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Effect of (CuPb) Substitution on Optical Parameters of $Bi_{2-x}(CuPb)_xSr_2Ca_2Cu_3O_{10+\delta}$ Thin Films

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Abstract

Thin films of $Bi_{2-x}(CuPb)_xSr_2Ca_2Cu_3O_{10+\delta}$ compound (x = 0, 0.1, 0.2, and 0.4) were prepared by Pulse laser deposition (frequency 6 Hz, energy 500mJ, pulses 500, vacuum 10^{-1} Tor and 1 Cm distance between the substrate and the target) at room temperature of 300 nm thickness onto cleaned glass substrates. Optical measurements for all values of x indicate the same value of transmittance (97.76) but at different positions of wavelengths with shifting towards short wavelength within the extreme wavelength range (200-1100) nm. High optical energy gap for films is at x = 0. The reflectance approaches to zero at for all values of x. Atomic force microscopy and photoluminescence for the films are studied. [DOI: 10.22401/ANJS.00.2.05]

Keywords: Bi compound, Thin Films, Pb compound

1. Introduction

Oxide of Bismuth Strontium Calcium Copper $Bi_2Sr_2Ca_{n-1}Cu_nO_{2n+4+x}$. is considered superconductors at high temperatures. Since discovered of Bi-Sr-Ca-Cu-O as superconductors, a great attention made to prepare it and solid-state reaction is the best method to prepare these oxides. The single phase Bi-2223 is interest due to its higher critical temperature but is difficult to prepare it [1]. Many researchers studied magnetic properties of the compound (BSCCO). Uehara et al (1988) studied the magnetic measurement of (BSCCO) and they calculated Curie temperature for the compound [2]. Pop (2006) studied Nano defects by doping Pb Bi-2223 superconductor compound and many others [3]. Our previous work, we prepared Bi-2223 compound and the doping by $(CuPb)_x$ as ($Bi_{2-x}(CuPb)_xSr_2Ca_2Cu_3O_{10+\delta}$) and studied its structure and AC conductivity [4, 5]. In the present work, a study of this compound as thin films bydoping $(CuPb)_x$ in Bi:2223 which were prepared by pulse laser deposition and studied the optical properties at different values of x like transmittance, optical energy gap, and refractive index. The obtained results indicated the semiconductor behavior of $Bi_{2-x}(CuPb)_xSr_2Ca_2Cu_3O_{10+\delta}$. In addition, surface morphology was studied.

2. Experimental Detail

$Bi_{2-x}(CuPb)_xSr_2Ca_2Cu_3O_{10+\delta}$ compound of (x = 0, 0.1, 0.2, 0.4) were prepared by powder technology which was explained in detail in ref.[4, 5]. Pulse laser deposition (frequency 6 Hz, energy 500mJ, pulses 500, vacuum 10^{-1} Tor and 1 cm distance between the substrate and the target) used to deposit films at room temperature onto cleaned glass substrates at 300 nm thickness, which measured by physio fringes of light of 6000 nm wavelength. Spectrophotometer UV-160 used within (200-1100) nm to measure film transmittance.

3. Results and Discussions

3.1Transmittance:

Figure 1 describes the transmittance vs. photon energy. The transmittance is approximately constant along the extreme of visible region but decreases with the increase of x values of (CuPb). The transmittance has a constant peak value (99.76) for each value of x at different positions of photon energy (i.e., wavelengths) but it shifts to high photon energy (low wavelengths) with the increase of x values. Table 1 indicates the values of peaks with x values. The variation of photon energies of peak value is due to the variation values of optical energy gap, which varies with x values as shown in Table 2.

