

# Photoluminescence Dynamics of ZnO films grown under oxygen-rich conditions

Elżbieta Guziewicz<sup>1</sup>, Krzysztof P. Korona<sup>2</sup> and Wojciech Woźniak<sup>1</sup>

<sup>1</sup> *Institute of Physics, Polish Academy of Sciences, Al. Lotnikow, 02-668 Warsaw, Poland*

<sup>2</sup> *Faculty of Physics, University of Warsaw, ul. Pasteura 5, 02-093 Warsaw, Poland*

The origin of the commonly observed high background donor conductivity of zinc oxide has been a subject of extensive research. After years of investigations, it became clear that an interplay of native defects and impurities unintentionally introduced during the growth process are responsible for the observed background *n*-type conductivity. In this context oxygen-rich growth conditions are of great importance when low background electron concentration is going to be achieved.

In the present study we show the results of photoluminescence (PL) and ultrafast time-resolved PL (TRPL) studies on undoped ZnO films grown by Atomic Layer Deposition (ALD) under oxygen- or zinc-rich conditions, which in the ALD process can be achieved by changing the growth temperature from 100°C to 200°C [1]. From electrical measurements it has been found that electron concentration of undoped films increased by 3 orders of magnitude (from  $\sim 10^{16}$  to  $\sim 10^{19}/\text{cm}^3$ ) when ALD growth conditions are changed from oxygen-rich ( $T_g = 100^\circ\text{C}$ ) to zinc-rich ( $T_g = 200^\circ\text{C}$ ). Low electron concentration is accompanied by a high hydrogen content as measured by SIMS [1]. Low temperature photoluminescence studies show that the sample deposited at lowest temperature (100°C) revealed the brightest emission, which mostly came from donor-acceptor pairs (Fig. 1). The time-resolved PL allowed to determine decay time of this emission as 0.15 ns, which was comparable with decay time for a commercial single ZnO crystal (Mateck) and much longer than that decay time of thin ZnO film deposited at 200°C (0.07 ns).

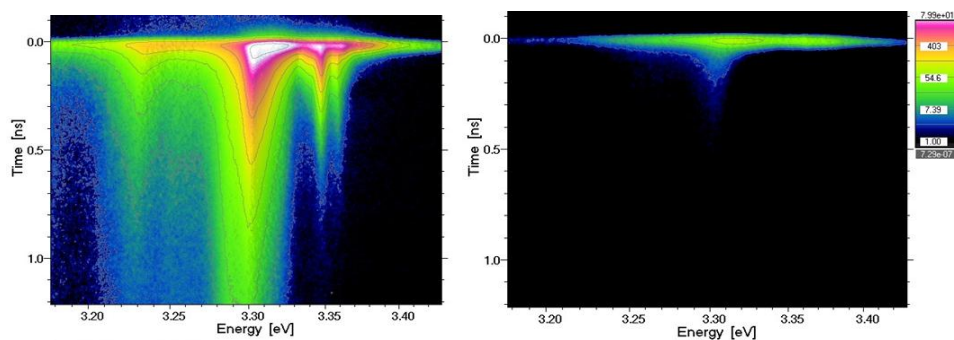


Fig. 1. TRPL spectra of annealed  $\sim 350$ -nm thick ZnO-ALD films grown under oxygen-rich (100°C, left) and zinc-rich (200°C, right) conditions.

The paper was supported by the Polish National Centre for Research and Development (NCBiR) through the project PBS2/A5/34/2013.

[1] E. Guziewicz et al., *Semicond. Sci. Technol.* 27, 074011 (2012)

[2] E. Guziewicz et al., *ACS Appl. Mat. & Int.* 9, 26143-26150 (2017)