Dielectric Properties of $Bi_{2-x}(Pb,Nd)_xSr_2Ca_2Cu_3O_{10+\delta}$ Superconducting System

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***Abstract*—Bulk polycrystalline samples with a nominal composition $Bi_{2-x}(Pb,Nd)_xSr_2Ca_2Cu_3O_{10+\delta}$ for (0≤x≤0.6) have been prepared by solid state reaction method. The frequency dependent dielectric properties such as dielectric constant (ε_1, ε_2) and ac-conductivity (σa.c) have been investigated by mean of capacitance (c) and conductance (G) measurements with the test frequency (ω) in the range of (5kHz -5 MHz). It has been found that there is a relationship between the conductivity and the frequency in the high frequency region. In addition, the relation between the real part of dielectric constant and frequency found to be decrease continuously with increasing frequency.**

Keywords—Bi-2223;Superconductor; Dielectric Properties

I. INTRODUCTION

Superconductivity phenomenon has opened a new space of its type and developed technique which is used in practical and clinical scientific fields because the superconductive is related to electricity which become one of the most important requirement in our modern and feature life. If the magnetically levitated trains, electrical capacities, and super speed computers are considered as human's dream in our time, so there are a great number of tangible applications [1]. This field go on through progress and development, and enters in the manufacturing of a lot of equipment throughout discovering the high temperature superconductors' ceramics in 1986[2].

High temperature superconductors have a high transition temperature at (90-160) K above the boiling point of liquid nitrogen and they also have high value of critical current density of the copper element (at room temperature). One of the disadvantage side of superconducting materials is brittle and it is very difficult to arrange it as wires, or long rods more than 30cm, but the most argumentative of this short comings is its sensitivity for external magnetic field on it, (where the external magnetic field destroy superconductivity) especially when the existence of the magnetic field is regarded as an unavoidable matter in many of the scientific and particle applications [3].

Another point is that superconductor's materials have high T_c, so they experience thermal instability problems, and have a very small coherence length and antisymmetric which make the system very sensitive for every changes of crystal structure. The grains in the ceramic–materials are randomly polarized and the crystal structure is very complex and non-packed at the boundary of grains, therefore, the method of preparation of ceramic material and arrangement of crystals at the boundary of grains which is very important notes view. The technique multi-step method to prepare superconductor Appropriate superconductor materials is the most way to prepare the material (remote and arrange to crystals) becomes superconductor packing surface [4].

In this work we're trying to prepare and investigate the dielectric properties of $Bi_{2-x}(Pb, Nd)_xSr_2Ca_2Cu_3O_{10+\delta}$ system.

II. EXPERIMENTAL

Starting materials of high- purity powders (99.9%). of (Bi_2O_3, Pb_3O_4, $Sr(NO_3)_2$, CaO,CuO and Nd_2O_3) were used to prepare the system $Bi_{2-x}(Pb,Nd)_xSr_2Ca_2Cu_3O_{10+s}$ with (0≤x≤0.6). The mixture was calcined in a furnace in air that has programmable controller type (Eurptherm818) fo 24 hours at 800 °C. This mixture was then pressed into pellets 1.3 cm in diameter and (0.2 – 0.3) cm thick, using hydraulic type (SPECAC) under pressure of 0.7GPa.. The samples were sintered at 850° C for 160 hr

LCR meter model (Avcitive Awia , Agilent program pole) [5], was used to measure dielectric properties for the $Bi_{2-x}(Pb,Nd)_xSr_2Ca_2Cu_3O_{10+\delta}$ samples at different frequencies ranging from (50Hz-5MHz) at room temperature. The real part of dielectric constant (ε_1), and absolute dielectric loss factor |tan δ| , were calculated by measuring the capacitance (c) using LCR meter impedance analyzer, the value of the real part dielectric constant (ε_1) is calculated from the equation [6]:

$$\varepsilon_1 = \frac{ct}{A\,\varepsilon_o} \qquad (1)$$

Where t is the thickness of the pellet, A is the area of the electrode, ε_o is the permittivity of free space = $8.85*10^{-12}$ F / m.

III. RESULTS and DISCUSSION

Dielectric with low dielectric constant as well as high dielectric constant are important in electronic industry. Electronic insulation devices make use of low dielectric constant materials whereas capacitive elements in electronic circuits utilizer high dielectric constant materials [7]. Nowadays, superconducting ceramic exhibiting good dielectric properties are super desirable because of its comparatively lenient and easy manufacturing techniques [8].

The frequency dependent dielectric properties such as dielectric constant (ε_1, ε_2) and Ac-conductivity ($\sigma_{a.c}$) of $Bi_{2-x}(Pb,Nd)_xSr_2Ca_2Cu_3O_{10+\delta}$ with ($0\le x\le 0.6$) superconductor sintered at 850^{o}C have been investigated by mean of capacitance (c) and conductance (G) measurements with the test frequency (ω) in the range of (5KHz -5 MHz).

From the graphs drawn by plotting variation of conductivity on y-axis and frequency on x-axis {Fig. (1)}, it is noticed that the values of ($\sigma_{a.c}$) remain constant in low frequency region and becomes proportional to frequency in high frequency region i.e conductivity has lower values at low frequency region and it increase with increases in frequency slightly, this due to the decrease in polarization effect.

