International Journal of Physics and Mathematical Sciences ISSN: 2277-2111
An International Journal Available at http://www.cibtech.org/jpms.htm
2016 Vol. 6 (S1) October-December (Supplementary Issue), pp.55-62/Naresh et al.
Research Article

SPECTROSCOPIC INVESTIGATION ON LITHIUM YTTRIUM SILICATE GLASSES DOPED WITH V_2O_5

P. Naresh[1], S.Brammaiah[2], P. Ramesh Babu[3], K. Naveen Kumar[3] and *R. Vijay[3]
[1]*Department of Physics, VR Siddhartha Engineering College, Vijayawada-520007, A.P*
[2]*Department of Physics, Acharya Nagarjuna University, Guntur, A.P*
[3]*Department of Physics, Usha Rama College of Engineering & Technology, Telaprolu-521109, A.P*
**Author for Correspondence*

ABSTRACT
In this work, glass systems of the composition (40-x) Li_2O – $10Y_2O_3$ – $50SiO_2$: xV_2O_5 where (x = 0.2, 0.4, 0.6, 0.8, 1.0 mol%) have been prepared by the conventional melt quenching technique. The samples were characterized by the XRD. Optical absorption and IR of these glass samples have been investigated. Optical absorption spectra exhibits two broad absorption bands at about 640 and 1020 nm due to $^2B_2 \rightarrow ^2B_1$ and $^2B_2 \rightarrow ^2E$ transitions of VO^{2+} ions. With increase in the concentration of V_2O_5, the intensity of these peaks is observed to increase with a red shift. The IR spectral studies indicated that the glass samples contains various structural units with the linkages of the type Si–O–Si, Si–O–V, Y–O, V–O–V; the increasing content of V_2O_5 in the glass samples seemed to have weakened such linkages. Finally, the analysis of the results of OA spectra of the studied glass have indicated that a considerable proportion of vanadium ions do exist in V^{4+} state in addition to V^{5+} state, and the redox ratio increases with increase in the concentration of crystallizing agent V_2O_5.

Keywords: *Glasses, Optical Absorption, IR*

INTRODUCTION
Lithium silicate glasses with high thermal stability, chemical durability and good optical transparency over a wide range of wavelengths are particularly useful in data busses which cover short distances. When alkali silicate glasses are mixed with some sesquioxides (e.g., Sb_2O_3, Al_2O_3, Y_2O_3, La_2O_3, Sc_2O_3 etc.,), their thermo-physical, chemical and mechanical stability will be further improved. Such glasses were proved to be high efficient luminescence materials (Dikovska *et al.*, 2006; Alekseeva *et al.*, 2011; Hughes *et al.*, 2009; Kong *et al.*, 2005; Tokurakawa *et al.*, 2007; Guo *et al.*, 2004; Korzenski *et al.*, 2001; SrinivasaRao *et al.*, 2011; Marasinghe *et al.*, 1998; Venkateswara Rao *et al.*, 2008; Moguš-Milanković *et al.*, 2012; Salem *et al.*, 2012). Among various sesquioxides, the addition of Y_2O_3 to silicate glass systems widens the spectral range of transparency, enhances the refractive index and lowers phonon energies (SrinivasaRao *et al.*, 2011; Marasinghe *et al.*, 1998; Venkateswara Rao *et al.*, 2008).
In view of these qualities, Y_2O_3 mixed lithium silicate glasses were considered as excellent host materials for rare earth ion doping and proved to be efficient both in continuous wave operation as well as in pulsed regimes. Yb^{3+} doped laser materials are of interest for the next generation nuclear fusion (Graça *et al.*, 2003; Shapaan *et al.*, 2012) and are being used as gain media in the microchip laser at sufficiently high doping levels (Salman and Mekki, 2011). Energy level structure of Yb^{3+} ion is exceptionally simple, consisting of a ground state manifold, $^2F_{7/2}$, Stark-split into four sublevels and an excited-state manifold, $^2F_{5/2}$, Stark-split into three sublevels. Thus, excited state absorption (ESA) for both the pump and signal wavelengths is absent for this ion. The upper manifold lies approximately 10500 cm^{-1} above the ground level (Satyanarayana *et al.*, 2009). This large energy gap favors significant reduction of multi-phonon non radiative decay (Rao, 2002). The broad absorption spectrum due to Stark-splitting of this ion provides a wide choice of pump wavelengths. Further, the broad emission spectrum of Yb^{3+} ion and its large saturation fluencies enable to achieve lasing inverse level occupation and corresponding laser generation over a wide range of lasing region (~1–1.2 μm). Such interesting features of this rare earth ion make its host as an attractive medium for the generation and amplification of ultra-short pico-and femto second laser pulses (Ahmed *et al.*, 2012).

