Hybrid Metal-DBR Mirrors Designed for Mid-Infrared Vertical-Cavity Surface-Emitting Lasers

Monika Mikulicz[1], Michał Rygała[1], Tristan Smołka[1], Mikołaj Badura[2], Adriana Łozińska[2], Damian Radziewicz[2], Beata Ściana[2], Marcin Motyka[1*]

[1] Laboratory for Optical Spectroscopy of Nanostructures, Department of Experimental Physics, Faculty of Fundamental Problems of Technology, Wrocław University of Science and Technology, Wybrzeże Wyspiańskiego 27, 50-370 Wrocław, Poland
2 Department of Microelectronics and Nanotechnology, Faculty of Electronics, Photonics and Microsystems, Wrocław University of Science and Technology Janiszewskiego 11/17, 50-372 Wrocław, Poland

The mid-infrared source of light has a wide range of applications in medicine, industrial process control, environmental protection and as a key element of security systems [1]. Majority of these applications explore optical sensing of methane, ethane, ethylene, acetylene, formaldehyde, acetone and many other gases [2] which is main motivation to improve quality of source of light in mid-infrared spectral range. VCSELs (Vertical-Cavity Surface-Emitting Laser) type of lasers are promising candidate for aforementioned application due to several advantages in comparison to conventional edge-emitting semiconductor lasers. VCSELs are characterized by narrow emission line, circular and low-divergent output beam, and relatively easy to achieve single-mode emission [3] which is required for implementation of highly efficient gas detection systems.

Construction of VCSEL type of laser includes a DBR (Distributed Bragg Reflector) mirror which exhibit reflectivity above 99%, enabling it to create a resonant cavity with thickness of few micrometers. For mid-infrared spectral range growing mirror is challenging due to significant thickness of quarter-wavelength layers, which result in stress and tension in structure and moreover in difficulties in control of the process. To decrease dimension of the laser and production costs, we propose to implement deposited bilayer of metallization (Ti/Au) with high reflectivity, instead section of double semiconductor mirror layers, to achieve high reflectance and preserve wavelength selectivity. We develop our approach in two different material systems with well-established technology: GaAs and InP.

We present experimental results of reflectance measurements performed using a Bruker Fourier spectrophotometer for samples of both material systems. We achieved 87% and above 85% of reflectivity for 4 μm, in the case of DBR mirrors 8×AlAs/GaAs and 8×InGaAs/InP, respectively. There are very promising results for mid-infrared spectral range, which could be still improve by additional deposition of metallization. Experimental results are supported by calculations performed by filmetrics software based on the complex-matrix form of the Fresnel equations [4] which allow us to estimate the thickness and composition of DBR layers.

[1] H.I. Schiff, G.I. Mackay, J. Bechara, M.W. Sigrist (Ed.), (Wiley, New York 1994).
[2] P. Kluczynski, M. Jahjah, L. Naehle, O. Axner, S. Belahsene, M. Fischer, J. Koeth, Y. Rouillard, J. Westberg, A. Vicet, S. Lundqvist, Appl. Phys. B. **105**, 427 (2011).
[3] F. Koyama, J. Lightw. Technol. **24**, 12 (2006).
[4] https://www.filmetrics.com/

* This work was supported by the Polish National Science Centre within Project No. 2019/33/B/ST7/02591