World Academy of Science, Engineering and Technology
International Journal of Electrical and Computer Engineering
Vol:14, No:03, 2020

Temperature Dependence of the Optoelectronic Properties of InAs(Sb)-Based LED Heterostructures

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Abstract : At present, heterostructures are used for fabrication of almost all types of optoelectronic devices. Our research focuses on the optoelectronic properties of InAs(Sb) solid solutions that are widely used in fabrication of light emitting diodes (LEDs) operating in middle wavelength infrared range (MWIR). This spectral range (2-6 μm) is relevant for laser diode spectroscopy of gases and molecules, for systems for the detection of explosive substances, medical applications, and for environmental monitoring. The fabrication of MWIR LEDs that operate efficiently at room temperature is mainly hindered by the predominance of non-radiative Auger recombination of charge carriers over the process of radiative recombination, which makes practical application of LEDs difficult. However, non-radiative recombination can be partly suppressed in quantum-well structures. In this regard, studies of such structures are quite topical. In this work, electroluminescence (EL) of LED heterostructures based on InAs(Sb) epitaxial films with the molar fraction of InSb ranging from 0 to 0.09 and multi quantum-well (MQW) structures was studied in the temperature range 4.2-300 K. The growth of the heterostructures was performed by metal-organic chemical vapour deposition on InAs substrates. On top of the active layer, a wide-bandgap InAsSb(Ga,P) barrier was formed. At low temperatures (4.2-100 K) stimulated emission was observed. As the temperature increased, the emission became spontaneous. The transition from stimulated emission to spontaneous one occurred at different temperatures for structures with different InSb contents in the active region. The temperature-dependent carrier lifetime, limited by radiative recombination and the most probable Auger processes (for the materials under consideration, CHHS and CHCC), were calculated within the framework of the Kane model. The effect of various recombination processes on the carrier lifetime was studied, and the dominant role of Auger processes was established. For MQW structures quantization energies for electrons, light and heavy holes were calculated. A characteristic feature of the experimental EL spectra of these structures was the presence of peaks with energy different from that of calculated optical transitions between the first quantization levels for electrons and heavy holes. The obtained results showed strong effect of the specific electronic structure of InAsSb on the energy and intensity of optical transitions in nanostructures based on this material. For the structure with MQWs in the active layer, a very weak temperature dependence of EL peak was observed at high temperatures (>150 K), which makes it attractive for fabricating temperature-resistant gas sensors operating in the middle-infrared range.

Keywords : Electroluminescence, InAsSb, light emitting diode, quantum wells
Conference Title : ICCSD 2020 : International Conference on Compound Semiconductor Devices
Conference Location : Prague, Czechia
Conference Dates : March 19-20, 2020

Open Science Index, Electrical and Computer Engineering Vol:14, No:03, 2020 publications.waset.org/abstracts/122314.pdf