Fabrication of Complex Nanostructures of P(VDF-TrFE) by Dual Step Hot-embossing

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Ferroelectric nanostructures are of great interests owing to their promising applications in nanopiezotronic devices[1] and ultrahigh density ferroelectric memory.[2] Poly(vinylidenefluoride-trifluoroethylene), P(VDF-TrFE), as an organic ferroelectric polymer with excellent biocompatibility[3] can also find potential applications in both biology and medicine. However, such applications often require more complicated ferroelectric nanostructures.

In this work, a complex nanostructure in the P(VDF-TrFE) ferroelectric thin film was fabricated by a novel two-consecutive steps of hot-embossing process. Figure 1 illustrates the fabrication process of the dual step hot-embossing. P(VDF-TrFE) sol-gel was spin coated on the substrate with 100 nm Pt on Si to form a 300 nm thick P(VDF-TrFE) thin film followed by being prebaked on a hotplate at 100℃ for 3 minutes. The first hot-embossing process was undertaken at 137℃ under a pressure of about 5.8 MPa using a silicon template with a 500 nm line/spaces grating and the second hot-embossing was conducted at 137℃ under a slight lower pressure of about 5 MPa using another template with a dot array of 400 nm in diameter and 1 μm in pitch. Figure 2 presents the 3D atomic force microscope (AFM) topography of the complex nanostructure and the height profiles across the combined structure and the grating structure in P(VDF-TrFE). The height of the final pattern and the grating is about 100 nm and 35 nm, respectively, under the condition mentioned above. Figure 3 shows the hysteresis loop and butterfly loop measured by piezoresponse force microscope (PFM) on P(VDF-TrFE) nanostructure. Figure 3a indicates that the phase of the embossed thin film changes almost 180 degree. According to the piezoresponse equation, $A = d_{33}VQ$, where A is the amplitude and Q is the quality factor (~ 10 for P(VDF-TrFE)[4]), d_{33} of the embossed thin film calculated from Fig. 3b is about 75 pm/V, which agrees with the reported values between 48-81 pm/V[4] and demonstrates excellent ferroelectric and piezoelectric properties. A complex 3D nanostructure is successfully fabricated in the P(VDF-TrFE) ferroelectric thin film by dual step hot-embossing with excellent ferroelectric and piezoelectric properties.

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3 Mohammad A. Razian, and Matthew G. Pepper, IEEE Trans. Biomed. Eng.. **11**, 288 (2003).

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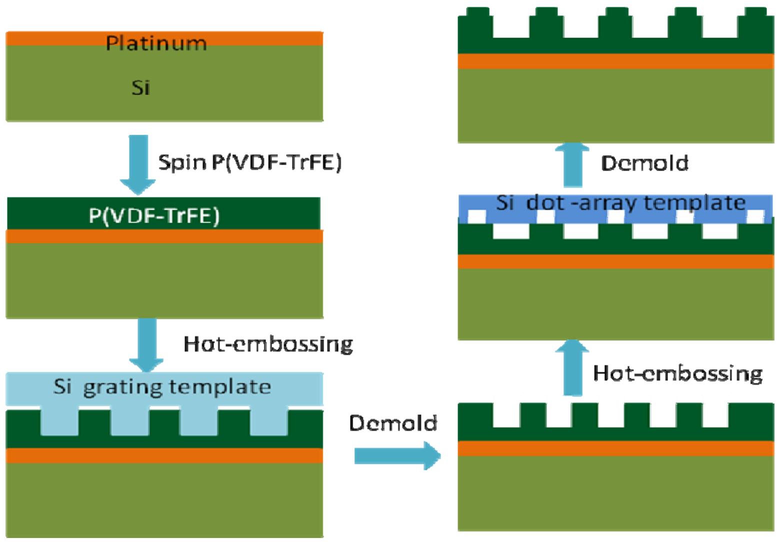

Figure 1. The fabrication process of twice hot-embossing.

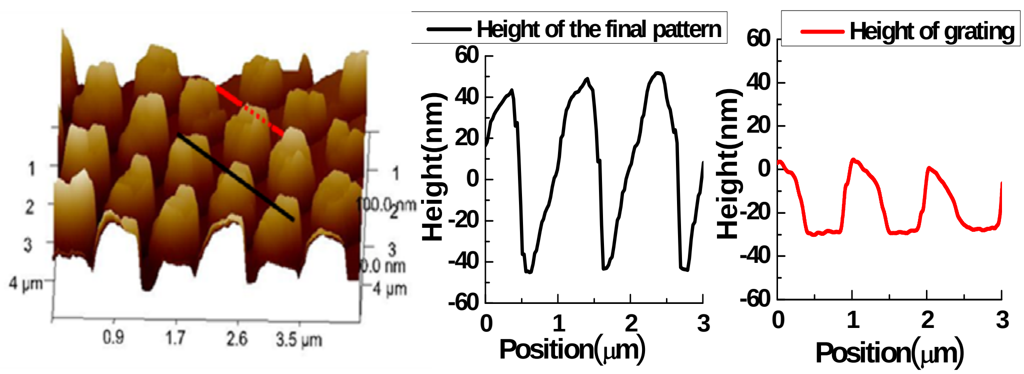

Figure 2. The 3D AFM topography (left) of the complex nanostructure of P(VDF-TrFE) thin film. The height profiles along the lines across the final nanostructure feature (middle) and the grating feature (right), respectively.

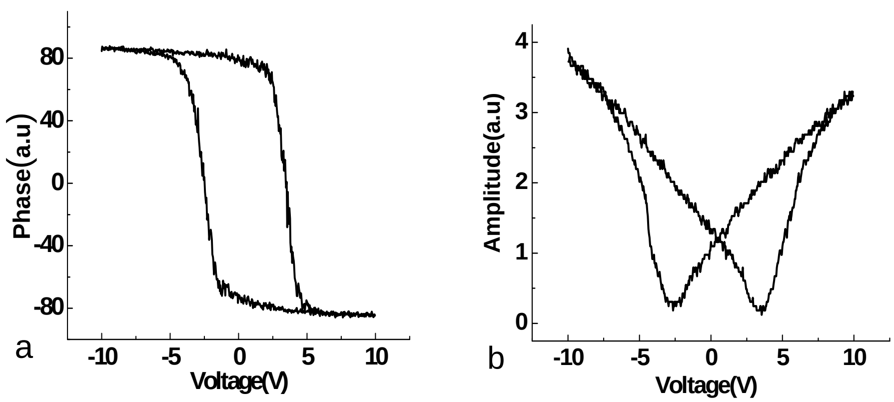

Figure 3. Ferroelectric hysteresis loop (a) and butterfly loop (b) of the PFM of the embossed P(VDF-TrFE) thin film.