Manipulation of indirect/direct bandgap character of hBN by alloying with Al

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The possibility of effective sterilization using light in the deep ultraviolet range (DUV, 200-280 nm, 4.4-6.2 eV) is a strong motivation for the development of semiconductor light sources operating in this spectral range. However, existing semiconductor technology so far only allows for very limited efficiency of DUV light sources (of the order several percent). A promising solution to this problem could be the application of hexagonal boron nitride (hBN). In spite of the indirect character of the bandgap, that is two-dimensional (2D) layered material is known for efficient photoluminescence, similar to direct-bandgap semiconductors. Alloying of boron nitride with other nitrides can influence the band structure increasing optical efficiency. Application of atomically thin layers of such compounds would enable an additional important functionality of such DUV light sources, which is elasticity.

In our research we study thin (~ 10 nm) layers of hBAlN which is 2D boron nitride alloyed with aluminum. The set of samples with an Al content of the order of a few percent was grown using metal organic vapor phase epitaxy (MOVPE) on 2-inch sapphire substrates.

The obtained $hB_{1-x}Al_xN$ layers were investigated using X-ray diffraction, scanning electron microscopy, atomic force microscopy (with nanomechanical mapping), UV-Vis, Raman and Fourier-transform infrared spectroscopies. The obtained experimental data revealed that the obtained materials remain sp^2-bonded crystal structure for all Al contents, which is novelty in research on BAlN-type material.

Interestingly, as presented in figure 1 we observed two strong absorption peaks for energies close to direct and indirect (which should be very weak) band 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.

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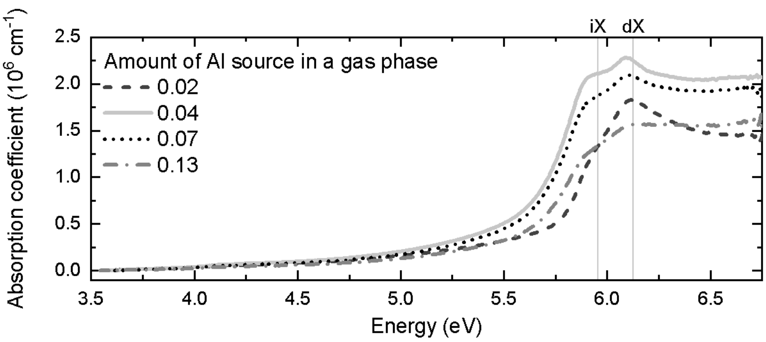

Fig. 1. Absorption coefficient measured at room temperature for samples grown with a different amount of aluminum precursor. Uncertainty is estimated to be 10^5 cm^{-1}. The vertical lines correspond to the energies of direct (dX) and indirect (iX) bandgaps in hBN.