Energy harvesting with a focus on Vibration to electricity conversion base on MEMS

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ABSTRACT

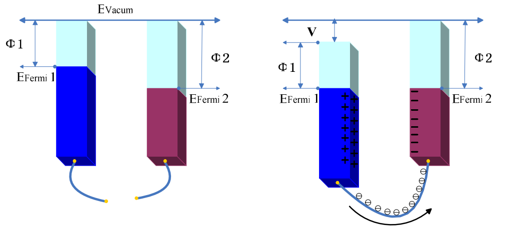
Ambient energy harvesting of MEMS-based devices, which can convert mechanical energy into electrical energy by some methods, have attracted much interest in both the military and commercial sectors. We present a MEMS-based vibration energy harvester. The device is like sandwich structure with area of about 1cm^2. The structure is fabricating on the silicon-on-insulator (SOI) wafer, on which beams, mass and moving Al electrode are fabricated by etching or depositing process. The whole device is packaged by glass wafers in two sides. Experimental measurement results show that this new vibration energy harvester can meet the application of providing power for microsystems. In addition, an integrated process flow of MEMS converter is also presented in this paper

1. INTRODUCTION

The development of modern electronic device is tending to implement completely autonomous, self-powered. Although less energy is available to shrink electronic system, the external power limits the device lifetime and the range of employment. That is why a self-renewing energy source comes out, and continually replenishes the energy consume. As a results, the microsystem generators and transducers can be such self-renewing sources. So energy harvesting is defined as capturing trace amounts of energy from the environment and transforming them into electrical energy. Most of current research has been concentrating on developing on-site generators, which can transform mechanical energy into electrical energy. It will be widely used in the future in many fields of wireless and autonomous systems, such as vibration energy harvester enabling autonomous microsystems and acceleration and pressure sensor in automobile tires.

2. DESIGN DEVICE

Traditionally, there are three main strategies for the vibration energy harvesting: piezoelectric, electrostatic and magnetic. MEMS variable capacitors are fabricated with relatively mature silicon micromachining techniques, which rely on the changing capacitance of vibration-dependent variable capacitor. Variable capacitor is initially charged and, as vibrations separate its plates, mechanical energy transforms into electrical energy. The most attractive feature of this method is its IC-compatible nature. Therefore the strategy of electrostatic is used in our device. However, an additional voltage source required in the system increases the difficulty and cost of the fabricating processes. For the sake of conquering, the traditional disadvantage in our vibration-energy harvesting device, a build-in voltage is generated by the connection of two parallel electrodes with different work functions, which can induce an electrical current and standing voltage forinitially charge. Fig. 1 illustrates this behavior schematically. Materials of appropriate should be chosen for generating max contact potential, adequate materials such as aluminium (Al) with $\varphi1 = 4.08$ eV and platinum (Pt) with $\varphi2 = 6.35$ eV. This results in a contact voltage of V = 2.27V. [1]



(a) Before electrical contact (b)After electrical contact

Figure 1 Metal and metal contact schematically

By applying this method, we designed a model of spring-mass-system base on state space equation. As showed by Figure 2.

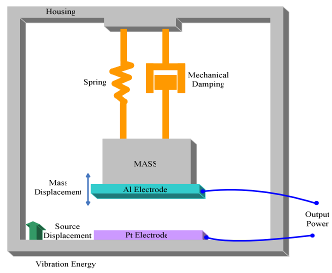


Figure 2 Schematic design of the energy harverst

The whole device is such as sandwich structure (Figure 3). SOI (Silicon-On-Insulator) wafer and Pyrex 7740 glass are used to make the function elements and vacuum sealing package. SOI wafer is in the middle and glass wafers are bonded on both the upper and the lower side of SOI wafer. The SOI wafer consists of beam, mass and the movable electrode. The counter electrode and the capacitor gap are formed in the upper glass wafer. The lower glass wafer defines the beam vibration range. The two glass wafers encapsulates device, and keep the device operating under low pressure conditions.

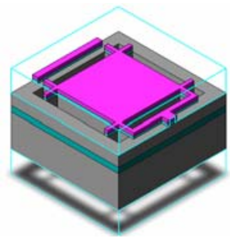


Figure 3 Energy harvester 3-D model

With the aid of the finite element software, the converter dimensions are designed with maximum energy conversion efficiency (Figure 4).

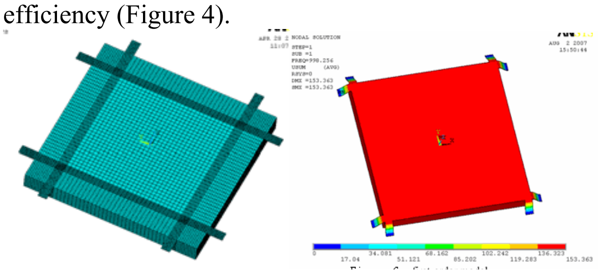


Figure 4. The part of SOI modal and first-order modal

Through the analyzing, the dimension of the energy harvester is ensured: beam 310×450×7 um, and mass 6×6×0.5 mm.

