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Whispering gallery modes and random lasing in ZnO microstructures

V V Ursaki[1], A Burlacu[1,2], E V Rusu[2], V Postolake[3] and I M Tiginyanu[2,3]

[1] Laboratory of Low-Dimensional Semiconductor Structures, Institute of Applied Physics, Academy of Sciences of Moldova, MD-2028, Chisinau, Moldova
[2] Laboratory of Nanotechnology, Institute of Electronic Engineering and Industrial Technologies, Academy of Sciences of Moldova, MD-2028, Chisinau, Moldova
[3] National Center for Materials Study and Testing, Technical University of Moldova, Stefan cel Mare avenue 168, MD-2004, Chisinau, Moldova

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Abstract
Hexagonal ZnO microdiscs and hemispherical ZnO microstructure built from hierarchical nanostructures have been grown by metal–organic chemical vapour deposition and carbothermal evaporation technologies, respectively. The technologies ensure as high an optical quality of the produced structures so as to act as a gain medium for stimulated emission in the ultraviolet spectral region in combination with high quality factor laser resonators. The ZnO microdisc resonators with diameters of around 1.8 μm and thicknesses of 100 nm support whispering gallery modes with a quality factor of 640, while the lasing in the hemispherical ZnO microstructure represents a combination of whispering gallery modes in microrods with a quality factor of 640–800 and random lasing in an array of ZnO nanowires with a quality factor of around 3000.

Keywords: nanocrystalline materials, laser materials, microcavity and microdisc lasers, random lasers

1. Introduction

With a wide bandgap of 3.36 eV at room temperature and a large exciton binding energy of 60 meV, ZnO nanostructures with various interesting morphologies demonstrate great promise as building blocks for photonic and optoelectronic devices, including microlasers [1–3]. A variety of ZnO nanostructures have been demonstrated to be suitable for lasing [4–19]. The lasing characteristics are, to a large extent, determined by the feedback mechanism. Different types of resonators have been realized in ZnO nanostructures and microstructures, including Fabry–Perot cavities for longitudinal modes in nanorods [4], nanowires [8] and tetrapod legs [15, 16], as well as guided modes due to multiple total internal reflections in nanorods [6, 18, 19] and pairs of tetrapod legs [17]. Whispering gallery modes have been demonstrated in microdiscs [12, 13] and microwires [14]. Additionally, random lasing has been demonstrated in arrays of ZnO nanorods [7], nanowires [9], nanoneedles [10] and nanobelts [11]. To discriminate between the types of resonators is not an easy issue in hierarchical ZnO nanostructures.

In this paper, we show that whispering gallery modes are the only possible feedback mechanism in ZnO microdiscs produced by metal–organic chemical vapour deposition (MOCVD), while a combination of microcavity and random lasing is realized in a hemispherical microstructure composed of hierarchical ZnO nanostructures grown with carbothermal evaporation in a vapour transport and condensation process. The produced structures are expected to find applications in integrated nanoscale optoelectronics, photonics and sensor technologies.

2. Experimental details

The MOCVD growth was performed in a horizontal double furnace MOCVD set-up consisting of a source furnace and a main furnace, as illustrated in the schematic diagram in figure 1(a). Zinc acetylacetonate hydrate (Aldrich) was used as the source material introduced into the source furnace. The vapours were transported into the main furnace by Ar gas flow which was mixed with another flow of Ar and O_2 gases

