# Abstract

## *Growth technology and its impact on optical and structural properties of boron nitride grown by MOVPE*

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Boron nitride is a material that has been known for a long time, but has remained in the shade of other compounds studied and used in solid state physics. The recent spark of interest in layered materials led to an appreciation of their extraordinary properties. In addition to very high resistance to harsh external conditions of boron nitride (such as high temperature, pressure and the presence of reactive chemical compounds), and a wide energy gap in the far ultraviolet range, it can crystallize in a $sp^2$-hybridized structure, making it compatible with other layered materials. In today's optoelectronics, it can therefore not only act as an active layer (light source), but also as a protective layer or an insulating barrier. Few materials can boast such a wide range of applications and therefore work on obtaining $sp^2$-hybridized boron nitride of highest quality and in any quantity is carried out in many research centers around the world. The methods of high-quality bulk material growth cannot provide crystals larger than a one millimeter, while epitaxial techniques, which allow obtaining large areas of the material on the entire substrate scale, are still burdened with the occurrence of a large number of defects.

The aim of this doctoral dissertation was to thoroughly investigate boron nitride obtained by MOVPE by using different experimental techniques, mainly Raman spectroscopy, photoluminescence, X-ray diffraction and scanning electron microscopy, and correlate its optical and structural properties to the growth conditions. Hypotheses about the growth mechanisms associated with different modes were proposed, and new techniques and growth methods were developed to obtain material of an increasingly better quality. Mid-gap luminescence spectra were also analyzed, and several characteristic bands observable in the spectra of all samples were identified.

The first chapter focuses on boron nitride itself and gives an introduction to aspects related to both, the III-nitride family and layered materials. The properties, applications and commonly used methods of obtaining boron nitride are also presented here.

The second chapter describes the technology of epitaxial growth from metalloorganic compounds in detail, which is used at the Faculty of Physics, University of Warsaw. In addition to the

discussion of the epitaxy system and additional devices for *in situ* growth monitoring, the specific growth modes used for the boron nitride obtaining are discussed.

The third chapter presents experimental techniques used in the research framework of this thesis. Physical phenomena used in specific measurements and devices that were employed for the research are described. A discussion of the current state-of-the-art regarding measurements of boron nitride has been added to each technique.

The main part of the work is the fourth chapter - it contains the results obtained in the course of the Ph.D. studies. At the beginning of the chapter, the applied growth modes are described: the classical ones, used for other materials, and the novel ones, developed on the basis of our own results. In the next part, all boron nitride samples were divided into three groups: polycrystalline, epitaxial, and homoepitaxial samples. In the following subsections, the surface morphology, structural properties, and optical properties are characterized in detail for each of these groups. These properties were also associated with changes in individual growth parameters. The growth mechanisms for all modes were explained and the nature of the defects responsible for mid-gap luminescence was proposed.

The fifth chapter summarizes the most important results obtained for boron nitride grown by the MOVPE method. Four aspects that constitute a significant added value to the current knowledge about this material were described: the relationship between the growth parameters and the properties of samples grown in the standard growth modes, newly developed methods of growth of high-quality large-area boron nitride, the nature of defects appearing in boron nitride grown by MOVPE, application potential of boron nitride obtained by MOVPE.

The last chapter is a short summary of the entire dissertation and the results obtained. It also includes a list of publications and conference presentations of the author.