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Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis / Pre-examination statement for Aalto University

Name of Candidate: Alexey Tsapenko

PhD Program: Physics

Title of Thesis: Enhancing Optoelectronic Performance of Randomly Oriented Single-Walled Carbon Nanotube Films

Supervisors: **Prof. Albert Nasibulin, Skoltech, Russia**

Prof. Esko Kauppinen, Aalto, Finland

Chair of PhD defense Jury: Prof. Nikolay Gippius, Skoltech ***Email:***N.Gippius@skoltech.ru

Date of Thesis Defense: October 4, 2019

Name of the Reviewer: Georgy Fedorov

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Signature:** **Date: 07-08-2019**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury / Pre-examiner before the thesis defense. The members of PhD defense Jury / pre-examiner are asked to submit signed copy of the report at the latest on August 13th. The Reviewers are asked to bring a copy of the completed report to the thesis defense and to discuss the contents of each report with each other before the thesis defense.

If the reviewers have any queries about the thesis which they wish to raise in advance, please contact the Chair of the Jury.

Reviewer's Report

Please write your statement / summary of issues to be addressed before the thesis defense here. The guidelines were provided to you in the examination request:

Carbon nanotubes are expected to satisfy at least partially the ever-increasing demand for novel materials for optoelectronic applications. The thesis under consideration highlights an important advance in this direction. The work starts with a detail description of synthesis and functionalization of CNT films that results in a conductive and transparent material that demonstrates characteristics almost matching those of ITO currently used as transparent conductive film (TCF) in modern gadgets. Unlike ITO CNT film is flexible and biocompatible which significantly enhances its area of applications.

The work of A. Tsapenko describes important advances in fabrication of CNT based TCFs. Fabrication procedures are provided as well as detailed characterization data and analysis. Optical properties of the fabricated films in wide spectral and temperature range are investigated. The results give insight into carrier dynamics inside an individual CNT as well as at a junction between CNTs. Finally the thesis provides possible pathways for further applications of obtained CNT films, such as ultrafast, optically controlled THz modulators.

Scientific impact of thesis is confirmed by the level and amount of published papers, while the personal contribution of Alexey can be deduced to be significant due to thorough and clear explanations of the employed approaches and procedures as well as obtained results and their analysis.

Despite the overall high quality of the thesis several remarks have to be made regarding the contents of the work:

CHAPTER 2

- *Figure 2.3.4-1. Electronic band structures and density of states (DOS) of (a) metallic and (b) semiconducting SWCNTs*

Is misleading since it shows zero DOS for metallic CNT.

- The term "*NHE*" (*Figure 2.3.4.3. caption*) is never explained neither in text nor in the "List of abbreviations and symbols"

- The effect of film doping is discussed poorly in the *section 2.3.4* Figure 2.3.4.3 should be Figure 2.3.4.2. The term "*absorption doping*" probably should be replaced by "adsorption doping"

CHAPTER 3

3.3 Aerosol measurements. After reading this section one still does not understand what does it help for making transparent conducting films. Probably it is important to control the properties of the as grown films but it is not clear from the text of the section.

CHAPTER 4

4.1 Charge carrier dynamics

Figure 4.1.1.1 there are black lines and black dotes. They cannot be distinguished.

the shaded area on the middle panels of Figure 4.1.1.1 can be hardly seen. Should be made as a separate figure

"With a mean-free path in our films $l = 0.1$ μm (see below) we have $l/L = 0.25$ confirming that our films are practically free of impurities. The value $L = 0.4$ μm"

this discussion is too primitive. The origin of the so called "THz peak" is still widely debated in literature. Therefore, it is important to provide extensive discussion of the matter. The fact that "average distance" between defects (or in other words plasmon confinement length) is four time the MFP should be justified more accurately. Relation between the plasmon velocity and Fermi velocity is not discussed at all

- Typo on page 39: "$V_F = 107$" instead of ""$V_F = 10^7$"
- There are no green circles in the *fig. 4.1.2-1.* as stated in the caption. They were supposed to show the width of a peak as a function of (?) frequency as stated in the caption and discussed in the text.
- *fig. 4.1.2-1.* Trend of $t \Rightarrow \infty$ does not follow the trend $F \Rightarrow 0$, therefore something is wrong.
- No "definition" of effective mass m^* is provided, although the term is used throughout the chapter 4. Is it the cyclotron mass p_F/v or is it $(d^2E/dp^2)^{-1}$?
- References to *supporting information* remain from copy-pasting from the paper text in the *section 4.2.3.*

Georgy Fedorov

Provisional Recommendation

☉ ***I recommend that the candidate should defend the thesis by means of a formal thesis defense***

☐ *I recommend that the candidate should defend the thesis by means of a formal thesis defense only after appropriate changes would be introduced in candidate's thesis according to the recommendations of the present report*

☐ *The thesis is not acceptable and I recommend that the candidate be exempt from the formal thesis defense*