A vanadate-based glass exhibits good semiconducting properties, relatively high electrical conductivity and chemical durability and also posses low crystallization tendency, melting point (Montani and Frechero, 2006; Prashant Kumar and Sankarappa, 2008; Reddy *et al.*, 2008; Saddeek *et al.*, 2009; Khattak *et al.*, 2009; Murawski, 1984; Shaaban *et al.*, 2009; Narayana Reddy C and Anavekar, 2008; El-Desoky, 2005).

These properties make vanadate glasses potential candidates for technological applications such as in electrical threshold, threshold switching, memory switching, optical switching devices as well as cathode materials for solid state devices and optical fiber (Ovshinsky, 1968; Drake *et al.*, 1969; Livage *et al.*, 1990; BalajiRao *et al.*, 2004; Pascuta *et al.*, 2008; Montani *et al.*, 1992; Ghosh and Chaudhuri, 1988). V_2O_5 is known as a conditional glass former which does not form glass on their own, but readily forms glass only with a modifier such as alkali, alkaline earth and transition metal oxides (TMO) or other glass formers (Saddeek *et al.*, 2009; Singh *et al.*, 1988; Chiodelli *et al.*, 1982; VeerannaGowda VC and Anavekar, 2004).

Vanadate glasses also belong to the class of amorphous oxide semiconductors (Maniu *et al.*, 2004) where in this system the vanadium ions can adopt two different valence states, V^{4+} and V^{5+}. The electrical conduction is attributed to the hopping of $3d^1$ unpaired electron from a V^{4+} site to a V^{5+} site which induces polarization of the lattice forming a polaron (Sayer and Mansingh, 1972; Mott, 1968; Austin and Mott, 1969; Chung and Mackenzie, 1980; Owen, 1977; Ghosh, 1990).

In the present paper we have synthesized $Li_2O–Y_2O_3–SiO_2$ glasses doped with different concentrations of V_2O_5 and investigated the structural changes that take place due to the varied oxidation states of vanadium ions using optical absorption and IR spectral studies.

MATERIALS AND METHODS

For the present study, a particular composition viz., (40-x) $Li_2O–10Y_2O_3–50SiO_2$: x V_2O_5 (with x ranging from 0 to 1.0) is chosen.

The details of composition are:

V_0: 40.0 $Li_2O–10Y_2O_3–50SiO_2$
V_2: 39.8 $Li_2O–10Y_2O_3–50SiO_2$: 0.2 V_2O_5
V_4: 39.6 $Li_2O–10Y_2O_3–50SiO_2$: 0.4 V_2O_5
V_6: 39.4 $Li_2O–10Y_2O_3–50SiO_2$: 0.6 V_2O_5
V_8: 39.2 $Li_2O–10Y_2O_3–50SiO_2$: 0.8 V_2O_5
V_{10}: 39.0 $Li_2O–10Y_2O_3–50SiO_2$: 1.0 V_2O_5

Among various compositions, this range of concentration seems to have formed a relatively clear and transparent glass. The starting materials used for the preparation of the glasses were Analytical grade reagents (99.9% pure) of $LiCo_3$, Y_2O_3, SiO_2 and V_2O_5. Powders of these compounds in appropriate amounts (all in mol%) were thoroughly mixed in an agate mortar and melted in a platinum crucible in the temperature range of 1400–1450 ^{0}C in a PID temperature controlled furnace for about 1/2 h till a bubble free liquid was formed. It may be noted here that by trial and error we have found this particular range (1400–1450 ^{0}C) of temperature is the lowest possible temperature at which the samples could clearly be melted. The resultant bubble free melt was then poured on rectangular brass mold (containing smooth polished inner surface) kept at room temperature. The samples were subsequently annealed at 400^{0}C in another furnace and cooled to room temperature at the rate of about 1 ^{0}C/min. The amorphous state of the prepared glasses was checked by X-ray diffraction spectra recorded on Xpert PRO, pan alytical X-ray diffractometer. Optical absorption spectra of V_2O_5 doped glasses were recorded to a spectral resolution of 0.1 nm at room temperature in the spectral wavelength range covering 300–2100 nm using JASCO Model V-670 UV–vis–NIR spectrophotometer. IR transmission spectra of these glasses were recorded in KBr matrices in the range 400–2000 cm^{-1} using potassium bromide pellets (300 mg) containing pulverized sample. These pellets were pressed in a vacuum die at -680 MPa.

