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Abstract

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PHYSICS

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RADIATION OF n - p JUNCTIONS ON CRYSTALS OF SOLID SOLUTIONS OF INDIUM PHOSPHIDE–GALLIUM ARSENIDE

In previous works (^{1,2}) it was established that in the indium phosphide–gallium arsenide system there exists a continuous series of solid solutions. A study of the absorption spectra of alloys of the binary InP–GaAs system (²) showed that the dependence of the forbidden-band width on composition deviates considerably from the additive straight line and passes through a maximum in the middle concentration region.

It is of great interest to determine the possibility of obtaining radiating junctions on crystals of solid solutions of indium phosphide–gallium arsenide over the entire concentration range. In earlier works, radiation at n - p junctions of indium phosphide was studied (^{3–7}). Electron–hole junctions on solid solutions of indium phosphide–gallium arsenide have not been investigated up to the present time. Using the previously described methods for synthesizing alloys and obtaining large-crystalline samples (¹), as well as methods for obtaining n - p junctions on indium phosphide (⁸), we prepared n - p junctions on cleaved crystals of five compositions of solid solutions.

The electron–hole junctions were prepared by diffusion of zinc from the gas phase. Ohmic contacts to the n - and p -sides were made by alloying indium and gold, followed by soldering of leads.

In the present work, radiation emerging from n - p junctions through cleavages located practically perpendicular to the junction plane was studied. The spectra of recombination radiation were studied with an ISP-51 spectrometer. The radiating diode was placed in a specially designed cryostat in which a specified temperature was maintained. The radiation intensity was recorded with an FEU-28 photomultiplier. Instead of a photographic plate, an UF-1 optical slit was installed in the ISP-51 spectrometer, immediately behind which the cathode of the photomultiplier was located. The signal from the photomultiplier was amplified by a linear pulse amplifier and, after detection, was fed to an EPSH-09 electronic self-recording instrument. The motion of the recorder tape, on which the diode emission spectrum was recorded, was synchronized with the rotation

Fig. 1 and Fig. 2

Figure 1: Fig. 1 and Fig. 2

of the spectrometer drum. Rectangular current pulses of duration $1.5 \mu s$, with a repetition frequency of 50 Hz, were passed through the investigated diode in the forward direction.

Figure 1a shows the spectrogram of the radiation of a diode made from an alloy containing 90% gallium arsenide, and Fig. 1b presents the emission spectra of $n-p$ junctions. The maximum of the recombination-radiation spectra of an $n-p$ junction on indium phosphide at liquid-nitrogen temperature corresponds to a wavelength of about 9000 \AA ⁽⁴⁾. Among all the compositions studied, its radiation is the most long-wavelength. With an increase in the gallium arsenide content in the solid solution, the wavelength at the radiation maximum decreases. The most short-wavelength radiation was obtained at $n-p$ junctions in crystals of a solid solution containing 70% gallium arsenide. The emission spectra of electron-hole junctions on solid solutions are distinguished by greater width in comparison with the emission spectra of junctions on the compounds indium phosphide and gallium arsenide.

The calculated values of the quantum energies corresponding to the maxima of the emission spectra are close to the values of the forbidden-band width.

Figure 2a gives curves of the change in the wavelengths and quantum energies of the maxima of the recombination-emission spectra as a function of composition for temperatures of 77 and 293°K. With increasing temperature, the energy of the emitted quanta, as well as the value of the forbidden-band width, decreases.

The investigation of the temperature dependence of the emission spectra at a constant current density through the diodes (250 A/cm^2) showed,

Fig. 1. a—spectrogram of the emission of a diode fabricated from a crystal of $0.1 \text{ InP} \cdot 0.9 \text{ GaAs}$; **b**—spectral distribution of the emission of $n-p$ junctions on crystals of solid solutions of indium phosphide—gallium arsenide at 77°K: 1—InP; 2—GaAs; 3— $0.9 \text{ InP} \cdot 0.1 \text{ GaAs}$; 4— $0.7 \text{ InP} \cdot 0.3 \text{ GaAs}$; 5— $0.5 \text{ InP} \cdot 0.5 \text{ GaAs}$; 6— $0.3 \text{ InP} \cdot 0.7 \text{ GaAs}$; 7— $0.1 \text{ InP} \cdot 0.9 \text{ GaAs}$.

Fig. 2. a—dependence of the wavelengths of the maxima of the recombination-emission spectra of InP—GaAs solid solutions: 1—at 77°K, 2—at 293°K; **b**—dependence of the temperature coefficient $\alpha = \partial h\nu_{\text{max}}/\partial T$ on composition.

that with increasing temperature the intensity of the principal line of the emission spectrum decreases, the line width increases, and the spectral-distribution curves shift toward longer wavelengths. Figure 3 shows the distribution curves of the spectral density of emission of the principal spectral line at temperatures of 77, 178, 240, and 293°K for a diode fabricated from an alloy containing 90% gallium arsenide. The change in the emission intensity at the maximum of the

Fig. 3

Figure 2: Fig. 3

Fig. 4

Figure 3: Fig. 4

spectral line as a function of temperature can, to a rough approximation, be represented by a linear function of inverse temperature.

The change in the quantum energy at the maximum emission intensity $h\nu_{\max}$ as a function of temperature for indium phosphide [4] and for all the investigated compositions of the solid solutions is practically a linear function of temperature (Fig. 4), the slope of the straight lines $h\nu_{\max} = f(T)$ increasing somewhat on approaching the limiting compositions of the solid-solution system.

Figure 2b shows the curve of the change in the temperature coefficient of the quantum energy at the maxima of the spectral lines of recombination emission, $\alpha = \partial h\nu_{\max} / \partial T$, in eV/deg, as a function of the composition of the material from which the emitting $n-p$ junction was fabricated.

The investigation carried out has shown that emitting diodes can be obtained on crystals of alloys of the indium phosphide-gallium arsenide system, whose recombination radiation covers a wide range of wavelengths from visible light to the near-infrared region.

Fig. 3. Curves of the spectral distribution of the radiation of an $n-p$ junction on a $0.1\text{InP} \cdot 0.9\text{GaAs}$ crystal at temperatures 77°K (1), 178°K (2), 240°K (3), and 293°K (4).

Fig. 4. Temperature dependences of the energy of quanta at the maximum of the emission spectra for indium phosphide (1), gallium arsenide (2), and solid solutions $0.9\text{InP} \cdot 0.1\text{GaAs}$ (3), $0.7\text{InP} \cdot 0.3\text{GaAs}$ (4); $0.5\text{InP} \cdot 0.5\text{GaAs}$ (5); $0.3\text{InP} \cdot 0.7\text{GaAs}$ (6); $0.1\text{InP} \cdot 0.9\text{GaAs}$ (7).

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