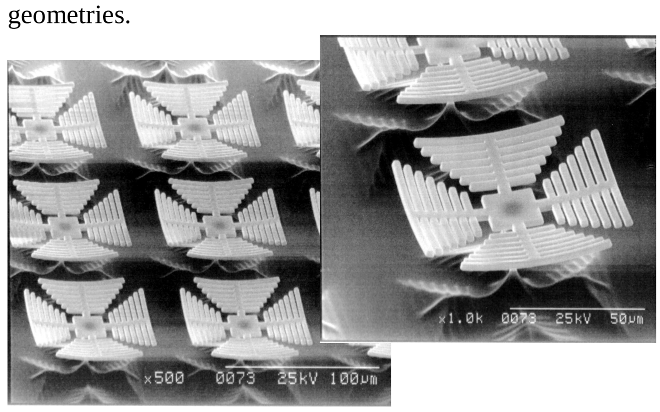

Figure 4. Splayed finger SHARPS structures for multiscale surface conformation.

References

1. Arzt E., G.S., Spolenak R., From micro to nano contacts in biological attachement devices PNAS, 2003. **100**(19): p. 10603-10606.
2. Autumn, K., *et al.*, Evidence for van der Waals adhesion in gecko setae PNAS, 2002. **99**(19): p. 12252-12256.
3. Russell, A.P., A contributioin on the functional morphology of the foot of the tokay, Gekko gecko (Reptilia, Gekkonidae). J. Zool. Lond., 1975. **176**: p. 437-476.