In the present paper we have synthesized $Li_2O–Y_2O_3–SiO_2$ glasses doped with different concentrations of V_2O_5 and investigated the structural changes that take place due to the varied oxidation states of vanadium ions using optical absorption, IR spectral studies.

RESULTS AND DISCUSSION

Figure 1 shows the XRD patterns of in $Li_2O–Y_2O_3–SiO_2$ doped with different concentrations of V_2O_5. These X-ray diffraction patterns confirm the amorphous nature of the samples.

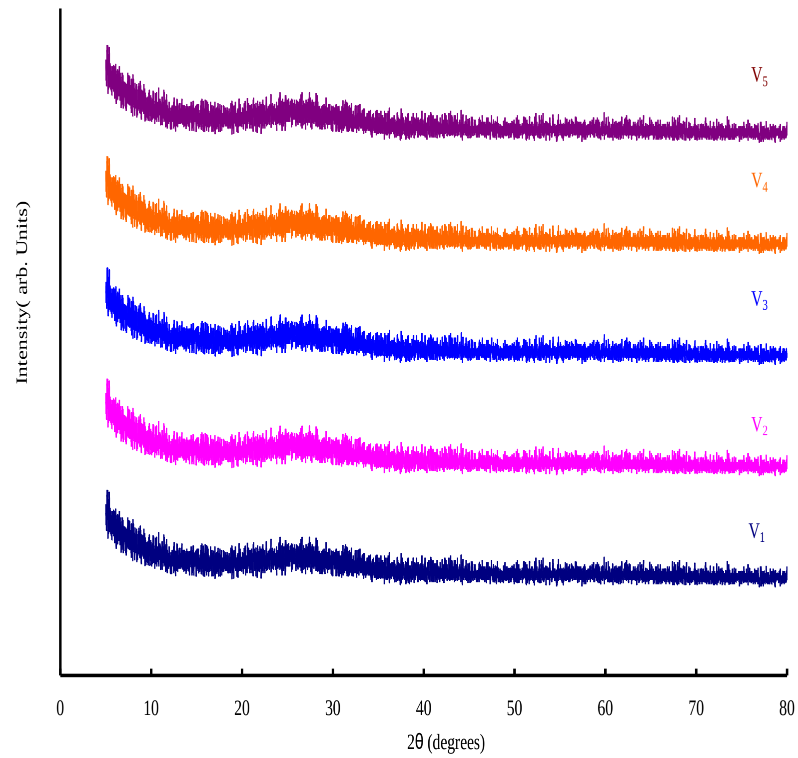

Figure 1: XRD Patterns of Li_2O-Y_2O_3-SiO_2 Doped with Different Concentrations of V_2O_5

Figure 2 shows the optical absorption spectra of $Li_2O–Y_2O_3–SiO_2:V_2O_5$ glasses. The absorption edge observed at 340 nm for pure glass and it is found to be shifted gradually towards higher wavelength with an increase of the concentration of V_2O_5. Additionally, the spectra of glasses doped with 0.2 mol% of V_2O_5 have exhibited two broad absorption bands at 650 and 1080 nm corresponding to ${}^2B_2 \rightarrow {}^2B_1$ and ${}^2B_2 \rightarrow {}^2E$ transitions of VO^{2+} ions (Ballhausen and Gray, 1962); with increase in the concentration of V_2O_5 up to 1.0 mol%, the half width and peak height of these bands are observed to increase and shifted slightly towards higher wavelength.

