Skoltech
Skolkovo Institute of Science and Technology

Jury Member Report – Doctor of Philosophy thesis.

Name of Candidate: Mohammad Owais

PhD Program: Materials Science and Engineering

Title of Thesis: Design and characterization of thermally conductive polymer nanocomposites with tunable electrical resistivity

Supervisor: Dr. Sergey Abaimov, Skoltech

Name of the Reviewer: Igor Shishkovsky

I confirm the absence of any conflict of interest (Alternatively, Reviewer can formulate a possible conflict)	**Date: 03-09-2023**

The purpose of this report is to obtain an independent review from the members of PhD defense Jury before the thesis defense. The members of PhD defense Jury are asked to submit signed copy of the report at least 30 days prior the thesis defense. 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

Reviewers report should contain the following items:

- Brief evaluation of the thesis quality and overall structure of the dissertation.
- The relevance of the topic of dissertation work to its actual content
- The relevance of the methods used in the dissertation
- The scientific significance of the results obtained and their compliance with the international level and current state of the art
- The relevance of the obtained results to applications (if applicable)
- The quality of publications

The summary of issues to be addressed before/during the thesis defense

Brief evaluation of the thesis quality and overall structure of the dissertation.

This experimental thesis is clearly written and well organized. It presents novel scientific results in the areas of Materials Science and Engineering. Obtained results are of practical importance and devoted to the synthesis of effective thermally conductive polymer nanocomposites, with a focus on their application within the electronic industry in the industrial sector.
The quality of publications is high. The results have been published in the leading journals of the research field.

The relevance of the topic of dissertation work to its actual content

The motivation, objectives and scope of dissertation are clear indicate. The topic of the thesis is very relevant for industrial applications, where the efficient heat dissipation is necessary, primarily such as wearable electronics, including microelectronics, aviation or automotive industries.
The content is highly relevant to the topic. The thesis was separated to 6 chapters. The first and second chapters are good reviews of current literature on thermal management materials (TMMs), polymers as a matric for heat dissipation, thermally conductive frameworks. Chapter 3-5 describes the Ph.D. research. Last chapter is conclusions.

The relevance of the methods used in the dissertation

All experimental methods of material synthesis and characterization, Fourier-transform infrared, SEM with EDS microanalysis, DSC and TGA, AFM, XRD, UV and Raman spectroscopy, optical contact angle, thermal conductivity and electrical resistivity measurements are relevant to thesis objectives.

The scientific significance of the results obtained and their compliance with the international level and current state of the art

Reviewer believes there are several significant results.
- Flexible thermally conductive polymer films with a remarkably low filler concentration (10 wt.% reduced graphene oxide) produced and shown an outstanding thermal conductivity of approximately 5.1 W/mK.
-CNT-based epoxy composites exhibited a notably high thermal conductivity of 0.48 W/mK, achieved with a mere 2 wt.% SWCNT loading concentration.
- 3D frameworks of thermally conductive 3D framework demonstrated isotropic thermal conductivity properties, i.e. an elevated in-plane thermal conductivity of approximately 0.76 W/mK at an out-of-plane thermal conductivity of around 0.63 W/mK are fabricated thereby.

Reviewer has some additional and more specific comments for clarification of the thesis results:

1. The author has conducted a comprehensive investigation into the thermal and electrical properties of synthesized polymer-filled composites. However, there are certain aspects related to heat transfer at the interface that have not been addressed. Heat transfer at the interface, particularly in

cases of different media such as solid-liquid and solid-gas interfaces, plays a crucial role in determining the efficiency of heat removal from the heated object.

2. When discussing the measurement of the wetting angle in paragraph 3.43 or 4.4.2.1, the author has not considered the impact of temperature changes on the heat sink. It is important to note that the coefficient of surface tension, and consequently the value of the wetting angle, is influenced by temperature variations.
3. In paragraph 3.46, the diffraction peaks are mentioned as (002), (100), and (004), but there is a need for further clarification and specification. In the provided Appendix 1, the author has included explanations; however, it would be beneficial to associate each diffraction peak with specific materials. As different modifications of the BN phase are recognized, providing separate diffractograms for PVA and BN would help elucidate the situation and enhance clarity.

Others comments by thesis text:

- Contents of the Second Chapter (Page 12): It appears that Paragraph 2.3 is duplicated within this chapter.
- Paragraph 2.1.1: It is not immediately clear in this paragraph about the distinctions between thermal 'paste', 'grease', and 'pad'.
- Caption in Figure 3: The significance of blue and red particles in Figure 3 is not explained in the caption.
- Figure 5: The figures labeled as 'a)' and 'b)' are missing in Figure 5.

No issues to be addressed further.

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*~~