Manipulating hBN Bandgap Properties With Aluminum

Jakub Iwański, Mateusz Tokarczyk, Krzysztof P. Korona, Piotr Tatarczak, Jan Pawłowski, Aleksandra K. Dąbrowska, Johannes Binder, Roman Stępniewski and Andrzej Wysmołek

Faculty of Physics, University of Warsaw, Pasteura 5, 02-093 Warsaw, Poland

Research on artificial light sources led to the development of semiconductor emitters that have a number of advantages, e.g. small size, long lifetime, high efficiency. To obtain shorter-wavelength emitters one usually alloys GaN-based structures with aluminum to increase the bandgap of the material (to 6.2 eV for pure AlN). However, by using this technology one can so far obtain only low luminescence efficiencies in the deep UV (DUV, 4.4-6.2 eV). This spectral region is of high importance for the sterilization of water, air and surfaces since light in the DUV can distrupt DNA of pathogenes.

In our research we focus on filling the efficiency gap in the DUV spectral range. We test an approach based on hexagonal boron nitride which despite of an indirect bandgap has a photoluminescence (PL) intensity of the band-edge transition that is more than two orders of magnitude higher than that of an AlN epilayer which has a direct bandgap [1]. Because the conduction band minima responsible for direct and indirect emission are close to each other in hBN, the emission efficiency can be potentially further enhanced when electronic states are properly manipulated [2].

In this work we study boron nitride layers grown with metalorganic vapor phase epitaxy (MOVPE) on 2-inch sapphire substrates [3-4]. The studied samples were alloyed with aluminum using different flows of trimethylaluminium (TMAl). Based on results obtained by UV-Vis, Raman and Fourier-transform spectroscopies, X-ray diffraction, scanning electron microscopy, atomic force microscopy and photoluminescence we will discuss how different flows of aluminum precursor affect the properties of the final epitaxial hBN layer.

As presented in figure 1, the absorbance spectra change with the amount of TMAl. The spectra revealed two peaks which energies coincide with direct (higher energy) and indirect (lower energy) transitions in hBN. The intensity ratio and the position of those peaks vary between the samples. This observation suggests that we are capable of manipulating the boron nitride bandgap by alloying with aluminum. The possible reasons and consequences of such a behavior will be discussed.

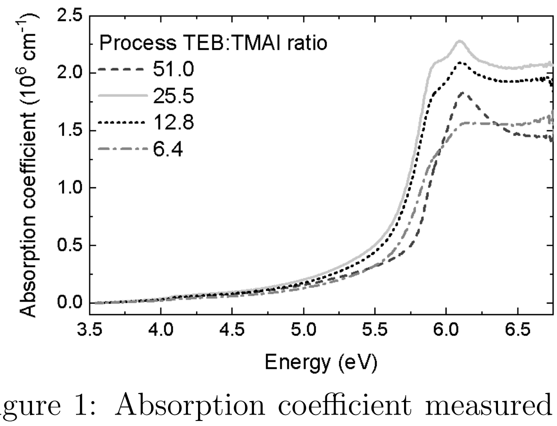

Figure 1: Absorption coefficient measured at room temperature for the samples grown with different TEB:TMAl ratio. Absorption coefficient uncertainty is estimated to be 10^5 cm^{-1}.

Acknowledgment: This work was supported by the National Science Centre, Poland, under decisions 2019/33/B/ST5/02766, 2020/39/D/ST7/02811 and 2022/45/N/ST5/03396.

[1] Maity, A., et al. *Progress in Quantum Electronics* 76 (2021): 100302

[2] Henck, H., et al. *Physical Review B* 95.8 (2017): 085410

[3] Dąbrowska, A. K., et al. *2D Materials* 8.1 (2020): 015017

[4] Tokarczyk, M., et al. *2D Materials* 10 (2023): 025010