From the observed absorption edges, we have evaluated the optical band gaps (E_o) of these glasses by drawing Urbach plots (Figure 3) of all glasses. From the extrapolation of the linear portion of these curves, the values of optical band gap (E_o) obtained for $Li_2O–Y_2O_3–SiO_2:V_2O_5$ glasses along with cut-off wavelengths and band positions are presented in Table 1. The value of E_o is found to decrease with the increase in concentration of V_2O_5. V^{4+} ion belongs to d^1 configuration with ${}^2D$ as the ground state. In the presence of pure octahedral crystal field, the ${}^2D$ state splits into ${}^2T_2$ and ${}^2E$, while an octahedral field with tetragonal distortion further splits the ${}^2T_2$ level into ${}^2E$ and ${}^2B_2$; among these, the ${}^2B_2$ will be the ground state. Further ${}^2E$ level splits into ${}^2A_1|3z^2-r^2\rangle$ and ${}^2B_1|x^2-y^2\rangle$where as ${}^2B_2$ splits into three $|xy\rangle$, $|yz\rangle$ and $|zx\rangle$ states. Thus, for the vanadyl ions we can expect 3 bands corresponding to the transitions ${}^2B_2 \rightarrow {}^2B_1$ ($d_{xy} \rightarrow d_{x^2-y^2}$), ${}^2B_2 \rightarrow {}^2E$ ($d_{xy} \rightarrow d_{zx,yz}$) and ${}^2B_2 \rightarrow {}^2A_1$ ($d_{xy} \rightarrow d_{z^2}$). However, in the spectra of the present glasses, only the first two bands are observed.

We can understand the observed decrease in the optical band gap with increase in the concentration of V_2O_5 is as follows: The gradual increase in the concentration of vanadyl ions, causes a creation of large number of donor centers; subsequently, the excited states of localized electrons originally trapped on VO^{2+} sites begin to overlap with the empty 3d states on the neighboring V^{5+} sites. As a result, the impurity band becomes more extended into the main band gap. This development might have shifted the absorption edge to the lower energy which leads up to a significant contraction in the band gap.

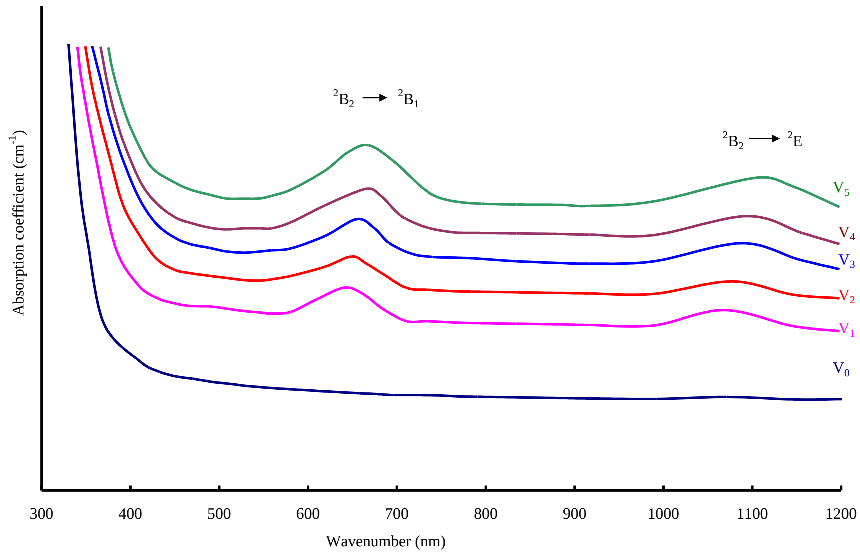

Figure 2: Optical Absorption Spectrum of Li_2O-Y_2O_3-SiO_2 Doped with Different Concentrations of V_2O_5

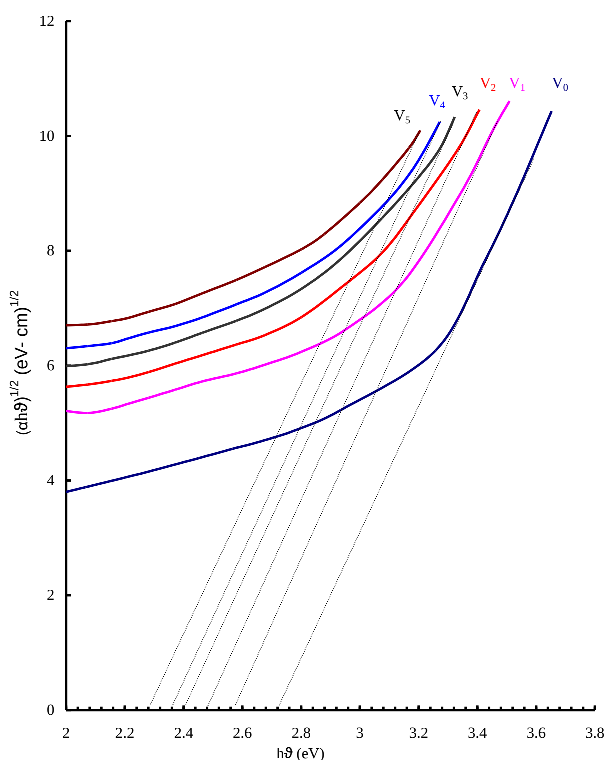

Figure 3: Tauc Plots of Li_2O-Y_2O_3-SiO_2 Doped with Different Concentrations of V_2O_5

