Brno University of Technology
Central European Institute of Technology BUT

Supervisor's report

Academic year: **2024/2025**

Student: **Mgr. Oleh Martyniuk**

Doctoral programme: **Advanced materials and nanosciences**

Field of study**: Advanced nanotechnolgies and microtechnogies**

Supervisor: **doc. Dr. Ing. Petr Neugebauer, Ph.D.**

Co-Supervisor: **Dr. Abdelouahad El Fatimy, Ph.D.**

Title of doctoral thesis**: New generation of graphene bolometers**

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

Oleh Martyniuk's PhD research focused on developing a new generation of graphene-based bolometers, utilizing quantum dot (QD) structures fabricated from CVD-grown graphene. His work encompassed the design, fabrication, and characterization of graphene quantum dot (GQD) bolometers, aiming to optimize impedance and enhance responsivity. The research addressed key challenges in miniaturization, impedance matching, and scalability by leveraging the unique thermal and electronic properties of graphene.

The dissertation presents a comprehensive examination of bolometric principles, the advantages and challenges of graphene absorbers, and the roles of quantum confinement and Coulomb blockade effects in achieving high sensitivity. The thesis is structured into standard sections: Introduction, Aims, Theoretical Background, Fabrication, Characterization, Results, Conclusions, Author Publications, References, and Appendices, all on 101pages.

The Introduction establishes the motivation for THz detection, emphasizing the "THz gap" and the benefits of bolometers over ionizing detection methods. It positions graphene as a promising absorber material. The Aims of the thesis ware threefold: 1. To adapt the fabrication process of GQD bolometers using CVD graphene; 2. To reduce impedance and increase responsivity via multi-parallel quantum dot arrays with back-gate tuning; 3. To characterize the resulting devices using advanced nanoscale measurement techniques. The Theoretical Background chapter explores bolometric concepts in depth, covering responsivity, noise-equivalent power (NEP), and practical applications. It highlights graphene's exceptional carrier mobility, low electronic heat capacity, weak electron–phonon coupling, and high optical absorption, underpinning the advantages of quantum confinement and Coulomb blockade for enhancing temperature-dependent resistance. In the Fabrication chapter, the thesis details the nanofabrication workflow, including photolithography, electron beam lithography (EBL), etching, and deposition. A comparison of UV, X-ray, and EBL methods underscores the advantages of EBL for patterning nanoscale graphene structures. The research introduces a multi-parallel GQD architecture that increases active graphene area while optimizing impedance for integration with high-frequency antennas. The chapter Characterization Techniques include Raman spectroscopy, scanning electron microscopy, and THz FraScan spectrometry. These were employed both iteratively during fabrication and for final device evaluation. The Results chapter presents three key findings: 1. Successful fabrication of GQD bolometers, showing strong temperature-dependent resistance due to quantum confinement effects; 2. Demonstrated scalability and impedance optimization through the multi-parallel QD design; 3. Effective tuning of

resistance and responsivity via back-gate voltage modulation. In the Conclusions, the research highlights substantial progress in addressing fabrication challenges—such as CVD graphene uniformity and lithographic limitations—while demonstrating scalable, high-performance graphene bolometers. Potential applications include molecular magnet detection, THz sensing, and DNA sequencing.

Overall, this thesis is well-structured with minimal typos, technically rigorous, and contributes to the field of graphene-based THz detectors. While further benchmarking and validation are needed, the work presents a viable path forward for addressing challenges in impedance and scalability. Oleh research sits at the intersection of materials science, nanofabrication, and device physics, bridging fundamental graphene properties with practical detector applications.

Furthermore, Oleh Martyniuk actively presented his work at scientific conferences and completed multiple international research internships, including placements at Ecole Centrale Casablanca (with Dr. Abdelouahad El Fatimy), the Charles Coulomb Laboratory in France (Dr. Frédéric Teppe), and Mohammed VI Polytechnic University in Morocco. His primary research has been published in *J. Phys. D: Appl. Phys.* (2025), and he co-authored an additional article in *Mater. Chem. Front.* (2025) as part of a side project.

Oleh has consistently demonstrated diligence, initiative, and scientific maturity throughout his doctoral studies, earning a reputation as a dedicated and capable researcher.

Finally, in our opinion, the reviewed thesis **fulfils** all requirements posed in theses aimed at obtaining a PhD degree. This thesis is ready to be defended orally in front of the respective committee.

Brno, 21st August 2025:

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doc. Dr. Ing. Petr Neugebauer, Ph.D.

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Dr. Abdelouahad El Fatimy, Ph.D.