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Enhanced Dielectric and Ferroelectric Properties in Holmium Substituted Stoichiometric and Non-Stoichiometric SBT Ferroelectric Ceramics

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Abstract : A large number of ferroelectric materials have been intensely investigated for applications in non-volatile ferroelectric random access memories (FeRAMs), piezoelectric transducers, actuators, pyroelectric sensors, high dielectric constant capacitors, etc. Bismuth layered ferroelectric materials such as Strontium Bismuth Tantalate (SBT) has attracted a lot of attention due to low leakage current, high remnant polarization and high fatigue endurance up to 1012 switching cycles. However, pure SBT suffers from various major limitations such as high dielectric loss, low remnant polarization values, high processing temperature, bismuth volatilization, etc. Significant efforts have been made to improve the dielectric and ferroelectric properties of this compound. Firstly, it has been reported that electrical properties vary with the Sr/ Bi content ratio in the SrBi2Ta2O9 compsition i.e. non-stoichiometric compositions with Sr-deficient / Bi excess content have higher remnant polarization values than stoichiometic SBT compositions. With the objective to improve structural, dielectric, ferroelectric and piezoelectric properties of SBT compound, rare earth holmium (Ho3+) was chosen as a donor cation for substitution onto the Bi2O2 layer. Moreover, hardly any report on holmium substitution in stoichiometric SrBi2Ta2O9 and non-stoichiometric Sr0.8Bi2.2Ta2O9 compositions were available in the literature. The holmium substituted SrBi2-xHoxTa2O9 (x= 0.00-2.0) and Sr0.8Bi2.2Ta2O9 (x=0.0 and 0.01) compositions were synthesized by the solid state reaction method. The synthesized specimens were characterized for their structural and electrical properties. X-ray diffractograms reveal single phase layered perovskite structure formation for holmium content in stoichiometric SBT samples up to x ≤ 0.1. The granular morphology of the samples was investigated using scanning electron microscope (Hitachi, S-3700 N). The dielectric measurements were carried out using a precision LCR meter (Agilent 4284A) operating at oscillation amplitude of 1V. The variation of dielectric constant with temperature shows that the Curie temperature (Tc) decreases on increasing the holmium content. The specimen with x=2.0 i.e. the bismuth free specimen, has very low dielectric constant and does not show any appreciable variation with temperature. The dielectric loss reduces significantly with holmium substitution. The polarization–electric field (P–E) hysteresis loops were recorded using a P–E loop tracer based on Sawyer–Tower circuit. It is observed that the ferroelectric property improve with Ho substitution. Holmium substituted specimen exhibits enhanced value of remnant polarization (Pr= 9.22 μC/cm²) as compared to holmium free specimen (Pr= 2.55 μC/cm²). Piezoelectric co-efficient (d33 values) was measured using a piezo meter system (Piezo Test PM300). It is observed that holmium substitution enhances piezoelectric coefficient. Further, the optimized holmium content (x=0.01) in stoichiometric SrBi2-xHoxTa2O9 composition has been substituted in non-stoichiometric Sr0.8Bi2.2Ta2O9 composition to obtain further enhanced structural and electrical characteristics. It is expected that a new class of ferroelectric materials i.e. Rare Earth Layered Structured Ferroelectrics (RLSF) derived from Bismuth Layered Structured Ferroelectrics (BLSF) will generate which can be used to replace static (SRAM) and dynamic (DRAM) random access memories with ferroelectric random access memories (FeRAMS).

Keywords : dielectrics, ferroelectrics, piezoelectrics, strontium bismuth tantalate
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