SCREEN PRINTED PZT/PZT THICK FILM BIMORPH MEMS CANTILEVER DEVICE FOR VIBRATION ENERGY HARVESTING

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Piezoelectric transduction for the purpose of harvesting ambient mechanical vibrations for energy supply of small systems has received significant attention over the last decade. A typical MEMS energy harvester is based on a bimorph cantilever beam, which consists of the active piezoelectric ceramic and a passive mechanical support structure, anchored at one end and with a proof mass at the other [1][2][3][4]. The piezoelectric ceramic used is InSensor® TF2100, which has been deposited with a thickness of around 30 µm using screen printing [5]. This technique has previously been used in fabrication of a piezoelectric accelerometer [5]. With the use of PZT thick film, instead of PZT thin film, a mechanical support material is no longer needed in the final device, since the beam may be thick and strong enough, however a bimorph structure is still needed to produce an output signal. Therefore the PZT/PZT bimorph cantilever beam shown in Figure 1 is used; here both layers are active and thus the strain energy from both layers is harvested. The advantage of such a structure is that all strain energy is harvested, while in conventional structures with inactive support materials the strain energy in these is not harvested and thus wasted.

The energy harvester presented here has lateral dimensions are limited to 10 mm × 10 mm. The medial dimension along the motion of vibration should also be limited to just a few millimetres. The PZT thick film deposition method combined with standard MEMS technology allows fabrication of small scale energy harvesters. The fabrication steps are shown in Figure 2. The backside of a SOI wafer (a) is patterned and etched using a DRIE process (b). Then a 1 µm thick silicon dioxide is grown as an etch stop for a final RIE etch, releasing the structure (c). The topside of the SOI wafer is then patterned and a Pt bottom electrode deposited (d), followed by deposition of 30 µm PZT thick film (e), Pt middle electrode (f), 30 µm PZT thick film and Au top electrode (g). The oxide on the backside is etched in BHF, while the topside of the SOI wafer is protected. The backside of the SOI wafer is then etched in RIE until the device layer is removed and the cantilever released (h), see Figure 3. An electric field applied between the top electrode and the bottom electrode is used to polarize the PZT layers. Both the top and bottom PZT layers may serve as energy harvesting materials. The measurements shown here are done on the top part, i.e. measured between middle and top electrode. Impedance measurements are shown in Figure 4 where the typical resonance/antiresonance features are seen. Results from shaker measurements are shown in Figure 5 and 6. The decrease in the resonant frequency with increasing acceleration, see Figure 5, is caused by a nonlinear effect [3]. The resonant frequency is 328 Hz at 0.84*g* and can be lowered by increasing the weight of the proof mass. The power output as a function of acceleration is shown in Figure 6, at 1*g* the power is 2 µW, which is comparable to the best performing MEMS harvesters reported in the literature.

In conclusion, we present the first MEMS based PZT/PZT bimorph energy harvester with screen printed PZT thick film. The fabricated bimorph energy harvester is extremely robust and can be exposed to more than 7*g* at resonance without breaking. PZT/silicon cantilevers with similar design have been shown to break below 3*g* at resonance. Results obtained for bimorph energy harvesters polarized in same direction as well as opposite direction will be shown.

Word Count: 597

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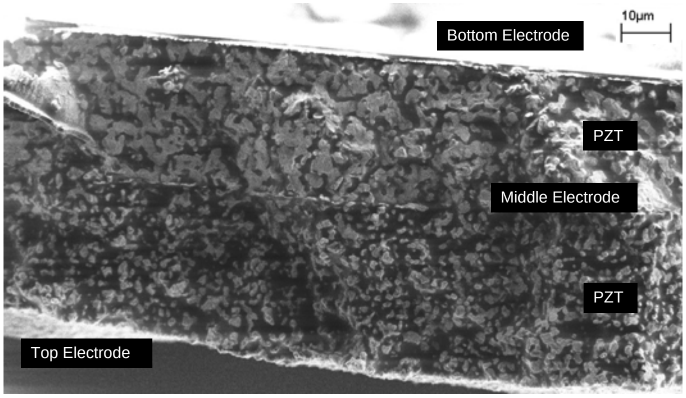

Figure 1: A SEM picture showing a cross-section of the PZT/PZT bimorph cantilever. The middle electrode separates the two PZT layers.

