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Designing multifunctionality of laser processed thin films/nanostructures through chemical pressure and epitaxial strain

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Exhibiting a wide range of functional properties, from normal to relaxor ferroelectrics, lead-free perovskites have become very attractive for novel photovoltaic, photocatalytic, and electronic applications. One such example is bismuth ferrite ($BiFeO_3$-BFO), which is studied intensively for its photovoltaic and photocatalytic applications. BFO exhibits both ferroelectric and ferromagnetic properties, having high remnant ferroelectric polarization (95 $\mu C/cm^2$) and elevated Curie temperature (Tc ~ 1103 K). The band gap value of $BiFeO_3$ is Eg~2.71 eV, corresponding to maximum absorptivity at visible wavelengths. This value can be decreased by doping with Yttrium or Lanthanum. However, $BiFeO_3$, by far the most promising and investigated multiferroic material, has two major drawbacks: low dielectric susceptibility and high dielectric loss. We show how both the enhancement of dielectric constant and loss diminishing can be achieved through the joint effects of appropriate doping and epitaxial strain engineering. High resolution transmission electron microscopy (HR-TEM) and geometric phase analysis (GPA) evidenced nanostripe domains with alternating compressive and tensile strain in the Y-doped $BiFeO_3$ epitaxial thin films; the highly efficient response of these nanodomains to electrical stimulus is considered to be the mechanism responsible for the enhancements of dielectric properties.

The enhancement of dielectric and piezoelectric responses through strain engineering could also be evidenced for $(Ba_{1-x}Ca_x)(Zr_yTi_{1-y})O_3$ (BCZT) materials. Our recent studies have demonstrated the possibility to obtain lead-free $(Ba_{1-x}Ca_x)(Zr_yTi_{1-y})O_3$ (BCZT) thin films having very high dielectric permittivity and piezoelectric coefficients [1, 2]. Epitaxial thin films of BCTZ have been deposited on single-crystalline substrates with different lattice parameters ($SrTiO_3$, $SrLaAlO_4$, $LaAlO_3$, $GdScO_3$) by pulsed laser deposition. Apart from possessing high structural quality, the high dielectric permittivity of BCZT thin films was attributed to the enhanced susceptibility of the nanoscale domain configuration to a small external perturbation. The enhanced switching of such nanodomain configuration was probed by piezoforce microscopy, and values of up to 230 pm/V have been obtained for d33 piezoelectric coefficients.

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