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Effect of Li on the Dielectric Properties of $Bi_{2-x}Li_xPb_{0.3}Sr_2Ca_2Cu_3O_y$ Compound

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This work was performed to investigate the effect of Li substitution on the dielectric properties of $Bi_{2-x}Li_xPb_{0.3}Sr_2Ca_2Cu_3O_y$ compound with $x = 0$, 0.1, and 0.3. The samples were prepared by using a solid state reaction method. X-ray diffraction analysis showed an orthorhombic structure for all the samples. The dielectric properties for the samples such as AC conductivity, dielectric constant, and loss of factor as a function of frequency in a range (1000 Hz–5 MHz) were determined. The values of AC conductivity remained constant till a certain value of frequencies, and then increased at higher frequencies. The dielectric constants and the dielectric loss of the samples were found to be strongly dependent on the frequency of the applied field, as well as on the Li concentration.

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PACS/topics: dielectric properties, Bi-based superconductors, Li substitution

1. Introduction

The study of dielectric properties and AC-conductivity of the materials at different frequencies and temperatures can give useful facts about the conduction and polarization mechanisms. The conduction mechanisms of the diversity of electronic devices depend onto several parameters such as fabrication conditions, doping concentration and impurity interface states [1, 2]. Several attempts were carried out by scientists and engineers to develop new materials with unusual properties, to be used in the advanced electronic devices. Materials based on the perovskite structure such as cuprate superconductors exhibit a wide range of unusual properties. One of the most important superconductor is $Bi_2Sr_2Ca_2Cu_3O_y$, which has had three $Cu–O_2$ planes sandwiched between Bi–O bilayers. The two insulating Bi–O can act as charge reservoirs for hole or electron to the three $Cu–O_2$ layers [3]. The charge reservoir layer, grain-boundaries, impurities, and voids behave as dielectric media, which can be polarized by displacing the charge carriers from their equilibrium position with external applied field [4]. Although these materials have been characterized as superconductors, there has been little work on their dielectric properties. In this research we try to investigate the effect of partial substitution of Li on Bi sites on the dielectrical properties of the samples.

2. Materials and equipment

$Bi_{2-x}Li_xPb_{0.3}Sr_2Ca_2Cu_3O_y$ samples (with $x = 0.0$, 0.1, and 0.3) were synthesized by the solid state reaction method. Molar ratios of the high purity powders of $Bi_2(CO_3)_3$, Li_2CO_3, Pb_3O_4, $Sr(NO_3)_2$, CaO, and CuO were well mixed. The mixture was calcined in air at 800 °C for 24 h. The powder was pressed into pellets and was sintered in air by three steps with intermediate re-grinding and repressed in first two steps. The samples were sintered twice at 850 °C for 50 h while in the third step the samples were sintered at 830 °C for 40 h. The structure of the samples was investigated by using X-ray diffractometer type Philips. The frequency-dependent dielectric measurements of samples were carried out by LCR meter model 4194A in the range 1000 Hz–5 MHz.

3. Results and discussion

XRD analysis showed polycrystalline structure with two phases: high-T_C phase (2223) as a dominate phase and low-T_C phase (2212) as shown in Fig. 1. The values of parameters a, b, c, and V prove that all samples have an orthorhombic structure as presented in Table I. Random variation with the increase in Li concentration notic for those values. This probably happens due to the charge ordering phenomenon (probably induced by Li, known as a pair breaker) and change in oxygen content or oxygen ordering effects.

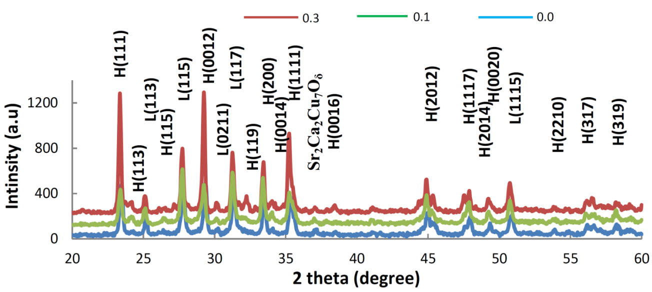

Fig. 1. X-ray diffraction patterns of the samples.

