Blue, Red, and Green Emission from Chromium and Copper Metal Doped Lithium Borate Glass
I. Kashif*, A. Ratep

*Physics Department, Faculty of Science, Al-Azhar University, Nasr City, Cairo, Egypt.
Department of Physics, Faculty of women for Art, science & education, Ain Shams University, Heliopolis, Cairo, Egypt

Email: ismailkashif52@yahoo.com, Tel.01006609924 Fax: 24558035

Abstract The influence of copper metal on the structural and optical properties (absorption and emission) of the lithium borate glass samples containing chromium considered. The analysis of FTIR spectra measured, indicated the copper and chromium ions act as network former and modifier depend on the concentration of everyone in the sample content. The ratio between the BO₄ groups to the total boron groups (BO₄+BO₃) decreases with the copper content increases up to 2 mol % and then increase. The optical properties that the Dq/B decreases with the increase the copper and higher than 2.3 which indicates the glass samples containing Cr³⁺ ions in the high-field sites and produce conventional laser action. The emission spectra show the intensity emission bands at 440 nm, 540 nm, and 730 nm for relative strong blue, green and red bands respectively.

Keywords: Lithium borate glass; FTIR spectroscopy; optical properties (absorption and emission); blue, green and red emission

1. Introduction
Borate glasses have low melting point, high thermal stability, optical transparency, large non-linear optical properties, and good rare earth RE /transition metal (TM) ion solubility; this makes it suitable for potential applications in nonlinear optics. The addition of alkali oxide to metaborate glasses improved its various technical and industrial applications. What's more, the borate glasses imparts semiconducting/conducting nature to an otherwise insulating material. Borate glasses doped with heavy metal ions or transition metals considered to have good nonlinear optical properties[1][2][3]. Transition metal ions contribute partially filled d-orbital to glass, and electro-optical behavior observed between ions in lower and higher oxidation state[4].

Glasses containing divalent cations such as Cu²⁺ have semiconducting semiconductor properties and glasses with a trivalent ion such as Cr³⁺ show luminescent and magnetic properties[5]. The anomalous behavior of the borate glass makes them of interest due to super structural units formed by BO₃ and BO₄ units. These two supercooled structural units were formed either from the so-called supercooled or from various structural groups such as diporate, tetraborate, pentameric, boroxol rings, etc[4].
The presence of copper in the glass sample has many advantages as they are (i) Potential materials due to their natural abundance.
(ii) Easiness of Cu oxidation (Cu$^{2+}$ and Cu$^{+}$ ions)[6].

(iii) May also exist as Cu$^{0}$ ions.

(vi) Promising for photovoltaic energy conversion, display bright photoluminescence depending on the host.

(vii) The disintegration of little amounts of copper particles in glass networks makes the glasses colored and emphatically impacts the structural and optical properties[7]. Chromium ions are very effective and useful nucleation agents from the different transition metal ions as it exists in different valence states (Cr$^{3+}$ and Cr$^{6+}$), Cr$^{3+}$ ions occupy the octahedral sites because the 3d$^3$ electronic configuration has maximum stabilization energy in the six-fold octahedral coordination[5][8]. Lesniewski et al.[9] contemplated the optical spectroscopic portrayal of calcium tetraborate glasses containing Cr$^{3+}$.

The luminescence excitation comprised of two broadband peaks corresponding to transitions from the $^4A_{2g}$ to the $^4T_{1g}$ and $^4T_{2g}$ levels of the octahedral coordinated Cr$^{3+}$ ions.

Kaczmarek[10] studied Li$_2$B$_4$O$_7$ glasses containing Cr, Co, Eu, and Dy. They found that the sample containing Cr$^{3+}$ ions are good optical quality, giving clear luminescence.

Stefan et al.[6] studied the effect of copper content on the structural and optical properties of zinc borate glasses and they found that the copper ions act as the network modifier and formed the NBOs in the examined glasses.

Many researchers[7][11][12][13] studied the effect of addition, copper in borate glass and they found that some glass samples have various characterizations reveal that highly transparent, thermally steady, amorphous, and homogeneous with precise elemental traces.

