Bio-Inspired Medical Devices via Piezobionics

Dr. I. Y. (Steve) Shen
Professor
Department of Mechanical Engineering
Box 352600, University of Washington
Seattle, WA 98195-2600, USA

Abstract

Piezobionics is an art of developing novel medical devices using piezoelectric sensors and actuators. A good example is development of miniaturized piezoelectric acoustic actuators and sensors to be inserted in human cochlea to enhance performance of existing cochlear implants. Through our development, we recognize that actuators and sensors developed under existing design principles may not be efficient or sensitive enough to restore physiological functionalities of human ears, which have evolved for millions of years. One way to remedy this situation is to adopt a new design philosophy that mimics what natural selection has done for biological systems for years. As an example, human hearing is achieved through motion of hair cells in human cochlea responding to an incoming sound (pressure) wave. The large number of hair cells significantly increases drag forces acting on the basilar membrane and thus the sensitivity of hearing. Therefore, one possible way to design an intra-cochlear microphone is to mimic human hair cells in the form of cilia structures to significantly increase the sensitivity of the microphone. Similarly, the same cilia structure can be used as an actuator, and the large number of cilia will enhance the efficiency of the actuator. A possible design consists of a thin substrate, arrays of nanorods, and a thin sensory/actuator film. The nanorods have a high aspect ratio (e.g., above 100:1) to enhance sensitivity and efficiency. For sensor applications, the design can adopt a flexible substrate (e.g., PMMA), polymeric nanorods, and a PVDF piezoelectric sensory film. For actuator applications, the design can adopt a stiff substrate (e.g., silicon), silica nanorods, and a PZT piezoelectric actuation film.

Bibliography

Dr. I. Y. (Steve) Shen is a Professor of Mechanical Engineering Department of the University of Washington. Professor Shen received his B.S. and M.S. degrees from National Taiwan University and Ph.D. from the University of California (Berkeley), both in Mechanical Engineering. Professor Shen's general research area is vibration, sensing, and actuation. In particular, his expertise includes PZT thin-film micro-sensors/actuators and spindle/rotor dynamics. In the areas of PZT thin films, he is developing micro-sensors and actuators for future medical devices, such as hybrid cochlear implants and bio-inspired medical devices. He has published more than 100 technical articles, and is a Fellow

of American Society of Mechanical Engineers (ASME). Professor Shen has also chaired ASME Information Storage and Processing Systems Division, 2006 ASME/ISPS-JSME/IIP Joint Conference on Micromechantronic Intelligent and Precision Equipment, and an NSF Workshop on "Cyber-Enabled Discoveries and Innovations" Initiative in Conjunction with 2007 ASME International Mechanical Engineering Congress & Exhibition. Professor Shen has also served on the Editorial Board and as a guest editor of *Microsystem Technologies*. He is currently an Associate Editor of ASME Journal of Vibration and Acoustics.