Characterization of Nanoembossed PZT Ferroelectric Films

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The development of miniaturized ferroelectric field effect transistors (FeFETs) and random access memories (FeRAMs) has called for fabrication of high-quality ferroelectric nanostructures. How to retain excellent ferroelectricity in nanoscale patterned structures posts a great challenge, as the small thickness of ultra thin films as well as the damages and defects introduced by the conventional photo and e-beam lithography could drastically degrade the ferroelectric properties. Better controlling the quality of the ultrathin ferroelectric films and alternative patterning techniques are, therefore, highly required.

In this paper, we apply nanoembossing technique to fabricate PZT nanostructures and investigate the influence of the embossing process on the ferroelectric properties. Figure 1 shows the schematics of the nanoembossing process and the electric test structure. Thin $Pb(Zr_{0.3},Ti_{0.7})O_3$ films were prepared on $Pt/Ti/SiO_2/Si$ substrates by the sol-gel method. The sol-gel films were then embossed under the same pressure at various temperatures using a silicon template with 500nm line width and 1um period. Pattern morphology including embossing depth and side-wall angle were measured from Scanning Electron Microscopy images (see Fig. 2). Figure 3 presents the dependence of the embossing depth on the pre-bake temperature with the pressure on at 120℃. The PZT film embossing depth decrease sharply at the pre-bake temperature above 120℃ and down to zero at 180℃. The electric characterization was carried out after putting top Au/Cr electrode pads on the films with annealing at 650℃ for 15 minutes. X-ray diffraction measurements were performed from PZT films after various processes. The unannealed film is mostly amorphous. Compared to the un-embossed PZT film, the (100) and (200) Brag peaks from the ferroelectric phase increase greatly for the embossed PZT films, while the (111) peak of the ferroelectric phase is reduced. The embossing temperature seems to have little effect on the film orientation. The hysteresis loops of the embossed region and the un-embossed region on the same PZT thin film (Fig. 5) shows larger polarization in the embossed region.

In conclusion, we have systematically investigated nanoembossing process of sel-gel PZT films. It was found that the orientation of the ferroelectric phase could be controlled by applying pressure on PZT films, while the embossing temperature has minor effect on it.

The un-embossed film is preferably (111) oriented, whereas the embossing process reorients the film more along (100) and thus enhances polarization of the PZT films.

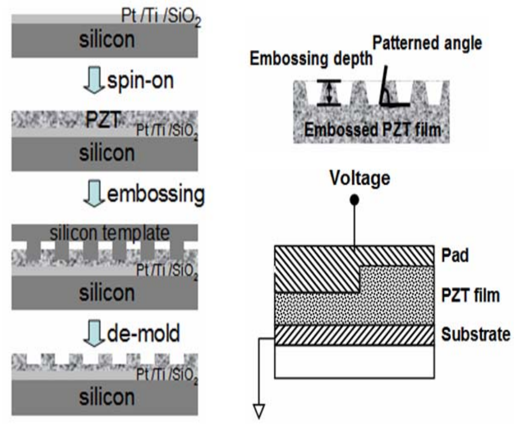

Figure 1. Schematics of the embossing process and the electric test structure.

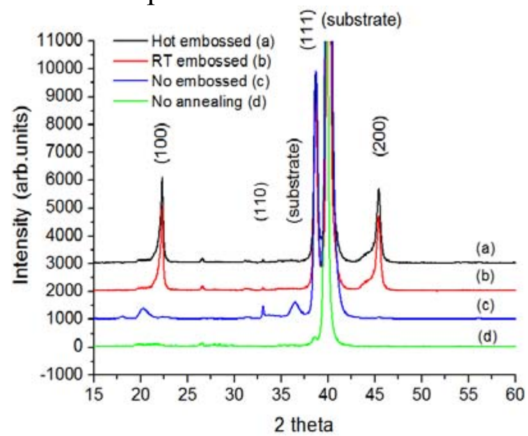

Figure 4. XRD patterns from hot room temperature embossed (b), without embossed (c), without annealing (d).

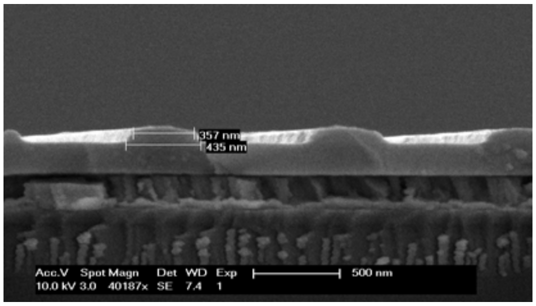

Figure 2. SEM images of hot-embossed PZT films on $Pt/Ti/SiO_2/Si$ with 90˚C prebake /120˚C post-bake before anneal.

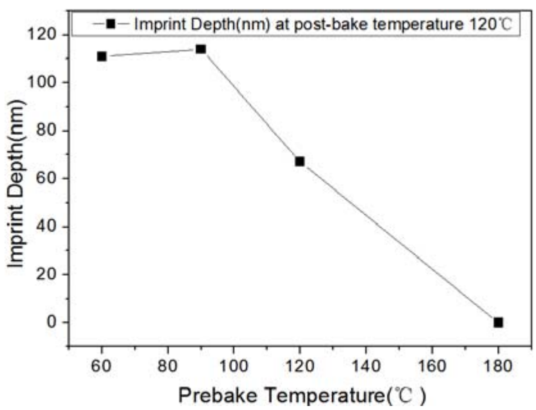

Figure 3. Embossing depth as function of prebake temperature.

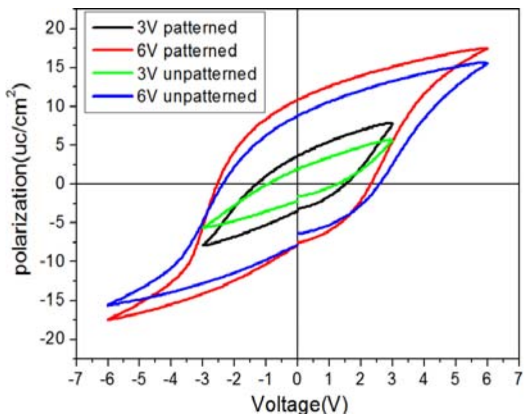

Figure 5. Hysteresis loops of the embossed and un-embossed regions with 500nm line width and 1um period template on the same PZT film under external voltage of 3 and 6V.