InAs/GaAs Quantum Dot Laser Directly Grown on Si

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1. Introduction

Due to the discrete energy levels of quantum dots (QDs), III-V QD lasers have been demonstrated which exhibit low threshold currents and high operating temperatures [1]. In addition, QD-based devices have an insensitivity to crystal defects. For these reasons, III-V QD growth on silicon (Si) is a core technology for the monolithic integration of light sources in Si-photonics. In order to avoid crystal defects such as anti-phase domains (APDs) and threading dislocations, QD lasers are generally grown on an inclined Si substrate or on a processed substrate. However, these substrates are not compatible with the current Si photonics platform. Recently, InAs/GaAs QD lasers grown on on-axis Si(001) using an intermediate GaP buffer layer have been reported [2-4]. In this paper, we report epitaxial growth of InAs/GaAs QD lasers on on-axis Si(001) substrates using only III-As materials. The threshold current density attained here is the lowest among any QD lasers grown on Si(001) just substrate.

2. General Instructions

The samples were grown only using a conventional solid-source molecular beam epitaxy (MBE) with arsenic tetramer (As_4). N-type Si (001) on-axis substrates were used for this work. After the native oxide layer removing, a 40 nm-thick $Al_{0.3}Ga_{0.7}As$ seed layer and an 800 nm-thick GaAs layer was grown directly on the substrate. 5 layers of $In_{0.15}Ga_{0.85}As$(10 nm) / GaAs(10 nm) strained layer superlattice (SLS) followed by a 400 nm-thick GaAs layer were grown. This growth step was then repeated a further 2 times. 8 layers of InAs / GaAs QD were then grown between two 1400 nm $Al_{0.4}Ga_{0.6}As$ cladding layers. Finally, the structure was capped with a 400 nm-thick GaAs layer (see Fig. 2). Lasers with 7 μm width were fabricated by photolithography and wet etching. AuGeNi/Au was used for both of the p- and n-contacts. After lapping the backside silicon to 100 μm, the structures were cleaved to make 1.1 mm long devices.

Figure 1 shows the temperature dependence of the I-L characteristics under the CW condition. The threshold current at room temperature is 27.6 mA, and the corresponding threshold current density is as low as 370 A/cm^2. CW operation was observed in a fabricated device up to 101 °C. The characteristic temperatures (T_0) are 47 K from 25 to 90°C. The lasing wavelength at 101 °C was ~1.27 μm.

3. Conclusions

We have successfully demonstrated the high temperature CW operation of InAs QD laser, which is directly grown on Si (001) on-axis substrates by MBE. This study suggests that QD laser is a realistic candidate for integration with silicon CMOS technology, which requires high temperature operation.

Acknowledgements

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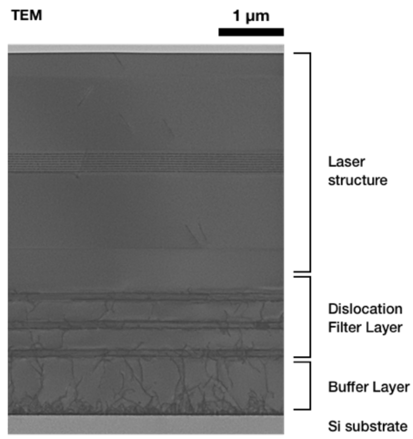

Fig. 1 Cross-sectional TEM image of InAs/GaAs QD laser structure directly grown on a Si (001) on-axis.

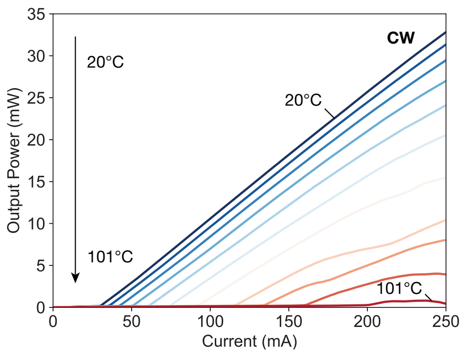

Fig. 2 Temperature dependence of L-I characteristics under CW operation for an InAs/GaAs QD laser grown directly on a Si (001) on-axis substrate.