From our previous work[12][14] lithium tetraborate glass containing chromium metal has more thermal stability, high transmission and emission intensity than the glass with chromium oxide. The addition of copper metal to borate glass increases the glass homogeneity and can act as a filter to cut the light in the UV and infrared range. Also, increases the NBOs than CuO. And have higher transmission intensity.

The addition of copper or chromium metal on a borate glass system introduces a defect like the color center and wrong bond in the glass. In view of the above focal points, so in the present article, the point of this examination is fascinating to research the impact of the glass creation and the replacement of copper metal by chromium metal concentration on the spectroscopic properties, the stability of glass, the transmission and the emission properties of lithium metaborate glasses.

2. Experimental work

Glass samples composition 48 Li$_2$O–48 B$_2$O$_3$–(4-x) Cr metal–x Cu metal [x= 0, 1, 2 and 3] mol % synthesized. The melt quenching technique used in the prepared of glass samples. The pure chemicals mixed and placed in high temperature furnace (1100°C) in a porcelain crucible. The differential thermal analysis (DTA) a Shimadzu 50 Analyzer used to estimate the thermal parameters. The glass samples crushed to fine powder and examined by X-ray diffraction system, (Philips Analytical type PW3710).

The density of the glass samples determined using an Archimedes method. The FTIR absorption spectra of the glass samples obtained at room temperature in the range 2000–400 cm$^{-1}$ by an infrared spectrometer (type JASCO FTIR-4100, Japan) utilizing
the KBr plate method. The structural groups of the glass samples determine by deconvoluting of the FTIR spectra using the winding program. The optical absorption spectra obtained using a UV-Vis-NIR spectrophotometer (type JASCO, V-570) in wavelength range 190-2500 nm. The emission measurement utilizing (JASCO- FP-6300) Spectrofluorometer in the wavelength range (200– 800 nm).

3. Results and discussion
Figure 1 demonstrates the XRD glass samples. A broad diffraction peaks observed in all X-ray patterns of the glassy samples. This confirms the absence of any crystalline phase and indicates the amorphous state of the glass samples.

![X-ray diffraction pattern of the glass samples](image)

**Figure 1** X-ray diffraction pattern of the glass samples

The structural analysis of glass samples describes by FTIR measurements. Figure 2 shows the FTIR spectra of glass composition 48 Li₂O – 48 B₂O₃ – (4-x) Cr metal –x Cu metal [x= 0, 1, 2 and 3] mol %.
The functional groups of borate glasses observed in three IR spectral regions[4][12]. (I) The range is 1600 cm\(^{-1}\) to 1200 cm\(^{-1}\), which assigns to the BO3 vibration group (containing connecting and non-bridging oxygen). ii) The range between 1200 cm\(^{-1}\) and 800 cm\(^{-1}\) due to the Boron tetrahedral vibration units. (iii) From 800 cm\(^{-1}\) to 600 cm\(^{-1}\) because of the bending vibrations of triagonal and tetrahedral of borate groups.

From figure 2, the band at 412 cm\(^{-1}\) [15][16] appears in the spectrum of glass sample containing 4 mol % Cr may be due to vibrations of (CrO\(_4\))\(^{2+}\) structural units and vibrations of Cr\(_2\)O\(_3\) units. This band shifted to the wave number 428 cm\(^{-1}\) with the increase of copper substitution and overlap with the band at 435 cm\(^{-1}\) that represent the vibrations of CuO\(_6\) units[12]. The band at 485 cm\(^{-1}\) attributed to the B—O—B linkage[17]. From the FTIR result, it may understand that the transition metal may bridge with the borate band and formed M—O—B band (M is the transition metal).

**Figure 2** the FTIR spectra of glass samples

**Figure 3** the deconvolution in Gaussian bands of the infrared spectrum for the glass containing 4 mol% Cr.
The broad FTIR band of the glass was attributed to the overlapping of some individual bands with each other. Gaussian deconvolution converted the broad infrared spectra into groups of sections for each individual to reflect the more information about their structural groups.

