

SUPER LUMINESCENCE PHENOMENON IN TERNARY COMPOUNDS OF TYPE $CdGa_2S_4$

*V. Pîntea, PhD, A. Maciuga, PhD, Assoc. Prof., R. Radu, PhD, Assoc. Prof., P. Stoicev, Dr.Sc,
Prof., M. Kulev, PhD, Assoc. Prof.
Technical University of Moldova*

INTRODUCTION

In the family of new multifunctional materials, one scientific interest, both fundamental and applicative, presents ternary compounds $A^{II}B_2^{III}C_4^{VI}$, namely $CdGa_2S_4$ which are materials with unusual crystalline structure and with physical properties that are unique and remarkable: fairly wide interval of optical transparency, high values of the coefficient of nonlinear optical susceptibility, particularities which determine the application of these compounds for nonlinear optics domain, optoelectronics and photonics.

From the family of ternary compounds $A^{II}B_2^{III}C_4^{VI}$, the compound $CdGa_2S$ has been studied. For this compound, advanced technologies of growth, experimental methods of composition and crystalline lattice structure control have been implemented. Luminescence properties of $CdGa_2S$ are widely studied in a number of works by applying different types of excitation: photons [1], accelerated electrons, X-rays [2].

EXPERIMENTAL RESULTS AND THEIR ANALYSIS

The technology of preparation of the samples under investigation is exposed in [3] and

is based on the chemical reactions of transport in which iodine is used as the carrier agent.

The investigations carried out by us, luminescence excitation was performed with a stream of accelerated electrons and X-rays with energies from the range $(50 \div 100) keV$. The experimental installation was assembled based on electron microscope $УЭМБ-100K$.

The sample was fixed on a support of copper, cooled by means of liquid nitrogen and introduced into the working chamber of the microscope, in which the vacuum, not less than $10^{-4} mm Hg$, was maintained.

The system of the luminescence radiation capture and recording adjusted by electron microscope is represented in figure 1. This system contains the optical component which enables to accumulate optical radiation from the crystal surface and the cathode luminescence recording component.

By using the quartz lenses and mirrors, the flow of light from the sample surface was focused on the photomultiplier and the opening of device M-2. There were used a photomultiplier $\PhiЭУ-18$ and other recording devices for the wavelengths in the range $(3800 - 7800) \text{ \AA}$.

It was also used the modulator engine of type ДИД-2, which possesses a stable circular frequency and is powered by a three phase generator with the frequency $360 Hz$ and amplitude $36 V$. The given system modulation allowed obtaining

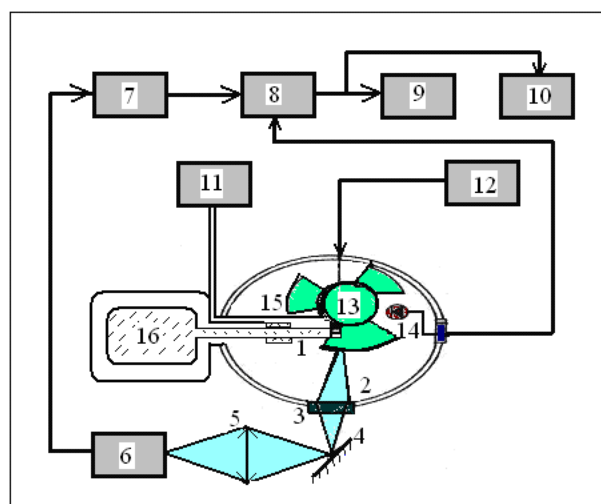


Figure 1. The system of the luminescence radiation capture and recording: 1-sample for research; 2,5-quartz lens; 3-the window of quartz; 4-mirror; 6-dispersing system based on diffraction mirror; 7-photomultiplier; 8-synchronous detector; 9-potentiometer recorder; 10-electronic voltmeter; 11-temperature stabilizer; 12-power block for modulator; 13-modulator; 14- base power source; 15- thermocouple; 16-vessel Diuar.

current flow impulse duration of $100 \mu s$.

To establish the temperature in the range $(80 \div 300) K$, an electric stove that is powered by a stabilizer included within the microscope has been used. Temperature control is performed using a thermocouple "copper - constantan".

In figure 2 are exposed super luminescence spectra for mono-crystals $CdGa_2S_4$ at temperature $80 K$. For purpose of detailed researches of stimulated radiation in $CdGa_2S_4$, the investigations on the cathode-luminescence of mono-crystals $CdGa_2S_4$ have been performed in the range of energies $(2,00 \div 2,30) eV$ at temperature $80 K$ and the density of the current flow $j_1 = j_2 = 1,5 \cdot 10^{-3} A \cdot cm^{-2}$. The electrons beam energy in both cases was $100 keV$.

