Telecom-Band InAs/GaAs Quantum Dot Lasers on Silicon Operating at 100 °C

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Abstract

We present 1.3 μm InAs/GaAs quantum dot lasers on Si substrates operating at 100 °C. Our lasers are fabricated through epitaxial growth on GaAs substrates of the InAs/GaAs quantum dot laser double heterostructure and subsequent GaAs/Si wafer bonding and layer transfer onto Si substrates. This result verifies the suitability of III-V quantum dot lasers as a light source in Si photonic integrated circuits.

1. Introduction

Silicon photonic integrated circuits are a promising component for the realization of ultrahigh-speed, large volume computation and telecommunication. III-V semiconductor compound lasers integrated onto Si platform are thought to be an excellent solution for the absence of a practical light source made out of silicon. There has been however no laser on silicon operating at the telecommunications band at or above 70 °C, a standard requirement for such applications. Quantum dot (QD) lasers are particularly suitable for this application because of their low threshold current and high thermal stability relative to the conventional quantum-well lasers [1]. In this study, we have fabricated 1.3 μm InAs/GaAs QD lasers on Si substrates by wafer bonding and layer transfer. Our lasers for both fabricated with direct bonding and metal-mediated bonding operate at 100 °C.

2. Experimental

The InAs/GaAs lasers on Si substrates used in this study were fabricated in similar ways as those shown in Ref. 2 for the direct-bonded sample and Ref. 3 for the metal-mediated-bonded sample, respectively, but importantly we adopted the p-type modulation doped QD laser wafers [4-6] used in Ref. 7, rather than the undoped ones for Refs. 2 and 3, for higher temperature stability.

A double heterostructure InAs/GaAs QD laser structure was grown on a GaAs substrate and layer-transferred onto a Si substrate by means of GaAs/Si direct [2] or metal-mediated bonding [3] and subsequent removal of the GaAs substrate. The InAs/GaAs QD laser structure was grown on a GaAs (100) substrate by molecular beam epitaxy [4-6]. The laser structure consisted of GaAs layer embedded with eight layers of self-assembled InAs QDs with a per-layer density of 6 × 10¹⁰ cm⁻². The GaAs barrier layers in between the QD layers were partly p-type doped. The GaAs layer was clad with p- and n-type Al₀.₄Ga₀.₆As layers. An Al₀.₄Ga₀.₆As etch-stop layer with a thickness of 1 μm was grown between the GaAs substrate and the lower Al₀.₄Ga₀.₆As clad.

The QD laser structure wafer was bonded at 300 °C onto an epi-ready p-type Si (100) wafer doped with boron with a doping concentration of 3 × 10¹⁹ cm⁻³ by direct [2] or metal-mediated wafer bonding [3]. The GaAs growth substrate was then removed by multistep selective wet etching. Following the wafer bonding and layer transfer, broad-area Fabry-Perot lasers with cleaved facets and a cavity length of 2 mm were formed by applying Au/AuGeNi electrodes by means of electron-beam evaporation to the top (100-μm-wide stripes) and bottom of the structure. A high-reflection coating was not applied to the cleaved edges.

3. Results and Discussion

Fig. 1 shows the light-current curves of the InAs/GaAs QD laser on a Si substrate fabricated by the GaAs/Si direct wafer bonding technique, under 500 Hz, 400 ns pulsed pumping at varied temperatures. Both of our direct-bonded and metal-mediated-bonded lasers on Si substrates operate at 100 °C. This lasing temperature is significantly higher than the cases of the previous works for quantum well and QD lasers on silicon [8, 9]. This result verifies that III-V QD lasers on Si fabricated by wafer bonding are promising for light sources in high-density photonic integrated circuits.
Fig. 1 Light-current curves of the 1.3 µm InAs/GaAs QD laser on a Si substrate at varied temperatures fabricated by GaAs/Si direct wafer bonding.

4. Conclusions

In summary, we have fabricated 1.3 µm InAs/GaAs QD lasers on Si substrates by direct- and metal-mediated wafer bonding technologies. Both of the on-Si lasers exhibit lasing temperature of 100 °C. This result is an encouraging demonstration for III-V QD lasers integrated on Si chips as a promising light source in the future silicon photonic integrated circuits.

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