proceedings

Abstract

Transparent PZT Capacitors on Glass for Actuating Applications †

Franklin Pavageau *, Christel Dieppedale, Kevin Benedetto, Christophe Licitra, Laurent Frey, Fabrice Casset and Gwenaël Le Rhun

CEA-Leti, Univ. Grenoble Alpes, F-38000 Grenoble, France; gwenael.le-rhun@cea.fr (G.L.R.)
* Correspondence: franklin.pvg.pro@gmail.com
† Presented at the XXXV EUROSENSORS Conference, Lecce, Italy, 10–13 September 2023.

Abstract: Fully integrated transparent ITO/PZT/ITO capacitors on glass were obtained thanks to a recently developed wafer-to-wafer layer-transfer process to bypass the thermal budget issue associated with the high crystallization temperature of PZT (~700 °C). The fabricated devices show an average transparency of around 80% (and up to 94%) in the visible spectrum thanks to the use of SiO_2 passivation acting as an anti-reflector and a transverse piezoelectric coefficient of up to 10.25 C/m^2, which is suitable for the actuating purpose. The actuation of a vibrating glass plate (3.12 cm × 3.12 cm) was highlighted using a PZT capacitor (35.9 mm^2) in agreement with the modeling.

Keywords: MEMS; actuator; piezoelectric; glass; transparent; PZT; surface functionalization

1. Introduction

Transparent piezoelectric thin-film stacks, mainly based on PZT, have been increasingly attracting attention in recent years for their potential use as transducers and actuators in various applications, such as photoacoustic imaging, haptics, acoustics, and, more generally, surface functionalization. However, the high temperature needed for getting optimal PZT films (reference piezoelectric material for actuation application) can be detrimental for common transparent electrodes such as ITO and glass substrates. In this paper, we present the ferroelectric and actuating performances of fully integrated transparent ITO/PZT/ITO capacitors indirectly obtained on glass.

2. Transparent Piezoelectric PZT Stack on Glass

The transparent piezoelectric stack on glass was obtained following a recently developed wafer-to-wafer layer-transfer process [1]. It allows bypassing the PZT growth issues related to high thermal budget. Indeed, the crystallization temperature of PZT (700 °C under O_2) can be harmful to ITO's electrical and optical performances, as well as the glass-substrate integrity. Briefly, state-of-the-art PZT film is grown by the sol–gel method on a platinized 200 mm Si wafer and covered with an ITO layer. The PZT wafer is then bonded to a glass wafer by SiO_2-SiO_2 direct bonding. The bonded wafers are mechanically separated at the lowest energy interface (Pt-SiO_2 ~ 1 J/m^2), and the top Pt layer is replaced by ITO film. To finish, the piezoelectric PZT stack was fully integrated into capacitor devices using the MEMS technological process (five mask levels).

Figure 1a shows the patterned PZT capacitor stack composed of ITO pads/SiO_2 passivation/ITO top electrode/PZT/ITO bottom electrode/SiO_2 bonding layer/glass. Transparency of the devices (up to 94%, enhanced by the passivation layer acting as an anti-reflective coating) is evidenced in Figure 1b by placing the transparent stack on a colored picture.

check for updates

Citation: Pavageau, F.; Dieppedale, C.; Benedetto, K.; Licitra, C.; Frey, L.; Casset, F.; Le Rhun, G. Transparent PZT Capacitors on Glass for Actuating Applications. *Proceedings* **2024**, *97*, 158. https://doi.org/10.3390/proceedings2024097158

Academic Editors: Pietro Siciliano and Luca Francioso

Published: 7 April 2024

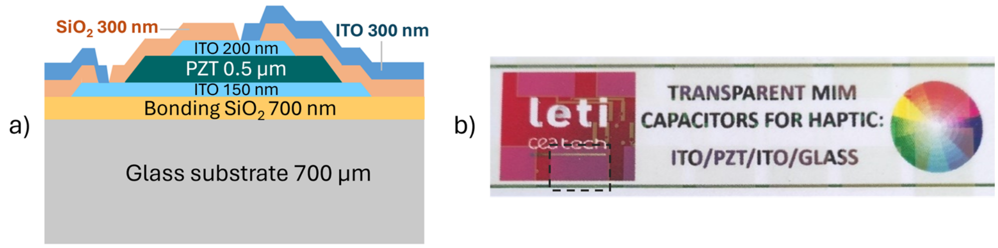

Figure 1. (**a**) Piezoelectric stack (5 mask levels integration). (**b**) Transparency of capacitors evidenced.

