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Improved ferroelectric, magnetic and photovoltaic properties of Pr doped multiferroic bismuth ferrites for photovoltaic application

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ABSTRACT

Multiferroic $Bi_{1-x}Pr_xFeO_3$ (x = 0.0, 0.05, 0.10, 0.15, 0.20) ceramic samples have been synthesized by sol-gel method. A detailed investigation has been made on structural, magnetic, electrical, optical and photovoltaic properties of Pr doped bismuth ferrites. A structural phase transition has been observed from (R3c) rhombohedral for pristine sample $BiFeO_3$ to (Pnma phase) orthorhombic structure for $Bi_{0.85}Pr_{0.15}FeO_3$ sample. A coexistence of (R3c) rhombohedral and (Pnma) orthorhombic phases were observed for $0.05 < x \le 0.15$ samples. It is observed that the dielectric properties depend on Pr percentage in BFO. The values of dielectric constants for BFO, $\varepsilon' = 64.21$ and $\varepsilon'' = 9.09$ have been increased with Pr doping and maximum for Pr = 0.20 sample with values, $\varepsilon' = 111.79$ and $\varepsilon'' = 55.79$ at 100 Hz. The magnetization value 0.24 emu/g for BFO increases with Pr doping to maximum value 0.50 emu/g for $Bi_{0.8}Pr_{0.2}FeO_3$ sample. The P-E loop study of the samples shows the modified ferroelectric behavior with Pr doping. The enhanced ferroelectric properties show increase in photocurrent upon illumination of light. Energy band gap value Eg = 2.44 eV for BFO, decreases with Pr doping and minimum value, Eg = 2.27 eV for Pr = 0.15 sample. The improved ferroelectric, magnetic and photovoltaic properties of Pr doped bismuth ferrites offer a new application in ferroelectric/multiferroic based photovoltaic devices.

Introduction

Multiferroics is the class of the materials which exhibits two or more ferroic order simultaneously. These materials have been huge interest due to coexistence of ferroelectric and magnetic order simultaneously in the single-phase compound. Coupling of their electric and magnetic ordering allows us to control magnetic properties of material by an applied electric field and vice versa. This magnetoelectric coupling opens a new path for technological potential applications in information storage devices, magnetoelectric sensor devices etc. Among all single phase multiferroic materials, bismuth ferrite is the only single phase multiferroic compound with high ferroelectric Curie temperature (T_C = 1103 K) and Neel temperature (T_N = 643 K) [1–3]. BFO is not only attracted great attention because of their magnetoelectric coupling but also attracts attention due to photovoltaic applications because of its smaller band gap (2.16 eV) which lies within the visible light range [4–6]. BFO has a rhomboherally distorted perovskite type structure with symmetry space group R3c. BFO has large polarization due to its distorted perovskite structure. It has been reported that in non-centrosymmetric ferroelectric crystal a photocurrent can be generated which can be utilized for electrical energy production [7,8].

Today, solar cell production is largely dominated by crystalline silicon modules. Due to the relatively high cost of silicon wafers used in solar cell and low power conversion efficiency, there is major issue of power harvesting. Therefore, ferroelectric materials based solar energy harvesting is one of the latest additions among renewable energy sources and this research area is known as ferroelectric photovoltaic (FEPV). A schematic presentation of ferroelectric/multiferroic photovoltaic device and its working principle is given in Fig. 1. The photovoltage in ferroelectrics depends on remnant polarization, domain-walls, interface between FE-electrodes and Schottky, intensity of incident light, absorption coefficient and band-gap. An efficient and cost-effective strategy to manufacture perovskite, exhibited a maximum efficiency of 20.2–23%, which is one of the best performances in perovskite solar cells [9–11]. Low band gap (in visible spectrum) ferroelectric materials are promising in energy devices. Low band gap BFO with room temperature ferroelectric properties is a key factor for future solar cell applications. In this work, we synthesize Pr doped $BiFeO_3$

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