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TABLE I

Values of a, b, c and V of the samples

x	a [Å]	b [Å]	c [Å]	c/a	V [Å^3]
0.0	5.3063	5.4751	37.0213	6.9768	1075.56
0.1	5.4286	5.4493	37.0179	6.8190	1095.09
0.3	5.4084	5.4730	37.1851	6.8754	1100.70
0.5	5.4392	5.4565	37.0860	6.8182	1100.69

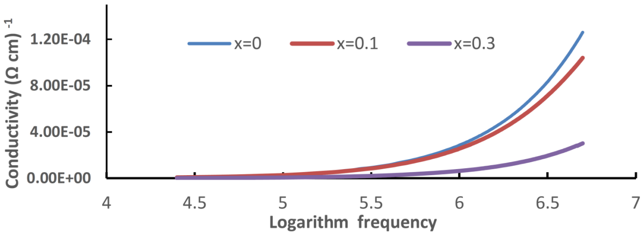

Fig. 2. Variation of AC conductivity with logarithm of frequency of the samples.

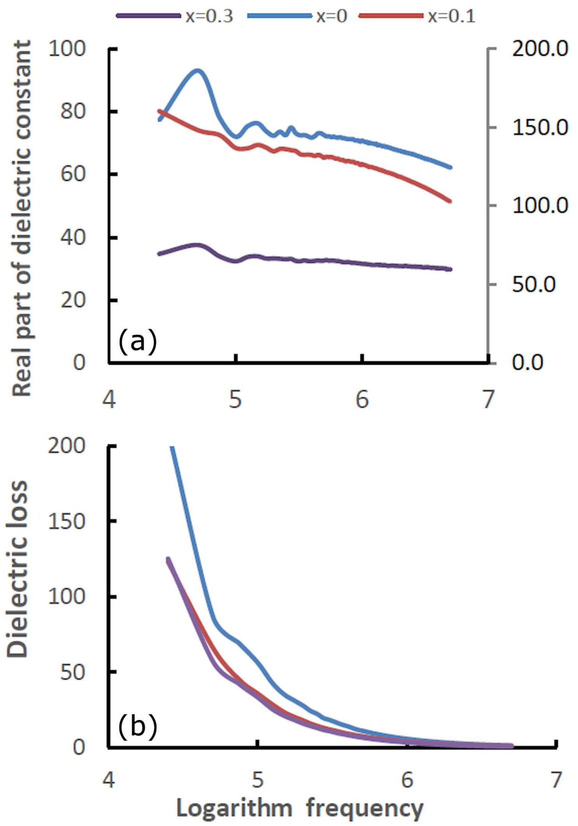

Fig. 3. Variation of (a) real part of dielectric constant, (b) dielectric loss with logarithm frequency of the samples.

Figure 2 shows the behaviour of AC conductivity with logarithm of frequency. Figure 3a and b shows the variation in the real part of dielectric constant and dielectric loss of the samples as a function of logarithm of frequency, respectively. The values of AC conductivity remain constant until a particular value of frequencies which depend on the x content. If the time constant of the applied field is shorter than the time constant of dipolar polarization, then AC conductivity increases with increase in frequency. The dielectric structure is founds by a layer that consists of well conducting grains and separated by a poorly conducting thin layer that forms the grain boundary. These grain boundaries are more active at lower frequencies. Hence, the hopping frequency of electrons between Cu^{3+} and Cu^{2+} ions is less at lower frequencies. As the frequency of the applied field increases, the conductive grains become more active, thereby increasing the hopping frequency. However, at higher frequencies the hopping between the ions takes place and the conduction process shows non-linear behaviour of amorphous distribution for grains. Similar trend of virile has been observed by many workers such as Mahajan et al. [5]. In addition, the effect of molar ratio on the conductivity increases with decrease in the amount of Li for the all samples.

4. Conclusion

X-ray diffraction analysis showed an orthorhombic structure for all the samples. The values of AC conductivity remained constant till a particular value of frequency, and then increased at higher frequencies. The dielectric properties of the samples were strongly dependent on the frequency of the applied field, as well as on the Li concentration.

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