



# Role of copper metal or oxide on physical properties of lithium borate glass



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## ABSTRACT

The effect of the addition of copper metal or copper oxide on lithium tetraborate glass was studied using X-ray powder diffraction, Optical, density and FTIR. The effect of adding Cu metal has a large effect than the addition of CuO and contributes to increase the NBOs than CuO. And the addition of Cu metal increases the homogeneity of lithium tetraborate glass. The glass sample containing 2 mol % CuO has the higher value of optical band gap  $E_g^{opt}$ , lower the fraction of four-coordination boron atoms N4 and Urbach energy ( $E_u$ ) than the other samples containing different copper metal or copper oxide concentration. And the decrease in Urbach energy indicating that decreasing localized states in forbidden gap due to decrease in NBOs. The glass sample containing 2 mol % CuO can be used as a narrow band color filter (band width = 250, band half width = 130 and band center = 486 nm).

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## 1. Introduction

Tetraborates can be obtained in both crystalline and glassy states. Tetraborate compounds are good candidates to study the nature of point defects [1].

The glasses containing copper have been used for decorative purposes because of their characteristic yellow, orange or red color, due to the dotted particles of cuprous or cupric oxides as well as metallic copper clusters in glass samples [2]. The electronic structure of the copper atom is  $[Ar] 3d^{10}4s^1$ , and the stable ionic states of copper ion are  $Cu^{2+}$  and  $Cu^+$ . The cuprous ( $Cu^+$ ) ions having its five d orbital occupied do not produce separate coloring, while cupric ( $Cu^{2+}$ ) ions form characteristic color centers with at least a broad absorption band in the visible region [3–6]. The absorption band at 800 nm found in silicate, borate and borosilicate glasses containing copper, that is due to  $Cu^{2+}$  ion in octahedral coordination with strong tetragonal distortion [7–9].

In previous work the optical band gap ( $E_{opt}$ ) of borate glass containing copper oxide was calculated [10–12] and found that the addition of CuO content decreases the  $E_{opt}$  values. Where the copper addition introduces defect in the glass matrix.

Padyak et al. [1] studied tetraborate glasses doped with copper and found that the Cu ions in to the lithium and potassium tetraborate glass as the  $Cu^{2+}$  ( $3d^9$ ) and  $Cu^+$  ( $3d^{10}$ ) ions and the broad optical absorption band around 750 nm in the tetraborate glasses, doped with Cu was assigned to the  ${}^2B_{1g} \rightarrow {}^2B_{2g}$  transition of the  $Cu^{2+}$  centers. Also observed an intense absorption in the UV region ( $\lambda < 350$  nm) was related to the  $Cu^{2+} \rightarrow O^{2-}$  charge-transfer band.

Nebolova et al. [2] studied the preparation and properties of copper-containing optical planar glass wave guides and found that the rate of ion exchange in  $Cu^{2+}$  salt-based melt is much higher than in  $Cu^+$  salt-based melts, the exchange reaction proceeds predominantly via  $Cu^+ \leftrightarrow Na^+$ .

The aim of the present work, investigate the difference of the role of CuO and Cu metal in the structure of lithium borate glasses. XRD, deconvolution of infrared (IR) spectra and analysis of ultraviolet (UV) spectra were employed.

## 2. Experimental work

Samples of  $(100 - x) Li_2B_4O_7$  mol %. X Cu mol % and  $(100 - x) Li_2B_4O_7$  mol %. X CuO mol % (where  $x = 1, 2, 3$  and 4 mol %) were prepared. All the chemicals were weighed accurately using an electrical balance; the used raw materials were all of chemically pure grade. The chemical were melted in porcelain crucible at

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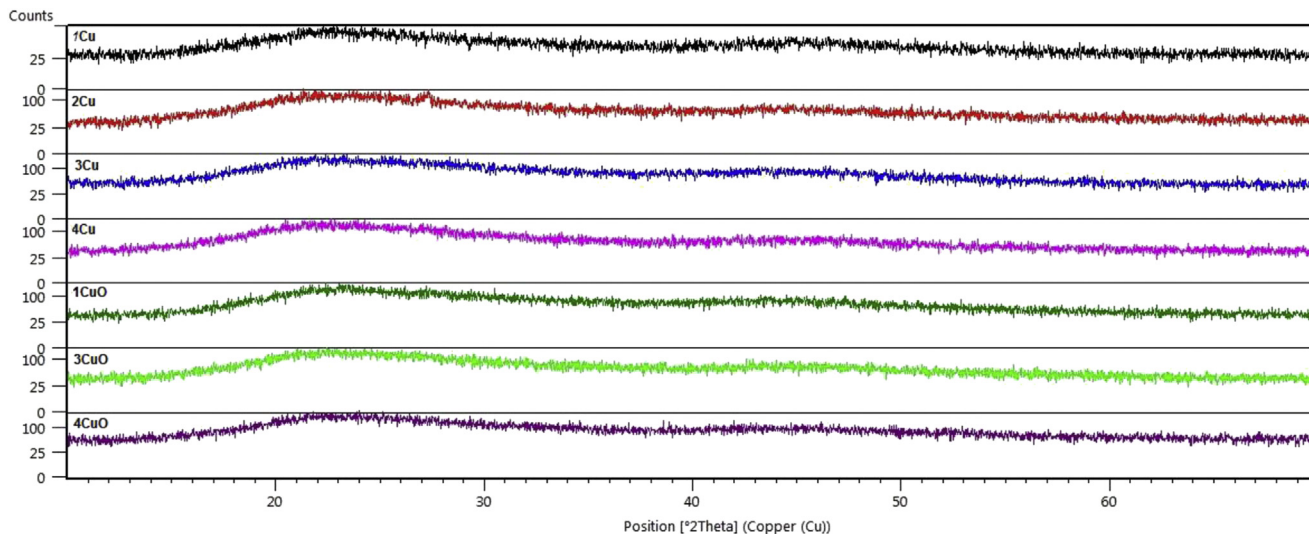


Fig. 1. The XRD of glass samples containing Cu and CuO.