Table 1. Simulation Parameters in ANSYS

Parameter	density	Young's modulus	Poisson ratio	Element type
Value	2.33 kg/m3	1.65×1011 N·m-2	0.3	solid45

3. DEVICE

An integrated process of MEMS technology about SOI wafer and glass is showed by Figure 6. The process of he lower glass wafer is similar the upper glass wafer, so we just give the last process as showing on (g)sputter Al.

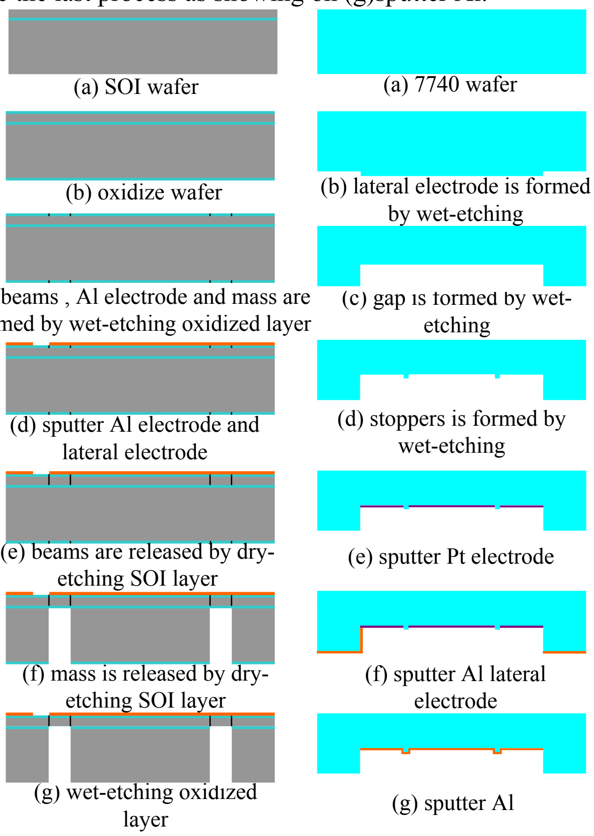


Figure 5. Process flow of SOI and 7740 wafer

Glass-Silicon-Glass triple stack anodic bonding is performed in two stages, which is showed by Figure 6. The first stage is a standard glass to silicon anodic bond under normal processing conditions. In order to protect the polished back side of the SOI wafer from potential scratch damage from the lower platen it is recommended that another only one side polished silicon wafer is placed under the SOI wafer to for protection. The setting parameters are given below:

Temperature 370°C
Voltage 800V

The second stage is bonding the second glass wafer to the first wafer pair. The second glass wafer should be placed on top of the silicon wafer of the bonded pair. As the first glass will be in contact with the metal of the lower platen, the silicon wafer is placed non polished side up on the lower platen.. The problem with triple stack bonding is that there is a large resistance in the first wafer pair, so it necessary to increase the voltage and temperature settings. The setting parameters are given below:

Temperature 370°C
Voltage 1200V

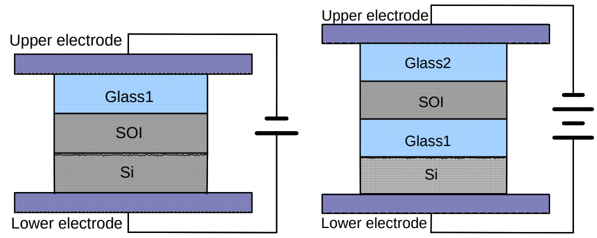


Figure. 6 The process of bonding

Ultimately, three wafers become sandwich-structure via anodic bonding under low pressure, displayed by Fig 7.

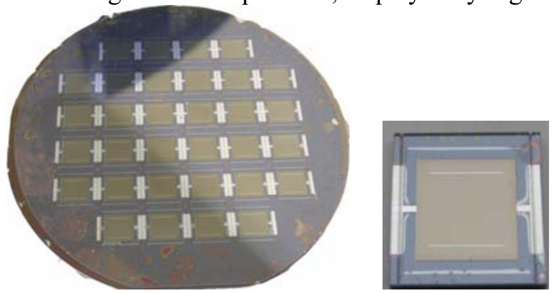


Figure 7. Sandwich-structure

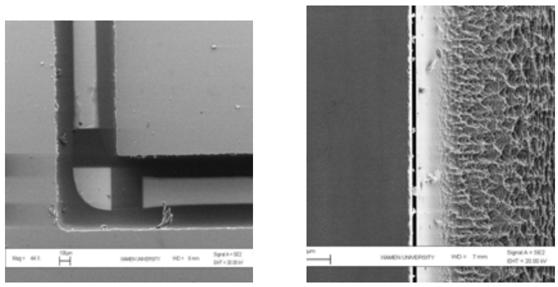


Figure 8. Beam and the distance between the movable and stable electrode SEM picture

4. CONCLUSIONS

A capacitive vibration-to-electrical energy harvester has been designed and optimized by using ANSYS simulation tool to meet the 1kHz variation available in environment. The eight-beam-structure after the dimension optimization results in the best performance of the capacitive harvester. The process flow has been developed and the prototype harvester was successfully fabricated in the Pen-Tung Sah MEMS research center of Xiamen University.

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