Tristate ferroelectric memory effect in Fe, Nb co-doped $Bi_{1/2}(Na_{0.8}K_{0.2})_{1/2}TiO_3$ lead-free ceramics

H. Zhang, W. Jin, J. Zhou, J. Shen, T. Wang, W. Chen

State Key Laboratory of Advanced Technology for Materials Synthesis and Processing, School of Materials Science and Engineering, Wuhan University of Technology, Wuhan 430070, P. R. China
chenw@whut.edu.cn

Ferroelectric memory is currently regarded as one of the most promising candidate technologies for the future universal memories, due to its advantages including non-volatile, fast read/write speed, high endurance, low power consumption, etc. The high cost and the low data storage density are the main challenges in extensive applications of ferroelectric memories [1]. To develop ferroelectric memories with higher storage densities, multistate ferroelectric memory has attracted great research interests in recent years [2-4]. To date, most of the proposed concepts of multistate ferroelectric memory are involved with complex fabrication techniques. To meet with the low cost requirement, more facile ways to multistate ferroelectric memory are still remained to be explored.

Herein, we demonstrate the tristate ferroelectric memory effect in $Bi_{1/2}Na_{1/2}TiO_3$ (BNT)-based relaxor ferroelectrics. This tristate ferroelectric memory effect utilizes the presence of relaxor state, which serves as an intermediate polarization state between the two ferroelectric remanent states with opposite polarization directions. This is an inherent nature of some modified BNT-based materials, and therefore no complex fabrication techniques are required. We show that this tristate ferroelectric memory effect can be realized in conventionally sintered ceramics. To experimentally verified the tristate ferroelectric effect, the ferroelectric behavior of $Bi_{1/2}(Na_{0.8}K_{0.2})_{1/2}TiO_3$ (the MPB composition) ceramics is elaborately tailored by Fe, Nb co-doping. Ceramic sample in composition of $Bi_{1/2}(Na_{0.8}K_{0.2})_{1/2}(Ti_{0.955}Fe_{0.030}Nb_{0.015})O_3$ (BNKTFN) exhibits a slightly pinched *P-E* hysteresis loop with an obviously non-zero remanent polarization, which is the desired ferroelectric behavior for the tristate ferroelectric memory effect. A "write/read" experiment is performed on the BNKTFN ceramic sample. Results show that the tristate ferroelectric memory can be operated as proposed, and the programmability and retention ability are fairly good. We also propose a phenomenological model for the unique ferroelectric behavior of BNKTFN. This model successfully predicts the polarization change during the write/read operations, and therefore is thought to be useful in the future device design. This study provides a new potential facile way to the multistate ferroelectric memory technology.

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