# 압전 외팔보 기반 에너지 수집소자의 신뢰성 향상기법 연구

# Reliability Improvement of MEMS based Piezoelectric Cantilever Energy Harvesting Device

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## 1. Introduction

In the past several years, the integration of piezoelectric thin film with micro electromechanical system (MEMS) has been received much attention to generate an electricity from ambient vibration [1]. As shown in [2-3], there were hundreds of studies on transduction of electrical energy from vibrating beam using PZT thin or thick films with platinum electrodes. Although these devices exhibited good performances, PZT fatigue characteristics and adhesion/delamination problems caused by the Pt electrode have been still left not to be solved. In this paper, a bulk micromachined energy harvesting device using IrOx interdigital electrode was investigated to improve the electrical and mechanical reliability of the PZT based energy harvesting devices.

## 2. Design and Fabrication

As shown in Fig. 1, the MEMS energy harvester was comprised of multi-layered cantilever and initial mass to vibrate from induced ambient vibration. The multi-layered cantilever was composed of supporting silicon membrane, piezoelectric layer, and inter-digital electrodes and had a dimension of 800×1000×20 $\mu m^3$. Lead Zirconate Titanate (PZT) was considered for the piezoelectric material. In order to prevent the mechanical failure and polarization fatigues of PZT thin film which degrade the performance of energy harvester, IrOx electrode was applied [4]. The proof mass, which was made of silicon with volume of 1000×1000×500 $\mu m^3$, was built at the free end of cantilever to adjust the resonant frequency.

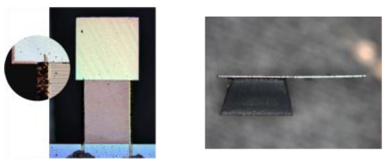
In order to confirm the improvement of reliability in the electrical and mechanical fatigue characteristics of the PZT based energy harvesting deice with an IrOx electrode, two MEMS energy harvesting devices with Pt and IrOx electrodes have been fabricated, measured and compared. These devices were fabricated by using a SOI wafer with a 20 μm of silicon device layer and 1.5 μm of the $Pb(Zr_{0.52}Ti_{0.48})O_3$ thin film layer deposited by using the sol-gel spin coating method. The Pt and IrOx electrodes were sputtered on top of the cantilever shaped PZT thin film and formed as inter-digital shaped electrodes with 5 μm of width and spacing. The detailed fabrication sequence has been reported at [3].

## 3. Experimental Results and Discussions

Fig.2 shows the measured remnant polarization characteristics which the hysteresis curves were clearly observed in the Pt and IrOx electrodes. Table 1 shows the measured sheet resistances of these fabricated electrodes. While IrOx electrode degraded the electrical properties of PZT thin film, they show that the IrOx electrode is highly applicable to the harvesting devices. For accurately characterizing the fabricated MEMS energy harvesting devices, the resonant frequency was firstly founded by using impedance analyzer. Its resonant frequency was observed at 1.475 kHz and 1.664 kHz for the IrOx and Pt electrodes, respectively. Fig. 3 shows the electrical performances of fabricated energy harvesters. The energy harvesting device using the IrOx electrode generated approximately 1 μW of output power. It is approximately 85% of the output power of the device with Pt electrode. The fatigue analysis was also performed as shown in Fig. 4. As shown in Fig. 4, the electrical failure of the harvesting device with IrOx electrode has been started at $2\times10^6$ cycle which is much larger than the device with Pt electrode. Furthermore, the mechanical failure was also observed at the device with Pt electrode.

## 4. Conclusion

This paper presented a highly reliable piezoelectric MEMS energy harvester with IrOx electrode to generate electrical power from ambient vibration sources. While the harvesting device with IrOx electrode generated slightly lower electrical power than the device with Pt electrode due to the higher electrical resistance, it exhibited much higher electrical and mechanical reliability, as expected.



(a) (b)

Fig. 1 Photomicrographs of fabricated energy harvesting device with IrOx electrode (a) and its cross-sectional view (b)

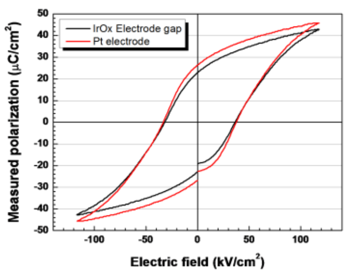



Fig. 2 Measured polarization curves of PZT based cantilever energy harvesters with different electrodes

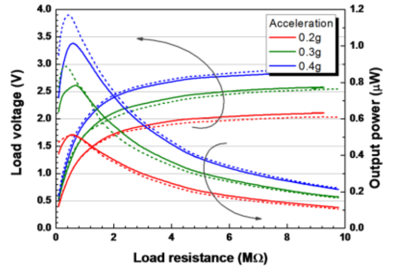



Fig. 3 Load voltages and powers of fabricated energy harvesters with interdigital IrOx (solid line) and Pt (dotted line) electrodes at various load resistances and acceleration.

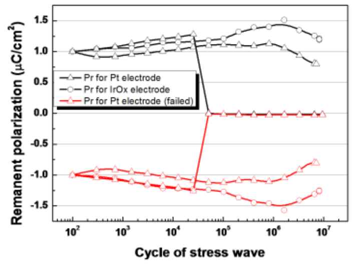



Fig. 4 Measured remanent polarization of fabricated energy harvesters with IrOx electrode (circle) and Pt electrode (triangle) at each cycle of stress waveform (rectangular wave with 50V and 100Hz).

Table 1 Measured sheet resistances of IrOx and Pt electrodes fabricated on the PZT film.

| Electrode | Measured sheet resistance (Ω/□) | | | | | Average |
|---|---|---|---|---|---|---|
| Pt | 1.38 | 1.39 | 1.33 | 1.4 | 1.38 | 1.36 |
| IrOx | 3 | 2.69 | 2.8 | 2.93 | 3.17 | 2.92 |

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