P09

Dry-etched facets for InAs/AlSb quantum cascade lasers compatible with monolithic integration

Algimantas Lukša[1], Mindaugas Kamarauskas[1], Virginijus Bukauskas[1], Viktorija Nargelienė[1], Karina Pokaliuk[1], Ramūnas Levinas[2] and Jan Devenson[3]

[1]*Department of Physical Technologies, Center for Physical Sciences and Technology, Sauletekis av. 3, Vilnius, Lithuania*
[2]*Department of Catalysis, Center for Physical Sciences and Technology, Sauletekis av. 3, Vilnius, Lithuania*
[3]*Department of Optoelectronics, Center for Physical Sciences and Technology, Sauletekis av. 3, Vilnius, Lithuania*
Email: algimantas.lukša@ftmc.lt

Quantum cascade lasers (QCLs) are compact, electrically-pumped semiconductor sources of mid-infrared (MIR) radiation, uniquely suited for applications spanning trace-gas spectroscopy, chemical sensing, and free-space optical communications [1]. Conventional QCL fabrication relies on wafer cleaving to form laser mirror facets. While cleaving yields optically smooth surfaces, it is fundamentally incompatible with monolithic photonic integration. Replacing cleaved mirrors with lithographically defined, dry-etched facets enables the realization of fully monolithic mid-infrared photonic integrated circuits. Such platforms are especially compelling for surface plasmon polariton (SPP) integrated gas sensors, where QCL sources, plasmonic waveguides, and detectors must be co-integrated on a single substrate to exploit the strong evanescent field overlap between SPP modes and the molecular absorption fingerprints of target analytes [2, 3].

In this work we demonstrate InAs/AlSb QCLs emitting near 9.5 μm in which the mirror facets are formed entirely by inductively coupled plasma reactive ion etching using a BCl_3-Cl_2-Ar-based process chemistry. Scanning electron microscopy (SEM) image (Fig. 1) confirms that the etched sidewalls are smooth and nearly vertical, with a measured etch angle below 2° from the normal to the wafer surface. Atomic force microscopy characterization of the etched floor reveals a surface roughness below 2.5 nm RMS. This level of smoothness is compatible with direct metal deposition for SPP waveguide fabrication, where interface roughness between the metal film and the semiconductor surface is critical for minimizing plasmonic propagation losses.

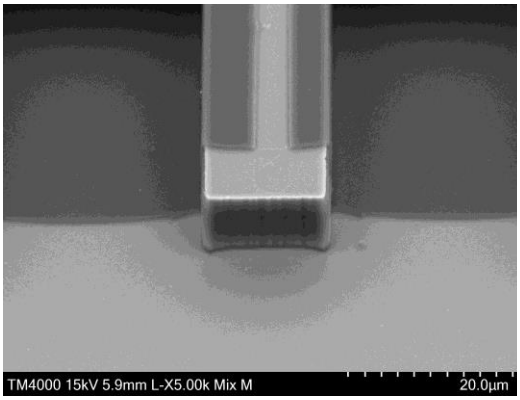

Fig. 1 SEM image of dry-etched QCL mirror facet

REFERENCES

[1] Yao, Y., Hoffman, A. & Gmachl, C. Mid-infrared quantum cascade lasers. Nature Photon 6, 432–439 (2012).
[2] Schwarz, B., Reininger, P., Ristanić, D. et al. Monolithically integrated mid-infrared lab-on-a-chip using plasmonics and quantum cascade structures. Nat Commun 5, 4085 (2014).
[3] Qiangqiang Guo, Jinchuan Zhang, Ke Yang, Yixuan Zhu, Quanyong Lu, Ning Zhuo, Shenqiang Zhai, Junqi Liu, Lijun Wang, Shuman Liu, and Fengqi Liu, "Monolithically integrated mid-infrared sensor with a millimeter-scale sensing range," Opt. Express 30, 40657-40665 (2022)