For instance, the deconvolution in Gaussian groups as shown in figure 3 for the glass containing 4 mol % copper metal. It is plainly the $N_4$ (the ratio between boron tetrahedral concentration to the BO3 and BO4) decreasing with the increasing the copper metal content[18]. The reduction in the number of BO4 groups with the substitution of Cr by copper depending on the amount of oxygen and changed BO4 to BO3 groups and form non-bridging oxygen (NBO). Which demonstrate that the copper metal enters the glass as a modifier until 2 mol %, and after that enters as network former and a modifier.

Figure 5 shows the change in the relative area under the FTIR curves in the region containing BO4 units have the inverse shape in the region containing BO3 units, meaning that Cu replacement Cr and enters the borate matrix to form BO4 units at the expense of BO3 units without forming non-bridging oxygen.

![Figure 4](image)

**Figure 4** the N4 value as a function of composition.

![Figure 5](image)

**Figure 5** the change in the relative area for BO4 and BO3 units under the IR curves.
Figure 6: the density and molar volume of glass composition

The density (ρ) is a vital physical property which accustomed to investigating the tightness, changes in the structural units of material[13]. Many factors affect the density of glass samples[14]. The density increases with the substitution Cr by Cu metal as appeared in figure 6. This continued increase with the increase in copper metal content which has a higher molecular weight. From figure 6 it very well may watch that the molar volume decrease, which caused the glass to become more compact. The structure compaction is more obvious conduct of the molar volume curve. The molar volume[14] can compute from the density estimations communicated in the relation.

\[ V_m = \frac{M_w}{\rho} \text{ cm}^3/\text{mol} \]

Where \( M_w \) is the total atomic weight of the component of glass system. The molar volume decreases due to the reduction of non-bridging oxygen[19]
Figure 7 the DTA of lithium borate glass with the composition 48 Li₂O–48 B₂O₃–(4-x) Cr metal–xCu metal [x= 0, 1, 2 and 3] mol %

The thermal stability and glass framing ability of glass characterized by the glass transition temperature (Tg) and the crystallization temperature (Tc)[20]. Figure 7 outlines the differential thermal analysis, investigation curves of glass samples. The estimations of thermal for glass samples decided from curves and recorded in table 1. The glass transition temperature depends on numerous factors[21]. From table 1, it can see that the sample containing 3mol% Cu has a larger value of Tg that is illustrated as the sample containing more BOs than the other samples. The thermal parameters determined from the DTA result obtained, such as (S=Tc-Tg and Hrubý (HR = (Tc-Tg)/(Tm-Tc)) [22] are useful to know the glass stability and measures the ability of a system to become glass, glass said to be thermally steady if S >100 °C. As a whole, it is difficult to prepare glasses with HR ≤ 0.1. Otherwise, the glass stability is higher with a larger HR value [22]. The obtained values of S and HR as shown in table 1, indicating that all glass samples has high glass forming ability and thermal stability.

Table 1 the DTA values and thermal parameters.

| Conc(mol%) | Tg °C | Tc °C | Tm °C | S °C | HR |
|-----------|-------|-------|-------|------|----|
| 4 Cr      | 468   | 605   | 748   | 137  | 0.96|
| 3Cr-1 Cu  | 465   | 617   | 731   | 152  | 1.33|
| 2Cr-2Cu   | 462   | 599   | 740   | 137  | 0.97|
| 1Cr-3 Cu  | 482   | 612   | 750   | 130  | 0.94|
Figure 8 shows the optical absorption of lithium borate glass containing different concentration of copper and chrome metal.

