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Microwave irradiation of gallium arsenide

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Abstract. To study an influence of the microwave irradiation on a spectrum of defect states in semiconductor compound GaAs, we used measurements of luminescence spectra within the range 0.5 to 2.04 eV at 77 K before and after long (up to 13 min) treatments in air in the operation chamber of a magnetron at the frequency 2.45 GHz and surface power density 7.5 W/cm^2. It was obtained that, already on the smallest irradiation exposure, the spectra of defects in researched samples essentially changed as well as concentrations of local centers changed. A "transfer" of intensity from the band with the peak 1.04 eV to the that peaking at 1.3 eV was observed.

Keywords: luminescence, microwave irradiation, spectrum of defects.

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1. Introduction

Gallium arsenide is widely used in modern microelectronics and, first of all, in solid-state devices that provides generation of microwave radiation. However, requirements imposed on physical parameters of this important material are still far from final solution, what inhibits full use of potential opportunities of these devices. Among them there is the possibility of purposeful control of impurity-defect structure of semiconductors.

Therefore, search of new technological methods to control the structure of this material is actual now. And one of the ways suitable for solving this task is microwave irradiation, efficiency of which in the impurity-defect control of this structure has been confirmed in researches of Si [1]. At the same time, the influence of microwave irradiation on GaAs impurity-defect structure has not been studied yet. Though researches performed on Si have shown essential influence of a microwave irradiation on a condition of the defect subsystem in this semiconductor.

2. Experimental

Gallium arsenide of *n*-type with the surface orientation (100) and concentration of carriers from $\sim 5\cdot 10^{16}$ to $1\cdot 10^{17}$ cm^{-3} was the object of our researches. The samples were exposed to microwave irradiation in free space in a centimeter ($f = 2.45$ GHz) range of wavelengths. The intensity of the microwave treatment was varied by changing the exposure time.

The defect structure of our samples was studied using the photoluminescent (PL) method at 77 K in the spectral range $\Delta h\nu = (0.50\ldots 2.04)$ eV. We used a powerful lamp ПЖ-100 as an exciting radiation source. Its emission spectrum was cut with corresponding filters to separate their radiation with $h\nu \geq 2.0$ eV. The absorption coefficient of investigated semiconductors in this spectral range was $\sim 10^5$ cm^{-1}. Thus, the spectrum of defects was studied within the subsurface layers with the depth close to $\sim 10^{-5}$ cm. A PbS photoresistor served as a detector of luminescent light.

3. Results and discussion

PL spectra of GaAs samples before and after microwave ($f = 2.45$ GHz) treatments, which contained two bands peaking at 1.3 and 1.04 eV are shown in Fig. 1. To reveal the features of influence of the microwave irradiation on radiative recombination, we consider changes of parameters of PL bands with the exposure irradiation value in details. The frequency positions of PL peaks and their intensity as related to the exposure value are shown in Fig. 2.

The position of the PL peak with $h\nu = 1.3$ eV at small irradiation times (≤ 3 min) is shifted to the side of low frequencies as compared to that of the sample in initial conditions, and the position of the peak with $h\nu = 1.04$ eV is not changed. During the further irradiation, the frequency position of PL peaks does not vary. The influence of microwave irradiation on the intensity of PL bands results in the following features.