3. Piezoelectric Actuator Demonstration

The functionality of the capacitors was verified using the ferroelectric tester TF2000 associated with the double-beam laser interferometer (DBLI) from aixACCT. Typical hysteresis loops, characteristic of ferroelectrics, were obtained. The piezoelectric coefficient $d_{33,f}$ = 108 pm/V was extracted using DBLI. The transverse piezoelectric $e_{31,f}$, obtained using a dedicated aix 4PB system, reaches a value of 10.25 C/m^2, which is comparable to the state of the art. Then, a 3.12 × 3.12 cm^2 glass plate with a 35.9 mm^2 actuator in its center was designed using a finite-element method (FEM) model (Figure 2a). The dimensions of the device were chosen from the modal, and under actuation simulations, to obtain the maximum displacement amplitude at the resonance frequency, which is 4.6 kHz according to COMSOL Multiphysics software. Electromechanical measurements were performed using a POLYTEC laser vibrometer (MSA400) on the test device (Figure 2b). An electrical signal of 10 Vac was applied to the PZT actuator, and the out-of-plane velocity was measured at the center of the plate between 2 kHz and 7 kHz. Actuation of the glass plate at a resonant frequency of 4.375 kHz following the mode of interest was evidenced (Figure 2c). A reasonable deviation of about 4.9% with the simulated/theoretical frequency was observed, which could be explained by the uncertainties on the sample sawing, the stress exerted by the flexible connectors on the plate, and the adhesive tapes, which are not perfectly placed at the vibration nodes. A maximum dynamic displacement of 300 nm at the center of the plate was obtained by applying a 30 Vac sinus signal at 4.375 kHz. This result confirms the potential of our technology for realizing a transparent piezoelectric actuator.

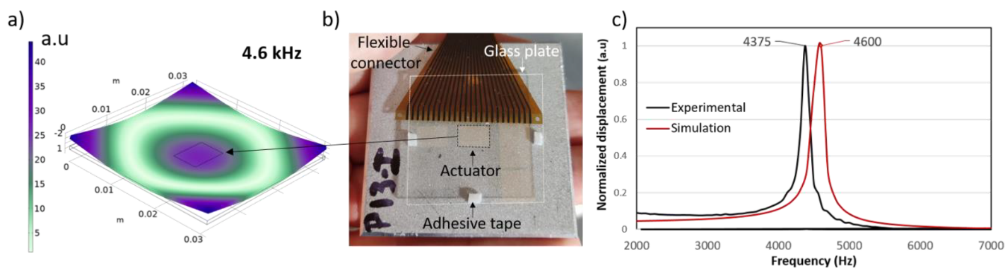

Figure 2. (**a**) Simulation of the plate's vibration mode. (**b**) Photography of the actuator device and its connector. (**c**) Comparison of the simulated resonance frequency (COMSOL) and the measured one.

Author Contributions: Conceptualization, G.L.R. and F.C.; methodology, F.P., F.C. and G.L.R.; software, F.P. and L.F.; validation, G.L.R. and F.C.; investigation, F.P., C.D., K.B. and C.L.; writing—original draft preparation, F.P. and G.L.R.; writing—review and editing, G.L.R. and F.C. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The data that support the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest: The authors declare no conflicts of interest.

Reference

1. Pavageau, F.; Dieppedale, C.; Perreau, P.; Liechti, R.; Hamelin, A.; Licitra, C.; Casset, F.; Le Rhun, G. Highly transparent piezoelectric PZT membranes for transducer applications. *Sens. Actuators Phys.* **2022**, *346*, 113866. [CrossRef]