Table 1: Data on Optical Absorption Spectra of $Li_2O–Y_2O_3–SiO_2$: V_2O_5 Glasses

Sample	Cut-off Wavelength (nm)	Optical Band Gap E_o (eV)	Position of $^2B_2 \rightarrow ^2B_1$ Band (nm)	Position of $^2B_2 \rightarrow ^2E$ Band (nm)
V_o	330	2.72	--	--
V_2	340	2.58	642	1068
V_4	351	2.48	649	1077
V_6	357	2.41	655	1081
V_8	366	2.36	665	1099
V_{10} 375	2.28	668	1104	

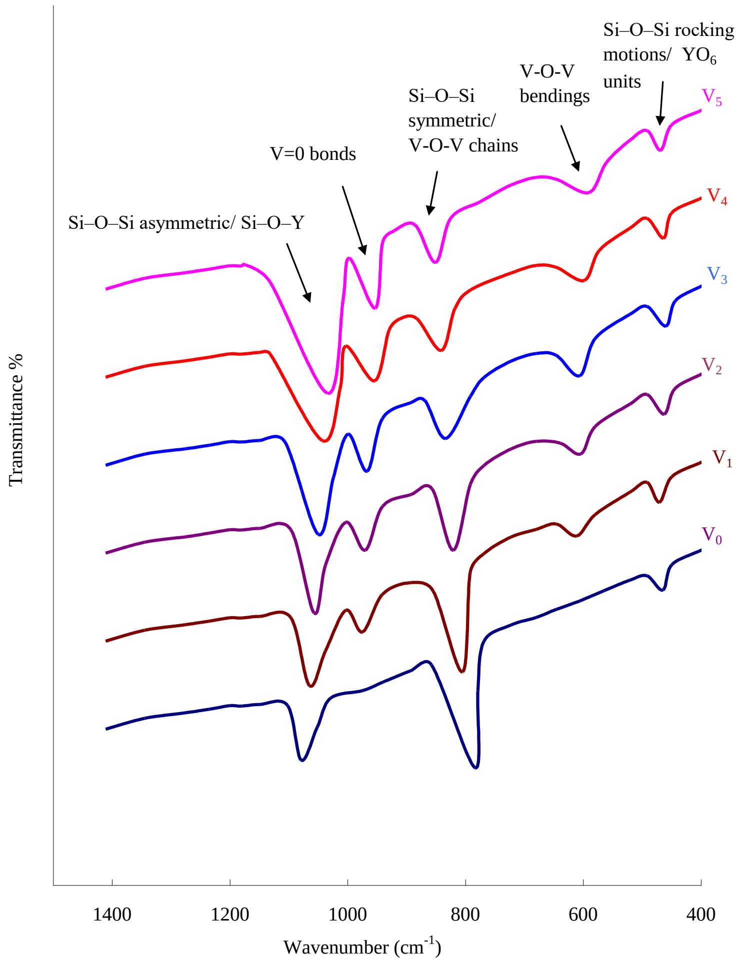

Figure 4: IR Spectrum of Li_2O-Y_2O_3-SiO_2 Doped with Different Concentrations of V_2O_5

Table 2: Data on Infrared Spectra $Li_2O–Y_2O_3–SiO_2$: V_2O_5 Glasses Recorded at Room Temperature (Assignment of Band Positions in cm^{-1})

Assignment	V_0	V_2	V_4	V_6	V_8	V_{10}
Si–O–Si asymmetric/ Si–O–Y	1079	1065	1057	1050	1043	1034
V=O	--	975	970	967	953	950
Si–O–Si symmetric/V-O-V chains	784	805	821	834	841	851
V-O-V bendings	--	611	604	606	598	590
Si–O–Si rocking motions/ YO_6 units	465	471	463	460	467	469