The absorption spectra of the glasses containing 48 B\textsubscript{2}O\textsubscript{3}, 48 Li\textsubscript{2}O, (4-x) Cr-x Cu where x=0, 1, 2, and 3 mol % depicted in Figure 8. From figure 8, it can see that the glass containing Cr metal has high absorption intensity and decrease with the substitution Cr with Cu metal. Broadband around 765 nm that represent the attendance of Cu\textsuperscript{2+} by the strong tetragonal distortion, with the transitions will give absorption bands lying together: \textsuperscript{2}B\textsubscript{1g}→\textsuperscript{2}B\textsubscript{2g}, \textsuperscript{2}B\textsubscript{1g}→\textsuperscript{2}A\textsubscript{1g} and →\textsuperscript{2}E\textsubscript{g}\textsuperscript{[23]}. The absorption band at wavnumber less than 350 nm is due to the Cu\textsuperscript{2+}→O\textsuperscript{2−} charge-transfer band\textsuperscript{[6]}\textsuperscript{[24]}\textsuperscript{[25]}. The absorption spectra observed in the violet region may ascribe to 3d\textsuperscript{10}→3d\textsuperscript{9} 4s\textsuperscript{1} forbidden transitions, they may occur due to low symmetry of a local electric field around Cu\textsuperscript{+} ions\textsuperscript{[26]}. The absorption spectrum exhibits three bands, two broad bands at 446 nm, 620 nm and a sharp band around 686 nm. It is characteristic for chromium ions (Cr\textsuperscript{3+}) in octahedral unit\textsuperscript{[10]}\textsuperscript{[27]}\textsuperscript{[28]}. The first broadband at 446 nm allocated to the spin-allowed transitions \textsuperscript{4}A\textsubscript{2g} (F)→\textsuperscript{4}T\textsubscript{1g} (F) and second at 620 nm, which due to \textsuperscript{4}A\textsubscript{2g} (F)→\textsuperscript{4}T\textsubscript{2g} (F) in the decreasing order of energy. The sharp band assigned to \textsuperscript{4}A\textsubscript{2g} (F)→\textsuperscript{2}E\textsubscript{g} (G) transitions. The Cr\textsuperscript{6+} ion has a strong and a weak absorption bands at 358 nm and at 318 nm \textsuperscript{[25]} refers to Cr\textsuperscript{6+}–O— complex of 3d\textsuperscript{0} configurations. The characteristic band from 600 to 750 nm \textsuperscript{[27]} can assign to the \textsuperscript{3}A\textsubscript{2}→\textsuperscript{3}T\textsubscript{1} (3F) of Cr\textsuperscript{4+} due to the splitting of the excited state in the lower symmetry of the crystal field. Figure 9 shows the Tanabe–Sugano diagram of tetrahedral coordinated Cr\textsuperscript{4+} ion. From Figure 9 we see an ideal tetrahedral position, the lowest free ion level for Cr\textsuperscript{4+} ion, \textsuperscript{3}F divided into three components, \textsuperscript{3}F→\textsuperscript{3}A\textsubscript{2} + \textsuperscript{3}T\textsubscript{2} + \textsuperscript{3}T\textsubscript{1}, with the energy of these levels being \textsuperscript{3}A\textsubscript{2}<<\textsuperscript{3}T\textsubscript{2}<<\textsuperscript{3}T\textsubscript{1}\textsuperscript{[14]}. Also, from the previous figure it is evident that when Cr\textsuperscript{4+} is at the high crystalline field sites, the \textsuperscript{3}T\textsubscript{2} level is upper the 1E level, while at the low field sites the arrangement is reversed\textsuperscript{[12]}. The energy transition of \textsuperscript{4}A\textsubscript{2g}(f)→\textsuperscript{4}T\textsubscript{2g}(f) give the ten times of crystal field splitting parameter Dq\textsuperscript{[14]}\textsuperscript{[29]} and the Racach parameters (B, C) for lithium borate glass containing Cu-Cr calculated from the measured energies of the absorption bands according to the following relation\textsuperscript{[14]}\textsuperscript{[30]} tabulated in table 2.
\[ D_q = \frac{E(\Delta_{A_g}) - E(\Delta_{T_g})}{10} \]

\[ D_q/B = \frac{15(X - 8)}{X^2 - 10X} \]

Where

\[ X = \frac{E(\Delta_{A_g} - 2\Delta_{T_g}) - E(\Delta_{A_g} - 4\Delta_{T_g})}{D_q} \]

