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LASER PROPERTIES OF GLASS $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$

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Absorption spectrum of a violet $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ glass found from a glass formation region in quasi-ternary system $\text{La}_2\text{S}_3\text{--Ga}_2\text{S}_3\text{--Nd}_2\text{S}_3$ using physical and chemical analysis methods was taken in a visible or close to IR-region at 300 K. Spectrum covers 0.5–8 mkm wavelength. Relevant radiation bonds of $^2\text{H}_{9/2}$, $^4\text{F}_{3/2}$ levels fall to 0.815 and 0.890 mkm wavelength. Laser radiation with the peak corresponding to 1.08 mkm wavelength is related to transition $^4\text{F}_{3/2} \rightarrow ^4\text{I}_{11/2}$. The change of dn/dT temperature index and high thermal widening in glasses increases optical properties. This is directly observed during joining of He/Ne IR laser group into Ti:sapphire group. When Ti:sapphire laser is adjusted to absorption frequency of neodymium the glass behaves as a strong lens for He/Ne laser group. Unlike relevant crystalline matrixes laser properties of Nd^{3+} ion is weaker in $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ glass. This is related to a higher radiation loss in glasses. But quality of laser can be increased due to optimum concentration of an activator and length of a sample.

Keywords: glass formation region, laser properties, semi-conductor, transparent glass, lanthanoides.

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Introduction

Chalcogenide glasses activated by lanthanoides are of great importance in the improvement of fibrous lasers and amplifiers. From the other side for their functional optical properties and "photostructure" changing ability thin films of glassy semi-conductors are indispensable materials in creation of optically active and passive wave-transmitters and other optoelectronic devices [1–9]. Development of modern optoelectronics made relevant the search of firm, non-fragile materials which are transparent in a wider region of the spectrum. From this point mixed cation sulfides of lanthanoides are prospective materials and research works are being carried out by authors [10–15]. In the works [16, 17] it was shown that in a region of the spectrum close to IR high lighting effect of Nd^{3+} ion in mixed cation sulfides matrixes of lanthanoides allows using these materials as a laser element. In cation glasses of lanthanoides mixed with gallium laser properties was studied insufficiently. In this work laser and optical properties of $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ glass was studied.

Experimental part

Synthesis of a sample: synthesis was carried out in a stoichiometric composition under mixed sulphur pressure consisting of initial components ($\beta\text{-Ga}_2\text{S}_3$, $\alpha\text{-La}_2\text{S}_3$, $\alpha\text{-Nd}_2\text{S}_3$), at 1425 K in a glassy-carbon crucible placed in a quartz re-

actor. Synthesis was conducted for 2.5 hours in a vertical synthesis furnace. Sharp freezing process is completed by dropping the reactor of a sample directly into water from synthesis temperature at 300 K [18, 19].

Absorption calculations in visible or close IR spectrum region were carried out at Perkin Elmer Lambda 9 spectrophotometer. Absorption in average IR region of the spectrum was measured using Fourier-transform spectrometer (Perkin Elmer System 2000 FTIR). After preparing 1.4 mm plate from the sample and polishing its surface optical properties were studied based on wavelength.

Results and discussion

Using the complex methods of physical and chemical analysis glass formation region in system $\text{La}_2\text{S}_3\text{--Ga}_2\text{S}_3\text{--Nd}_2\text{S}_3$ was determined and its boundaries were defined (Figure 1). As figure shows glass formation covers a relatively large surface area in density triangle of quasi-ternary system. Colors of these samples varies from light violet to dark grey depending on the amount of Nd_2S_3 . The sample $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ studied by us is violet (Figure 2). In this work $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ sample was synthesized privately from transparent glass area in $\text{La}_2\text{S}_3\text{--Ga}_2\text{S}_3\text{--Nd}_2\text{S}_3$ quasi-ternary system and ground state absorption spectrum of 1.40 mm polished glass was taken at 300 K in 5.2 mkm wavelength (Figure 3).

a *b*

Fig. 1. The concentration dependence of glass formation in the system $\text{La}_2\text{S}_3\text{--Ga}_2\text{S}_3\text{--Nd}_2\text{S}_3$.

Fig. 2. Photo of $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ glass.

Fig. 3. Ground state absorption spectrum (*a*) and photoluminescent spectrum (*b*) of $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ glass at 300 K.