In Figure 4, the IR spectra of V_2O_5 doped $Li_2O–Y_2O_3–SiO_2$ glasses are presented. The spectra have exhibited conventional vibrational band due to Si−O−Si asymmetric vibrations at about 1083 cm^{-1} and another band at about 787 cm^{-1} due to Si−O−Si symmetric vibrations or due to bending mode of bridging oxygen situated perpendicularly to Si–Si axis within the Si−O−Si plane (Nakamura *et al.*, 1984; Srikumar *et al.*, 2011). The octahedral band of yttrium ions (YO_6) is also located in these spectra at about 482 cm^{-1} (Yanmin Q and Hai, 2009; Lianga *et al.*, 2011). The band due to Si−O−Si rocking motion is also predicted in this region (Rao, 2002; Nakamura *et al.*, 1984). With the introduction of V_2O_5, an additional band at 970 cm^{-1} due to V–O stretching of V=O groups , band at 815 cm^{-1} due to V–O–V stretchings and band at 600 cm^{-1} due to V–O–V bending vibrations (Tanaka *et al.*, 1989). The bands observed in the spectra of glass V_1 at 980, 800 cm^{-1} can there be considered as common vibrational modes due to Si–O–V stretchings. As the concentration of V_2O_5 is increased in the glass samples gradually, the bands due to asymmetrical vibrations of silicate and other structural units are observed to grow at the expense of symmetrical bands. The relevant data related to IR spectra of these glasses are presented in Table 2.

Conclusion

The glass samples $Li_2O–Y_2O_3–SiO_2$ doped with different concentrations of V_2O_5 are prepared. The characterization of the samples by SEM clearly indicates the amorphous nature of the samples. The IR spectral studies indicated that the glass samples contains various structural units with the linkages of the type Si–O–Si, Si–O–Y, Si–O–V, V=O and V–O–V; the increasing content of V_2O_5 in the glasses seemed to have weakened such linkages. The analysis of the results of optical absorption spectra of the studied glass have indicated that a considerable proportion of vanadium ions do exist in V^{4+} state in addition to V^{5+} state, and the redox ratio increases with increase in the concentration of V_2O_5.

REFERENCES

Ahmed T, Vorobiev A and Gevorgian S (2012). Growth temperature dependent dielectric properties of $BiFeO_3$thin films deposited on silica glass substrates. *Thin Solid Films* **520(13)** 4470-4474.

Alekseeva I, Dymshits O, Tsenter M and Zhilin A (2011). Influence of various alkali and divalent metal oxides on phase transformations in NiO-doped glasses of the $Li_2O–Al_2O_3–SiO_2–TiO_2$ system. ***Journal of Non-Crystalline Solids* 357(11-13) 2209-2214.**

Austin G and Mott NF (1969). Polarons in crystalline and non-crystalline materials. *Advances in Physics* **18(71)** 41-102.

BalajiRao R, Gopal NO and Veeraiah N (2004). Studies on the influence of V_2O_5 on dielectric relaxation and ac conduction phenomena of $Li_2O–MgO–B_2O_3$ glass system. *Journal of Alloys and Compounds* **368(1)** 25–37.

Ballhausen J and Gray HB (1962). The electronic structure of the vanadyl ion. *Inorganic Chemistry* **1(1)** 111.

Chiodelli G, Magistris A, Villa M and Bjorkstam JL (1982). Structure and ion dynamics in AgI: Ag2B4O7 vitreous electrolytes. *Materials Research Bulletin* **17(1)** 1-12.

Chung CH and Mackenzie JD (1980). Electrical properties of binary semiconducting oxide glasses containing 55 mole% V_2O_5. *Journal of Non-Crystalline Solids* **42(1-3)** 357-370.

Dikovska AOG, Atanasov PA, Jiménez de Castro M, Perea A, Gonzalo J, Afonso CN and García López J (2006). Optically active Er^{3+}–Yb^{3+} codoped Y_2O_3 films produced by pulsed laser deposition. *Thin Solid Films* **500(1)** 336-340.

Drake CF, Scanlon IF and Engel A (1969). Electrical switching phenomena in transition metal glasses under the influence of high electric fields. *Physica Status Solidi (a)* **32(1)** 193-208.

El-Desoky MM (2005). Characterization and transport properties of V 2 O 5–Fe 2 O 3–TeO 2 glasses. *Journal of Non-Crystalline Solids* **351(37)** 3139–3146.

Ghosh A (1990). Electrical transport properties of molybdenum tellurite glassy semiconductors. *Philosophical Magazine B* **61(1)** 87-96.

Ghosh A and Chaudhuri BK (1988). Anomalous conductivity and other properties of V_2O_5-P_2O_5 glasses with Bi_2O_3 OR Sb_2O_3. *Journal of Non-Crystalline Solids* **103(1)** 83-92.

