Topic No. 7.1 Paper ID No: 0896
Oral or Poster

BIOLOGICAL MEASUREMENTS OF C. ELEGANS TOUCH SENSITIVITY WITH MICROFABRICATED FORCE SENSORS

Joseph C. Doll*, Nahid Harjee**, Nathan Klejwa**, Ronald Kwon*, Sarah M. Coulthard*, and Beth L. Pruitt*
*Department of Mechanical Engineering, Stanford University, Stanford, CA, USA
**Department of Electrical Engineering, Stanford University, Stanford, CA, USA

The ASH sensory neuron located in the nose of Caenorhabditis elegans is responsible for the avoidance of chemical repellants, osmotic shock and mechanical stimulation, however its properties are not well characterized. Ionic currents in response to light touch have been measured [1], however the range of force that mediates a response in normal behavior is not known and the relevance of the applied forces to normal animal behavior has not been quantitatively verified.

Previous efforts in studying microscale cell and organism locomotion have utilized both optical and electronic transduction mechanisms. Polydimethylsiloxane (PDMS) has been molded into pillars for optical force detection and used to study cell motility [2]. Force posts utilizing carbon-impregnated polyurethane and electronic detection have also been fabricated and characterized [3]. This paper reports new biomechanical measurements using a microfabricated force post system. Electronic detection enables good force resolution when studying millimeter scale organisms under a low magnification dissection microscope. The force post array design, fabrication, and characterization will be reported at Transducers '07 [4]. Additionally, initial biological measurements of fruit fly locomotion have been made to validate the force range; measurements of C. elegans locomotion and nose touch behavior with the force posts are underway.

An array of SU-8 force posts with gold strain gauge transducers was fabricated to enable these measurements (Fig. 1). Each force sensor consists of four suspended fixed-guided cantilevers with a vertical pillar located in the center. The deflection of the pillar by a force bends the cantilevers, inducing a strain in the cantilevers. The force is transduced via a metal strain gauge patterned on the top surface of each cantilever (Fig. 2). The strain gauges are connected to a Wheatstone bridge amplifier and differential measurements can be taken in both in-plane directions simultaneously. Out of plane forces can be calculated from the average force value of all four cantilevers.

The devices were fabricated on a quartz substrate by depositing and patterning a 50Å Cr / 200Å Au adhesion layer, a 5μm SU-8 cantilever layer, a 100Å Cr / 1000Å Au strain gauge layer, and a 300μm SU-8 pillar layer (Fig. 3). Finally, the substrate was etched by a 49% HF solution to suspend the sensors. Bake times and intermediate steps were chosen to minimize internal stresses in the thick SU-8 layer and to avoid delamination.

Measurements were performed with each axis of the device connected in a balanced Wheatstone bridge configuration with differential amplification. To characterize the devices a calibrated piezoresistive cantilever was mounted on a piezoelectric actuator and used to apply a measured force to the pillar tip. The sensors were modeled in order to calculate the output voltage for a given applied force and results were verified with finite element analysis. Device sensitivity and off-axis rejection were characterized (Fig. 4).

Initial biological measurements were made with the fruit fly Drosophila melanogaster. A fly was suspended over a device and leg forces were measured (Fig. 5). Data acquisition of C. elegans nose touch and locomotion behavior is currently underway.

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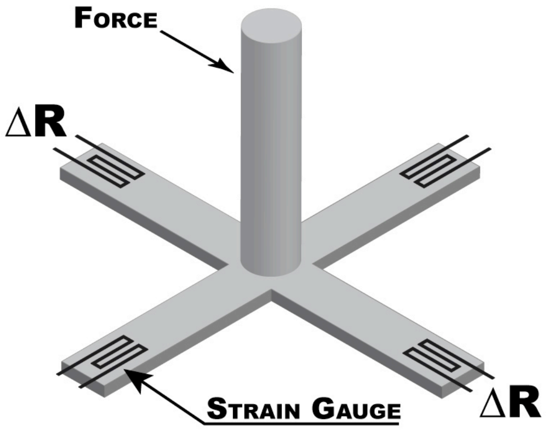

Figure 1: Schematic of a single sensor. Force is transduced into a change in strain gauge resistance and detected electronically via a Wheatstone bridge.

