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# A self-excited micro cantilever biosensor actuated by PZT using the mass micro balancing technique

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**Abstract**

A micro biosensor, which can be applied to a Lab-On-a-Chip (LOC), is developed in order to detect biomaterials such as protein or DNA. The biomaterials are detected by mass micro-balancing technique, which measures the change of the resonant frequency of the sensor structure. The sensor structure consists of a micro cantilever actuated by piezoelectric PZT film. The PZT film is designed to act as both a sensor and an actuator. The geometry of the micro cantilever is determined so as to maximize the sensitivity of the sensor, and environmental effects such as added mass effect in liquid are also considered in the structural analysis. The micro cantilever is 100 μm in length, 30 μm in width and 5 μm in thickness, and the PZT film thickness and length are 2.5 and 50 μm, respectively. The first resonant frequency of the PZT micro cantilever is 1.2 ∼ 1.3 MHz. Lastly the fabricated micro-biosensor using the self-excited PZT-micro cantilever is tested by detecting the human insulin-anti human insulin binding protein, the poly T-sequence DNA, the K20-Thiol DNA and the K40-Thiol DNA in air.


*Keywords:* Micro cantilever; PZT; Mass micro balancing; Self-excitation; Oscillating circuit

## 1. Introduction

A micro cantilever is applied to various researches such as a chemical sensor, a mass sensor, a biosensor and so on. A chemical/biochemical sensor [1–3] detects chemical or biochemical material, a mass sensor [4–6] detects mass of specific material and a biosensor [7] measures interaction force of an antibody–antigen. Most of the sensors basically use the mass-micro balancing technique measuring change of resonant frequency due to attached target material on a micro cantilever, and the frequency shift is measured by a laser and position sensitive detector (PSD). This optical detection method is not proper to apply to a Lab-On-a-Chip (LOC) because many external hardware and equipment are needed.

A micro cantilever with piezoresistive layer implemented can be used to eliminate the optical system as was used in measuring adhesion force between an antibody and antigen [7,8]. Since the change of the electric resistance due to deformation is very small and the additional actuator is needed to excite the micro cantilever, the piezoelectric layer may be the best choice for the additional layer of a compact micro cantilever biosensor for a LOC using micro balancing technique.

In addition, when the micro cantilever sensor is operated in a liquid such as water, environmental effects like viscous and added mass effects become dominant. Since these effects reduce the resonant frequency drastically, the sensitivity is decreased in the case of the sensors using resonant frequency shifts.

The biosensor developed in this article is composed of a micro cantilever and a piezoelectric PZT film. The mass micro balancing technique is adopted and the micro cantilever is operated in its first resonant frequency by an oscillating circuit, and a biomaterial attached on end of the micro cantilever is detected by measuring the frequency change using a frequency counter. An optimal structure is sought by use of structural analyses and numerical simulations. The fabricated micro cantilever has 100 μm in length, 30 μm in width and 5 μm in thickness, and the length and thickness of the PZT film are 50 and 2.5 μm. Lastly the oscillating circuit is made and tested that the micro cantilever can be self-oscillated. And some biomaterials, which are the human insulin-anti human insulin binding protein, the

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poly T-sequence DNA, the K20-Thiol DNA and the K40-Thiol DNA, are detected by using the self-excited micro cantilever.

## 2. Fabrication of the PZT-micro cantilever

The length, width and thickness of the micro cantilever are 100 μm, 30 μm and 5 μm, respectively and the PZT film has a 2.5 μm thickness. The PZT-micro cantilever was fabricated by MEMS technique depicted in Fig. 1 and the fabrication processes were as follows: (a) $SiO_2$ was deposited by thermal oxidation on top of a SOI wafer to insulate electrically between the bottom electrode and the upper silicon of the wafer. A bottom electrode layer, Pt/Ti, was deposited by sputtering and a 2.5 μm thickness of PZT film was coated by the sol–gel method. And a top electrode layer, Pt, was deposited by sputtering on the PZT layer. (b) The top electrode was made by dry-etching using gas of Ar and $Cl_2$. (c) Using Ar, $Cl_2$ and $CF_4$ the PZT film was dry-etched. (d) The bottom electrode was made in the same way as the top electrode. (e) To insulate the top and bottom electrode an isolating layer, 5000 Å thick $SiO_2$, was constructed by ion-assisted deposition (IAD). (f) The isolator was dry-etched. (g) A contact pad, Au/Cr, was constructed by lift-off in order to connect the top electrode and measurement equipment. (h) $SiO_2$ which was deposited thermally to insulate the bottom electrode and silicon

