High-temperature annealing of InAs quantum dots lasers structures

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Threshold and spectral characteristics of 1.3μm QD lasers subjected to high-temperature annealing were studied. InAs QDs after high-temperature treatment demonstrate over 350nm blue-shift with a light penalty in threshold characteristics. The shortest lasing wavelength achieved is 917nm with the threshold current density of only 250A/cm^2.

Quantum dots (QDs) are now considered as a promising choice for the active region of diode lasers of the spectral range from 1.1 to 1.3μm [1] and even 1.5μm [2]. Shorter wavelengths (less or around 0.9μm) are typically out of QD ability for GaAs-based structures. It is well known that high-temperature annealing of QD structures results in blue-shift of the emission wavelength [3,4]. This shift is typically strong in QD structures due to significant Ga/In intermixing which simultaneously affects size and shape of QDs as well as the material bandgap. This effect would make it possible fabricating diode lasers of various spectral bands from same QD epiwafer. From this viewpoint QD lasers of the longer as-grown wavelength would provide wider range of spectral tunability by structure annealing. The main issue that has not been stuied in detail so far is a behavior of laser threshold in structures subjected to high-temperature treatment.

The objective of the present work was to study effect of high-temperature annealing on threshold and spectral characteristics of QD lasers initially emitting at 1.3 μm. Two laser structures were MBE grown on n^+-GaAs(100) substrates. Long wavelength InAs quantum dots were obtained by activated spinodal decomposition as described in [5]. Each wafer was then cut into several pieces which were annealed at 700^{0}C for up to 4 hours or remained as-grown. Diode lasers were then fabricated and tested at room temperature. Lasing wavelength in as-grown structures is close to 1.3μm. QD structures demonstrate as-grown threshold characteristics in the 170-250 A/cm^2 range.

Dependences of the wavelength and threshold current density on annealing duration are shown in Fig.1. QD laser structures demonstrate strong blue-shift with annealing (roughly 250nm after the first hour of annealing). At the same time QD lasers still demonstrate relatively low threshold current density after at least 4-hour annealing. The shortest lasing wavelength reaches 916 or 970 nm while the threshold current density is only 370 or 250 A/cm^2 in two studied structures.

Fig.2 shows temperature dependences of the threshold current density and lasing wavelength for as-grown structures and after 4-hour annealing. In spite of the fact that lasing wavelengths are quite different, both lasers demonstrate equal characteristic temperature T_0=110K evaluated in the 20-60°C interval.

To our best knowledge this is the first demonstration of threshold characteristics of QD laser nearly insensitive to high-temperature treatment as well as the widest tunability range reported to date. These findings significantly extend the spectral range of GaAs-based QD lasers and make it possible fabricating diode lasers of various spectral bands from same QD epiwafer.

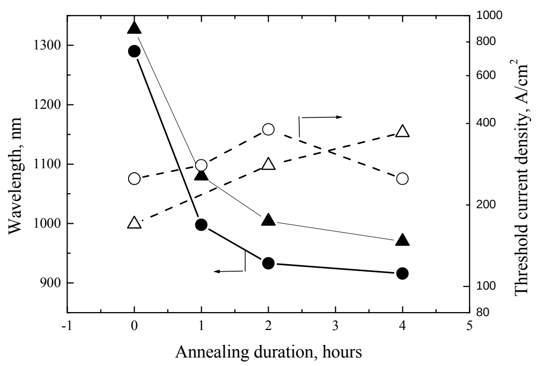

Fig.1. Dependence of lasing wavelength (open symbols) and threshold current density (solid symbols) on annealing duration.

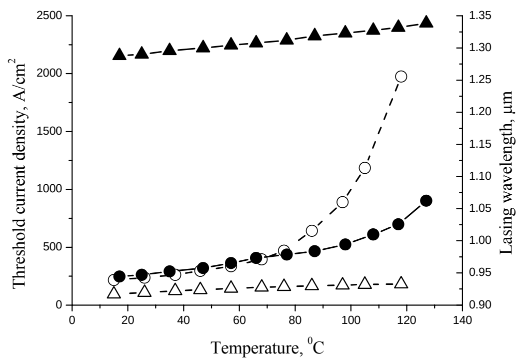

Fig.2 Temperature dependencies of the threshold current density (circles) and of the lasing wavelength (triangles). As-grown laser characteristics are shown by solid symbols, annealed laser characteristics are shown by open symbol

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