ISSN 2231-346X (Print)
JUSPS-A Vol. 32(4), 22-28 (2020). Periodicity-Monthly
Section A
(Online) ISSN 2319-8044

JOURNAL OF ULTRA SCIENTIST OF PHYSICAL SCIENCES
An International Open Free Access Peer Reviewed Research Journal of Mathematics
website:- www.ultrascientist.org
Estd. 1989

Bismuth Tellurite Glasses : UpConversion Luminescence Properties: A Review

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http://dx.doi.org/10.22147/jusps-A/320401

Acceptance Date 20th June, 2020, Online Publication Date 30th June, 2020

Abstract

Tellurite glasses are promising upconversion optical and laser materials. The upconversion efficiency is strongly influenced by maximum phonon energy of the host, tellurite glasses have lower phonon energy than many common oxide glasses. The characteristic glass transition temperature T_g and crystallization onset T_x, differential scaning calorimetry (DSC) is studied. Glassy structure is verified by XRD. Study of visible absorption spectra and upconversion spectra of rare earth ion doped Bismuth tellurite glasses designate it as futuristic photonic material.

Key words: Bismuth tellurite glasses RE Rare earth ions UC Upconversion.

Introduction

The phenomenon of conversion longer wavelength of light into shorter wavelength by multiple photon absorption is known as energy or frequency upconversion. The phenomenon of frequency upconversion gaining significant interest in the field of light amplification from visible to ultraviolet region and infrared-pumped visible lasers and in the potential applications in the area of color display sensors, optical amplifiers, energy amplifiers ,optical fibers[1,2] The phenomenon of upconversion (UC) is studied by Bloemberg in 1959 [3]. The UC emission in various system like phosphors, glasses, ceramics, nano-particles have been reported[4-14]. In the study of UC, rare earth elements play a significant role. When UC materials are mentioned, usually phosphors doped with rare-earth (RE) ions are meant.

Optical transitions in REdoped phosphors involve 4f orbitals, which are well shielded from their local environment by the completely filled $5s^2$ and $5p^6$ outer orbitals. Transitions between the different f levels are parity forbidden, and hence the absorption coefficient is low for these transitions. Further, due to these selection rules, the emission rates are rather slow and result in long-lived, linelike emission[15]. Tellurite base glasses gaining attention as base matrix for good transparency and low phonon energy[16-18]. Visible emission is which is attributed to cooperative upconversion from Yb3+ and Er3+ ions.[19]

Tellurite glasses containing bismuth oxides have attend great attention due to its high density, low phonon energy , and high linear and non-linear refractive index[20-22]. The phonon energy of host glass influence strength of UC efficiency[23] and the glass of lower phonon energy can lead to higher UC efficiency.

Characterization:

1. DSC

Differential scanning calorimetry (DSC) is a technique is used to study amount of heat required to increase the temperature of sample.DSC can be used to measure of the glass transition temperature tg. Xueyin Wang , Hai Lin and Dianlai Yang[24] synthesized Ho^{3+}/Yb^{3+} codoped bismuth tellurite glasses by melt quench technique. in order to characterize glass transition tg they carried out DSC of ($5Li_2O$-$5K_2O$-5BaO-$10Bi_2O_3$-$75TeO_2$) host glass,figure1shows the DSC curve which shows value of tg is 285 °C.

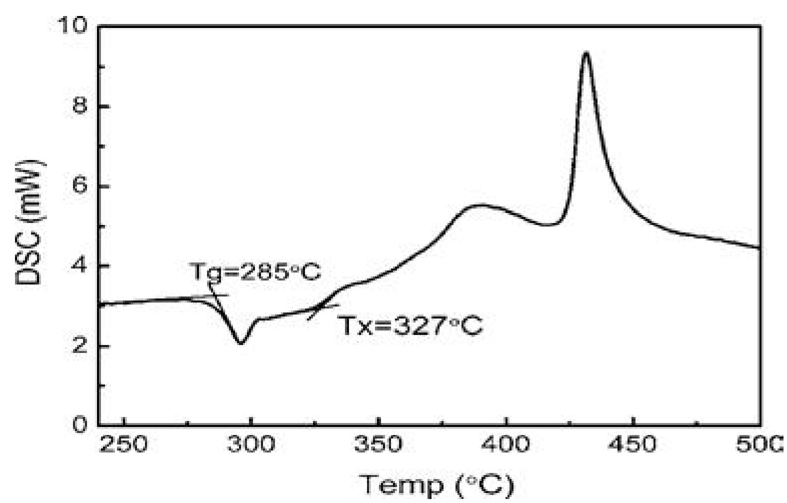

Figure1. DSC curve of $5Li_2O$-$5K_2O$-5BaO-$10Bi_2O_3$-$75TeO_2$ [24]

2. XRD :

The x-ray diffraction pattern of glass sample requires studying its atomic and molecular structure. H.M.Oo, H.M. Kamari and W. M. D. Wan-Yusoff [25] synthesized bismuth tellurite glass (TB) with raw material Bi_2O_3 and TeO_2 as $(Bi_2O_3)x(TeO2)100$-x, x=5,8,10,12, and 15 in mol%. The amorphous nature of glass samples confirmed by XRD pattern. figure 2 is the XRD pattern of the glass samples. It reveals that all glass samples exhibit a broad bump and no sharp peak, indicating the amorphous nature of these samples.

