Brno University of Technology
Central European Institute of Technology BUT

Supervisor's report

Academic year: **2024/2025**

Student's name: Krishna Sampathkumar

Doctoral program: **Advanced materials and nanosciences**

Field of study**: Advanced nanotechnologies and microtechnologies/Advanced materials**

Supervisor's name: prof. Dr., Ing. Pavel Neužil DSc.

Name of doctoral thesis topic: **Tailoring the physical properties of 2D materials**

Overall evaluation of the doctoral thesis and study of the doctoral student:

I am pleased to provide this evaluation of Mr. Krishna Sampathkumar, who joined CEITEC, Brno University of Technology, as a PhD student at the beginning of 2019 and took over his supervision in February 2021. Initially, he faced some confusion due to these changes, but he quickly became focused and well-organized under my guidance.

During his PhD period, Krishna established productive collaborations with researchers from Prague, Greece and Vienna. His thesis focuses on investigating simplified routes to tailor the properties of materials, specifically van der Waals (vdW) two-dimensional (2D) materials such as graphene and transition metal dichalcogenides (TMDs). His research primarily involved studying the optical properties of 2D materials and elucidating related properties through intensive use of steady-state Raman spectroscopy and photoluminescence (PL) as main analytical tools.

His thesis is well-written and structured, with proper citations providing evidence for all findings discussed. The results from his thesis explore different aspects of tuning the properties of 2D materials:

Chapter 5.1: Krishna discusses material fabrication techniques where he made substantial improvements to the traditional dry transfer stamping method, allowing the creation of suspended or free-standing 2D materials and their heterostructures such as MoS_2/graphene, MoS_2/WS_2, and hBN/MoS_2/hBN). These structures were thoroughly analyzed using Raman spectroscopy, PL, and high-resolution transmission electron microscopy (HRTEM).

Chapter 5.2: He addresses graphene thickness detection on native oxide substrates, where optical inspection is typically challenging. By coupling graphene with native oxide, he explored a novel approach to tuning material properties. Utilizing Raman spectroscopy combined with machine learning techniques, he provided a scalable solution with significant potential for further development.

Chapter 5.3: Krishna delves into graphene composite fabrication, mechanical wrinkle pattern formation, and transferring these patterns to compliant substrates. By leveraging the mechanical properties of 2D

materials, he created patterns ranging from nano- to microscale, demonstrating considerable scalability potential.

Chapter 5.4: He introduced a cost-effective and simplified technique to impose biaxial strain on 2D materials. Specifically, he studied graphene doped with diazonium salts under biaxial strain, revealing a new Raman peak split from the G peak. This novel observation was attributed to diazonium salt doping and was first reported in his work. Continuing this research, he studied MoS_2 without diazonium salt, revealing bandgap changes directly linked to tuning the material's electronic structure.

Chapter 5.5: Extending his studies to other 2D materials, he used PMMA as a medium to impose strain. Methanol and isopropyl alcohol (IPA) were utilized to expand the PMMA chain network. Studied their direct effect and mechanical strain effect using Raman spectroscopy, PL, atomic force microscopy (AFM), and fluorescence spectroscopy were effectively employed to understand the underlying changes in properties. These experiments have the potential to explain the funneling of exciton complexes in 2D materials.

Beyond his experimental studies, Krishna actively participated in several lectures and workshops, both virtual and in-person. He expanded his research network and engaged in practical studies of semiconductor techniques, including various lithography methods, etching, deposition techniques, and the development of new research ideas. His commitment to continuous learning is highly commendable and essential for a successful research career. I highly recommend Mr. Krishna Sampathkumar for the PhD defense.

In my opinion, the reviewed thesis **fulfills** all requirements posed on theses aimed for obtaining PhD degree. This thesis **is** ready to be defended orally, in front of respective committee.

Place: Brno, CZ date:08/11/2024 ……..

Prof. Dr. Ing. Pavel Neužil DSc.