ARTIFICIAL HAIR CELL SENSORS FOR FLOW, VIBRATION, AND FORCE IMAGING

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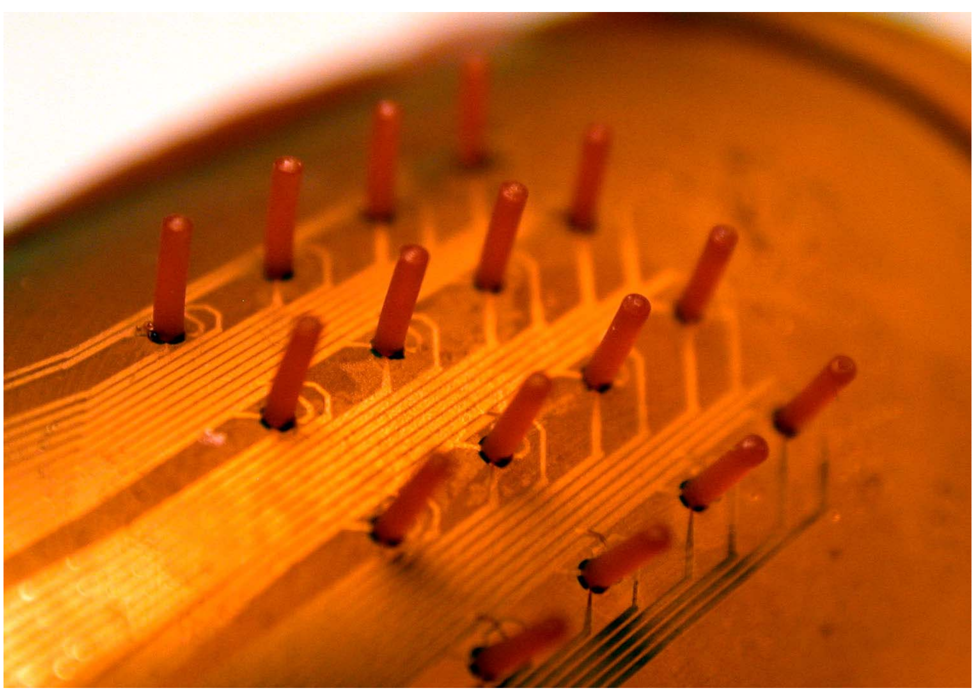
The biological hair cell sensory receptor is a versatile and exceedingly well-adapted mechanical transducer. Hair cells are used in the inner ear of birds, fish, and mammals for hearing, in insect joints for angle detection as well as insect hearing structures, and for hydrodynamic flow and vibration sensing in fish as well as insects [1]. The hair cell is a specialized cell that has a sensory hair (cilium) or array of hairs (cilia) at its top, which interface with the sensed medium. Biological hair cells are specialized depending on their application, with mammalian inner ear hair cells having cilia on the order of 2-8μm tall and 0.1-0.3μm in diameter [2]. In the lateral line of fish, these dimensions can be much larger, with a cupula structure enclosing the hairs up to 400 μm tall [3]. Filiform flow sensing hair cells found on the legs of crickets and spiders exhibit base diameters of 5-15μm and heights from 100-1400μm [4]. The common bond is outstanding sensitivity, flexibility, and robustness. For example, fish hair cells have been shown to be able to detect cilia deflections on the order of 5nm [5] with insect filiform hair cell dendritic detection thresholds of 0.05nm [4].

A number of researchers have recognized the utility of the hair cell transducer structure and have applied microelectromechanical systems (MEMS) techniques to produce micro-scale artificial hair cell (AHC) sensors. However, none of the work to date on piezoelectric [6], piezoresistive [7], capacitive [8], or strain-gauge based [9] AHCs has been able to produce a transducer that combines the sensitivity, robustness, and flexibility of the biological hair cells.

In an effort to meet this goal, our previous work with AHC MEMS flow sensors and elastomer patterning [10] has been combined to realize a wholly polymer flow-sensing structure constructed using flexible conductive polyurethane force sensitive resistors (FSRs) for sensing deflection of polyurethane cilia. Testing of these devices has shown that improved robustness and sensitivity compared to previous designs can be realized. Pictured is an example of a polyurethane based AHC fabricated on a flexible polyimide substrate. However, uniformity and viscoelastic creep remain significant issues. Work is underway to improve on existing designs and materials to yield workhorse AHCs that are robust, sensitive, and reliable.



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