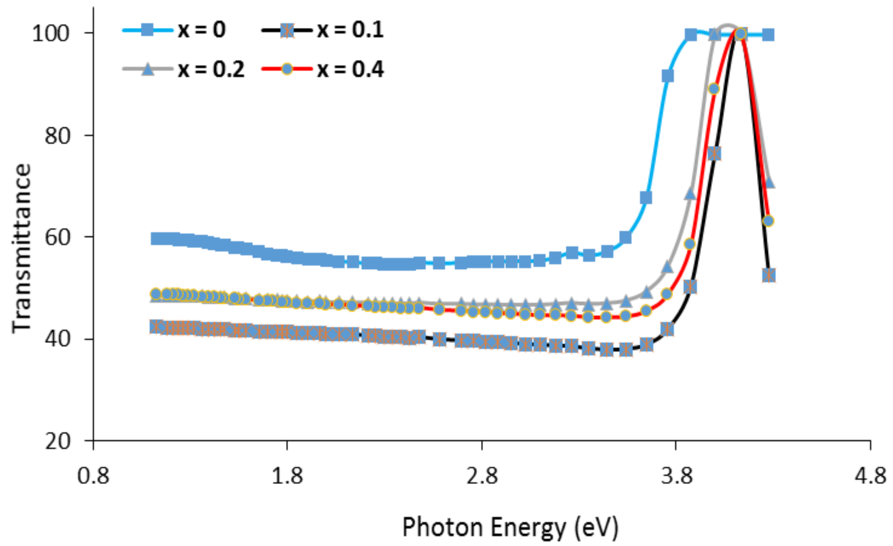

Figure 1 The transmittance spectra versus photon energy.

Table 1 Values of maximum transmittance.

x values	*Transmittance%*	*Photon Energy (eV)*	*Corresponding wavelength (nm)*
0	99.76	3.875	320
0.1	99.76	4.13	300
0.2	99.76	4	310
0.4	99.76	4.13	300

3.2 Optical energy gap

From the relation of absorption coefficient α for allowed direct transition, optical energy gap can be determined as [6, 7]:

$$(\alpha h\nu) = A(h\nu - Eg)^{1/2} \qquad \ldots(1)$$

where hν represents photon energy, E_g is optical energy gap, A is constant and (1/2) is constant for allowed direct transition. Figure 2 shows $(\alpha h\nu)^2$ as a function of photon energy hν for allowed direct transition. The optical energy gap E_g obtained from linear portion of the graph by extrapolating to intercept the photon energy axis [4]. Table 2 gives optical energy gap values. The range of optical band gap is (2.3-3.5) eV. The optical energy gap decreases and have minimum value at x = 0.2.

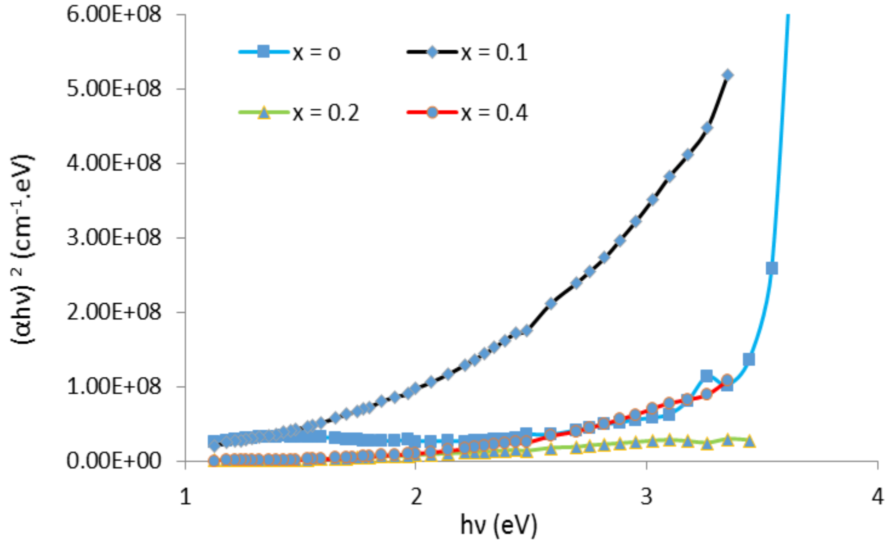

Figure 2 $(\alpha h\nu)^2$ spectra versus photon energy.

Table 2 values of energy gap.

x values	E_g (eV)
0	3.5
0.1	2.2
0.2	1.8
0.4	2.3

3.3 Reflectance Spectra

The study of reflectance behavior is important. Figure 3 shows the reflectance spectra which is approximately zero (no reflectance) specially at (x = 0, 0.2, 0.4) within the range of wavelength (200-1100) nm due to maximum transmittance within this region of wavelength as mentioned above. The reflectance increases in too small values with the increase of x ratios of (CuPb).

