Parametric Study of Polyimide - Lead Zirconate Titanate Thin Film Cantilevers for Transducer Applications

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Abstract

Micro-Electro-Mechanical Systems (MEMS) technology is based in microelectronics fabrication methods. The wide variety of materials available in this technology delivers advantages such as miniaturization and multiple components on a single chip for integrated Microsystems. These mentioned systems could be more consistent, less expensive, smarter and also less invasive than traditional macroscopic components and systems that could potentially be replaced.
In this paper we investigate the deflection of micro cantilevers using the piezoelectric actuation mechanism. The piezoelectric effect is a reversible process, which exhibits the so-called direct effect (internal generation of electrical charges resulting from an applied mechanical force) and its reverse effect (internal generation of a mechanical strain when an electrical field is applied). Due to its versatility of thin-film processing, Lead Zirconate Titanate (PZT) was chosen for the design of this project. PZT is the most common piezoelectric ceramic in use today, which exhibits a high coupling coefficient. Both sputtering and sol-gel have been researched for MEMS as well as other electronic technologies for more than 30 years [1].
Typically piezoelectric actuators are designed as a cantilever beam or membrane consisting of a thin structural material in support of the structure with a ferroelectric film between a top and a bottom electrode, as shown in Fig. 1 a). This makes use of the d31 piezoelectric coefficient. The in-plane strain X1 in the piezoelectric film is induced by an external electric field E3 normal to the plane. When a voltage is applied to the electrodes, the piezoelectric film contracts laterally for E3 parallel to the remanent polarization (Pr) of the film, which makes the beam bend up. An interdigitated electrode can be used for a larger electric field and polarization in plane with the ferroelectric film, as shown in Figure 1 b). The induced strain X3 resulting from an in plane electrical field E3. This transverse piezoelectric strain bends the cantilever; this mode in use is the d33 mode. The d33 coefficient is about twice the d31 coefficient; therefore the expected deflection actuated by the d33 coefficient is larger [1].
The cantilevers are composed by three layers: PZT (piezoelectric material), Platinum (electrodes) and Zirconium Oxide as the buffer layer of the PZT film. COMSOL Multiphysics® was used in order to simulate the d33 mode and calculate the appropriate parameters of the interdigitated electrodes to obtain larger deflections (Figure 2). The 2D and 3D geometries were modeled using COMSOL Multiphysics® by defining parameters of interest such as: PZT thickness, electrode finger width, gap between the electrodes and the length of the cantilever. Using the Piezoelectric Devices interface, a parametric study was performed to study the

inverse piezoelectric effect in the cantilevers.
It is expected to find a trend from the parametric study results and obtain the optimal parameters of the interdigitated electrodes. A comparison of the d31 and d33 modes and 2D and 3D models deflection will be studied. The direct piezoelectric effect could also be used for sensing applications (i.e. Flow sensor, accelerometer, etc.).

Reference

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Figures used in the abstract

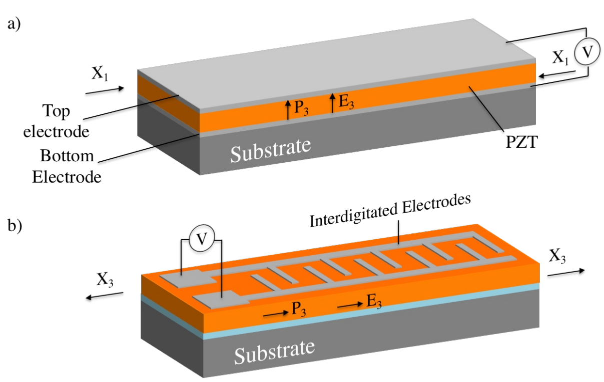

Figure 1: An schematic diagram of a cantilever actuated by a) d31 mode and b) d33 mode (drawings are not in any scale for demonstration purspose)

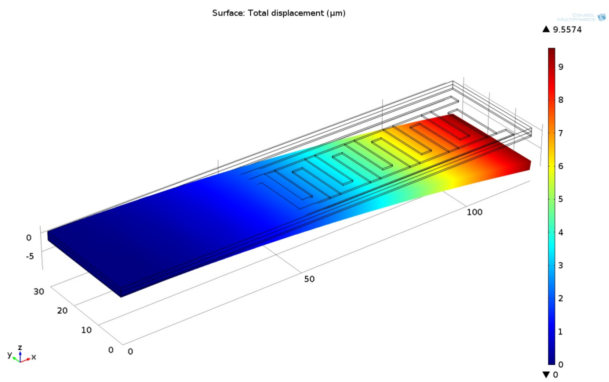

Figure 2: PZT-Polyimide Cantilever, interdigitated electrodes parameters: 3μm (electrode width), 3μm (gap), 1μm (PZT thickness).