MAR17-2016-009408

Abstract for an Invited Paper
for the MAR17 Meeting of
the American Physical Society

Tuning optical responses with strain in multiferroelectrics and ferroelectrics[1]

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The control of optical fields is usually achieved through the electro-optic or acousto-optic effect in single-crystal ferroelectric or polar compounds such as $LiNbO_3$ or quartz. In recent years, tremendous progress has been made in ferroelectric oxide thin film technology, a field which is now a strong driving force in areas such as electronics, spintronics and photovoltaics. Here, we investigate, both from experiments and first-principle techniques, if and how epitaxial strain engineering can tune the optical response of $BiFeO_3$ and $PbTiO_3$ thin films [Nat. Commun. 7, 10718(2016); Phys. Rev. Lett. 115, 267602 (2015)]. We find a very large variation of the optical index with strain in $BiFeO_3$, corresponding to an effective elasto-optic coefficient larger than that of quartz. We also observe there a concomitant strain-driven variation in light absorption, which is reminiscent of piezochromism and which we show can be manipulated by an electric field. This constitutes an electrochromic effect that is reversible, remanent and not driven by defects. We also predict large elasto-optic coefficients in two strain-driven monoclinic phases (of Pm and Cm symmetries) in $PbTiO_3$ films being under small tensile epitaxial strain. The origin of such large conversion between elastic and optical properties is further elucidated. Our findings broaden the potential of multiferroics towards photonics and thin film acousto-optic devices, and suggest exciting device opportunities arising from the coupling of ferroic, piezoelectric and optical responses.

[1]This work was supported by ONR Grant No. N00014-12-1-1034, and DARPA Grant No. HR0011-15-2-0038.