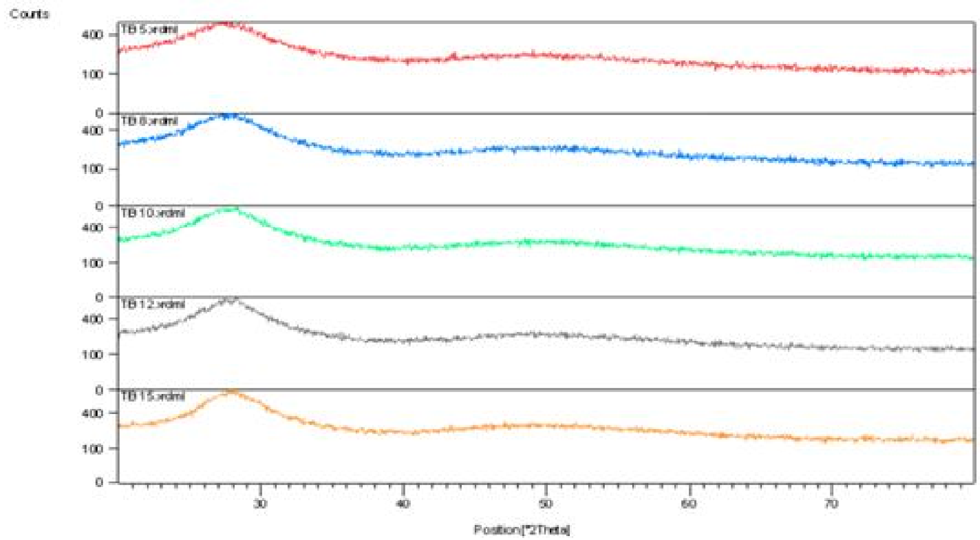

Figure 2. X-ray diffraction (XRD) analysis of the $(Bi_2O_3)x(TeO_2)100{-}x$ glass system[25].

3. Upconversion emission :

The up conversion emission (UC) of the rare earth doped glass ceramics has been studieng by several researchers since several decades. Yannick Ledemi, Danilo Manzani, Sidney J.L. Ribeiro, Younes Messaddeq[26] synthesized Bismuth Tellurite glasses by conventional melt quench method The matrix of glasses were taken $70TeO_2$-$15GeO_2$-$10Bi_2O_3$-$5K_2O$ as TGBR and TGBR2 with doping of Yb_2O_3(1.6%),Tm_2O_3(.4%) and Ho_2O_3(.2%). Visible absorption spectra recorded as shown in fig 3. The bands observed in this work are very near red (660nm), green (546nm) and blue (478nm), it due to Ho^{3+} ions.

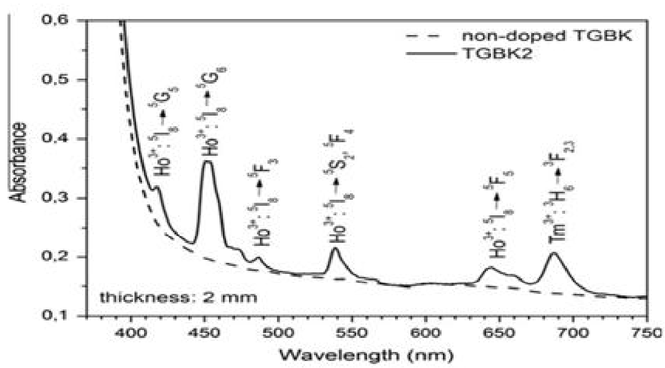

Figure 3. Visible absorption spectra of the non-doped TGBK and TGBK2 glass samples with the corresponding absorption transitions of Tm^{3+} and Ho^{3+} ions from their ground state (sample thickness is 2 mm)[26].