The C-value evaluated utilizing the relation:

\[ \frac{C}{B} = \frac{E(\Delta_{A_g} - 2\Delta_{E_g})}{B} = 7.9 + 1.8 \left( \frac{B}{D_q} \right) \]

Table 2: The values of Dq, Racah parameter (B and C), nephelauxetic parameters (h and β), the cutoff wavelength, optical band gap and urbach energy.

| Conc(mol%) | Dq  | Dq/B | Bcm⁻¹ | C cm⁻¹ | h    | β    | λc nm | Eg   | ΔE   |
|-----------|-----|------|--------|--------|------|------|-------|------|------|
| 4 Cr      | 1666.7 | 3.92 | 424.77 | 3771   | 2.59 | 0.46 | 640   | 1.93 | 0.67 |
| 3Cr-1 Cu  | 1666.7 | 2.89 | 576.59 | 3418   | 1.77 | 0.63 | 690   | 1.797| 0.6  |
| 2Cr-2Cu   | 1639.3 | 2.76 | 594.13 | 3375   | 1.68 | 0.65 | 440   | 1.67 | 0.6  |
| 1Cr-3 Cu  | --   | --   | --     | --     | --   | --   | 330   | 3.75 | 0.33 |

It can notice from the table that Dq / B decreased with increasing copper content indicating that the band became broader causing a weakening of the crystal field at the Cr³⁺ ionic site[29]. According to the Tanabe-Sugano diagram for Cr³⁺ ions as shown in figure 9, demonstrates that the Dq / B ratio influences the relative positions of the excited ⁴T₂₂g and ²E₂ state of Cr³⁺ ions.

The Cr³⁺ can center as a high or low field sites in the luminescence and can recognize by the shape of the emission lines and the value of Dq / B. When the emission shows the narrow lines that the energy of ⁴T₂₂g is higher than that of the ²E₂ state (Dq / B > 2.3) due to the ²E₂ → ⁴A₂g (R1-line) and ²T₁₂g→⁴A₂g (R2-line) spin-forbidden transitions. The Cr³⁺ ions in the high-field sites that produce yield conventional laser action. The energy of ⁴T₂₂g is lower than that of the ²E₂ state (Dq / B < 2.3) when the emission shows the broadband.
Figure 9 the Tanabe–Sugano diagram of tetrahedral coordinated Cr$^{4+}$ ion.

The Cr$^{3+}$ centers in glasses in the low-field sites that yield tunable laser action in disordered hosts[9][31][32]. From the values acquired from Dq / B, it can watch that the values bigger than 2.3 that show the luminescence consists of the sharp lines (R lines) that relate to parity- and spin-forbidden $^2E_g \rightarrow ^4A_{2g}$ transition decaying with ms timescale. The Racah parameter B indicates the inter-electronic repulsion in the d-shell[28], from table 2 it can watch the values of B increase as the increase of Cu concentration. The larger merit of B, it means that the more electrons localized on the copper metal ion. Also, from table 2 the values of B of all glass samples lower than the B value of free ion value of Cr$^{3+}$ (B$_{free}$ = 918cm$^{-1}$).The value of B used in study the type of the Cr–O bonding (ionic or covalent bond). By using the relation[33].

$$h = \frac{(B_{free} - B)}{B_{free}}$$

Where h and k are nephelauxetic parameters of the ligand and the metal ion, respectively. The k For Cr$^{3+}$ ion equal 0.21. The decrease in the h esteems represents the lessening in a covalent bond in the glass network and increment in the localization of the d-electrons due because of orbital overlapping with ligand orbital[30]. The nephelauxetic ratio, $\beta = B$ (complex) /B (free ion)[34] assessed for all the glasses exhibited in Table 2 as the $\beta$ values increase with the decrease of Cr metal concentration. These outcomes demonstrate a slow lessening in the covalent environment for chromium ions[34].
Figure 10 demonstrates the optical transmission spectra for all studied borate glasses. An unmistakable cutoff ($\lambda_c$) has watched for all samples firmly depends on Cr-Cu substitution content and varies from 640 nm to 810 nm (Table 2). The move in $\lambda_c$ proposes that the concentration of NBO in the glass network increment with Cu-Cr substitution[35]. From figure 10 it very well may watch that the glass sample containing 3 mol % Cu act as a narrow band color filter from 350 nm to 710 nm[12].

