Terahertz Electro-Optic properties of $PbZr_{0.52}Ti_{0.48}O_3$ and $BaTiO_3$ ferroelectric thin films

Lei Chen[1], Yuan Zhang[2], Quan Guo[1], Dong-wen Zhang[1], Xiang-li Zhong[2], Xiao-wei Wang[1], Zhi-hui Lv[1], Chao Meng[1], Yin-dong Huang[1], Yi-lei Ge[1], and Jian-min Yuan[1]
[1]Department of Physics, National University of Defense Technology, Changsha 410073, China
[2]School of Materials Science and Engineering, Xiangtan University, Xiangtan 411105, China

***Abstract*—Electro-optic effects of $PbZr_{0.52}Ti_{0.48}O_3$(PZT) and $BaTiO_3$(BTO) ferroelectric thin films in the terahertz frequency range are studied with high-sensitive terahertz time-domain spectroscopy (THz-TDS). A linear response of PZT film with the linear electro-optic coefficient rc=6.73×10-11 m/V, and a quadratic response of BTO film with the second-order electro-optic coefficient Rc=1.42×10-17 m2/V2, are observed at the frequency of 1 terahertz under the applied static electric field less than 80 kV/cm. The calculation of rc and Rc based on the Landau-Devonshire free energy theory explains the different electro-optic effects of PZT and BTO well.**

I. Introduction

TERAHERTZ (THz) communication has been proposed as a promising way to further improve the transmission rate and capacity due to its higher carrier frequency.[1] Although THz communication has many advantages over optical fiber and microwave communications, it has not been widely used in our daily life due to the lack of well-developed devices, such as effective THz external modulators.[2] The ferroelectric thin films, with large nonlinear polarizabilities and electro-optic coefficients, are good candidates for ultrafast nonvolatile memory devices because of their extraordinary properties such as short time response to electric field,[3] deep polarization modulation and high detection bandwidth, especially its stable dielectric constant in the THz band. PZT is a very promising candidate for ferroelectric nonvolatile memory devices because of the low coercive field and large remanent polarizations. BTO in the tetragonal ferroelectric phase at room temperature is the simplest perovskite structure in ferroelectrics.

II. Results

In our work, we prepare PZT and BTO ferroelectric films by pulsed laser deposition on $SrTiO_3$ substrates and study their material characteristics and electro-optic effects in the THz frequency range by measuring the electric field induced birefringence with the THz-TDS. Obvious electro-optic effects are observed in the THz frequency range. The PZT film exhibits a linear electro-optic effect while a predominantly quadratic and slightly asymmetric electro-optic behavior is observed for the BTO film. We also observe an obvious ferroelectric hysteresis phenomenon in BTO film in our experiments. The calculated electro-optic coefficients of the film samples in the terahertz range by means of the Landau-Devonshire free energy theory agree well with the experimental measurements.[4] Our findings indicate that these two materials are potential candidates of THz modulators. (Accepted by Appl. Phys. Lett.)

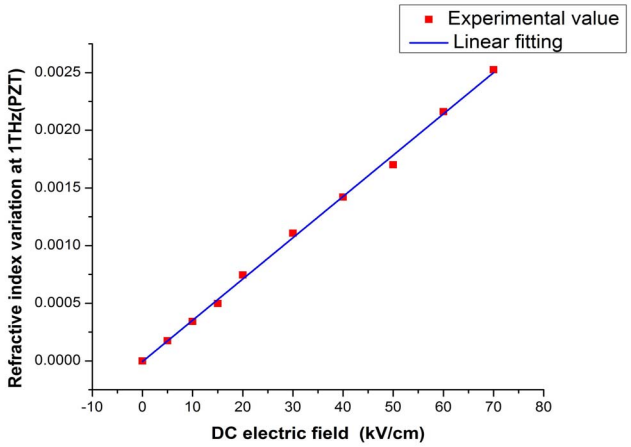

Fig. 1. Field induced birefringence of the (001)-oriented PZT thin film in an external electric field of up to 70 kV/cm. Red square dots are the experimental value. Blue line is the linear fitting curve.

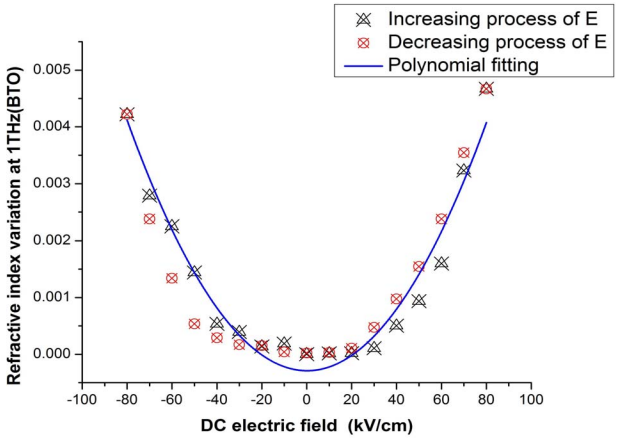

Fig. 2. Electro-optic response of the (001)-oriented BTO thin film in an external electric field of up to 80 kV/cm. Black triangle dots are experimental value of field increasing process. Red circle dots are experimental value of field decreasing process. Blue line is the polynomial fitting curve.

References

[1]. S. Koenig, D. Lopez-Diaz, J. Antes, et al, "Wireless sub-THz communication system with high data rate", Nat. Photonics, vol. 7, pp. 977-981, 5, 2013.
[2]. Wai Lam Chan, Hou-Tong Chen, Antoinette J. Taylor, et al, "A spatial light modulator for terahertz beams", Appl. Phys. Lett., vol. 94, pp. 213511, 2009.
[3]. Dal-Young Kim, Seung Eon Moon, Eun-Kyung Kim, et al, "Electro-optic characteristics of (001)-oriented $Ba_{0.6}Sr_{0.4}TiO_3$ thin films", Appl. Phys. Lett., vol. 82, pp. 1455, 2003.
[4]. N. A. Pertsev, A. G. Zembilgotov, and A. K. Tagantsev, "Effect of Mechanical Boundary Conditions on Phase Diagrams of Epitaxial Ferroelectric Thin Films", Phys. Rev. Lett., vol. 80, pp. 1988, March 1998.