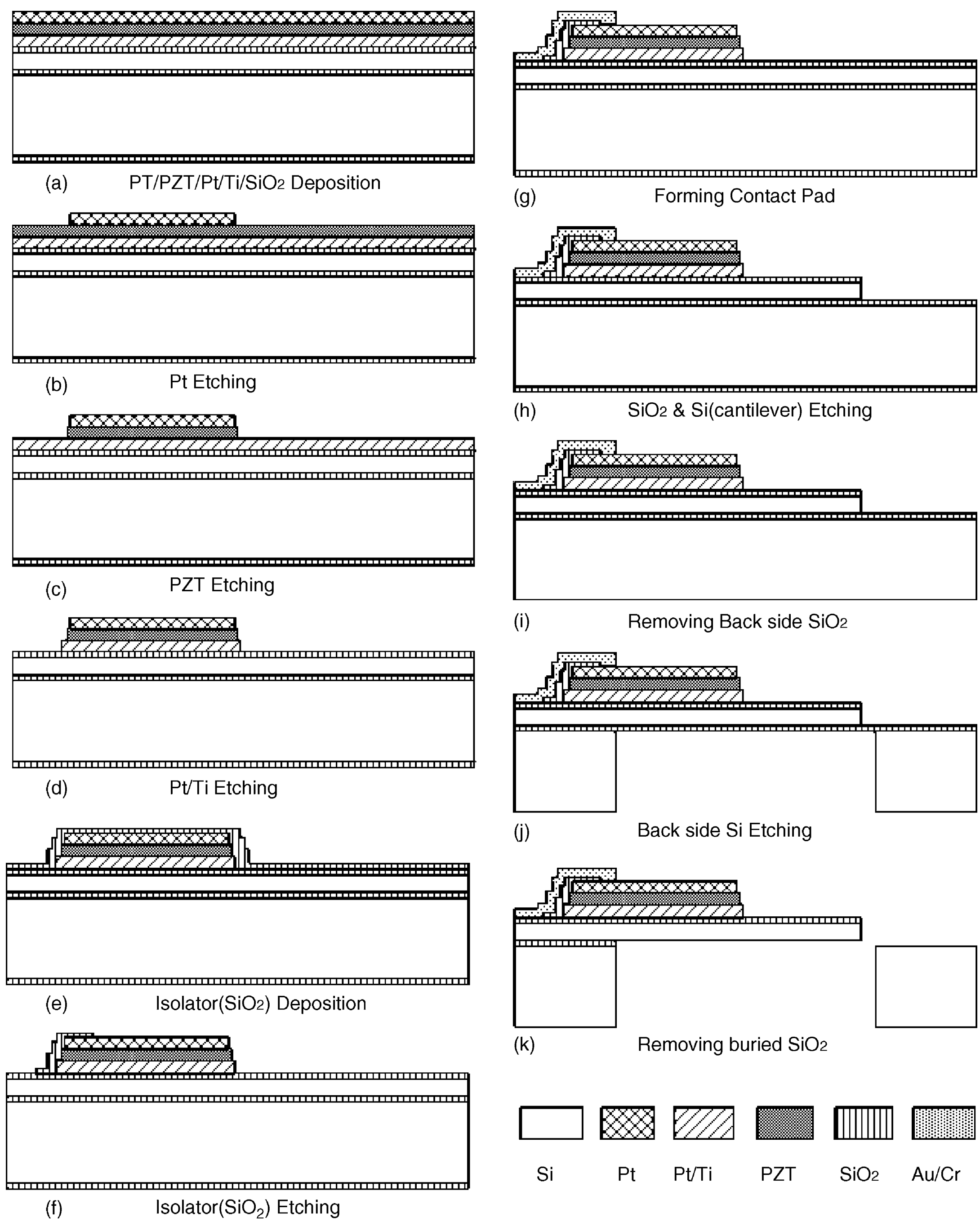


Fig. 1. Fabrication processes of the PZT-micro cantilever.