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Temperature Effect on Exciton Absorption of CuBr Nanocrystals in Potassium-alumina-borate Glass

A.N. Babkina, P.S. Shirshnev, B.A. Tsekhomsky, N.V. Nikonorov

Saint-Petersburg National Research University of Information Technologies, Mechanics and Optics,
49, Kronverkskiy pr., 197101 Saint-Petersburg, Russia

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The paper describes the research of temperature effect of potassium-alumina-borate (PAB) glass with CuBr nanocrystals, which was obtained in optical wavelength region for the first time. Temperature dependence of optical density at different wavelengths was examined. Melting and crystallization temperatures were evaluated for different nanocrystals sizes. Great changes of exciton absorption band influenced by temperatures below 100°C were recorded. Propositions for studied glass application as tunable filters in electro-optic circuit were suggested.

Keywords: CuBr nanocrystals, Exciton absorption band, Temperature dependence, Melting and crystallization temperature, Tunable filter.

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1. INTRODUCTION

Glasses with CuHal nanocrystals are known as material for optical filters in near UV region. Due to the large exciton binding energy the exciton absorption band has a very steep border [1,2]. Until recently borosilicate glasses with CuHal nanocrystals were only known. They have photochromic properties. Couples of years ago in the walls of our department new glasses with CuHal nanocrystals were obtained. They had PAB matrix and were not photochromic. Small angle X-ray scattering (SAXS) of these glasses showed quite unusual results while sample heating and cooling [3]. After that the decision of studying temperature influence on exciton absorption band of CuHal nanocrystals were accepted.

2. OBJECT OF RESEARCH

The paper examines PAB glasses with CuBr nanocrystals. The nanocrystals extraction took place during isothermal heat treatment. Glass transition temperature was defined by means of differential scanning calorimetry. Thermal heating was carrying out at temperatures above glass transition one during 10 hours. After heat treatment absorption spectra of samples were registered on spectrophotometer Lambda 650 (by Perkin Elmer) (Fig. 1).

3. CHARACTERISTIC TEMPERATURES EVALUATION

Optical density spectra were registered using a fiber spectrometer (by Avalar) while linear heating and cooling of samples every 0,3° increment. Heating and cooling of samples were carried out in thermal cell (portable oven).

3.1 Results of experiments

For each sample the location of exciton absorption band was defined. During heating and cooling of samples it does not change. So the temperature dependences of optical density in the wavelength of maximum of exciton absorption band were obtained (Fig. 2).

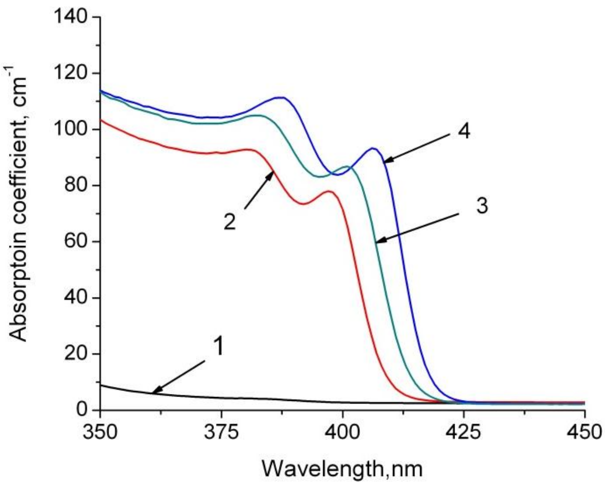

Fig. 1 – Absorption coefficients spectra of samples with different temperatures of thermal heating: 1 – initial sample, 2 - 390°C, 3 - 440°C, 4 - 450°C

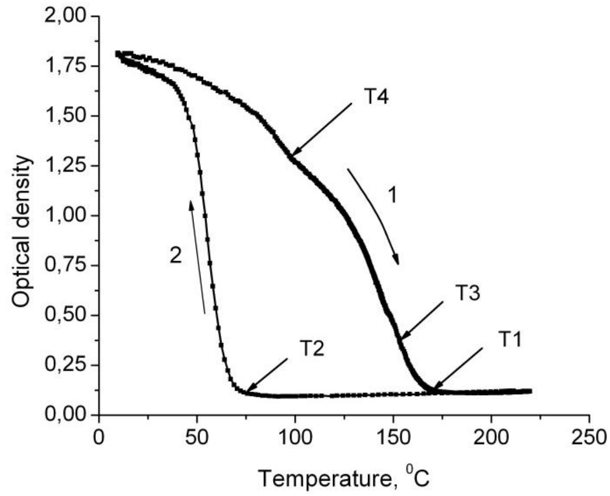

Fig. 2 – Temperature dependence of optical density for sample2 on 395nm: 1 – heating, 2 – cooling. T1 – temperature of melting ending, T2 – temperature of crystallization beginning

Compared to studies on borosilicate glasses [1,2], melting and crystallization temperatures are much lower. Melting point increases from 189°C to 236°C with the increase of temperature of sample heat treatment from 390°C to 450°C. So does happen with the crystallization temperature. It rises from 77°C to 105°C.

3.2 Discussion

The increase of the melting temperature by increasing the heat treatment temperature is mentioned in many papers [1,2,3].Such regularity is related to the size effect: increasing radius of the nanocrystalline phase increases its melting temperature.

Due to the low melting and crystallization temperatures these glasses can be used as a material for an optical trigger or switch. In this experiment the temperature of the sample surface was measured. CuBr nanocrystals can be heated to the required temperatures by absorbing UV radiation with a wavelength, which coincides with the absorption band of the exciton of CuBr. It will let us not to use a heating element and will protect the other components of the circuit.

4. CHANGING THE BORDER OF EXCITON ABSORPTION BAND

4.1 Results of experiment

When samples are heated to temperatures in the beginning of the melting curve (in the region of temperature T4 (Fig. 2)) and then cooled down, there is a shift of the exciton absorption band towards visible region (Fig. 3). Heating sample to T4, which is close to the melting temperature, makes absorption band return to the original position. During sample heating the location of spectrum does not chang. The shift takes place during the process of sample cooling.

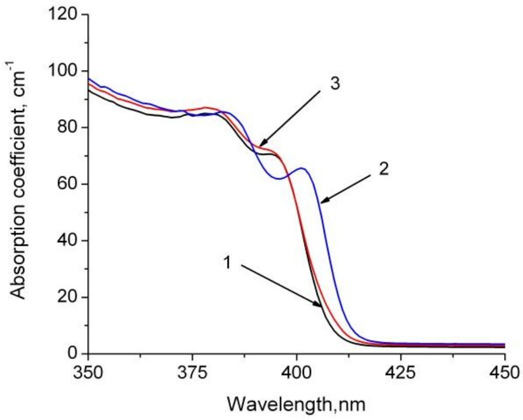

Fig. 3 – Exciton absorption band changing: 1 – initial spectrum, after heating to 2 – T4 and 3 – T3

4.2 Discussion

While heating samples to temperatures below 100°C the border of the absorption filter can be shifted up to 5nm in the visible region. Typically, such action is using a set of multiple filters. Our glass composition allows not to use several filters for this operation, only adjusting the duration and temperature of our tunable filter heating.

5. CONCLUSION

Potassium-alumina-borate glass with CuHal nanocrystals is a new optical material, which is very promising, both in terms of fundamental studies and practical application. Low temperatures of nanocrystalline phase transformations make it more accessible and easier to use than borosilicate glass.

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