Structural Phase and Polarization Pattering of Strained BFO Thin Films

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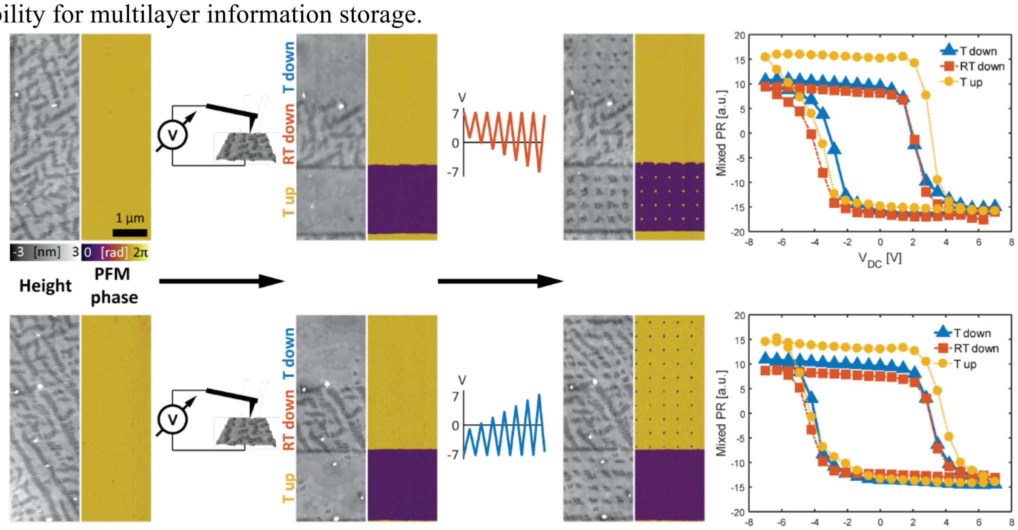
The multifunctionality of bismuth ferrite (BFO) arising from its electromechanical, magnetic, semiconducting and optical properties provides a wealth of applications such as magnetoelectric memory and spintronic devices, switchable diodes, nano- and microelectromechanical systems and integrated electro-optical and electro-acoustic elements.[1-3] Of particular interest are strained BFO thin films which consist of a mixture of crystallographic rhomboidal (R) and tetragonal (T) phases that exhibit pronounced differences in optical bandgaps and light absorption as well as in spontaneous magnetization and ferroelectric behavior.[1,2,4] It has been demonstrated that exposure to an electric field leads to phase transformations from as-grown mixed RT phases to T-like BFO or vice versa, allowing material properties to be modified.[1,2,4-6] However, to fully exploit the potential of multiphase BFO towards electrochromic devices and magnetoelectronic applications, deterministic control of the location and size of R and T phases is desirable. In this work, the impact of electric field history on the local distribution of induced R phases embedded in a T matrix and the corresponding electromechanical and conductivity behavior are explored using piezoresponse force microscopy and first order reversal curve (FORC) spectroscopy. By selectively applying dc voltages to a conductive tip while scanning across the sample surface, three areas were obtained: (i) +9 V: T-like phase, polarization "down", (ii) 0 V: pristine mixed RT phase, polarization "down" and (iii) -9 V: T-like phase, polarization "up". Furthermore, arrays of periodic RT phases formed along domain walls. Subsequently, FORC maps across these areas were acquired using two waveforms of opposite orientation to monitor piezoresponse and conductivity as a function of electric field. The initial structural phase and polarization as well as the polarity of the FORC waveform determine the resulting RT pattern, the ferroelectric properties and the conductivity (see figure). The coercive field is highest for the T up area and lowest for T down for both waveforms with direct implications for domain engineering. Although polarization switching and phase transitions occur in all areas, the conductivity behavior on T up differs from the other two areas by exhibiting conductivity for positive currents for positive voltages (~100 pA) and negative currents (~-200 pA) at negative voltages. In contrast, RT and T down areas only show conductivity at negative voltages (~-400 to -1000 pA). The obtained RT distribution ranges from RT stripes of >1 µm to localized R phases of ~100-200 nm width and may be further tunable. These findings provide a path to patterning areas with a specific density of localized R phases or alternating RT stripes and therefore allow the optical and magnetic properties to be tuned. Apart from the local crystallographic phases and corresponding topographic and material characteristics, polarization switching yields the possibility for multilayer information storage.



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