Graça MPF, Valente MA and Ferreira da Silva MG (2003). Electrical properties of lithium niobium silicate glasses. *Journal of Non-Crystalline Solids* **325(1)** 267-274.

Guo H, Zhang W, Lou L, Brioude A and Mugnier J (2004). Structure and optical properties of rare earth doped Y_2O_3 waveguide films derived by sol–gel process. *Thin Solid Films* **458(1)** 274-280.

Hughes MA, Suzuki T and Ohishi Y (2009). Compositional optimization of bismuth-doped yttria–alumina–silica glass. *Optical Materials* **32(2)** 368-373.

Khattak GD, Mekki A and Wenger LE (2009). X-ray photoelectron spectroscopy (XPS) and magnetic susceptibility studies of vanadium phosphate glasses. *Journal of Non-Crystalline Solids* **355(43)** 2148–2155.

Kong J, Tang DY, Zhao B, Lu J, Ueda K, Yagi H and Yanagitani T (2005). 9.2-W diode–end–pumped Yb: Y_2O_3 ceramic laser. *Applied Physics Letters* **86(16)** 161116.

Korzenski MB, Lecoeur P, Mercey B, Camy P and Doualan JL (2001). Low propagation losses of an Er: Y_2O_3 planar waveguide grown by alternate-target pulsed laser deposition. *Applied Physics Letters* **78(9)** 1210-1212.

Lianga H, Zhenga Y, Chena G, Wua L, Zhanga Z and Caob W (2011). Enhancement of upconversion luminescence of Y_2O_3: Er^{3+} nanocrystals by codoping Li^{+}–Zn^{2+}. *Journal of Alloys and Compounds* **509(2)** 409-413.

Livage J, Jollivet JP and Tronc E (1990). Electronic properties of mixed valence oxide gels. *Journal of Non-Crystalline Solids* **121(1-3)** 35-39.

Maniu D, Iliescu T and Astilean S (2004). Raman Study of Lead Vanadates Glasses. *Romanian Reports* **56(3)** 419-423.

Marasinghe GK, Karabulut M, Ray CS, Day DE, Booth CH, Allen PG and Shuh DK (1998). Redox Characteristics and Structural Properties of Iron Phosphate Glasses: A Potential Host Matrix for Vitrifying High Level Nuclear Waste. *Ceramic Transactions* **87(1)** 261-270.

Moguš-Milanković A, Pavić L, Srilatha K, SrinivasaRao C, Srikumar T, Gandhi Y and Veeraiah N (2012). Electrical, dielectric and spectroscopic studies on MnO doped LiI–AgI–B2O3 glasses. *Journal of Applied Physics* **111(1)** 013714.

Montani RA and Frechero MA (2006). Mixed ion-polaron transport in lithium vanadium–molybdenum tellurite glasses. *Solid State Ionics* **177(33)** 2911–2915.

Montani RA, Levy M and Souquet JL (1992). An electrothermal model for high-field conduction and switching phenomena in TeO_2- V_2O_5 glasses. *Journal of Non-Crystalline Solids* **149(3)** 249–256.

Mott NF (1968). Conduction in glasses containing transition metal ions. *Journal of Non-Crystalline Solids* **1(1)** 1-17.

Murawski L (1984). Ac conductivity in binary V_2O_5-P_2O_5 glasses. *Philosophical Magazine B* **50(6) 69-74.**

Nakamura M, Mochizuki Y, Usami K, Itoh Y and Nozaki T (1984). Infrared absorption spectra and compositions of evaporated silicon oxides (SiOx). *Solid State Communications* **50(12)** 1079-1081.

Narayana Reddy C and Anavekar RV (2008). Elastic properties and spectroscopic studies of Li_2O–B_2O_3–V_2O_5 glasses. *Materials Chemistry and Physics* **112(2)** 359–365.

Ovshinsky SR (1968). Reversible electrical switching phenomena in disordered structures. *Physical Review Letters* **21(20)** 1450-1455.

Owen AE (1977). The electrical properties of glasses. *Journal of Non-Crystalline Solids* **25(1-3)** 370-423.

Pascuta P, Borodi G and Culea E (2008). Influence of europium ions on structure and crystallization properties of bismuth borate glasses and glass ceramics. *Journal of Non-Crystalline Solids* **354(52)** 5475-5479.

