Universität zu Köln

II. Physikalisches Institut • Zülpicher Str.77 • 50937 Köln

**Mathematisch-
Naturwissenschaft-
liche Fakultät**

II. Physikalisches Institut

Prof. Dr. Alexander Grüneis

Telefon +49 221 470 3461
grueneis@ph2.uni-koeln.de
www.ph2.uni-koeln.de

To:
Dean to Natural Sciences Faculty
St. Petersburg State University
Petergof, Ulyanovskaya street
Russia

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<u>Regarding: PhD thesis of Viktor Shevelev</u>

I have studied the PhD thesis of Viktor Shevelev which deals with crystal structure and the electronic properties of graphene and hexagonal boron nitride (hBN) grown by chemical vapour deposition on cobalt.
The introduction sections of chapter 1 and 2 are an appropriate description of the state of the field and the methods although it would have been appropriate to describe the details of the Kolmogorov–Johnson–Mehl–Avrami model which is used later and forms one valuable result.
In chapter 3 of the thesis, the use of Raman spectroscopy for epitaxial graphene is shown. I consider the experiments of this chapter as a pioneering work as it corresponds to the first Raman study of epitaxial graphene on metals which is made difficult by the very low Raman cross section as the author writes. The candidate uses Raman to report a giant shift of the G band which he correctly attributes to strain (for the strain analysis a plot of G band versus 2D band frequency of polycrystalline gr/Co is used). The strain (~1.5%) is also consistent with the analysis of electron difraction. A model is presented as to why the 2D band is absent in single crystalline graphene on Cobalt.
In chapter 3, the candidate also investigates the recrystallisation of 2D graphene on cobalt. To that end he synthesises polycrystalline graphene which is heated in a UHV chamber while the diffraction spots are analyzed as a function of time and also the presence of hydrocarbon gases in the chamber. The recrystallization kinetics for

different samples and sample environments is analyzed within the framework of the Kolmogorov–Johnson–Mehl–Avrami model. Such a work could be very relevant for the fabrication of graphene with ultra high mobilities (>100 000 cm^2 / Vs). Unfortunately, no attempts have been made to actually correlate the crystal structure with electron mobility which would have required the transfer of the graphene layer.
Chapter 4 of the thesis deals with the interaction of graphene and hBN with oxygen. In my opinion, a very exciting result of this chapter is that the candidate managed to incorporate oxygen into the hBN lattice by annelaing hBN in a O_2 atmosphere. The oxygen replaces three or one nitrogen atoms and forms BO_3 and BN_2O structures. The candidate has used x-ray photoemission spectroscopy in order to assess the stoichiometry. These experiments were preformed on hBN/Cobalt. In order to study the effect of the substrate, the candidate intercalated one Au monolayer under hBN/cobalt. He then found that in the case of Au, the rate of oxygen incorporation is significantly lower. Apart from photoemission, the candidate used extensively PEEM, Nexafs and Raman spectroscopy to characterize the samples. This large variety in methods allows one to obtain a complete picture of the various electronic states (occuppied vs. empty) and phonons involved.

In conclusion, I consider this work as a very important contribution to the field of 2D materials science. The candidate, Mister Viktor Shevelev deserves to be awarded the PhD degree.

Mit freundlichem Gruß,

(Alexander Grüneis)