The estimations of the optical band gap can determine by numerous courses as from the relation[7].

$$E_g = \frac{hc}{\lambda}$$

Where $E_g$ is energy gap, $h$ is Plank's constant, $c$ is the speed of light, and $\lambda$ is the wavelength of incident photons.

The Urbach energy can calculate from the following equation[33]

$$\alpha(\nu) = A \exp \left( \frac{h\nu}{\Delta E} \right)$$

$A$ is a constant, $\Delta E$ is the Urbach energy and $\nu$ is the frequency of radiation. The values of $\Delta E$ can dictate by taking the reciprocal of the slant of $\ln(\alpha)$ vs. $\lambda\nu$ plot.

The variation in $E_g$ values on the variation of Cr-Cu concentration can comprehend as the structural changes occurring in the glass samples. It can observe as the glass sample containing 3 mol% of Cu have a large value of $E_g$, the small value of $\Delta E$ and this result agree with the literature[21]. The substitution of Cr with Cu content introduces additional defect states [4] like color centers, wrong bonds and short-range distortion in the glass structure make the $E_g$ and $\Delta E$ values to decrease. These results agree with the values of $h$ and $\beta$ that indicate the more electrons localized around the d orbital that decreases the number of bridging oxygen around the metal.
Figure 11 shows the photoluminescence of borate glass containing Cr and Cu metal with different concentration excited at (a) 274 nm and (b) 370 nm. From the figure, 11a observed that the high intensity emitted band at 540 nm due to chrome as the transitions $^4T_{1g} \rightarrow ^4A_{2g}$ spin-allowed transitions emit green emission[14]. Figure 11b shows the high intensity emitted band at 730 nm attributed to the transitions from $^4T_{2g} \rightarrow ^4A_{2g}$ spin-allowed transitions and $^2E_g \rightarrow ^4A_{2g}$ spin forbidden transition (red emission) from Cr metal[14]. From figure 11 observed that the emission peaks changed from the lower energy to higher energy with the increase of excitation energy it due to these bands belong to different types of activator centers.
Moreover, the emission spectra of Lithium borate glasses containing Cr\(^{3+}\) excited at 274 and 370 nm (36 497 cm\(^{-1}\) 4.53 eV). Showed strong visible emission in the green and orange-red region is due to d-d transitions within the Cr\(^{3+}\) formation.

The sample free from Cu and containing Cr metal excited (3.35eV) 370 nm emitted band at (740 nm 1.68 eV) attributed to the transitions from \(^{5}T_{2g}\rightarrow^{4}A_{2g}\) spin-allowed transitions and \(^{2}E_g\rightarrow^{4}A_{2g}\) spin forbidden transition (red emission). And observed the emission intensity has small increases as the chromium replacement by copper, which is due to the partition between the chromium ions diminishes as the quantity of Cr ions diminishes[14][36]. The Cr\(^{3+}\) ion in the high field local surroundings, the emission of the Cr\(^{3+}\) ions consists of the sharp lines connected with parity- and spin-forbidden \(^{2}E_g\rightarrow^{4}A_{2g}\) transition[31]. From the emission spectra and Tanabe–Sugano diagram can prove that the emission from Cr\(^{3+}\) state. From the figure 11 observed that the blue emission band at 440 nm from the excitation at 370 nm and weak emission band at 365 nm when the samples excited at 274 nm, in addition, the intensity increase with the increase of copper concentration. The two bands belong to the emission of copper due to the \(^{3}D_1\rightarrow^{1}S_0\) transition of isolated Cu\(^{+}\) ions and the emission from Cu\(^{2+}\)[4][36][37][38] respectively. An addition to the sample containing 3mol% Cu emitted broadband at 440 nm (2.82eV- 22727 cm\(^{-1}\)) due to the \(^{4}A_{2g}\) (F)→\(^{4}T_{1g}\) (F) transitions. Ignatouych et al. contemplated the emission from copper ions doped lithium tetraborate glasses. They obtained a broad emission band at 460 nm. This band attributed to 3d\(^9\) 4s→3d\(^{10}\) triplet transitions in Cu\(^{+}\) ions[39]. The same results obtained by Padlyak et al.[24][40]. The broadband emission at 440 nm of the sample containing 1Cr and 3Cu deconvoluted using Gaussian curves to determine the spectral position of all transitions (see the deconvolution of the band emission in Figure 12).

