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Microstructural Characterization of Thick PZT films on Cu Foils Deposited by Electrophoresis

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Piezoelectric and electrostrictive responses in poled and unpoled ferroelectric and relaxor ferroelectric compositions are of importance in transducers for converting electrical to mechanical impulses and vice-versa. Sensor applications make use of the very high piezoelectric constant dijk of the converse effect, which also permit efficient conversion of electrical to mechanical response [1]. One of the most important families of materials for piezoelectric applications is $Pb(Zr,Ti)O_3$ (PZT). The most widely studied composition of PZT lies at the boundary between the tetragonal and rhombohedral phases, known as the morphotropic phase boundary (MPB) and exhibits greatly enhanced dielectric and piezoelectric properties in bulk and thin film. In modern electronic applications, pyroelectric detectors, piezoelectric microsensors, and micromechanical pumps require the integration of PZT films into a variety of device structures. To get sufficiently large piezoelectric strains for optimization of the performance and reliability of the device, thick films in the thickness range of 5 - 50 µm are desired. On the other hand burying the device components within the substrate is of utmost importance for miniaturization [2]. In comparison to traditional surface mounted components embedded ones will free surface space for a higher functionality of the device, reduce solder points and increase device reliability. Additionally, to reduce the device costs the use of flexible copper foil as substrates is of particular interest. Its high conductivity and compatibility with printed circuit boards makes copper an attractive candidate substrate for embedded application. However, depositing PZT thick films on copper is not trivial, due to the conflict between the high temperature required to sinter PZT (~1150ºC) [3] and low melting temperature of Cu (~1050ºC), in addition to the easy oxidation of Cu. As a consequence the preparation of PZT thick films on Cu involves a complex route to decrease the ceramic sintering temperature and to control the oxygen partial pressure. So far, no successful deposition of PZT thick films on copper foils was reported.

This work is focused on the microstructural characterization of thick PZT films deposited by Electrophoretic Deposition (EPD) on Cu foils. Special focus is placed on the effect of sintering aids on the microstructure development of low temperature sintered PZT thick films. Commercial PZT powders with the morphotropic phase boundary composition were used for the electrophoretic deposition of thick films. Very fine PZT powders with an average particle size of 0.47 µm were mixed with 1 wt% of sintering aids of PbO and V_2O_5. As deposited green films were isostatically pressed at 200 MPa prior to the firing step. Sintering was conducted in an inert atmosphere from 800ºC to 900ºC for 30 min. Figure 1 depicts the interface microstructure of PZT films without sintering aids and sintered at 900ºC for 30min. As expected, SEM cross section views (fig.1a) clearly show that PZT thick films in which no sintering aids were added are porous, indicating that 900ºC is not high enough to densify PZT thick films. Meanwhile, TEM cross section images (fig. 1

b and c) show that the interface between PZT and Cu is not sharp and a layered structure was observed on Cu close to the film. EDS analysis revealed trace amounts of oxygen present in the Cu foil towards the film (fig.1d), while pure Cu was detected in the substrate away from the film (fig. 1e).

Figure 2 illustrates the interface microstructure of PZT films with 1wt% of sintering aids sintered at 850ºC for 30min. The SEM cross section (fig. 2a) clearly shows that although the sample was sintered at a lower temperature, the density is higher than the films prepared without sintering aids. With the addition of sintering aids, a glassy coating is observed on the surface of the grains (fig. 2b).

Figure 3a shows the surface morphology obtained by atomic force microscopy of PZT thick films with sintering aids sintered at 850ºC. A dense microstructure is observed with an average grain size of 0.8 μm. Ferroelectric domain switching and piezoelectric properties of PZT thick films were studied by piezo-force microscopy. Domain contrast is clearly revealed in fig. 3b) and a well defined piezo. d_{33} loop with dc field (fig. 3c) is depicted which indicates the good local piezoelectric response of these films. PZT thick films on copper foils were successfully deposited on Cu foils by EPD. Microstructural studies revealed that PZT film with 1wt% of sintering aids ($PbO+V_2O_5$) and sintered at 850ºC in inert atmosphere exhibit a sharp interface, dense microstructure and good piezoelectric response, suitable for applications as embedded components.

