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압전 MEMS 진동에너지 수집소자를 위한 졸겔 공법기반의 Pb(ZrTi)O3 박막의 특성 분석 및 평가

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Characterization of Sol-gel Coated Pb(ZrTi)O3 Thin film for Piezoelectric Vibration MEMS Energy Harvester

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Abstract-In this paper, sol-gel-spin coated $Pb(ZrTi)O_3$ thin film with ZrO_2 buffer-layer and $PbTiO_3$ seed-layer was investigated for vibration MEMS energy harvester to scavenge power from ambient vibration via d33 piezoelectric mode. Piezoelectric thin film deposition techniques on insulating layer is the important key for d_{33} mode of piezoelectric vibration energy harvester. ZrO_2 buff-layer was utilized as an insulating layer. $PbTIO_3$ seed-layer was applied as an inter-layer between PZT and ZrO_2 layer to improve the crystalline of PZT thin film. The fabricated PZT thin film had a remanent polarization of 5.3uC/cm^2 and the coercive field of 60kV/cm. The fabricated energy harvester using PZT thin film with PTO seed-layer generated 1.1uW of electrical power to 2.2MΩ of load with 4.4V_{pvp} from vibration of 0.39g at 528Hz.

1. Introduction

As the increase of demands for high technology devices, the chemical batteries have been met some limitations such as, life span and replacement. These limitations could result in considerable problems and costs for hazardous and harsh environment, and autonomous systems. Thus, energy harvesting from ambient energy has received much attentions.

The most familiar ambient energy is solar energy. And other examples are electromagnetic fields, thermal gradients, and etc. Among them, vibration energy is one of the most promising alternative because its harvesting has a relatively higher power density than the others, an infinite life time, and none physical connection to the outside of system and reliability from harsh environments [1].

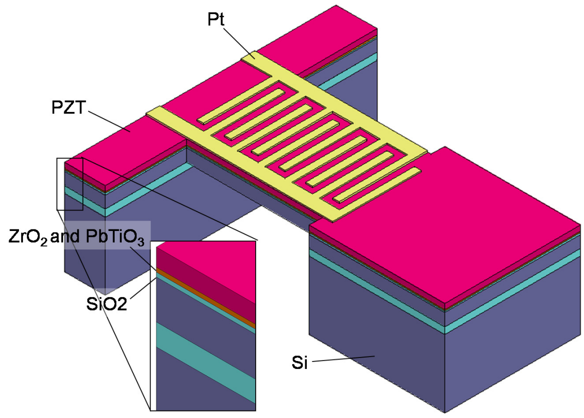
As shown in [2], many modes of transduction could be used for energy scavenging. There have been hundreds of studies on transduction of electrical energy from vibrating beam. These results drive to consent that these approaches are the most suitable for the uW-mW scale ranged applications with low acceleration.

In this paper, Piezoelectric thin film deposition techniques on insulating layer is presented for d_{33} mode of piezoelectric vibration energy harvester. ZrO_2 buff-layer is utilized as an insulating layer. $PbTIO_3$ seed-layer is applied as an inter-layer between PZT and ZrO_2 layer to improve the crystalline of PZT thin film. Vibration MEMS energy harvester using $Pb(ZrTi)O_3$ thin film with ZrO_2 buffer-layer and $PbTiO_3$ seed-layer is also investigated