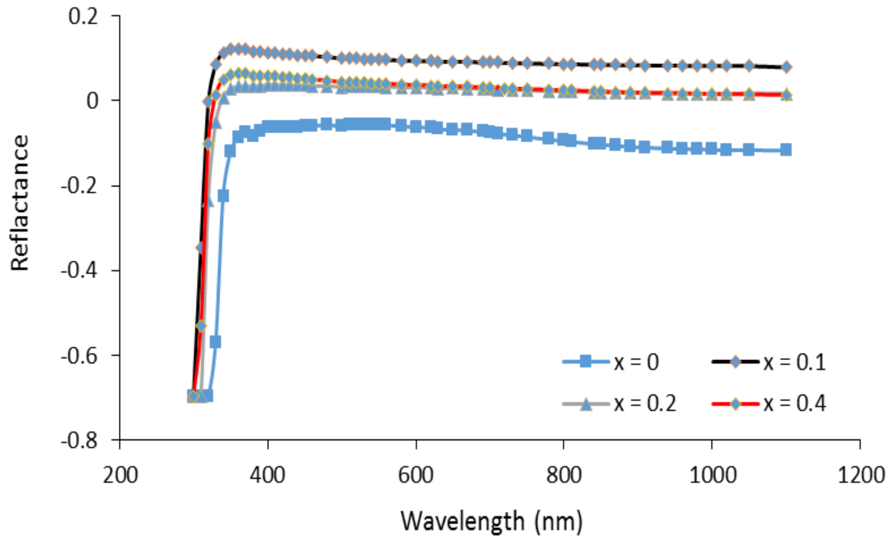

Figure 3 Reflectance spectra versus wavelength.

3.4 Atomic Force Microscopy (AFM)

Figure 4 (a, b, c, and d) show the morphology of films. Images indicated many different grains in (size and number). (AFM) images shows small grains with large numbers appeared at (x = 0, 0.1, and 0.4) but large size of grains at x = 0.2, according to small optical energy gap. Number of grains are (318, 114, 218, and 156), Average diameter of grains are (87, 60, 105, and 88) for samples (x = 0, 0.1, 0.2 and 0.4) respectively.

