PVDF Piezoelectric Nanofibers As Hair Cell Substitutes: A Feasibility Study

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Introduction: Sensorineural hearing loss is the most common sensory deficit in the world, and damage or loss of the primary sensory cells of the inner ear, known as hair cells is the most common cause [1]. For more severe cases cochlear implants are needed. We investigate the viability of electrospun piezoelectric nanofibers as hair cell substitutes.

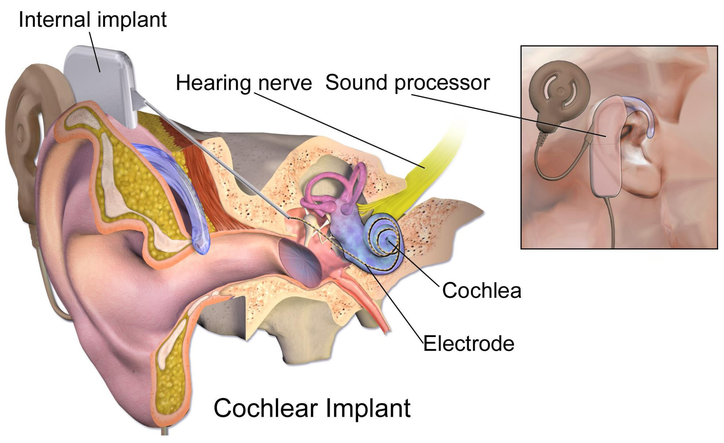

Figure 1. Ear with a cochlear implant. Inset shows external components (microphone and sound processor)

Computational Methods: While the precise mechanism of cochlear transduction remains debated [2], ultimately displacement of the stereocilia induce depolarization of the hair cell and hence nerve stimulation. We make use of Eigenfrequency and Frequency Domain first to determine optimal dimensions (fiber length and diameter) for 200-2500 Hz operation, then obtain transconductance characteristics for the fibers under both of the proposed models of cochlear operation.

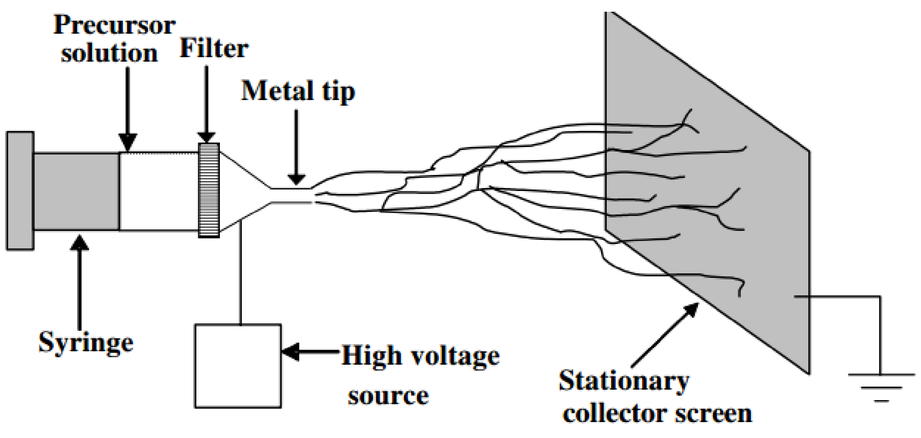

Figure 2. Schematic description of electrospinning setup

Results: While reaching comparable potentials (<200 mV) will not be an issue, gathering large enough currents (~1 nA) will require a large number of fibers per hair cell equivalent, and there needs to be contact rectification.

