PACS numbers: 42.55.Px; 42.60. Lh; 61.80 Ed
DOI: 10.1070/QE2015v045n03ABEH015589

Effect of thermal neutrons on emission characteristics of InGaAs/AlGaAs heterolasers

B.I. Makhsudov

Abstract. **It is studied how the threshold current of InGaAs/AlGaAs quantum-well injection heterolasers emitting near the wavelength λ = 0.7 μm changes under irradiation by thermal neutrons. It is found that the threshold pump current decreases at small doses (10^{-2} neutron cm^{-2}), while doses exceeding 6×10^7 neutron cm^{-2} cause an increase in this current and degradation of the structure. It is found that the main reasons for an increase in the threshold current at high irradiation doses are the nuclear reactions of the $_{49}In^{115}$ (n, γ) → $_{49}In^{116}$ type and the β-decay of the $_{49}In^{116}$ isotope, which results in the appearance of $_{50}Sn^{116}$ atoms.**

Keywords: *heterolasers, threshold current, thermal neutrons, nuclear reaction, irradiation dose.*

It is known that degradation processes occurring in optoelectronic devices due to penetration of heavy particles, as well as due to nuclear reactions with probable subsequent decay of their products, are related to the appearance of new atoms in the lattice, which affects the electrical and optical properties of devices. In this connection, it is interesting to study the effect of thermal neutrons on the emission characteristics of semiconductor lasers.

There exists a number of works [1–5] devoted to investigation of the influence of irradiation on the characteristics of heterostructures, but the physical nature of processes occurring in the active region of lasers under irradiation by thermal neutrons is far from understanding.

The aim of the present work is to study the effect of neutron irradiation on the threshold current of InGaAs/AlGaAs quantum-well heterolasers.

We studied typical low-power InGaAs/AlGaAs strained quantum-well heterolasers operating in the red spectral region.

The total number of samples was 40, and the average threshold current at 25 °C was 7 mA. Similar to paper [4], we evaluated the workability of lasers by using short-term (10 h) tests at a temperature of 70 °C and a constant radiation power before irradiation. The testing setup allowed us to simultaneously measure the light–current characteristics of 16 lasers.

Then, the samples were irradiated by thermal neutrons from a Pu–Be source (neutron energy 0–10 MeV) with doses from 4×10^7 to 3.5×10^8 neutron cm^{-2}. To produce thermal neutrons, a 5-cm-thick paraffin layer was placed between the source and the sample. After irradiation, the threshold current of lasers was measured again.

Figure 1 presents the light–current characteristic of some lasers before and after irradiation with different doses.

Figure 2 shows the dependence of the threshold pump current of lasers on the irradiation dose for different samples. Each point corresponds to a threshold current averaged over 10 samples. One can see that the threshold current decreases at doses of ~4×10^7 neutron cm^{-2} and begins to increase at

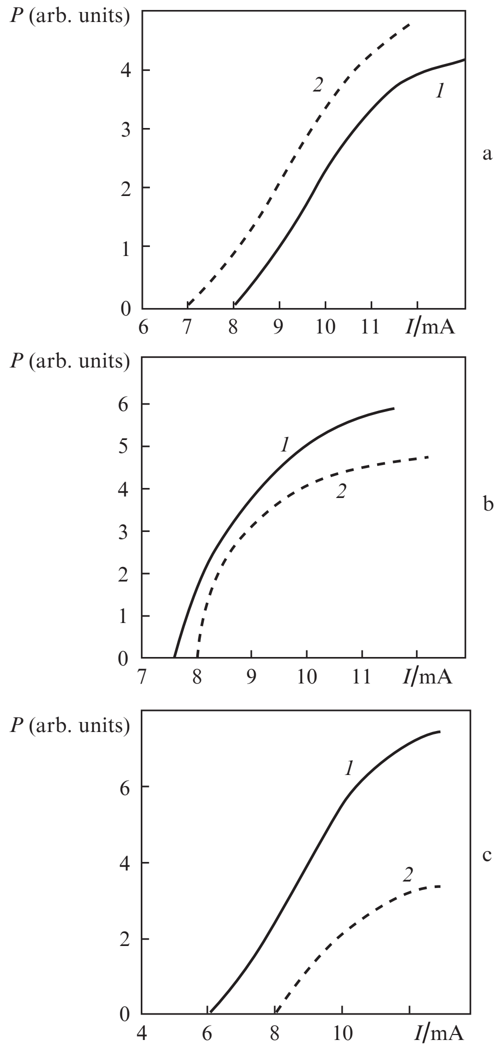

Figure 1. Light–current characteristic of InGaAs/AlGaAs heterolasers (*1*) before and (*2*) after irradiation by thermal neutrons with Φ = (a) 4.4×10^7, (b) 9.54×10^7 and (c) 1.35×10^8 neutron cm^{-2}.