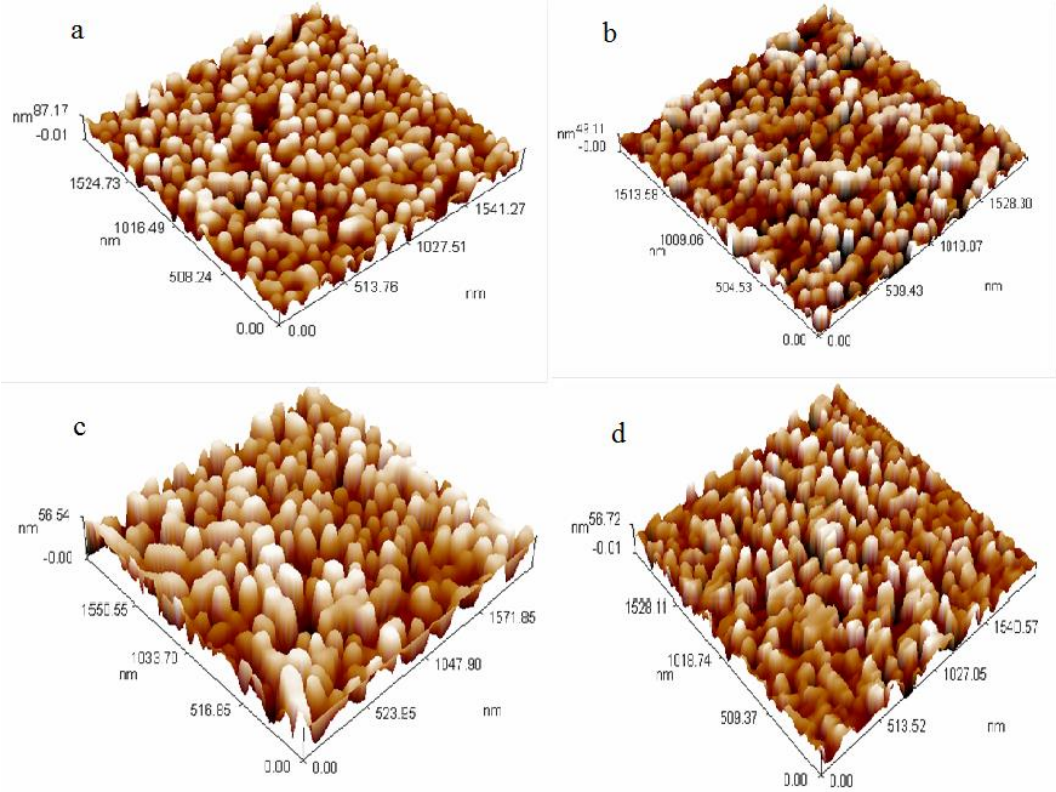

Figure 4 (a, b, c d) Atomic Force Microscopy at (a) x=0, (b) x=0.1, (c) x=0.2, (d) x=04.

3.5 Photoluminscence

Figure 5 shows the photoluminescence spectra at different x values. The behavior of photoluminescence for all ratios is the same. The figure indicates that the photo-luminescence has constant value (580) within the range (300-410) nm wavelength range at (x = 0, and 0.2) due to large number of grains but the constant value of photoluminscence increases to (1000) at (x = 0.1, and 0.4) within the range (316-388) nm due to less number of grains. For all values of x, the photoluminescnce has a peak at 480 nm corresponding to the exitation energy of radiation and this peak increases at x = 0.1. The figure indicates the absorbance of radiation due to the absorption edge [8, 9].

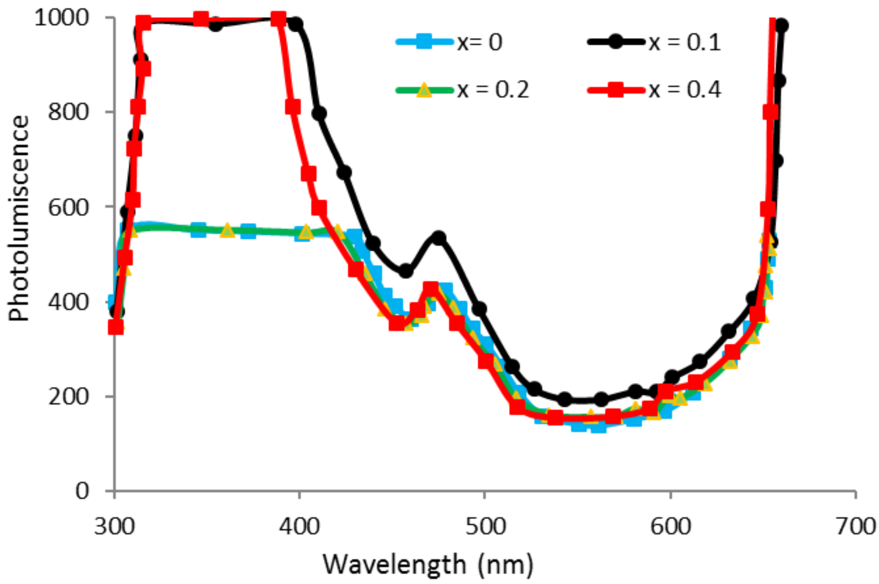

Figure 5 the photoluminescence spectra.

3.6 Conclusions

Thin films of $Bi_{2-x}(CuPb)_xSr_2Ca_2Cu_3O_{10+\delta}$ compound were prepared by pulse laser deposition (x = 0, 0.1, 0.2, and 0.4). The results indicate the same number of transmittance (97.67) for all different ratios but in different positions of wavelength shifting towards shorter wavelength. High optical energy gap at x = 0 and then decreases with increase x values having less value at x = 0.2. Surface morphology indicates large grains size at x = 0.2 and then decreases with the increase of x values. The results indicates that these film has full transmittance and no reflection especially at x = 0 which is fine property for solar cells applications as window layer.

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