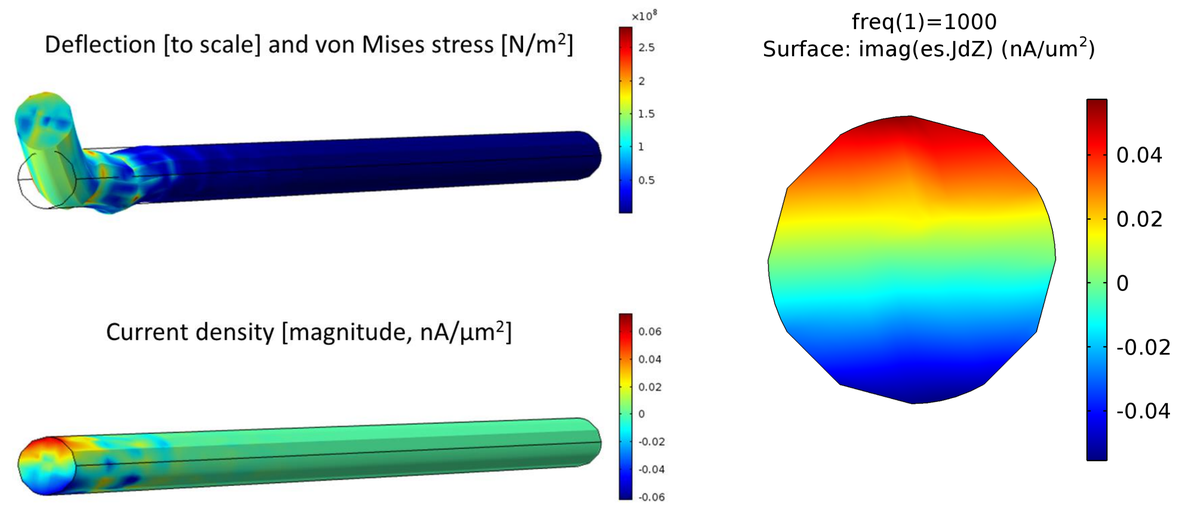

Figure 3. Deflection and current density of a 10 µm long, 200 nm wide fiber excited at the base at 1 kHz (left); Detail of the almost anti-symmetrical base current density (right)

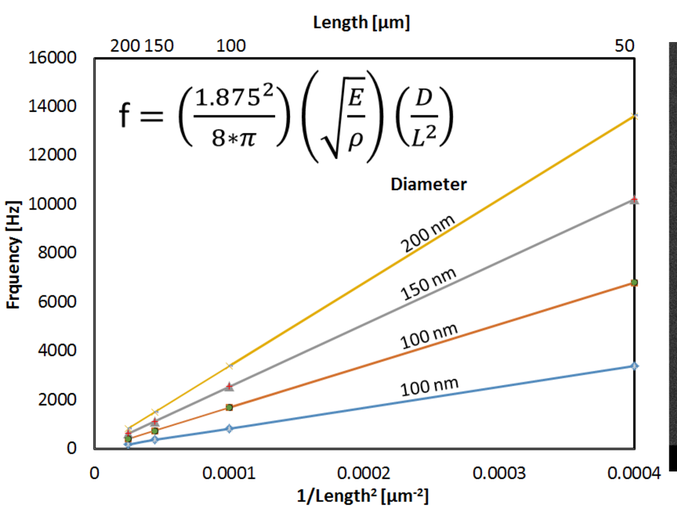

Figure 4. Natural frequency of oscillation of fibers

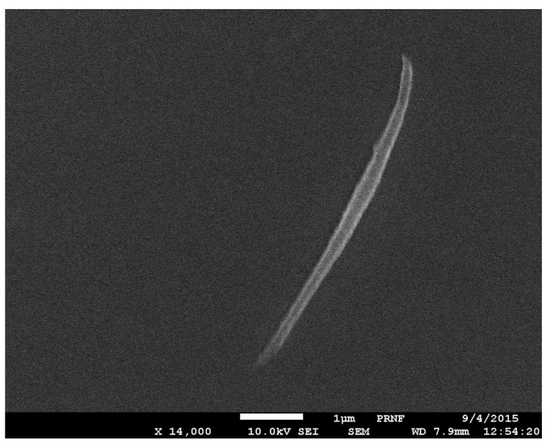

Figure 5. SEM of electrospun PVDF fiber

Conclusions: Piezoelectric fibers used in cantilever mode could potentially become a therapy for hearing loss. Targeted delivery of functional nanostructures will be an active area of research as methods are refined.

References:

1. G. S. G. Géléoc, J. R. Holt, "Sound Strategies for Hearing Restoration", Science, 344, 1241062 (2014).
2. A. Bell, “Hearing: Travelling Wave or Resonance?” PLoS Biol, 2, e337 (2004).