Prashant Kumar M and Sankarappa T (2008). DC conductivity in some alkali doped vanadotellurite glasses. *Solid State Ionics* **178(33)** 1719–1724.

Rao KJ (2002). *Structural Chemistry of Glasses*, (Elsevier, Amsterdam, Netherland).

Reddy CN, VeerannaGowda VC and SreekanthChakradhar RP (2008). properties and structural studies on lead–boro–vanadate glasses. *Journal of Non-Crystalline Solids* **354(1)** 32–40.

Saddeek YB, Shaaban ER, Aly KA and Sayed IM (2009). Characterization of some lead vanadate glasses. *Journal of Alloys and Compounds* **478(1)** 447–452.

Saddeek YB, Shaaban ER, Aly KA and Sayed IM (2009). Characterization of some lead vanadate glasses. *Physica B* **478(1)** 447-452.

Salem SM, Khalek EKA, Mohamed EA and Farouk M (2012). A study on the optical, structural, electrical conductivity and dielectric properties of a lithium bismuth germanium tungsten glasses. *Journal of Alloys and Compounds* **513(1)** 35-43.

Salman FE and Mekki A (2011). Dielectric study and ac conductivity of iron sodium silicate glasses. *Journal of Non-Crystalline Solids* **357(14)** 2658-2662.

Satyanarayana T, Kityk IV, Piasecki M, Bragiel P, Brik MG, Gandhi Y and Veeraiah N (2009). Structural investigations on PbO–Sb2O3–B2O3: CoO glass ceramics by means of spectroscopic and dielectric studies. *Journal of Physics: Condensed Matter* **21(24)** 245104.

Sayer M and Mansingh A (1972). Transport properties of semiconducting phosphate glasses. *Physical Review B* **6(12)** 4629.

Shaaban ER, Hassaan MY, Mostafa AG and Abdel-Ghany AM (2009). Crystallization kinetics of new compound of V_2O_5–PbO–Li_2O–Fe_2O_3 glass using differential thermal analysis. *Journal of Alloys and Compounds* **482(1)** 440–446.

Shapaan M, El-Badry SA, Mostafa AG, Hassaan MY and Hazzaa MH (2012). Structural and electric-dielectric properties of some bismuth-phosphate glasses. *Journal of Physics and Chemistry of Solids* **73(3)** 407-417.

Singh K, Ratnam J and Deshpande VK (1988). The influence of V_2O_5 on the electrical conductivity of Li_2O: B_2O_3 system. *Solid State Ionics* 28(4) **821** 28-30.

Srikumar T, Kityk IV, Srinivasa Rao C, Gandhi Y, Piasecki M, Bragiel P, Ravikumar V and Veeraiah N (2011). Photostimulated optical effects and some related features of CuO mixed Li_2O–Nb_2O_5–ZrO_2–SiO_2 glass ceramics. *Ceramics International* **37(7)** 2763-2779.

SrinivasaRao C, Kityk IV, Srikumar T, Naga Raju G, Ravi Kumar V, Gandhi Y and Veeraiah N (2011). Spectroscopy features of Pr^{3+} and Er^{3+} ions in Li_2O–ZrO_2–SiO_2 glass matrices mixed with some sesquioxides. *Journal of Alloys and Compounds* **509(37)** 9230-9239.

Tanaka K, Kamiya K and Yoko T (1989). ESR and Mössbauer studies of Bi_2O_3- Fe_2O_3 glasses. *Journal of Non-Crystalline Solids* **109(2-3)** 289-294.

Tokurakawa, M.T., Kazunori S., Akira U., Ken-ichi Y., Hideki Y., Takagimi K. & Alesander A. (2007). Diode-pumped 188 fs mode-locked Yb^{3+}:Y_2O_3 ceramic laser, Applied Physics Letters, 90, 7, 071101-071104.

VeerannaGowda VC and Anavekar RV (2004). Elastic properties and spectroscopic studies of lithium lead borate glasses. *Ionics* **10(1-2)** 103-108.

VenkateswaraRao P, Srinivasa Reddy M, Sudhakar KSV and Veeraiah N (2008). Influence of iron ions on dielectric properties of the PbO–Bi_2O_3–B_2O_3 glass system. *Philosophical Magazine* **88(11)** 1601-1614.

Yanmin Q and Hai G (2009). Upconversion properties of Y_2O_3:Er films prepared by sol-gel method. *Journal of Rare Earths* **27(3)** 406-410.