B.I. Makhsudov Tajik State National University, prosp. Rudaki 17, 734025 Dushanbe, Tajikistan; e-mail: maksudov_barot@mail.ru

Received 19 June 2014; revision received 23 September 2014
Kvantovaya Elektronika **45** (3) 216–217 (2015)
Translated by M.N. Basieva

doses exceeding ~6×10^7 neutron cm^{-2}. The latter dependence can be represented in the form

$$I = I_0(A\Phi + B),$$

where I_0 is the threshold current of lasers before irradiation; Φ is the irradiation dose; and the A and B coefficients are 3.3×10^{-9} cm^2 and -0.88, respectively.

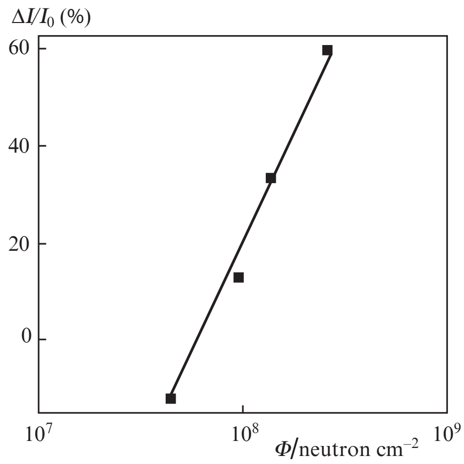

Figure 2. Dependence of the threshold current of GaAs/AlGaAs heterolasers on the dose of irradiation by thermal neutrons.

It should be noted that, in the case of gamma-irradiation, these coefficients were $B = 1$, $A_1 = 2\times10^{-15}$ cm^2 and $A_2 = 4.4\times10^{-18}$ cm^2 [4], which means that thermal neutrons stronger affect the properties of heterolasers than gamma photons.

It is known that thermal neutrons are easily captured by nuclei and the generated new isotopes frequently turn out to be radioactive. Decay of these isotopes results in the formation of impurity atoms in the active region of heterolasers. According to [6], the thermal neutrons activation cross section of isotopes of Al, Ga, As and In are 0.21, 1.4, 5.4 and 155 b, respectively. Thus, thermal neutrons most strongly affect indium nuclei. According to [7], neutrons cause the radiative capture reaction (n, γ). This reaction occurs with a higher probability in the case of slow neutrons with an energy from 0 to 500 keV. An example of the (n, γ) reaction is the process

$$_{49}\mathrm{In}^{115} + \mathrm{n} \rightarrow {}_{49}\mathrm{In}^{116} + \gamma.$$

The formed radioactive isotope $_{49}\mathrm{In}^{116}$ decays for 54 min as follows:

$$_{49}\mathrm{In}^{116} \rightarrow {}_{50}\mathrm{Sn}^{116} + e^- + \tilde{\vartheta}.$$

Stannum nuclei in the InGaAs/AlGaAs heterostructure are foreign. The appearance of defects in the crystal lattice distorts the structure of electronic levels, which changes the optical properties of the active region of heterolasers. These changes lead to a decrease in the number of radiative centres and to an increase in the threshold current of semiconductor lasers containing indium in the active region.

The experimental results show that InGaAs/AlGaAs heterolasers are highly sensitive to thermal neutrons and can be used as neutron detectors.

References

1. Huang M.B., Zhu J., Oktyabrsky S. *Nucl. Instrum. Meth. B*, **211**, 505 (2003).
2. Novikov A.V., Yablonskii S.V., Platonov V.V., Obolenskii S.V., Lobanov D.N., Krasil'nikov Z.D. *Fiz. Tekh. Poluprovodn.*, **44**, 3 (2010).
3. Bogatov A.P., Kochetkov A.A., Konyaev V.P. *Kvantovaya Elektron.*, **41** (2), 99 (2011) [*Quantum Electron.*, **41** (2), 99 (2011)].
4. Makhsudov B.I. *Kvantovaya Elektron.*, **42** (8), 745 (2012) [*Quantum Electron.*, **42** (8), 745 (2012)].
5. Makhsudov B.I. *Vestnik TNU*, **1/1**, 77 (2012).
6. Krasin A.K. (Ed.) *Spravochnik po yaderno-fizicheskim konstantam dlya raschetov reaktorov* (Handbook on Nuclear Physical Constants for Calculation of Reactors) (Moscow: Atomizdat, 1960).
7. Mukhin K.N. *Eksperimental'naya yadernaya fizika* (Experimental Nuclear Physics) (Moscow: Atomizdat, 1974).