Sub-mA Threshold Current Vertical Cavity Surface Emitting Lasers with a Simple Fabrication Process

Jack Baker[1], Sara Gillgrass[1], Craig P. Allford[1], Curtis Hentschel[1], J. Iwan Davies[2], Samuel Shutts[1], Peter M. Smowton[1]
[1]EPSRC Future Compound Semiconductor Manufacturing Hub, School of Physics and Astronomy, Cardiff University, Cardiff, UK, CF24 3AA;
[2]IQE plc, Pascal Close, St. Mellons, Cardiff, UK, CF3 0LW

***Abstract*— sub-mA threshold currents are achieved for VCSELs using a simplified fabrication process which employs etched oxidation-vias for definition of the VCSEL aperture, as well as ease in formation of a bond pad without the need for bisbenzocyclobutane planarisation.**

Keywords—VCSEL, manufacturing, fabrication

I. Introduction

The market for VCSELs has been rapidly expanding for the last few years as a result of the development of 3D imaging and structured light technology, and this is predicted to continue with the application to LiDAR technology. To meet this increased demand, manufacturers have scaled their production to 6-inch substrates and are looking to go further to 8-inch in the future [1]. This requires stringent quality-control to maximise the device yield across individual wafers as well as between different wafers and different growth runs. One of the preferred methods for this is the regular fabrication of working devices from sacrificial wafers, followed by wafer-mapping of the laser performance. This allows wafer uniformity to be assessed based on actual laser characteristics and facilitates the evaluation of any drift throughout a growth campaign.

This brings about the need for a simplified fabrication process for VCSELs which can produce representative devices for assessment of the epitaxial material quality, but also for comparison with full industry-standard devices. Additionally, the device design must be robust over large diameter wafers and be insensitive to fabrication tolerance. This work builds upon previous efforts to produce simplified Quick Fabrication (QF) VCSELs [2], by improving the device performance as well as further simplifying the fabrication. Principally, the aim of this work was to develop an appropriate QF device design that removed the leakage current associated with the previously reported QF VCSELs.

II. Device Fabrication

Previously, the approach to QF VCSELs was through the employment of a trench bridge-mesa design, whereby the VCSEL mesa is not fully isolated from the surrounding planar material, a diagram of which is shown in Fig. 1 (top). This simplified the fabrication process by removing the need for bisbenzocyclobutane (BCB) planarisation. Here, the approach is the formation of an oxide aperture through etched oxidation-vias, similar to a bond pad approach in [3]. A diagram for this design is shown in Fig. 1 (bottom).

The vias allow the outer regions of the large mesa to be fully oxidised but still facilitate a central aperture for confinement of both carriers and light. Therefore, the fabrication process for the oxidation-via VCSELs is simply; etch to just below high Al-content layers, formation of current blocking oxide layers by wet thermal oxidation, definition of top p-metal contact and deposition of global backside n-metal contact.

The epitaxial was grown by MOCVD on n+ GaAs substrates by IQE plc and designed for 940nm emission wavelength. The structures consist of a multiple quantum well inner cavity, sandwiched between GaAs/AlGaAs distributed Bragg reflector mirrors.

III. Experimental

Light-current-voltage and spectral measurements were compared for standard VCSEL structures, QF bridge-mesa structures and QF oxidation-via structures. We showed previously that the threshold current of oxide-confined bridge-mesa VCSELs is increased by 1.5mA, relative to a standard VCSEL design, due to the leakage current (see Fig. 2). Now, with the oxidation-via design we fully remove this contribution of the leakage current and hence sub-mA threshold currents can be achieved. In this way, the performance of the oxidation-via QF structures is closer to standard VCSELs, with a dramatically simplified fabrication process

J. Baker would like to acknowledge support from an EPSRC Industrial-CASE studentship co-sponsored by IQE plc.

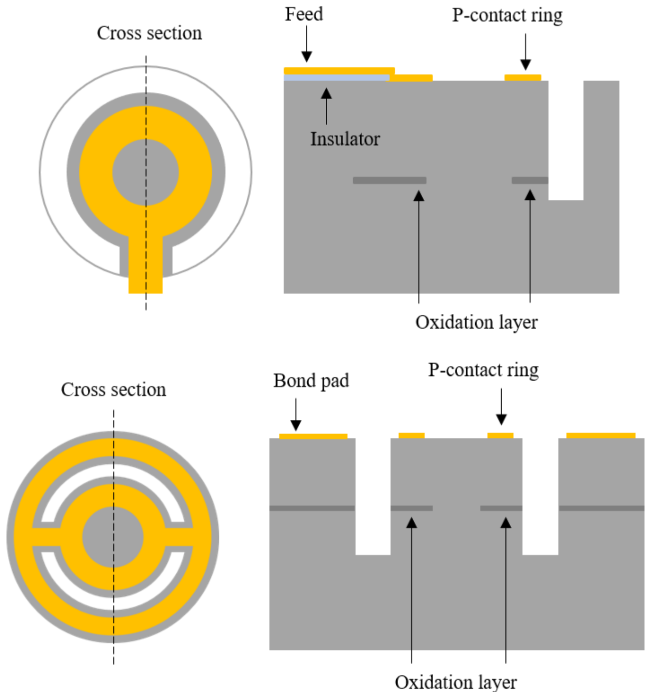

Fig. 1. Diagram of the structure of a Quick Fabrication bridge-mesa VCSEL (top) and Quick Fabrication oxidation-via VCSEL (bottom).

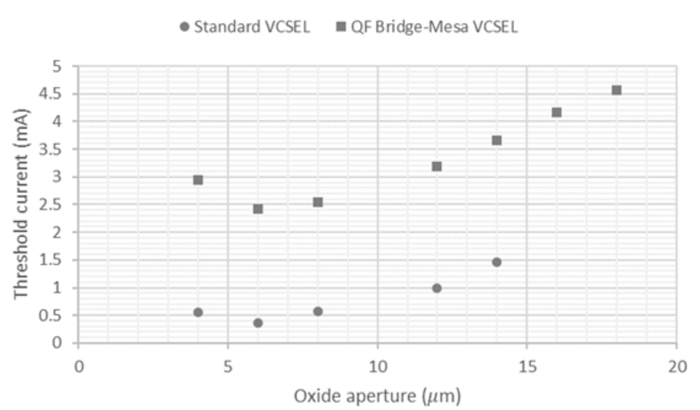

Fig. 2. Comparison of threshold current for standard VCSEL structures and Quick Fabrication bridge-mesa structures.

ACKNOWLEDGMENT

The authors would like to acknowledge the Institute for Compound Semiconductors at Cardiff University for fabrication of devices.

REFERENCES

[1] A. Johnson et al., "High performance 940nm VCSELs on large area germanium substrates: the ideal substrate for volume manufacture," Mar. 2021, vol. 11704, p. 1, doi: 10.1117/12.2583207.

[2] J. Baker et al., "Quick fabrication of 940nm emitting VCSEL arrays for commercial wafer characterization," Mar. 2021, vol. 11704, p. 5, doi: 10.1117/12.2578365.

[3] K. M. Geib, K. D. Choquette, A. A. Allerman, R. D. Briggs, and J. J. Hindi, "Comparison of fabrication approaches for selectively oxidized VCSEL arrays," in Vertical-Cavity Surface-Emitting Lasers IV, May 2000, vol. 3946, pp. 36–40, doi: 10.1117/12.384385.