Acknowledgements

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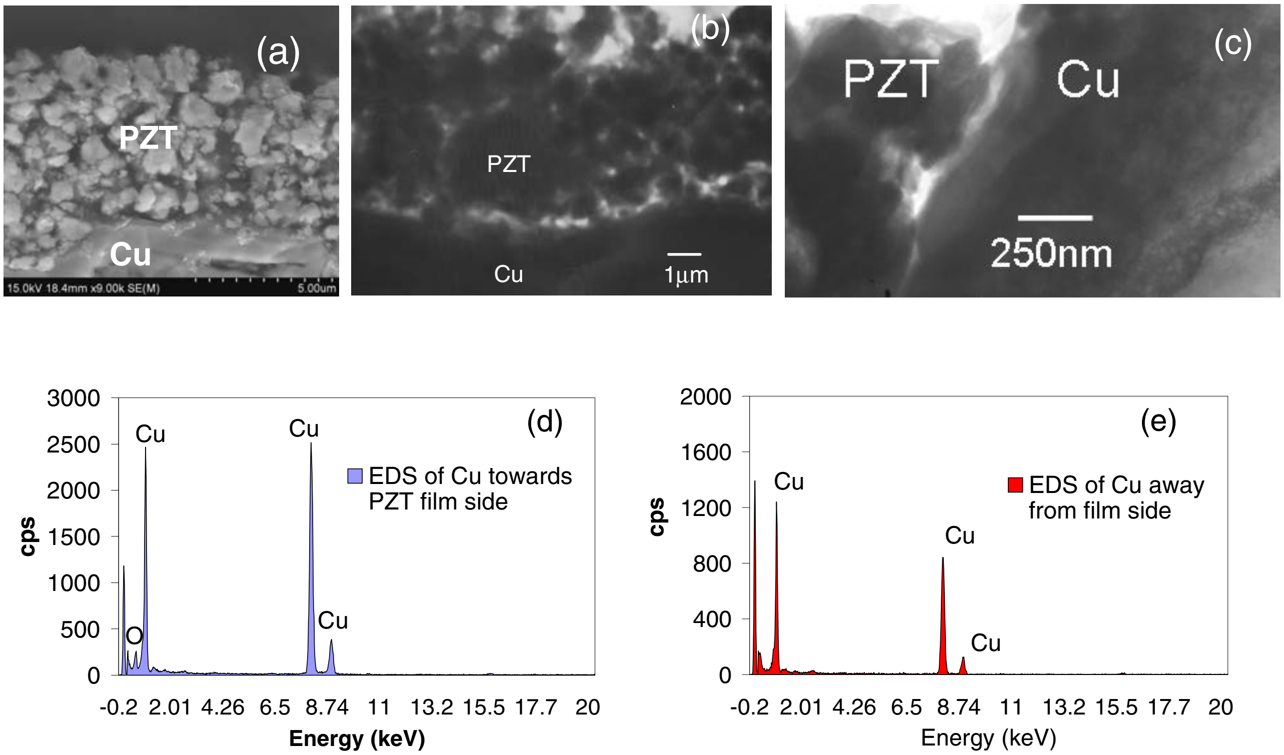

Figure 1 SEM cross section (a) and TEM cross section view (b, c) and EDS (d, e) of PZT film sintered at 900ºC without sintering aids.

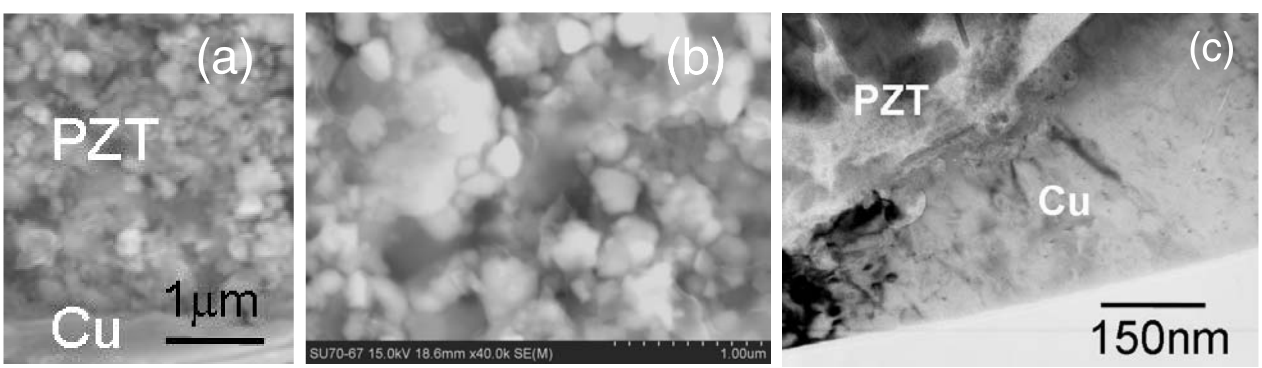

Figure 2 SEM cross section (a, b) and TEM cross section view (c) of PZT film sintered at 850ºC with 1wt% of sintering aids.

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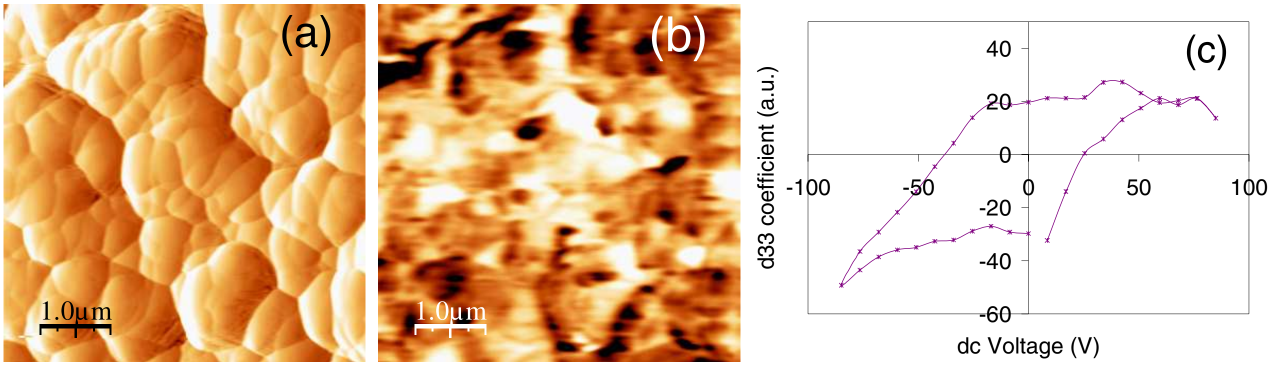

Figure 3 Surface morphology (a), piezo-response image (b) and local d33 hysteresis loop of PZT film sintered at 850ºC with 1wt% of sintering aids.

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