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Extended Abstracts of the 2013 International Conference on Solid State Devices and Materials, Fukuoka, 2013, pp992-993

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

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Abstract

We present 1.3 µm InAs/GaAs quantum dot lasers on Si substrates operating at 100 ºC. 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 telecommunication band at or above 70 ºC, 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 ºC.

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 a GaAs layer embedded with eight layers of self-assembled InAs QDs with a per-layer density of 6×10^{10} 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 $Al_{0.4}Ga_{0.6}As$ layers. An $Al_{0.7}Ga_{0.3}As$ etch-stop layer with a thickness of 1 µm was grown between the GaAs substrate and the lower $Al_{0.4}Ga_{0.6}As$ clad.

The QD laser structure wafer was bonded at 300 ºC onto an epi-ready *p*-type Si (100) wafer doped with boron with a doping concentration of 3×10^{19} 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 ºC. 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.

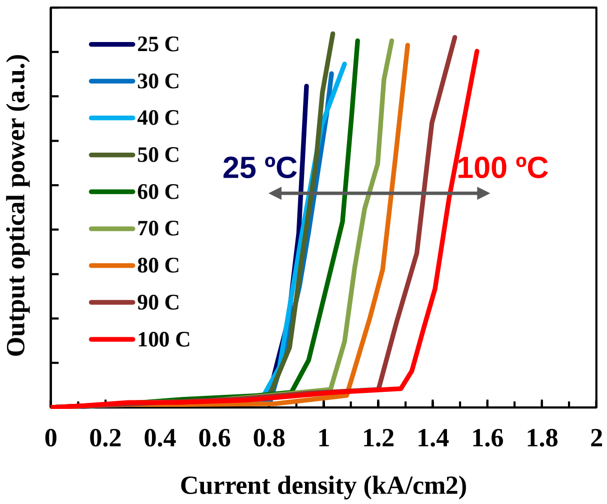

Fig. 1 Light-current curves of the 1.3 μm InAs/GaAs QD laser on a Si substrate at varied temperatures fabricated by GaAs/Si direct wafer bonding.

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 ºC. 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.

Acknowledgements

The authors would like to thank Kenichi Nishi and Mitsuru Sugawara of QD Laser, Inc. for their cooperation and discussion. This work was supported by the Japan Society for the Promotion of Science (JSPS) through the "Funding Program for World-Leading Innovative R&D on Science and Technology (FIRST Program)," the Ministry of Economy, Trade and Industry (METI), Japan, through the "Future Pioneering Projects," the Ministry of Education, Culture, Sports, Science and Technology (MEXT), Japan, through the "Project for Developing Innovation Systems," and Intel Corporation.

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