![Figure 12](image)

**Figure 12** the deconvolution in Gaussian bands of the emission spectrum for the glass sample containing 1Cr and 3Cu mol % metal.

From Figure 12, it tends to see that the broadband emission deconvoluted to four bands at 417, 438, 464 and 486 nm different shapes (broad or sharp) and in the intensity (less or more) indicating that the more transition dominant. The emissions at 417 and 486 nm are due to Cu\(^{2+}\) ions in the glass. Be that as it may, as indicated by
the before investigations, emission at 493nm emerges in view of a confined excitation of an isolated Cu$^{2+}$ ion[41]. The broad emission is due to, or resulting from, the transition between degraded T$_{1g}$ / T$_{2g}$ levels to the $^1$A$_g$ level of copper ions Cu$^{+}$, which arises from the interaction of non-bridged oxygen atoms bound by P with Cu$^{2+}$ ions in the glass[42][43]. Subsequently, in the luminescence studies, the presence of Cu$^{+}$ ions in the glass has inferred. With the addition of copper the center of emitted not affected. And then the intensity may be small increases.

4. Conclusion

Lithium borate glass samples containing copper and chromium metal synthesized by the melt quenching technique. XRD investigate the amorphous nature of glass samples. The FTIR investigation demonstrates that the Cu substitution Cr and enters the network structure and form BO$_4$ units at the expense of BO$_3$ units without forming non-bridging oxygen. Differential thermal analysis parameter of glass samples that demonstrates all the samples have the glass forming ability and thermal stability. The optical properties of glass samples containing copper and chromium metal obtained. The values of Dq / B represents that Cr$^{3+}$ ions in a high field and decrease with the copper content increase. Furthermore, the green and red emission due to the transitions from $^4$T$_{1g}$ and $^4$T$_{2g}$ excited states to the ground state of Cr$^{3+}$ ions. By the addition of Cu up to 3 mol%, the highest intensity variation observed at 440 nm (blue) band for transition in glass sample containing 1Cr-3Cu. As a result, interesting changes are observed in the emission spectra which correlate with changes in the glass lattice structure.
References

[1] Nalin M, Poulain M, Ribeiro S. J. L., and Messaddeq Y 2001 Journal of non-crystalline solids284 110–116

[2] Soga N, Hirao K, Yoshimoto M, and Yamamoto H 1988 Journal of applied physics63 4451–4454

[3] Balachander L, Ramadevudu G, Shareefuddin M, Sayanna R, and Venuadhar Y. C 2013 Science Asia 39 278–283

[4] Bhogi A, Kumar R. V, and Kistaiah P 2015 Journal of non-crystalline solids426 47–54

[5] Marzouk M. A, ElBatal F. H, and Abdelghany A. M 2013 Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy114 658–667

[6] Stefan R, Culea E, and Pascuta P 2012 Journal of non-crystalline solids358 839–846

[7] Obayes H. K, Wagiran H, Hussin R, and Saeed M. A 2016 Materials & Design94 121–131

[8] Krishna G. M, Gandhi Y, Venkatramaiah N, Venkatesan R, and Veeraiah N 2008 Physica B: Condensed Matter403 702–710

[9] Lesniewski T, Padlyak B V, Justyna Mahlik Barzowska, Sebastian Adamiv V T, Nurgul Z, Grinberg Marek, 2016 Optical Materials (Amst).59 120–125

