Reversible optical control of room temperature multiferroicity in $BiFeO_3$ thin films

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Manipulation of ferroic ordering via light stimuli is a fascinating topic for future technological developments, such as novel optoferroic devices for data storage and related optoelectronics applications. Thanks to the highly-interacting electrons in strongly correlated oxides, it become possible to achieve optical control of ferroic domain switching/wall motion through the interplays of lattice, charge, orbital, and spin degrees of freedom in these functional oxide materials with the participation of light stimuli. Bismuth ferrite ($BiFeO_3$, BFO), a classical multiferroic material, possesses both ferroelectric and antiferromagnetic properties as well as a weak ferromagnetic moment at room temperature. As suffering from a proper compressive strain, BFO becomes a mixed-phase system in which two phases (tetragonal-like and rhombohedral-like phase) coexist with a low energy barrier for phase transition. In this work, we present an optical method to manipulate multiple ferroic orders in mixed-phase $BiFeO_3$ thin film at room temperature. Scanning probe microscopy (SPM) is adapted to image the changes of surface topography, ferroelectric domain structure and charge distribution before and after the illumination of 532 nm CW laser. We observe that the focal laser beam drives mixed phase/T-phase BFO redistribution with ordered ferroelectric domain configuration. Micro-Raman spectroscopy is then employed to in-situ monitor the evolution behavior of mixed-phase BFO phonon during the light modulation process. Phase-field simulations indicate a light-driven

flexoelectric effect allows the targeted formation of ordered domains. We also demonstrate that the laser writing/erasing operation which switches between mixed phase and T-phase BFO fulfills the optical control of antiferromagnetic and ferroelectric properties. Through the elegant control of stimulation process, our results not only offer an efficient way to control the ferroic ordering of complex materials but also pave a promising route towards photonic modulation of multifunctionalities.