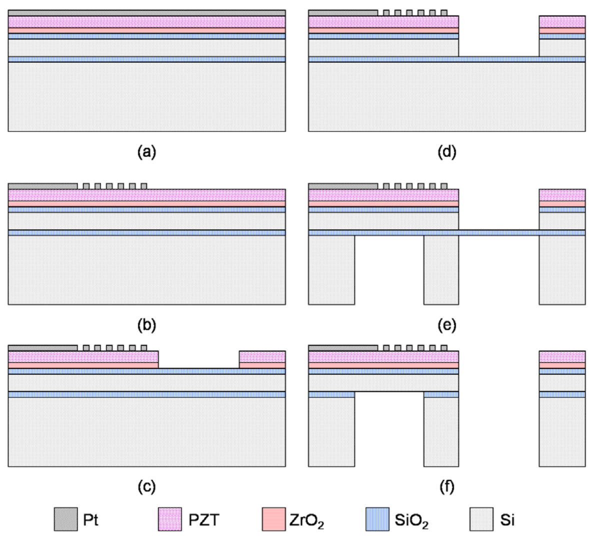
2. Fabrication

For d_{33} mode of piezoelectric vibration energy harvester, development of piezoelectric thin film deposition techniques on insulating layer is most important key. Because the formations of perovskite phase in PZT thin film is strongly affected the piezoelectric characteristic. In order to improve crystalline and ferroelectric properties, $PbTiO_3$ seed layer applied between PZT thin film and Pt bottom electrode for FRAM application [3]. Because, this $PbTiO_3$ seed-layer helps the transformation of perovskite phase in PZT thin film with less activation energy of nucleation.

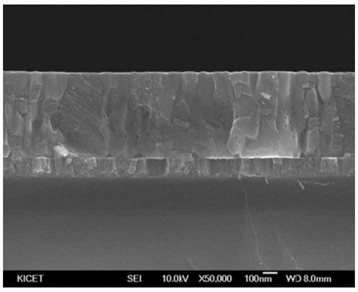
Fig. 1 presents d_{33} mode of MEMS energy harvester using PZT thin film. The PZT thin film was deposited on SOI wafer with 10um device layer and buried silicon oxide. Firstly, ZrO_2 buffer-layer was deposited as an insulating layer and $PbTiO_3$ seed-layer was newly applied as an inter-layer between the ZrO_2 and PZT thin film. 1um of PZT thin film was deposited with Zr/Ti ratio of 52/48. These thin films were processed by using sol-gel method. Pt layer was sputtered to form inter-digital electrodes with 5um of width and spacing. The Pt and PZT layer were patterned by inductively coupled plasma (ICP) dry etching technique. Si cantilever beam and proof mass were defined by front and back side silicon Deep RIE etching. Finally, the cantilever energy harvesting device was released with etching of the buried oxide. Figs. 2 shows fabrication steps of the energy harvester.



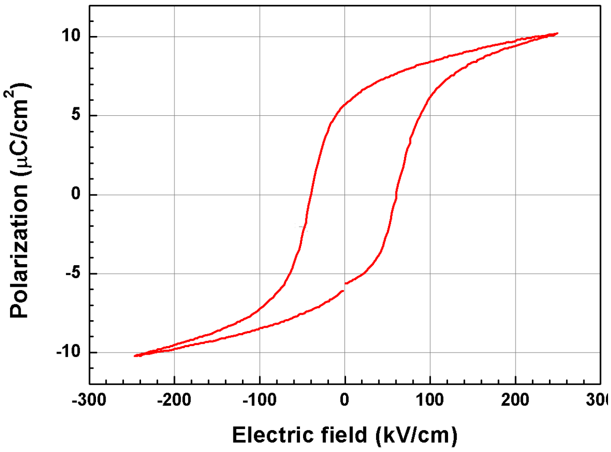
<Fig. 1> 3D structure of energy harvester using d_{33} piezoelectric mode



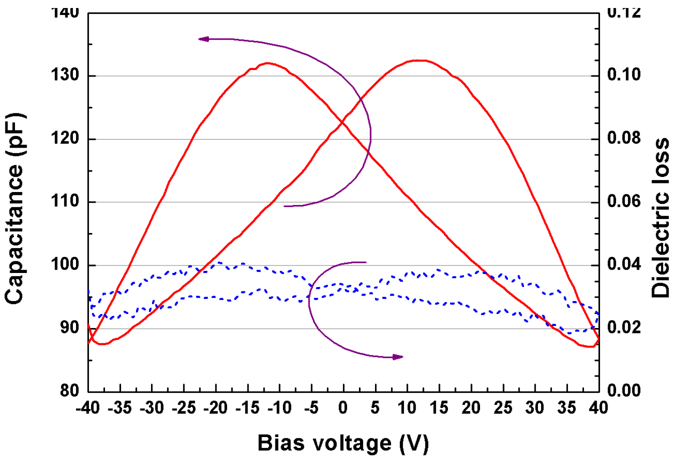
<Fig.2> Fabrication sequences: seed layer / PZT / electrode deposition (a), electrode patterning (b), PZT etching (c), Si beam patterning (d), proof mass patterning (e), and release via buried oxide etching (f).



