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Investigation of Dielectric and Ferroelectric Properties of Titanium Doped $AgNbO_3$ Ceramic

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Abstract: The electrical properties of the titanium doped $AgNbO_3$ system are defined in this paper. In the modified system, doping moderately replaced Nb^{5+} with Ti^{4+} ion where the ceramics are prepared using solid-state reaction technique. The dielectric characteristics were examined at frequencies ranging from 1 kHz to 100 kHz. The dielectric value of the modified systems increased substantially while the P-E curve emerged with a value of relatively increased spontaneous polarization.

Keywords: $Ag(Nb,Ti)O_3$; $AgNbO_3$; Dielectric properties; Ferroelectric properties;

Introduction

Silver niobate ($AgNbO_3$) is most exciting ferroelectric material, which has a polarization value of 52 µC cm^{-2} (Fu et al. 2007) has been extensively studied as a parent substance for electronic applications (Lines et al. 2001). At room temperature, the $AgNbO_3$ has skewed perovskite structure exhibits 6 reversible transitions in phase related to structural change, as confirmed by the dielectric dispersion. The number of multiple phase transitions associated with structural change in $AgNbO_3$ is due to the cations ordering i.e. A-site (Ag) and B-site (Nb) (Sciau et al. 2004; Levin et al. 2009). A previously supported result of the centrosymmetric Pbcm structure, which specifies antiferroelectricity in $AgNbO_3$, was later surpassed by groups of researchers who emphasized the $Pmc2_1$ structure to explain ferroelectricity in $AgNbO_3$ (Yashima et al. 2011; Chang et al. 2012). In perovskite structure of $AgNbO_3$, off centering A-site and B-site cations can be seen, which show strong A-O bonding covalency. According to previous theoretical research the Nb-site of $AgNbO_3$ has ferroelectric ordering, while the Ag-site atom has antiferroelectric ordering. As a base material, a lot of modifications have been done on $AgNbO_3$, where monovalent and pentavalent ions are doped into the Ag & Nb site, respectively. In this present work, we modified the $AgNbO_3$ system with heterovalent titanium (Ti^{4+}) cations and examine the electrical properties of the modified system which is expected to be helpful for basic research and application.

Experimental Procedures

Solid-state reaction technique is used for preparation of the samples. Powdered silver oxide Ag_2O (99.5%), niobium pentaoxide Nb_2O_5 (99.99%) and titanium dioxide TiO_2 (99.99%) were used as a base materials. The lower molecular weight quantity of TiO_2 (x = 0.02, 0.04) was used for modified $Ag(Nb.Ta)O_3$ system. All the materials first dried at 200 ˚C for 2 hrs to remove moisture and weighted in stoichiometric ratio. In next step all the materials manually mixed for 6 hrs and calcined at 850 ˚C for 6 hrs. The calcined powder pressed into 10mm pallets and sintered for 2 hrs at 1050 ˚C. XRD is used to characterize phase and crystallinity while SEM reveals the surface topography of the prepared samples. Dielectric permeability (ε) and Deviations in loss tangent (tan δ) were measured for distinct frequency ranges.

Result and Discussion

Structural Analysis

The XRD pattern are well correspond to orthorhombic $AgNbO_3$ verifying the emergence of requisite phases (Li et al. 2009; Shu et al.2010; Dong et al. 2014; Yang et al. 2015). The relocation of the peak intensity indicates that titanium was properly placed at the target destination. Fig.1 depicts the XRD patterns of the synthesized samples. Tiny marks are recognized as secondary phases which are inevitable regardless of synthesis conditions (Kravchenko et al. 2011).

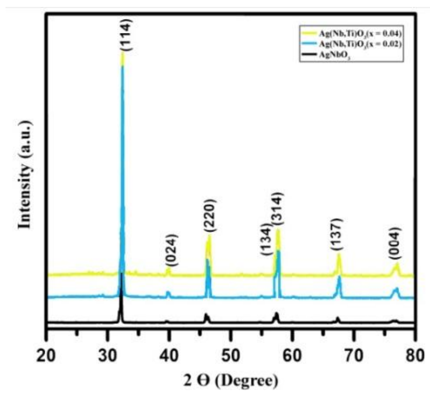

Fig. 1. The XRD graph of the titanium modified $AgNbO_3$.

