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Abstract

Piezoelectric Layer Transfer Process for MEMS †

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Abstract: Piezoelectric MEMS devices were fabricated on 200 mm Si wafers using both deposited and layer-transferred PZT films. In both cases, the PZT-based devices showed ferroelectric and piezoelectric properties at the level of current state-of-the-art devices. The wafer-to-wafer piezoelectric layer transfer process that was developed can thus be useful to bypass the thermal budgeting issue associated with the high crystallization temperature of PZT (~700 °C). It allows the integration of PZT capacitors on any kind of layer stack or substrate, for either actuator or sensor applications.

Keywords: MEMS; actuator; sensor; piezoelectric; film transfer

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1. Introduction

Lead zirconate titanate, Pb(Zr,Ti)O_3 (PZT), is currently widely used across a broad range of MEMS applications, particularly for piezoelectric actuators. However, one of the constraints that limit its use in microsystems is its high crystallization temperature, which usually ranges from 500 °C to 700 °C and can be incompatible with some substrates like CMOS or certain materials such as some metals and polymers. We developed a technological process that allows transferring film stacks from silicon substrate to any other substrate. In this paper, we show the potential of this process for realizing MEMS structures typically used for actuator and sensor applications.

2. Materials and Methods

The technological process that allows transferring of piezoelectric PZT film stacks from silicon substrate to any other substrate is depicted in Figure 1 [1]. High quality PZT film is first grown on platinized Si wafer. The PZT donor wafer is then bonded to a host wafer (annealing up to 300 °C is optional and depends on type of bonding layer). Finally, the bonded wafers are mechanically separated at the lowest energy interface, which is Pt-SiO_2. The piezoelectric PZT stack on the host wafer is then considered ready to go through the technological integration process.

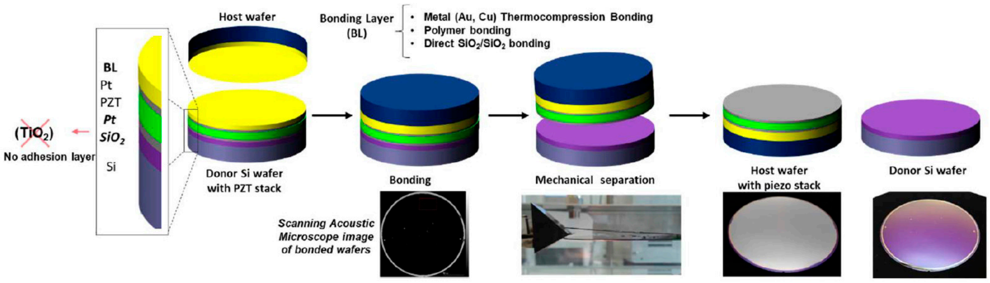

Figure 1. Wafer to wafer layer transfer process.

The piezoelectric PZT stack, either deposited or transferred (via Au-Au thermocompression and SiO_2-SiO_2 direct bonding) on 200 mm Si wafer covered with 5 µm thick poly

Si membrane, is eventually fully integrated into MEMS devices, such as cantilever beams and membranes (as illustrated in Figure 2), using a standard MEMS technological process (7 mask levels).

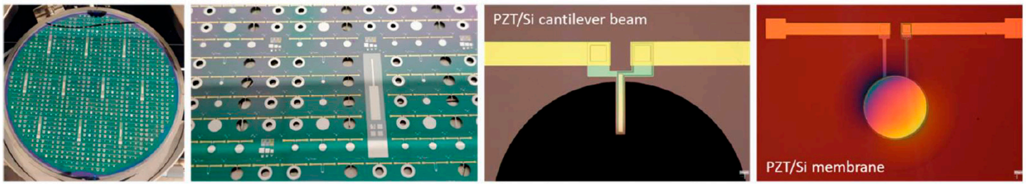

Figure 2. Photos of released piezoelectric MEMS structures fabricated using 200 mm Si technology.

3. Results

The dielectric, ferroelectric, and piezoelectric properties of PZT films were assessed using a double beam laser interferometer from aixACCT [2]. PZT piezoelectric behavior was almost the same regardless of how the PZT was deposited or reported, as illustrated by the displacement of the film under applied voltage (Figure 3a). The static deflection measurements of the MEMS structures under applied voltage were performed using Digital Holographic Microscopy (DHM) for the three types of PZT stack. Figure 3b shows the deflection vs voltage curves recorded for 500 µm long cantilever beams. Initial deflection is a function of the beam stress, and thus varies with the layer stacking. By normalizing the deflection, we show that the actuation performance is actually very similar in all three cases (Figure 3c).

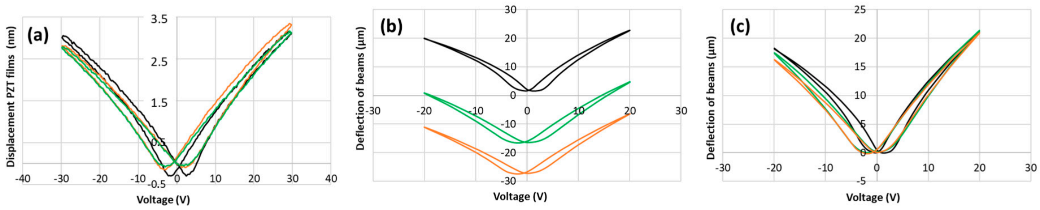

Figure 3. (**a**) Displacement of PZT films, and deflection curves of 500 µm long PZT beams (**b**) without and (**c**) with normalization of the deflection. For all 3 figures: PZT deposited (−), PZT reported via Au bonding (−), and PZT reported via SiO_2 bonding (−).

This process is of interest for integrating PZT films or other piezoelectrics, like KNN ($(K,Na)NbO_3$), on a CMOS substrate (process < 400 °C), or on a stack including a layer that does not tolerate the thermal budget necessary for the crystallization of the piezoelectric material.

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