Electromechanical transduction is a component of microelectromechanical systems (MEMS), which have applications in a wide variety of technologies including mobile computing, sensors, energy harvesting, and displays. These disparate applications have varying performance requirements, but in general transduction efficiency, mechanical precision, response time, cost, compatibility with photolithography and other fabrication processes, and operability at micro-scale are all desired metrics for MEMS devices. Piezoelectric transduction has significant advantages, particularly high precision of mechanical movement and high transduction efficiency which results in high energy efficiency and high quality factor (Q) but suffers from lower total mechanical displacements than other electromechanical transduction mechanisms. This makes piezoelectric devices well-suited for certain applications, such as high frequency oscillators, but limits their efficacy as actuators.

Currently, MEMS designers partially compensate for this limitation by creating compound piezoelectric devices to improve the displacements yielded by piezoelectric devices. One of the earliest and simplest solutions is the bimorph cantilever beam. The bimorph MEMS device comprises two separate piezoelectric layers and several electrically conductive layers. Different electrical signals are applied to each layer, inducing a different electric field in each layer. This results in one layer contracting horizontally (within the plane of the device), while the other layer expands along the same axis. These opposing strains result in a bending moment, causing the beam to bend vertically (out of the plane of the device.) This out-of-plane displacement can be substantially greater than the in-plane motion of either layer, increasing the utility of the piezoelectric structure as a MEMS actuator; however, this more complicated structure increases the number of photolithography steps required for fabrication, resulting in increased cost, more complicated processing, greater manufacturing times, and more opportunities for contamination or damage during fabrication.

This thesis proposes a novel design that can produce high magnitude, out-of-plane displacements using a single piezoelectric layer. An innovative electrode pattern induces a non-uniform electric field in the piezoelectric layer, resulting in out-of-plane bending using only a single piezoelectric layer and no more than two conducting electrode layers, substantially simplifying the fabrication process. By changing the orientation of the structure fabricated from the same piezoelectric layer, a torsional (twisting) response can be achieved, allowing increased versatility in device design. This paper also presents a comprehensive design for a piezoelectric actuator comprised of these elements.

Major: Electrical Engineering

Educational Career:
Bachelor's of Engineering Sciences (Bioengineering), BS, 2006, Harvard

Committee in Charge:
Reza Abdolvand, Chair, Department of Electrical Engineering and Computer Science
Xun Gong, Department of Electrical Engineering and Computer Science
Shin-Tson Wu, CREOL, The College of Optics and Photonics

Approved for distribution by Reza Abdolvand, Committee Chair, on June 17, 2019.

The public is welcome to attend.