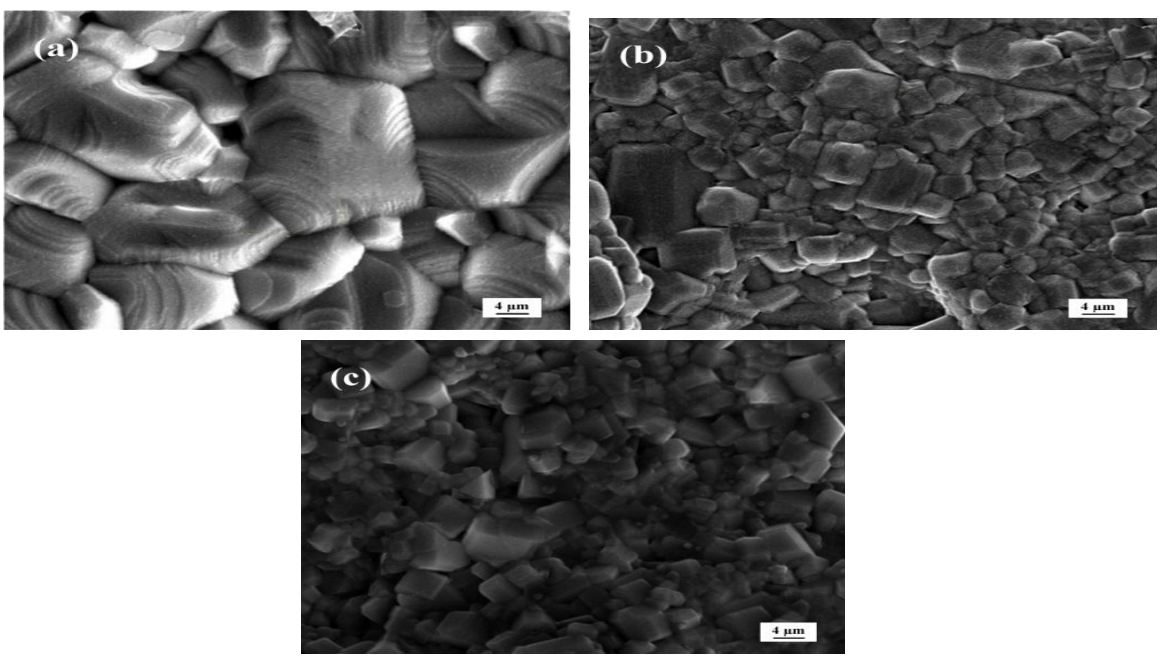

Fig. 2. The SEM image of (a) $AgNbO_3$, (b) $Ag(Nb,Ti)O_3$ (x = 0.02) and (c) $Ag(Nb,Ti)O_3$ (x = 0.04)

Titanium replacement has resulted in a reduction in grain size. Fig.2 demonstrates the SEM image of $AgNbO_3$ and its modified system. The particles in the $AgNbO_3$ sample are polyhedrons that scatter

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non-uniform and vary in size from 1.2µm to 5µm. The modified system exhibits non - uniform grain distribution from nano to micro level were grain structure shifted to cube or cuboid form.

Dielectric and Ferroelectric study

The dielectric dispersion and loss tangent for the modified system are shown in Fig.3. Four dielectric irregularities observed at 80 °C, 265 °C, 350 °C and 386 °C. The ferroelectric transition temperature noted near at 70 °C (Kania & Miga 2001; Hu et al.2006; Fu et al. 2009; Khan et al. 2012). According to previous report, the Ag^{1+} ion concentrations influence the variation of the ferroelectric transition temperature peak (Kania et al. 2014).

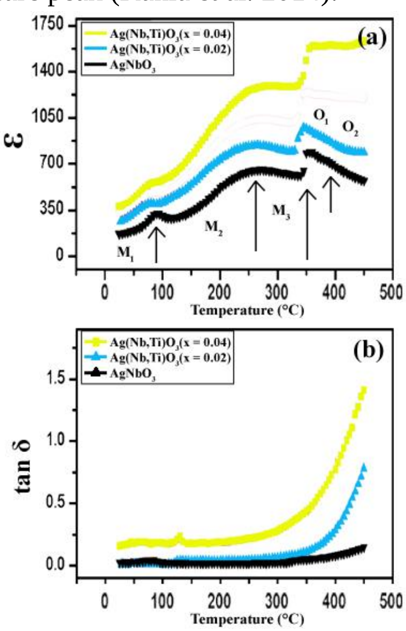

Fig. 3. (a) Dielectric dispersion (b) loss tangent of the titanium modified $AgNbO_3$ at 100 kHz frequency.

The dielectric characteristics of the modified systems show a noticeable improvement. The dielectric irregularity at low (T_C^{FE}) and high (T_C^{AFE}) temperature shifts to the lower and higher temperatures, respectively. The titanium modification increased the dielectric loss observed in increasing rate above the Curie point (T_C^{AFE}) and far below the specified point.

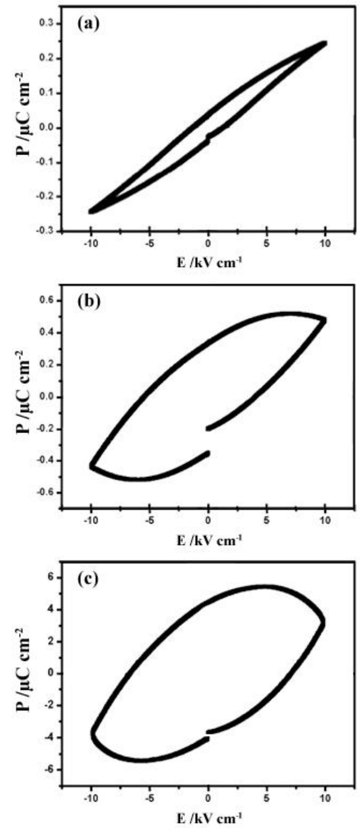

Fig.4. Hysteresis loop of (a) $AgNbO_3$, (b) $Ag(Nb,Ti)O_3$ (x = 0.02) and (c) $Ag(Nb,Ti)O_3$ (x = 0.04) for applied field of 10 kV.

The P – E graph of $AgNbO_3$ and its modified system is shown in the Fig.4. The titanium modification has altered the loop nature. As concentration increases, the slope in the maximum voltage field is continuously rounded and achieves a loss function that increases dielectric constant and polarization.

Conclusion

The titanium modified $AgNbO_3$ system was successfully prepared by solid-state reaction technique where Nb^{5+} is replaced by Ti^{4+} ion. Doping had a major impact on electrical properties of the system. The dielectric value notably increases with an increase in polarization. Furthermore, because of its enhanced electrical properties, the titanium doped $AgNbO_3$ ceramics is a versatile material for electro-optic applications.

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