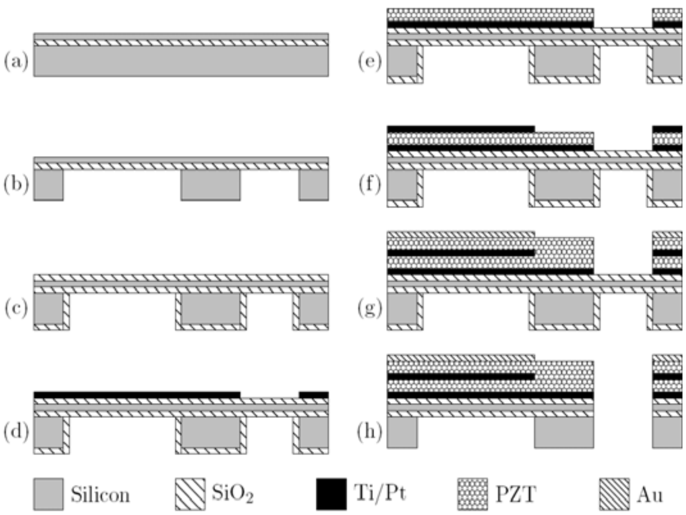

Figure 2: A cross sectional sketch of the fabrication process.

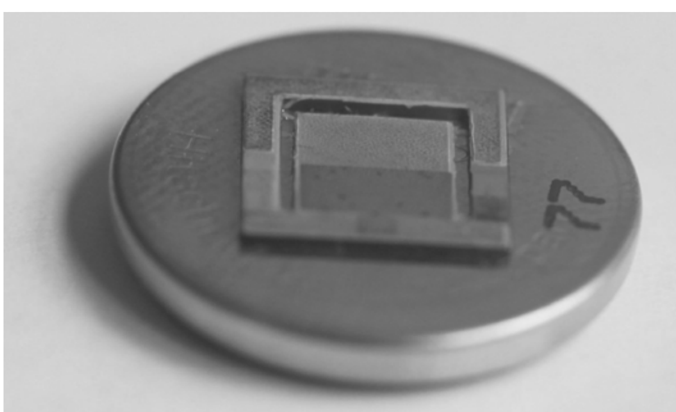

Figure 3: The MEMS energy harvester on top of a typical button battery. The harvester is 10 mm × 10 mm in the lateral dimension and about 600 µm in total thickness.

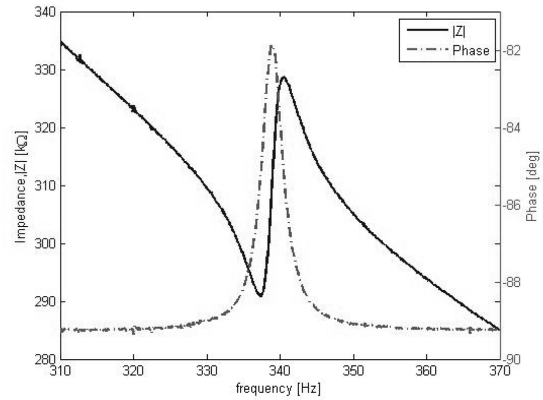

Figure 4: A typical impedance magnitude and phase measurement for the energy harvester using a source voltage of 0.5 V.

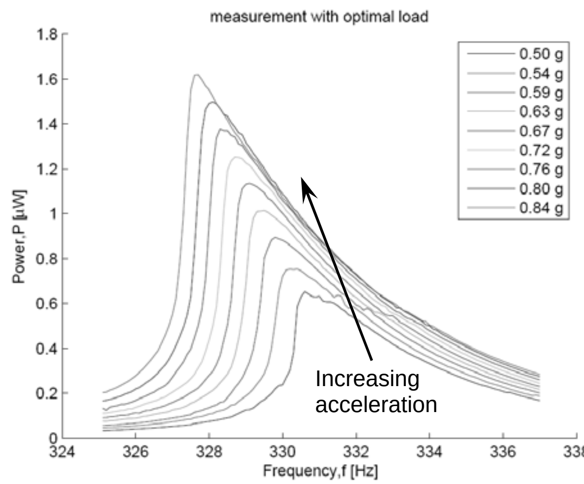

Figure 5: RMS power output as a function of frequency near the resonant frequency for different accelerations at an optimal resistive load of 287 kΩ. The apparent resonant frequency shift is caused by a nonlinear effect [3].

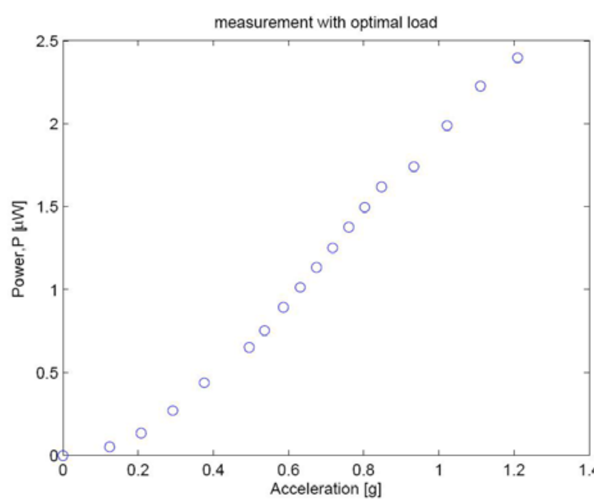

Figure 6: The RMS power output as the function of the acceleration at the optimal resistive load of 287 kΩ.