Also it is found that the composition $Bi_{1.8}Pb,Nd)_{0.2}Sr_2Ca_2Cu_3O_{10+\delta}$ has a higher value of A.c-conductivity in comparison with the pure sample. This could be explain the rising of (Pb,Nd) content up to 0.2 will increases of the carrier concentration, any more addition of (Pb,Nd) atoms decreases the conductivity. The decrease of the conductivity is related to the localization of charge carriers [9].

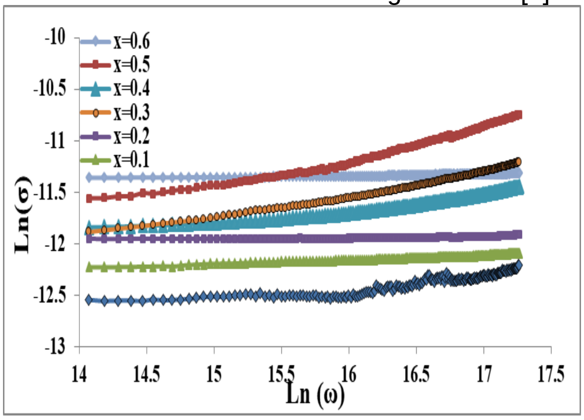

Fig. (1): Ln(σ) with frequency for $Bi_{2-}(Pb,Nd)_xSr_2$ $Ca_2Cu_3O_{10+\delta}$ sintered 850^{o}C for 160 h.

Fig. (2) shows the variation of real part of dielectric constant (ε_1) with rise of frequency up to 5MHz. The value of ε_1 is higher at lower frequency and is found to decrease continuously with increasing of frequency. When frequency is low grain boundaries are very effective and as a result there is a hoping of charge carriers this results in high dielectric polarization and hence high values of dielectric constant. As frequency increase, responses of dipoles decreases and the lag behind the applied field and this damping nature of dipoles reduces dielectric constant [10]. At higher frequencies the magnitudes of ε_1 for most the samples approach the same values i.e attains saturation value. This explained as follows when the frequency is increasing, polarization decreases until attaining constant value. Beyond this critical value of frequency, the electron exchange between two cations, cannot follow the alternating field. It can be notably observed from Fig. (3) the imaginary part of dielectric constant (ε_1) decreases with increasing frequency. Maximum value of (ε_2) is obtained for $Bi_{1.4}(pb,Nd)_{0.6}Sr_2Ca_2Cu_3O_{10+\delta}$ the imaginary part of the dielectric constant refers to the absorption and attenuation of energy across the interfaces (grain boundaries, localized defect and localized charge densities at the defect sites) under the applied external electric field.

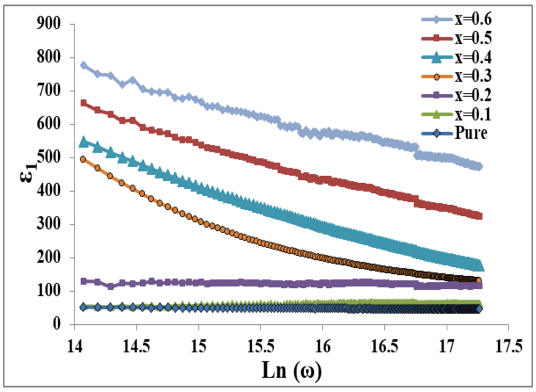

Fig (2): Real Dielectric constant (ε_1) with frequency for $Bi_{2-x}(Pb,Nd)_xSr_2$ $Ca_2Cu_3O_{10+\delta}$ sintered 850^{o}C for 160 h

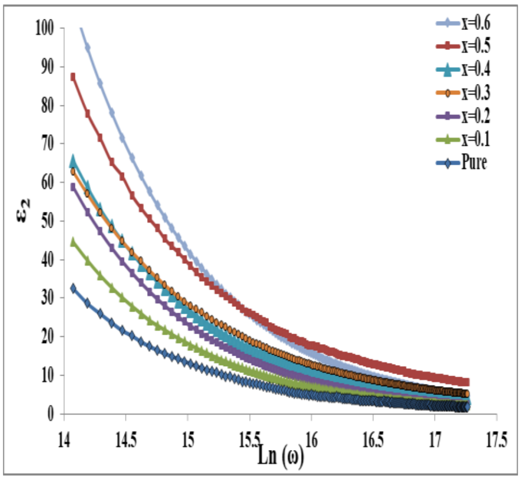

Fig (3): Imaginary Dielectric constant (ε_2) with frequency for $Bi_{2-x}(Pb,Nd)_xSr_2$ $Ca_2Cu_3O_{10+\delta}$ sintered 850^{o}C for 160 h.

IV. CONCLUSIONS:

$Bi_{2-x}(pb,Nd)_xSr_2Ca_2$ $Cu_3O_{10+\delta}$ has successfully prepared using solid state reaction. From the above results It is found that there is a relationship between the conductivity and the frequency especially in the high frequency region. In addition, the relation between the real part of dielectric constant and frequency found to be decrease continuously with increasing of the frequency.

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