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REYKJAVIK UNIVERSITY

Review Report on PhD Thesis

Faculty: Faculty of Mathematics and Physics
Carles University, Prague.

Academic year: 2022/2023

Student: Kristupas Kazimieras Tikuišis

Doctoral study program: Quantum Optics and Optoelectronics
Study branch: (P4F6)
Supervisor: RNDr. Martin Veis, Ph.D.
Reviewer: Prof. Sigurdur I. Erlingsson, Ph.D.

PhD thesis title: Optical and magneto-optical properties of topological and Dirac materials

Objective and scope of work:
The thesis aims to systematically study basic optical and magneto-optical properties of *Dirac materials*, namely the lead tin salts topological crystalline insulators and graphene. Non-destructive experimental techniques, i.e. spectroscopic ellipsometry and FTIR magneto-optical spectroscopy, were used to perform measurements from the IR to UV spectral regions. A four-band Hamiltonian model was derived to describe the most important band structure features of PbSnSe system placed in a magnetic field. This allowed the topological band structure parameters of the investigated samples to be extracted from measurement data. Extensive modeling results based on Kubo-Greenwood formalism and ab-initio simulations are presented to help validate the measurement results and predict the appearance of the topologically protected surface states.

In addition, epitaxial growth of graphene by intercalation of graphitized silicon carbide was investigated experimentally. An efficient parametrized model dielectric function over a wide spectral region from IR to UV was presented. The spectral response in terms of the sharpness of the excitonic peak suggests intercalated graphene to be optically similar to exfoliated graphene and thus a suitable candidate for potential applications.

Problem solving and dissertation results:
The thesis of 134 numbered pages consists of five chapters, followed by a short summary and conclusion, along with 159 references. The topics of particular chapters were carefully chosen, and the text flow is good and cover the thesis's topics well. Following the Introduction chapter containing the thesis motivation and goals, the second chapter gives an overview of Dirac material and the various properties of the materials experimentally investigated here, i.e. PbSnX and graphene. Chapter three contains an overview of the experimental methods, i.e. spectroscopic ellipsometry and magneto-optical spectroscopy. Chapters two and three are well written an provide a good foundation for the fourth chapter. In that chapter PbSnSe materials are analyzed, first by

deriving a three parameter theoretical model for fitting purposes, followed by sample preparation and various measurements. The experimental part is well written clearly indicates the problems solved by the candidate both in the measurements and the subsequent data analysis.

The fifth, and last chapter, deals with epitaxial graphene. The chapter covers sample preparation, ellipsometry measurements and data analysis. The results indicate that the epitaxial graphene has quality comparable to the exfoliated graphene.

The thesis is well written in English language with minimal grammar errors and misprints. The thesis clearly describes all activities of the applicant during his doctoral studies and contains original and partially already published results.

Importance for practice or development of the discipline:
The results represent a significant contribution to furthering the understanding of the topological properties of 3D Dirac material probed by Landau level spectroscopy. It can have an impact on further development in this field. The goals of the thesis were achieved.

Questions:
I have two questions for the applicant:
1) As is stated in the introduction the topological protection in topological crystalline insulator comes from mirror symmetry, in addition to time reversal symmetry. In random alloys the mirror symmetry is broken. Can the candidate explain why one can still expect to observe signatures of topologically protected states in random alloys?
2) Hybridization of bulk and surface states is mentioned as a possible cause of the absence of surface states in the Landau level spectroscopy. Can the candidate indicate the possible sources of hybridization, and also to address how it would be possible to experimentally test or verify any of the mentioned mechanisms of hybridization.

Conclusion:
The presented thesis is a solid piece of scientific work which clearly present the ability of applicant to fulfill all requirements for independent individual scientific research. In my opinion, the reviewed thesis fulfills all requirements for obtaining PhD degree. This thesis is ready to be defended orally, in front of respective committee.

Reykjavik, Iceland, July 4, 2023

Prof. Sigurdur I. Erlingsson, PhD

Department of Engineering
School of Technology
Reykjavik University
Iceland