Ti:sapphire and He/Ne lasers were used to excite the sample. For laser experiments in 50 mm radius different entrance devices and in 1.08 mkm high reflective hemisphere reactor was used. Glass sample is placed tightly on the glass surface.

Spectrum covers a large area beginning from UB absorption region – 0.5 mkm to 8 mkm. Absorption bands are clearly seen in 0.815 and 0.890 mkm wavelength corresponding to $^4\text{H}_{9/2}$, $^4\text{F}_{5/2}$, upper $^4\text{F}_{3/2}$ laser levels and $^4\text{F}_{3/2} \rightarrow ^4\text{I}_{11/2}$ transitions.

In 0.890 mkm lesser absorption coefficient reduces thermal loading of a glass and in-

creases homogeneous vibration in sample. Depending of wavelength in 0.815 mkm absorption is 88%, but in 0.890 mkm it is 50%. In sulfide glasses the change of dn/dT temperature index and high thermal widening increases optical properties. This is directly observed when He/Ne IR laser group joins to Ti:sapphire group. When Ti:sapphire group is adjusted to absorption frequency of neodymium the glass behaves like a strong lens for He/Ne laser group.

Absorption coefficient (2.0 mm) of $^4\text{F}_{3/2}$ level is 3 times higher than absorption coefficients of $^2\text{H}_{9/2}$ and $4\text{F}_{5/2}$ levels (0.7 mm). Photoluminescent property of Nd^{3+} ion was

calculated by exciting $^2H_{92}$, $^4F_{52}$ levels in 0.815 μm using Ti:sapphire laser. Multiphononic radiation is related to transformation from $^2H_{92}$, $^4F_{52}$ levels to $^4F_{32}$ level within 70 μsec . Laser spectrum is given separately in figure 3b. As figure shows the peak of a laser radiation corresponds to 1.08 μm wavelength and is related to $^4F_{32} \rightarrow ^4I_{11/2}$ transition. For the first time we studied laser properties in $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ glass from Ga_2S_3 – La_2S_3 – Nd_2S_3 system. It was detected that the sample shows laser properties in 1.08 μm wavelength at room temperature. This glass can be used as a laser element in preparation of amplifiers with 1.3 μm wavelength for telecommunication in fibrous communication systems. Laser properties of Nd^{3+} -ion is weaker than relevant crystalline matrixes. This is related to a higher radiation loss in glasses. The quality of a laser can be increased due to optimum density of an activator and length of sample.

Analysis of literature data and our studies show that even though participation of gallium in glassy semi-conductors increases dissolution of lanthanoides the formation of crystalline centers of new compounds under the chemical interaction of gallium and lanthanoides sulfides worsen optical properties of glasses. To eliminate this shortage the nature of lanthanides used only as an activator and the composition of matrixes must be studied in parallel. The influence of gallium compounds on even distribution of active lanthanide ions in glasses, change of their optical properties, absorption band, ion degree of lanthanide ions must be considered. Research works are being carried out in this direction.