[10] Kaczmarek S. M 2002 Optical Materials (Amst).19 189–194

[11] Ikeda H, Murata T, and Fujino S 2015 Mater. Chem. Phys.162 431–435

[12] Kashif I and Ratep A 2015 Journal of Molecular Structure1102 1–5

[13] Shailaja S, Geetha K, Vasantharani P, and Kadhars P. S. A 2015 Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy138 846–856

[14] KashifI and RatepA 2016 Optical and Quantum Electronics 48 516

[15] Cozar O, Ardelean I, Brutul I, Ilonca G, and Simon S 1993 Solid State Communnication, 86 569–572

[16] Yusub S and Rao D. K 2014 Journal of non-crystalline solids398 1–9

[17] Sumalatha B, Omkara M, Rao T. R, and Raju C. L 2011 Journal of non-crystalline solids357 3143–3152

[18] Kashif I, Abd El-ghany A, Abd El-Maboud A, Elsherbiny M. A, and Sanad M. 2010 Journal of Alloys and Compounds.503 384–388

[19] Kumar D, Rao S. M, and Singh S. P 2017 Journal of non-crystalline solids464 51–55

[20] Dalal S et al. 2015 Materials Research Bulletin70 559–566

[21] Kashif I and Ratep A 2015 Applied Physics A120 1427–1434

[22] Mhareb M. A et al. 2016 Journal of Luminescence177 366–372

[23] Moustafa Y. M, Hassan A. K, El-Damrawi G, and Yevtushenko N. G 1996 Journal of non-crystalline solids194 34–40

[24] Padlyak B et al. 2010 Journal of non-crystalline solids356 2033–2037

[25] A. ElBatal M, Abdelghany A. M, and Alil S 2012 Journal of non-crystalline solids358 820–825

[26] Rao L. S, Reddy M. S, Rao D. K, and Veeraiya N 2009 Solid state Science11 578–587

[27] Ma H, Liu P, Yang Q, Deng D, and Xu S 2014 Materials Letter116 13–15

[28] Kesavulu C. R, Chakradhar R. P. S, Muralidhara R. S, Rao J. L, and Anavekar R. V 2010 Journal of Alloys and Compounds496 75–80
[29] ChakradharR. P. S, MuraliA, and RaoJ. L 1998 Journal of Alloys and Compounds 281 99–107
[30] AhmadF 2014 Journal of Alloys and Compounds586 605–610
[31] PisarskiW. A, PisarskaJ, Dominiak-DzikG, and Ryba-RomanowskiW 2009 Journal of Alloys and Compounds484 45–49
[32] PadyakB. V, Ryba-RomanowskiW, LisieckiR, AdamivV. T, V BurakY, and TeslyukI. M 2012 Optical Materials (Amst).34 2112–2119
[33] Sundari G. R et al. 2014 Optical Materials (Amst).36 1329–1335
[34] Naga RajuG, VeeraiahN, NagarjunaG, and SatyanarayanaP. V. V 2006 Physica B: Condensed Matter373 297–305
[35] RaniS, SanghiS, AhlawatN, and AgarwalA, 2014 Journal of Alloys and Compounds597, 110–118
[36] KaurS, KaurP, SinghG. P, KumarS, and SinghD. P 2015 Optical Materials (Amst).47 276–284
[37] V NikonorovN, SidorovA. I, TsekhomskiiV. A, and ShakhverdovT. A 2013 Opt. Spectrosc.114 379–383
[38] BabkinaA. N, V NikonorovN, SidorovA. I, ShirshnevP. S, and ShakhverdovT. A 2014 Optics and spectroscopy116 84–90
[39] PedriniC 1978 Physica status solidi87 273–286
[40] SrinivasuluK, OmkaramI, ObeidH, KumarA. S, and RaoJ. L 2012 Physica B Condensed Matter407 4741–4748
[41] ThulasiramuduA and BuddhuduS 2006 Journal of Quantitative Spectroscopy and Radiative Transfer97 181–194
[42] RamkumarJ et al. 2008 Journal of non-crystalline solids354 1591–1597
[43] ChanshettiU. B, SudarsanV, JogadM. S, and ChondhekarT. K 2011 Physica B Condensed Matter406 2904–2907