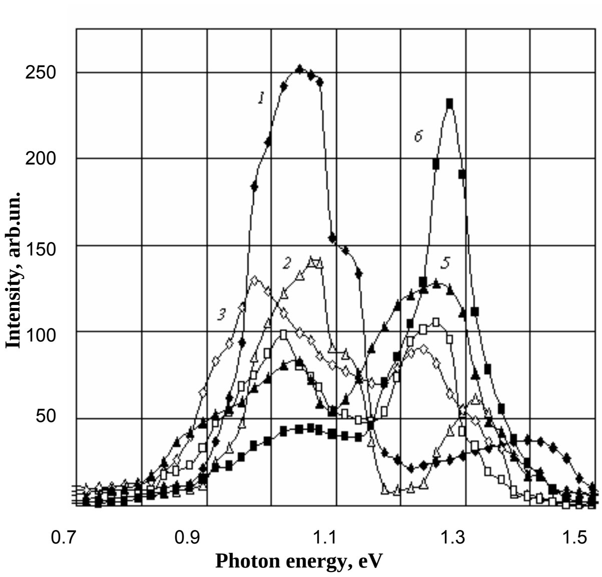

Fig. 1. Spectra PL of the GaAs samples before (1) and after the microwave irradiation during 1 min (2), 2 (3), 3 (4), 8 (5), 13 (6).

The growth of 1.3 eV peak intensity with increasing the irradiation time is accompanied by lowering the peak at $h\nu = 1.04$ eV. Besides, a nonmonotonic change of the band halfwidths in the course of treatments has the most strong influence on their intensity.

As the physical and chemical nature of the centres responsible for the luminescent bands 1.3 and 1.04 eV is not finally ascertained, we should believe according to [2] and [3] that they are related with a level of an acceptor caused by a background copper impurity. It is well known that various complexes with participation of copper cause luminescent bands peaking at 1.26…1.32 and 1.02 eV. In addition, the point defect Cu_{Ga} is responsible for the peak 1.02 eV, and Cu_{Ga}+D – for the band with the peak close to 1.30 eV.

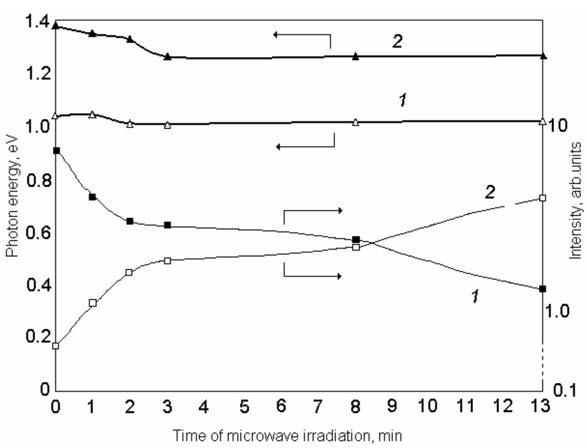

Fig. 2. Frequency position of the peak of PL bands, and their intensity from duration of an irradiation (1 – to band 1.04 eV, 2 – to band 1.3 eV).

The association of the donor and acceptor, amplified due to the microwave irradiation, should result in the change of its band position $h\nu_{max}$ that can be both red-blue shifted as compared with the initial value depending on the depth of the donor level E_D, because of:

$$h\nu_{max} = h\nu_{max_0} + \Delta k - E_D ,$$

where Δk is the value of the position shift for this peak due to Coulomb interaction between the acceptor and donor [4].

However, this strong displacement of the PL peak with $h\nu = 1.3$ eV, which was obtained in our experiment, apparently, is the consequence of a new luminescence centre appearance. The fact of the intensity increase for this band confirms it. The decrease of the intensity for the PL peak at $h\nu = 1.04$ eV and its stable frequency position is caused, perhaps, by a decrease of the center concentration responsible for this band. For example, due to participation of defects, that form the latter when the new centers create.

It is possible to expect that use of more powerful microwave irradiation should give much more appreciable processes of transformation and generation of luminescence in semiconductor compounds A^3B^5. However, it is an open question.

4. Conclusions

Analyzing the obtained data, it is possible to draw the following conclusions. A microwave treatment results in a change of local center concentrations that are responsible both for radiative and nonradiative recombination. A "transfer" of the intensity from the band with $h\nu = 1.04$ eV to that with $h\nu = 1.3$ eV is observed. New centers of luminescence caused by disintegration of donor-acceptor pairs (for example Cu_{Ga}+V_{As}) appear.

Thus, interaction of a microwave with gallium arsenide is accompanied by semiconductor impurity-defect structure modification that is caused by action of both thermal and nonthermal factors. To establish micromechanisms of observable structural reorganization, additional researches are required.

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