References

1. Kertman A.V. Opticheskaia sulfidnaia keramika. Sorosovskii obrazovatelnyi zhurnal. 2000. T. 6. № 2. S. 93–98.
2. Borisov E.N., Smirnov V.B. Tver'yanovich A., Tver'yanovich Yu.S. Deposition of Er^{3+} doped chalcogenide glass films by excimer laser ablation. J. Non-Cryst. Sol. 2003. V. 326. & 327, P. 316–319.
3. Tsendin K.D., Bogolovskiy N.A. Physics of Switching and Memory effects in chalcogenide. Glassy semiconductors. ISSN 10637826. Semiconductors Pleiades Publishing. Ltd. 2012. Vl. 46. No 5. P. 559–590.
4. Liaw S.K., Wang H., Hsu K.H., Lin S.C., Chen N.K., Shin C.S., Tver'yanovich Y. Linear-Cavity Fiber Laser in Nearly Single-Frequency Operation using Faraday Rotator Mirror. Laser Physics. 2012. V. 22. No 2. P. 437–440.
5. Chen N. K., Hsu K.C., Lin J. W., Liaw S. K., Liu F. Z., Chen Y. N., Hsu J. M., Manshina A., and Tver'yanovich Y. "Wavelength-tunable Er^{3+} doped fs mode-locked fiber laser using fundamental mode cutoff filters" FOAN 2010 conf. Moscow, Russia, Oct. 18–20. 2010. Page(s):1009–1011. DOI:10.1109/ICUMT.2010.5676497 Published in: Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2010, International Congress on Publisher: IEEE.
6. Liaw S.K., Wang S., Shin C.S., Yu Y.L., Chen N.K., Hsu K.C., Manshina A. and Tver'yanovich Y. Linear-cavity fiber laser using subring-cavity incorporated saturable absorber for single-frequency operation. Laser Physics. 2010. V. 20. No 8. P. 1744–1746.
7. Liaw S. K., Wang S., Shin C. S., Chen N. K., Hsu K. C., Manshina A., Tver'yanovich Y., Su C.F. and Wang L.K. Single-longitudinal-mode linear-cavity fiber laser using multiple subring-cavities. Laser Physics. 2010. V. 20. No 7. P. 1608–1611.
8. Liaw S.K., Hong K.L., Zhong G.S., Ivanova T.Yu., Manshina A. A., and Tver'yanovich Yu.S. Pump Slope-Improved Fiber-Ring Laser by Recycling the Residual Pumping Power. Laser Physics. 2008. V. 18. No 9. P. 1040–1043.
9. Vasilyeva A.S., Borisov E.N., Klotchenko S.A. Tver'yanovich, Yu.S. Tver'yanovich. Vitreous Films of $\text{Ga}_6\text{Ge}_{17}\text{S}_{43}$ composition as a Biochip Substrate. Glass Physics and Chemistry. 2014. V. 40. No 4. P. 467–469.
10. Bakhtiyarly I.B., Abdullaeva A.C., Mirzoeva A.A., Aliev A.B. Fiziko-himicheskie svoistva stekol sostavov $(\text{Ga}_2\text{S}_3)_{0.60}(\text{La}_2\text{S}_3)_{0.20}(\text{Sm}_2\text{S}_3)_{0.20}$ i $(\text{Ga}_2\text{S}_3)_{0.55}(\text{La}_2\text{S}_3)_{0.15}(\text{Sm}_2\text{S}_3)_{0.30}$. 1st Int. Chem. Chem. Eng. Conf. Baku. Azerbaijan. 17–21 april 2013. P. 345–351.
11. Bakhtiyarly I. B., Abdullaeva A. S., Kurbanova R.C., Kerimov R.I., The ternary system La_2S_3 – Ga_2S_3 – EuS and glass formation. Azerb. Chem. J. 2016. № 3. P. 113–120.
12. Bakhtiyarly I. B., Fatullaeva G. M., Kerimli O. Sh. Glass Formation in the Ternary System La_2O_3 – As_2S_3 – Er_2O_3 . ISSN 0036-0236. Russian J. Inorg. Chem. 2018. V. 63. No 7. P. 962–965.
13. Bakhtiyarly I.B., Neimatova A.B., Mamedov F.M., Fazovye ravnovesiia v troinoi sisteme La_2S_3 – Bi_2S_3 – La_2O_3 . Zhur. neorg. himii. 2010. T. 55. № 4. S. 671–675.
14. Bəxtiyarlı İ.B., Kərimov O.Ş., İsmayılova Ş.B., La_2O_3 – Ga_2S_3 – Eu_2S_3 üçlü sistemində şüşə əmələgəlmə. Azerb. Chem. Jour. 2011. № 1. S. 107–110.
15. Bakhtiyarly I.B., Abdullaeva A.S., Mirzoeva A.M., Fiziko-himicheskie svoistva stekol v sisteme

- La_2S_3 – Ga_2S_3 – Nd_2S_3 . Azerb. Chem. Jour. 2012. № 3. С. 82–84.
16. Bakhtiyarlı I.B., Asadlı L.Sh., Kerimli O.Sh., Geidarova E.A. Stecloobrazovanie v troinykh sistemakh La_2O_3 – Ga_2S_3 – Nd_2O_3 . Chemical Problems. 2006. № 3. S. 569–570.
17. Flahaut J., Guittard M., Loireau A.M. Rare earth sulphide and oxysulphide glasses. Glass Technology. 1983. V. 24. No 3. P. 149–156.
18. Bəxtiyarlı İ.B., Kərimov O.Ş. Lantanoidlərin qalliumla oksisulfid şüşələri. Chemical Problems. 2003. № 3. S. 27–29.
19. Bakhtiyarlı I.B., Abdullaeva A.S., Kerimli O.Sh., Mirzoeva A.A., Farhatova N.B. Oblast stecloobrazovaniia v sisteme Sm_2S_3 – Ga_2S_3 – EuS . Zhurn. neorg. mater. 2019. T. 55. № 6. S. 666–671.

