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| | **Uniwersytet im. Adama Mickiewicza w Poznaniu** |
| | Szkoła Doktorska Nauk Ścisłych |
| | **Transport and topological states in two-dimensional systems** |
| | Prof. UAM dr hab. Anna Dyrdał |

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| **Dziedzina/ dyscyplina** | Dziedzina nauk ścisłych i przyrodniczych / nauki fizyczne<br>Natural sciences / physical sciences |
| **Rodzaj zajęć** | Wykład monograficzny / special topic lecture |
| **Język** | Angielski / English |
| **Liczba godzin** | 15 |
| **Cel zajęć** | This lecture aims to overview modern aspects of solid-state physics related to electronic, spin, and transport properties in new 2D materials such as graphene and graphene-like crystals, topological insulators, interfacial hybrid structures (e.g., semiconductor or oxides interfaces). The scope of this lecture contains the following topics:<br>(i) Symmetry and topological properties of matter, e.g., Berry Phase (Zak phase), topological invariants, skyrmions<br>(ii) Band structure – modelling and construction of effective Hamiltonians based on symmetry consideration<br>(iii) Description of transport and spin effects |
| **Treści kształcenia** | 1. Nobel Prizes in Physics in years 2007, 2010, and 2016 for discoveries that indicated the main directions of modern solid-state physics and spintronics<br>2. Crystallographic structure and tight-binding model of graphene, low-energy model (kp method, Kane-Mele Hamiltonian)<br>3. Symmetries in graphene and graphene-like materials (space groups, symmetry operations, time-reversal symmetry, chiral symmetry, pseudospin)<br>4. Overview and characteristics of graphene-like crystals and van-der-Waals heterostructures<br>5. Introduction to the physics of topological insulators; Models describing topological states of matter ( e.g., Haldane model, Kane-Mele model, Rice-Mele model, Bernevig-Hughes-Zhang model); PyTB and kwant packages<br>6. Quantum Hall effect, Quantum Spin Hall effect, and anomalous Hall effect and their connection to topological invariants, anomalous velocity<br>7. Formalism used to electron transport description in 2D systems: Landauer Formula, Landauer-Buttiker Formalism, Green's function methods, Kubo formula, Boltzmann theory, Floquet theory; introduction to kwant package<br>8. Selected spin and transport phenomena determined by band structure in graphene, graphene-like systems, topological insulators, semiconductor heterostructures, e.g., Klein tunnelling, anomalous, spin, valley Hall effect, Andreev reflection in graphene, exchange interaction in topological insulators, superconductivity, anomalous and spin Hall effect in semiconductor heterostructures, spin-orbit torque |

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| | 9. DMI interaction, skyrmions, transport in systems with noncollinear magnetization, domain waals and skyrmions dynamics, introduction to spirit package |
| **Wymagania wstępne** | In terms of knowledge: it is expected that PhD student has already passed courses such as quantum physics, mathematical methods in physics, solid-state physics and magnetism.<br>In terms of skills: the ability to use literature, work with a computer, basic knowledge of Wolfram Mathematica, elementary knowledge of python (recommended but not compulsory) |

| **Efekty kształcenia** | |
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| **Po zakończeniu zajęć doktorant potrafi:**<br>[podano symbole efektów uczenia się wg. Zał. Nr 1 do Uchwały nr 295/2018/2019 Senatu UAM z dnia 27 maja 2019 r.] | **Metody weryfikacji** |
| PhD student can describe the basic models and electronic properties of graphene, other graphene-like materials, and topological insulators [E_W01, E_U02, E_U05] | Oral exam / semester work/ presentation |
| PhD student can prepare works/reports and presentations in the area of transport and topological properties of condensed matter (based on literature, materials for this lecture, and self-study) [E_W01, E_U02, E_U05, E_U06, E_K05] | Oral exam / semester work / presentation |
| PhD student knows basic transport theory methods applied to 2D systems and can perform simple analytical calculations of electronic structure and characteristics describing topological properties of a topological insulator, graphene, and other 2D structures. ) [E_W01, E_U02, E_U05, E_U06, E_K05] | Oral exam / semester work / presentation |
| PhD student can prepare works/reports and presentations in the area of transport and topological properties of condensed matter (based on literature, materials for this lecture, and self-study) ) [E_W01, E_U02, E_U05, E_U06, E_K05] | Oral exam / semester work / presentation |

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| **Literatura** | 1. Original articles provided during the lecture<br>2. Books:<br>- L. E. F. Foa Torres, S. Roche and J.-Chr. Charlier, Introduction to Graphene-Based Nanomaterials. From Electronic Structure to Quantum Transport, Cambridge 2020<br>- V. Litvinov, Magnetism in Topological Insulators, Springer 2019<br>- Shun-Qing Shen, Topological Insulators. Dirac Equation in Condensed Matters, Springer 2012<br>- G. Tkachov, Topological Insulators. The physics of Spin Helicity in Quantum Transport, Pan Stanford Publishing 2016<br>- J. Inoue, A. Yamakage, S. Honda, Graphene in Spintronics, Pan Stanford Publishing 2016<br>- G. D. Mahan, Many-Particle Physics, Springer 2000<br>- S. Seki, M. Mochizuki, Skyrmions in Magnetic Materials, Springer 2016<br><br>- N.W. Ashcroft, N.D. Mermin, Solid State Physics<br>- Ch. Kittel, Introduction To Solid State Physic<br><br>The all literature used during the lecture and suggested additional literature will be provided by the lecturer. |
| **Szczegółowe informacje** | The detailed information will be provided by the lecturer – email: adyrdal@amu.edu.pl |