1100 °C in an electrically programmable heated furnace, type-VAF15/10 lenton thermal designs, equipped with automatic temperature controller. The molted materials quenched in air and poured at room temperature. The samples were examined by using Philips Analytical X-Ray diffraction system, type PW3710 based with Cu tube anode. The density was measured by the Archimedes method using toluene as the immersion liquid. The FTIR absorption spectra of the prepared samples were measured at room temperature in the range 2000–400  $\text{cm}^{-1}$  by an infrared spectrometer (type JASCO FT/IR-4100, Japan) using the KBr disc technique. The transmission spectra for the samples were measured in a wide range of wavelength: UV, visible and IR. The transmission spectra near the absorption edge of glasses with different thicknesses were measured using V570JASCO spectrophotometer.

### 3. Results and discussion

The XRD patterns of the quenched lithium tetraborate glasses containing copper metal and copper oxide are shown in Fig. 1. From Fig. 1 can be observed that the all samples in glassy amorphous nature.

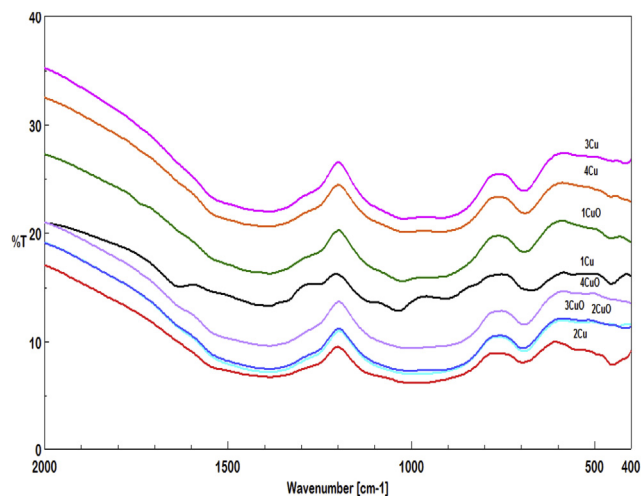


Fig. 2. The FTIR of glass samples containing Cu and CuO.

The FTIR spectra of glass samples are shown in Fig. 2. FTIR spectroscopy was used to obtain the information concerning the arrangement of the structural unit groups of these glasses. From Fig. 2 can be observed two broad bands in range from 1200 to 1600  $\text{cm}^{-1}$  and from 800 to 1200  $\text{cm}^{-1}$  addition to third band at 700  $\text{cm}^{-1}$ . The first broad band attributed to B–O symmetric stretching vibration of  $\text{BO}_3$  units; the second broad band attributed the B–O bond stretching of  $\text{BO}_4$  tetrahedral units, the third band due to B–O–B bend vibrations of borate network [11,13–15]. From Fig. 2 can be seen that the two bands at 1388 and at 1110  $\text{cm}^{-1}$  can arise from pyroborate units and metaborate units [7]. The band at 1338  $\text{cm}^{-1}$  is due to B–O symmetric stretching in  $\text{BO}_3$  units from varied types of borate groups [10]. The B–O symmetric stretching in  $\text{BO}_4$  centered around 1249  $\text{cm}^{-1}$  [10]. The band at 878–885  $\text{cm}^{-1}$  and 1023–1051  $\text{cm}^{-1}$  are due to the stretching vibrations of B–O bonds units from tri, tetra and pentaborate group [12]. The band at 825  $\text{cm}^{-1}$  is assigned to non-bridging oxygen [15]. The band at 671  $\text{cm}^{-1}$  is due to pentaborate units [7] and it can be due to the bending B–O–B linkage in borate network [12]. The band at 455  $\text{cm}^{-1}$  is assigned to specific vibration of Li–O bonds [15] or it may be due to the specific vibrations of Cu–O in  $\text{CuO}_6$  units [11]. As the increase of Cu in borate glass, the bands become broad which indicate that the glass samples become more homogeneity.

The addition of modifier or intermediate oxide to borate glass samples changes the structural vibration group unit. The addition of copper metal or copper oxide (Cu or CuO) were changed the

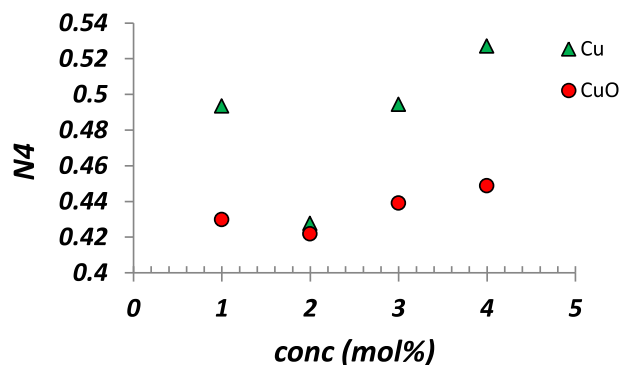


Fig. 3. The N4 of glass samples.

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