

Micromachined Sensors for Biological Measurements

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Our work in the Stanford Nanofabrication Facility has fallen into two general categories: multi-axis force sensors and atomic force microscope (AFM) cantilevers designed for biological measurements.

Collaborating with members of the UC Berkeley Integrative Biology department, we fabricated a novel micromachined multi-axis force sensor designed to study biomechanical forces produced by insects such as cockroaches. Shown in Figure 1, these devices allow high-resolution three-axis measurements of the ground reaction foot forces produced by running insects. Each sensor consists of a rigid 5mm-square central plate supported at each corner by thin flexure beams 550 μm long, 75 μm wide, and 20 to 75 μm thick. Each beam element is instrumented with a pair of ion-implanted piezoresistors which provide sensitivity to both normal and in-plane forces applied to the sensor plate. While sensors were originally designed for studying cockroach biomechanics, they have also enabled the first detailed measurements ever made of biomechanical forces produced by ants as small as 4mg.

Our cantilever fabrication efforts focused on two primary areas. First, we explored the force resolution and sensing limits of piezoresistive cantilevers. Cantilevers less than 700 Angstroms thick were fabricated using an ultra-thin doped silicon epitaxy process to achieve the desired doping profiles. We also fabricated low-stiffness ($1\text{e-}5$ to $1\text{e-}3\text{N/m}$) silicon nitride cantilevers with tall, sharp tips for use in optical beam-bounce AFM. These cantilevers were designed to enable study of the cell membrane stiffness of single-cell organisms during cell division. Figure 2 shows a prototype ultrathin cantilever produced as part of this work.



Figure 1: Carpenter ant *C. vicinus* with multi-axis force sensor

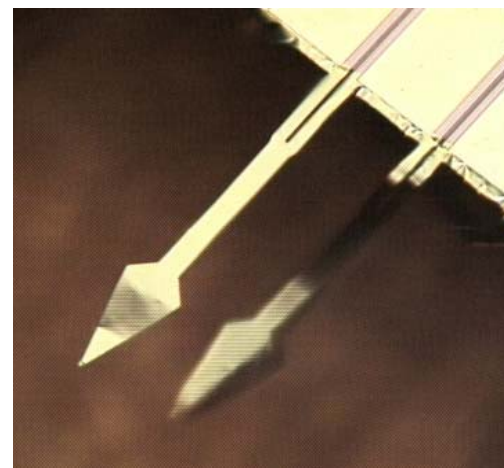


Figure 2: 25 μm wide, 430Å thick cantilevers