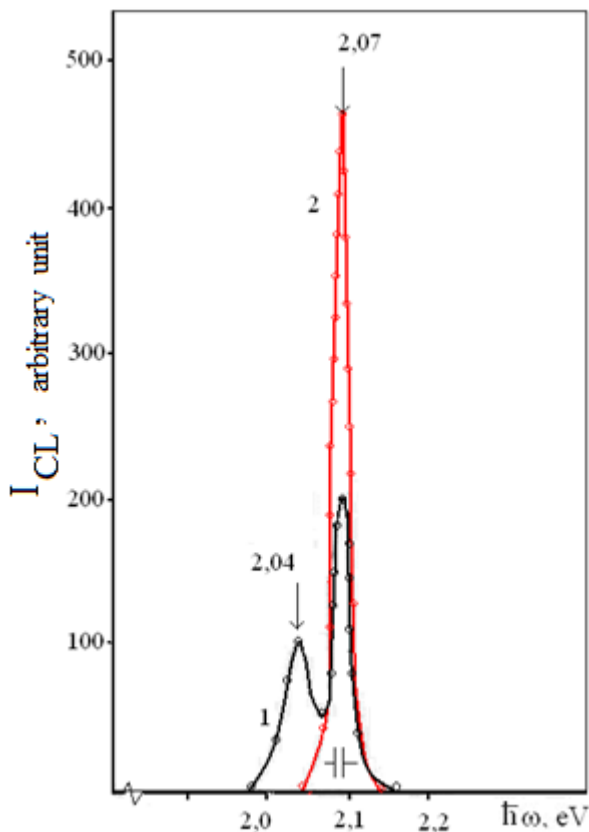


Figure 2. Super luminescence spectra of mono-crystals $CdGa_2S_4$ at $80 K$.

Excitation densities and impulse durations:
 $U = 100 keV$; $j_1 = j_2 = 1,5 \cdot 10^{-3} A \cdot cm^{-2}$;

$$\tau_1 = 10^{-3} s; \quad \tau_2 = 10^{-2} s.$$

Corresponding results obtained under this experiment and based on analysis of mono-crystals $CdGa_2S_4$ cathode-luminescence spectra, energy maximums (peaks) at $2,07$ and $2,04 eV$ were registered; the top has semi-width $0,10 eV$. It is known [4] that in the conditions of given excitation, super luminescence, namely the stimulated radiation, is characterized by a nonlinear increasing of the luminescence intensity into energy maximum of the spectrum and a nonlinear narrowing of emission strip semi-width at $80 K$. Penetration depth of the electrons reached about to $32,4 \mu m$.

Based on the investigations results we propose the model of energetic levels and optical transitions in the energy band gap, which ensures super luminescence phenomenon in this compound, the model in which an evident role plays holes and electrons traps (CA and CE) (fig. 3).

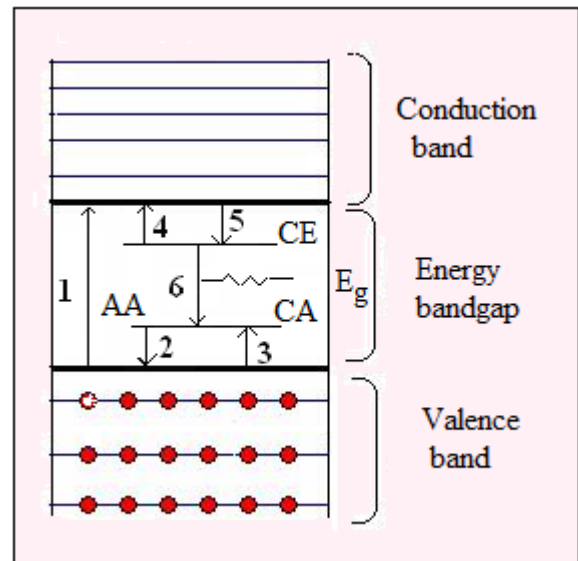


Figure 3. The model of energetic levels and optical transitions in the energy band gap in mono-crystals $CdGa_2S_4$ which ensures the super luminescence phenomenon: CE - electron traps; CA - traps for acceptors (holes); AA - deep acceptors: 1 - transitions in the conduction band; 2, 3 transitions in CA; 4, 5 - transitions in CE; 6 - emission transition which ensures super luminescence.

Transition direction of electrons and holes ensures the process of accumulation of electrons and, respectively, of holes in deep traps of the

appropriate type. Captured electrons and also holes can be released as heat and under the action of electromagnetic radiation, in this case - of accelerated electrons [5]. Based on release of electrons concentrated on deep traps, the intensive recombination of them with holes from ionized centers occurs, that causes a transitions avalanche of type 6, which produces the phenomenon of super luminescence in $CdGa_2S_4$.

Thus we notice that the model of energetic levels and optical transitions in the energy band gap which ensures the super luminescence phenomenon in compounds $CdGa_2S_4$ exposed in figure 3 is also confirmed by luminescence of high persistence for some samples of this type synthesized in special conditions [6].

Certain characteristics of the mono-crystals $CdGa_2S_4$ cathode-luminescence spectra at temperature 80 K are exposed in table 1.

Table 1. Characteristics of the mono-crystals $CdGa_2S_4$ cathode luminescence spectra at 80 K .

No	Excitation density (j)	Impulse duration (τ)	Semi-width in the emission strip	Position of energy max.
	$A \cdot cm^{-2}$	s	eV	eV
1.	$1,5 \cdot 10^{-3}$	10^{-3}	0,20	2,07
2.	$1,5 \cdot 10^{-3}$	10^{-2}	0,10	2,04

The results of investigations carried out on the nonlinear optical properties of $CdGa_2S_4$ and in the first place, the possibility to determine the experimental conditions in which the phenomenon of super luminescence occurs is a problem solving which would open real perspectives for promoting this material as an active element for lasers.

CONCLUSIONS

According to results of experimental researches we conclude that for the ternary mono-crystals of type $CdGa_2S_4$ grown by transport

chemical reactions method with iodine as a carrier agent, in the excitation with accelerated electrons, the super luminescence phenomenon has been recorded – the cathode luminescence strip with the maximum energy 2,07 eV , the semi-width of top in the emission strip constituting 0,10eV , its intensity is of the order of 10^2 times greater than strips recorded by the excitation with impulses whose duration is ten times less.

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