Controlling AlGaAs oxidation anisotropy for VCSEL applications

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The standard fabrication technique to make Vertical-Cavity Surface-Emitting Lasers exploits a compositionally-selective lateral oxidation of AlGaAs layers to define buried aperture(s) which set(s) both the device optical and electrical characteristics [1]. The crystalline nature of the to-be-oxidized materials leads to the introduction of an anisotropic reaction and thereby to a deformation of the oxide aperture from its original mesa shape. This deformation is anticipated to negatively affect the efficiency of singlemode emitters which are predicted to form the backbone of the next generation of high-speed datacenters.

In this contribution, we will present our recent investigations on methods to mitigate the oxidation anisotropy involving a particular selection of the oxidation process parameters and/or using oxidation mesas presenting specifically-designed shapes.

Using real-time in-situ measurements and parametric squircle fitting of the oxide apertures resulting from the anisotropic oxidation starting from circular mesas, we establish that oxidations at high temperature tend to exhibit lower anisotropy [2]. To gain further insight into the influence of the anisotropy, an erosion-based model of the oxidation has been developed and shown to enable an accurate reproduction of the measured evolution [3]. Finally, this erosion model was exploited to introduce a method to determine the mesa shape that should be etched to lead to circular apertures upon an anisotropic oxidation [4].

As a conclusion, we have shown that the oxidation anisotropy can be controlled or mastered to enable the fabrication of circular-apertured devices whose prime example is the singlemode VCSEL.

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[3] S. Calvez, G. Lafleur, A. Arnoult, A. Monmayrant, H. Camon, et G. Almuneau, « Modelling anisotropic lateral oxidation from circular mesas », *Opt. Mater. Express*, vol. 8, n° 7, p. 1762-1773, janv. 2018.
[4] S. Calvez, A. Arnoult, A. Monmayrant, H. Camon, et G. Almuneau, « Anisotropic lateral oxidation of Al-III–V semiconductors: inverse problem and circular aperture fabrication », *Semicond. Sci. Technol.*, vol. 34, n° 1, p. 015014, janv. 2019.