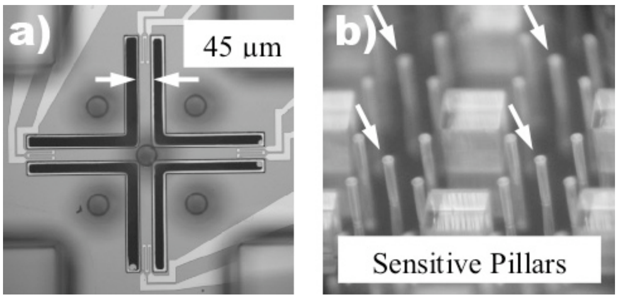

Figure 2: Optical micrograph of a finished device from the top (a) and side (b).

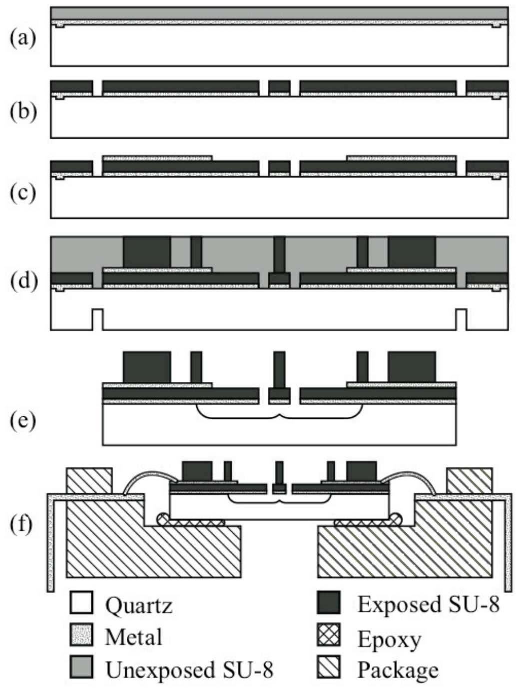

Figure 3: Device fabrication process. Etch alignment marks, deposit adhesion layer and SU-8 cantilever layer (a) and pattern cantilevers (b). Deposit and pattern strain gauges (c) and SU-8 pillar (d) before development (e) and final packaging (f).

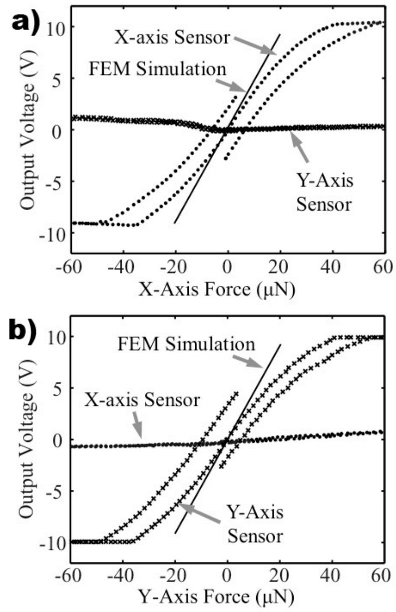

Figure 4: Sensor output and finite element analysis results in the X-direction (a) and Y-direction (b).

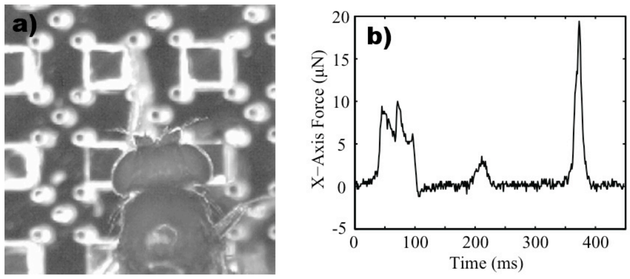

Figure 5: Optical micrograph of D. melanogaster suspended over a device (a) and leg forces (b).

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