<Fig. 3> SEM image of fabricated PZT thin film



<Fig. 4> Measured polarization and electric field curve



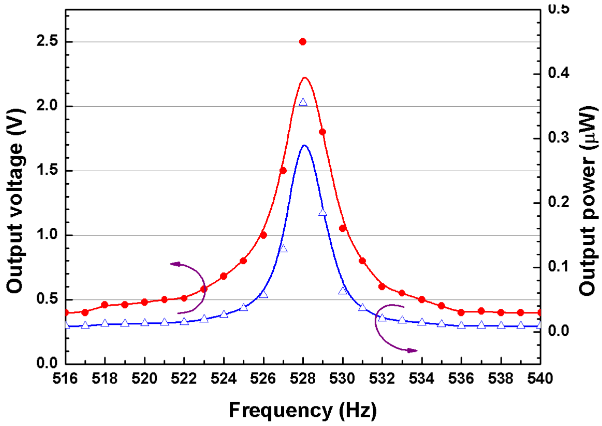
<Fig. 5> Measured capacitance and bias voltage characteristic

2. Experimental Results

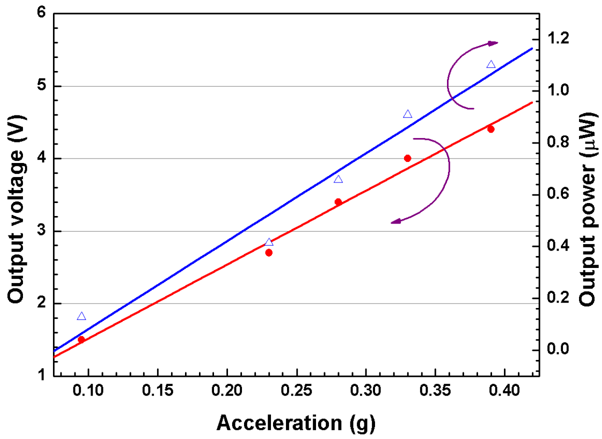
Experiments of fabricated energy harvester were carried without polling process. Fig.3 shows FESEM image of PZT thin film with $PbTiO_3$ seed layer on ZrO_2 insulating layer. Firstly, the polarization characteristic of PZT thin film was measured by RT-66A measurement system of Radiant Technologies, inc. Fig. 4 and 5 show P-E hysteresis loop and CV characteristic of d_{33} mode of the fabricated PZT film on the $PbTiO_3$ seed layer. The fabricated PZT film has remnant polarization of 5.3uC/cm^2 and the coercive field of 60kV/cm.

Fig. 6 shows the fabricated energy harvester. Figs. 7 and 8 show the performance characteristics of fabricated energy harvester at various vibration and accelerations with fixed load impedance. As shown in these results, the maximum power was generated to the optimum load at its resonant frequency and the developed energy harvester generated 1.1uW of electrical power from low acceleration of 0.39g. The corresponding power density was 2.8mWcm^{-3}g^{-1}.

<Fig. 6> Fabricated energy harvester



<Fig. 7> Measured output voltages and powers at various excited frequencies



<Fig. 8> : Measured output voltages and powers at various accelerations

3. Conclusion

This paper presented PZT thin film for d_{33} mode of piezoelectric MEMS energy harvester which was targeted to scavenge low-level ambient vibration energy. In order to improve the crystalline of PZT thin film, $PbTiO_3$ seed-layer was applied as an inter-layer between PZT and ZrO2 insulating layer. The fabricated PZT thin film showed ferroelectric properties. The fabricated energy harvesting device using this PZT thin film also showed excellent performance characteristics at low operating frequency.

In near future, we will investigate and analyze the PZT thin film for energy harvesting device to improve the output power at lower level vibration.

[참 고 문 헌]

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