Piezoresistive Transduction of MEMS Resonators

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Abstract:
A straightforward means of electrical transduction of resonator motion is investigated using MHz-frequency micromechanical resonators made from multi-layer film stacks. Devices are fabricated using polysilicon films stacked on top of each other with intermediate layers of insulating material. Electrical or optical drive is used to induce motion in the resonators and electrical transduction allows for direct detection of the resonator motion. Electrical transduction is afforded by piezoresistivity of the intermediate insulating layer. We have verified the effect with both silicon dioxide and silicon nitride as insulating layers. This work was partially supported by the Office of Naval Research and DARPA.

Summary of Research:
We have fabricated resonator devices using multi-layer film stacks comprised of a top layer of highly doped polysilicon, and intermediate insulating layer which also serves as a piezoresistive transducer, and a bottom layer of highly doped polysilicon. The film stack sits atop a sacrificial layer of silicon dioxide atop the silicon handle wafer (see Figure 1). One is able to control the resistance and piezoresistivity between the two layers by applying a dc voltage between the layers to “breakdown” the insulator. When the piezoresistive intermediate layer is current biased, and when the resonator is driven through resonance, a large out-of-plane deflection results in a detectable voltage signal resulting from the changing resistance of the intermediate layer (a model is shown in Figure 2). We have driven and detected these microelectromechanical systems (MEMS) devices using optical and electrical methods (Figure 3). We have also confirmed the flexural dependence of the piezoresistivity of the intermediate layer using static measurements (Figure 4). This transduction mechanism is effective at providing a straightforward means of detecting resonator motion using a fabrication-based mechanism that is easily tailored to any device geometry. Unlike conventional piezoresistors which must be patterned lithographically, this method essentially incorporates the transducer directly into the structure.
Figure 1: A side-view profile of the film stack used to make the resonators and piezoresistive transducer.

Figure 2: A side-view schematic showing the piezoresistive transducer model. The intermediate insulating film is compressed during resonant motion and its resistance is significantly altered.

Figure 3: Data showing the resonator response from optical drive and piezoresistive electrical detection. Inset shows the response of multiple resonators in parallel from capacitive electrical drive and piezoresistive electrical detection.

Figure 4: Current-voltage data for device under static tension. Changing tension in the structure is shown to alter the resistance of the intermediate layer.