Piezoelectric Micro Power Generator (PMPG): A Novel MEMS Based Electrical Power Source – MEM

Personnel
Rajendra Sood, Yong Bae Jeon, Sang Gook Kim, (Sanjay Sarma)

Sponsorship
Auto-ID Center

Concept and Key Idea
A MEMS-based energy harvesting device is designed and fabricated that converts ambient, acoustical energy to electrical energy via the piezoelectric effect. The electrical energy is subsequently stored within the device to act as a constant, electrical power source in replacement of a common battery or wired supply.

Design and Fabrication
The PMPG (Piezoelectric Micro Power Generator) is a device currently in the microfabrication stage. It converts ambient acoustical and/or vibrational energy to electrical energy via the piezoelectric effect. Unlike conventional batteries, the PMPG will provide power for an infinite duration of time provided there is ambient energy available. It consists of a composite cantilever beam with top interdigitated electrodes and an added proof mass.

The ambient energy is coupled into the first resonance mode of the mechanical structure. When the device is in resonance, the generated electrical signal will be sinusoidal in nature. The signal must therefore be rectified before the resulting charge can be stored. The PMPG is designed to deliver a high open circuit voltage and electrical power specification due to its exploitation of the d<sub>33</sub> excitation mode of the piezoelectric material (PZT). The d<sub>33</sub> mode has been calculated to provide up to 20 times the open circuit voltage value of a d<sub>31</sub> device with the same beam dimensions. The converted electrical energy is then stored, effectively creating a portable, electrical power source capable of driving low power digital circuits among other applications. These devices are therefore suitable for powering small wireless sensors or Auto-ID tags. The PMPG would replace chemical batteries in these low power applications and would, in fact, be better because the PMPG will have a virtually infinite operation lifetime.

Figure 6 shows a picture of the ideal, released PMPG. The device employs a surface micromachining process using XeF<sub>2</sub> vapor etcher in order to create the released micro-cantilever structure. The composite beam includes a SiO<sub>2</sub>/ZrO<sub>2</sub> membrane layer that acts as an electrical diffusion barrier, a PZT piezoelectric layer and a Pt interdigitated electrode layer. Figure 7 is an electrical equivalent circuit model of the PMPG, along with the rectifying circuitry necessary before charge storage. Figure 8 contains two polarization curves of a sample PMPG device. After poling, the electric dipoles within the PZT are aligned, allowing for device operation. A small array of these devices is expected to permit a power density of approximately 10µW/mm<sup>2</sup>. The final PMPG is released from the bulk silicon by way of a XeF<sub>2</sub> isotropic etch step. Acoustic operation frequency is set between 20 kHz and 40 kHz, outside of the audible range. Figure 9 shows an overhead view of an actual, pre-released device.
Fig. 6: Surface micromachined PMPG device

Fig. 7: Electrical equivalent circuit model of PMPG with full-wave rectifier

Fig. 8: PE hysteresis curves of the PMPG device before and after poling

Fig. 9: Top View of interdigitated PMPG fabricated