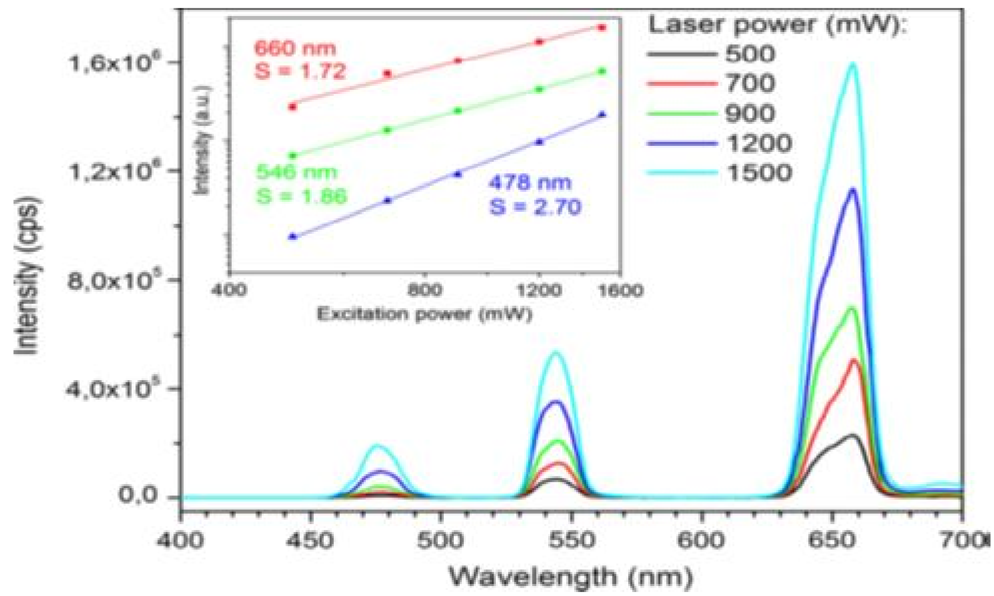

Figure 4. Up conversion emission spectra of the TGBK2 glass as a function of the excitation power at 980 nm. Inset: Dependence of up conversion emission intensity on excitation power of the bands centered at 478, 546 and 660 nm [26].

The sample TGBR2 excited at 980nm under 500 to 1500mW shown in fig.4. up conversion bands intensities at 478,547,and 660nm depicted as function of pump power. The upconversion emission intensity I_{uc} depends upon the pump intensity I_{exct} according to $I_{uc} \alpha (I_{exct})^n$ where n is accounts for the number of excitation infrared photons involved in upconversion excitation mechanism.

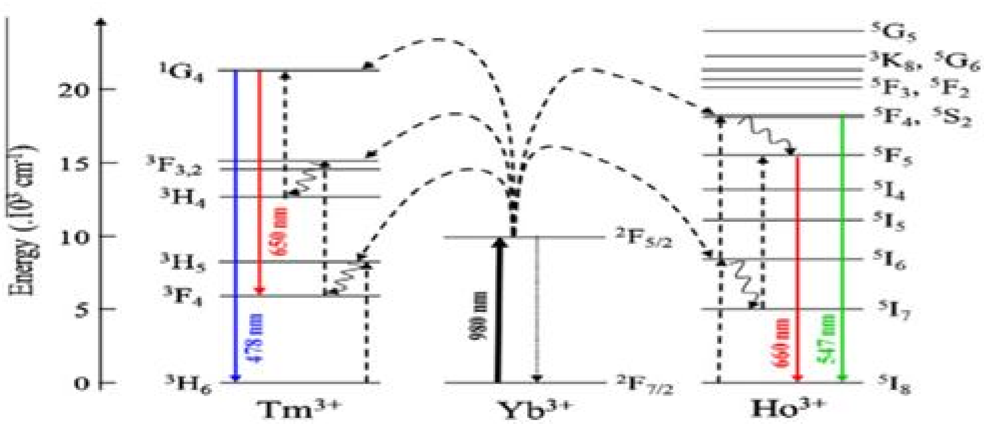

Figure 5. Energy level diagram of Yb^{3+}, Tm^{3+} and Ho^{3+} ions with the proposed upconversion mechanisms in the TGBK glass matrix upon 980 nm laser excitation[26].

Energy level diagram of Yb^{3+}, Tm^{3+} and Ho^{3+} ions in TGBK glasses with the radiative electronic transitions corresponding to the three emission bands shown in fig 5. The Yb^{3+} ions absorb efficiently the 980 nm radiation and transfer the excitation energies to both Tm^{3+} and Ho^{3+} ions. On one hand, Tm^{3+} ions are excited through three successive energy transfer (ET).

Conclusions

The density of bismuth tellurite glass samples is high due to the fact that the atomic mass of bismuth ions is higher than that of tellurite ions, and that the atomic radius of bismuth is also greater than that of tellurite ions. Additionally, the refractive index increases due to the increase of polarity of the Bi^{3+} ion content in tellurite based glasses. The rare earth doped material has great importance to a wide range of application in energy upconversion, two to three photon upcoversion observed with doping of Ho^{3+} and Tm^{3+} ions.

Scope of Future work :

From pairs of excited Yb^{3+} ions and Er^{3+} ions doped bismuth tellurite glasses may produce cooperative upconversion luminescence in visible region, Since Er^{3+} ions is having absorption range from 450nm to 900nm and Yb^{3+} ions is at 450nm.

Acknowledgments

The authors would like to thanks to Madhyanchal Professional University,Bhopal, India, for providing the laboratory and library Facilities.

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