$(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ TƏRKİBLİ ŞÜŞƏNİN LAZER XASSƏLƏRİ

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Fiziki-kimyəvi analizin kompleks metodları ilə La_2S_3 – Ga_2S_3 – Nd_2S_3 kvaziüçlü sistemində aşkar edilən şüşə əmələgəlmə sahəsindən $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ tərkibli bənövşəyi rəngli şüşənin 300 K-də görünən və yaxın İQ sahədə absorbsiya spektri çəkilmişdir. Spektr $0.5 \div 8$ mkm dalğa uzunluğunu əhatə edir. Orada $^2\text{H}_{9/2}$, $^4\text{F}_{3/2}$ səviyyələrinin uyğun şüalanma zolaqları 0.815 və 0.890 mkm dalğa uzunluğuna düşür. Maksimumu 1.08 mkm dalğa uzunluğuna uyğun gələn lazer şüalanması isə $^4\text{F}_{3/2} \rightarrow ^4\text{I}_{11/2}$ keçidi ilə əlaqədardır. Sulfidli şüşələrdə dn/dT temperatur indeksinin dəyişməsi və yüksək termiki genişlənmə optiki xassəni artırır. Bu hadisə He/Ne infraqırmızı lazer dəstəsinin Ti:sapfir dəstəsinə qoşulması zamanı birbaşa müşahidə olunur. Ti:sapfir lazerini neodimin absorbsiya tezliyinə uyğunlaşdırıldıqda təqdim olunan şüşə özünü He/Ne lazer dəstəsi üçün güclü linza kimi aparır. Nd^{3+} ionunun müvafiq kristallik matrisələrlə müqayisədə $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$ tərkibli şüşədə lazer xassəsi zəifdir. Bu da, şüşələrdə şüa itkisinin nisbətən çox olması ilə əlaqədardır. Lakin ola bilər ki, aktivatorun optimal qatılığı və nümunənin uzunluğu hesabına lazerin keyfiyyətinin yüksəldilməsi mümkün olsun.

Açar sözlər: şüşə əmələgəlmə sahəsi, lazer xassəsilər, yarımkeçirici, şəffaf şüşə, lantanoidlər.

ЛАЗЕРНЫЕ СВОЙСТВА СТЕКЛА СОСТАВА $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$

А.С.Абдуллаева

Снят спектр абсорбции в видимой близкой к ИК- области при 300 К стекла фиолетового цвета состава $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$, обнаруженного области стеклообразования квазитройной системы Ga_2S_3 – La_2S_3 – Nd_2S_3 которые были исследованы методами физико-химического анализа. Спектр охватывает длину волны от 0.5 до 8 мкм. Соответствующие уровни излучения $^2\text{H}_{9/2}$, $^4\text{F}_{3/2}$ опускаются до длины волн 0.815 и 0.890 мкм. Лазерное излучение с максимальной длиной волны 1.08 мкм связано с переходом $^4\text{F}_{3/2} \rightarrow ^4\text{I}_{11/2}$. Изменение dn/dT температурного индекса в сульфидных стеклах и высокое термическое расширение увеличивает их оптические свойства. Это наблюдается непосредственно при соединении ИК-лазерного пучка He/Ne, с группой Ti: сапфир. При соответствии лазера Ti:сапфир частоте адсорбции неодима, стекло проявляет себя как сильная линза лазерного пучка He/Ne. В соответствующих кристаллических матрицах Nd^{3+} - иона лазерного свойства слабее в стекле $(\text{Ga}_2\text{S}_3)_{0.70}(\text{La}_2\text{S}_3)_{0.25}(\text{Nd}_2\text{S}_3)_{0.05}$. А это связано со свойством стекол терять большую часть излучения. Однако свойства лазера могут быть увеличены за счет оптимальной концентрации активатора и длины образцов.

Ключевые слова: область стеклообразования, лазерные свойства, полупроводник, прозрачное стекло, лантаноиды.