



Examiner Report of Ph.D. Thesis

Ph.D. Candidate: Mykola Telychko, Charles University in Prague

Thesis Title: Studying possibilities of graphene functionalization using AFM and STM techniques

30<sup>th</sup> July, 2016

The Ph.D. thesis is focused on characterization of graphene, and B/N/BN doped graphene grown on SiC support. The author combines experimental data acquired by probe microscopies (STM and AFM) with other surface characterization techniques (XPS, NEXAFS, LEEDF) and supports them by theoretical calculations, in order to establish a complex picture about structural and chemical features of the analyzed materials. Specifically, the author addresses structure, growth mechanism and electronic structure of graphene on SiC(0001) support together with structural and electronic features of boron or/and nitrogen doped graphene on the same support.

The Ph.D. thesis is divided into three chapters. Chapter 1 provides introduction to the used techniques and brief information concerning the experimental setup and sample preparation. Chapter 2 deals with growth, structure and electronic properties of graphene on SiC(0001) support. The last chapter 3 studies on effects of N and B dopants on graphene electronic structure. I would like

to note that part of the Ph.D. thesis was already published in five papers, which the Ph.D. candidate coauthored in three cases as the first author. This clearly illustrates major contribution of the Ph.D. candidate to the scientific work, which resulted in the publications. In addition, the papers were published in very prestigious scientific journals including, e.g., ACS Nano, which underlines importance of the scientific topics and quality of the research addressed by the Ph.D. candidate. This fact makes it easier to evaluate the scientific parts of the Ph.D. thesis, as they were subject of rigorous peer-review process in the renowned scientific journals. On the other hand, the text of the Ph.D. thesis would benefit from linguistic editing and some polishing, as it contains a number of errors and unusual phrasing. In addition, the author should add papers he co-authored as a supporting material/appendix as a courtesy for the reader.

I would like to state that the Ph.D. thesis deals with structural and electronic properties of graphene and doped graphene, which is an intensively studied topic of current nanomaterial chemistry because of its application potential, e.g., in electronics. The candidate analyzed the respective materials by very advanced experimental techniques and with the support of theoretical calculations, he established some principles of modulation graphene and doped graphene on SiC electronic structure. I would like to emphasize that the conclusions are well supported by results, scientifically relevant and significantly broaden our current knowledge in the field. They may help in future design of research in nanoscience focused on electronic applications of graphene.

Without any doubt, the Ph.D. thesis, that I had the opportunity to evaluate, represents a high-quality Ph.D. work. The presented research significantly contributes to our knowledge on graphene-based nanomaterials and brings new,

important and original findings. The candidate well documents his ability to conduct an independent research and has a very good starting position for his future scientific carrier. Finally, I declare, that it is my great pleasure to recommend to the scientific committee **to award the Ph.D. degree to Mykola Telychko.**

I would also like to contribute to the scientific discussion placing a few questions, which might be answered during his Ph.D. thesis defense:

Some authors suggested that formation of N-N bonds in doped graphene impairs graphene's stability (of course at high doping levels, *cf.* J. Am. Chem. Soc. 2015, 137, 11688). Have you ever observed some upper limit for N/B doping of graphene and/or structural instability in highly doped graphene spots?

Is there any preference (of local/nonlocal character) for A/B sublattice during N/B doping? Answering the question, could you also clarify please the x-axis of Figure 3.9.

Have you analyzed magnetic features of N/B doped graphenes?

Where do you see the major application potential of the doped graphene in practice?

How do you envisage further development in controlling of graphene doping?

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prof. Michal Otyepka, Ph.D.

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