Project 4.3 Chalcogenide nanostructures as a platform for quantum bits (experimental)

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www: http://www.ifpan.edu.pl/en/institute/scientific-divisions/international-centre-for-interfacing-magnetism-and-superconductivity-with-topological-matter-magtop/on6-2-device-epitaxy-group.html

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Background:

Quantum computing (QC) requires a systematic approach where interdisciplinary science must be involved in solving problems fundamentally intractable for classical computers. The essential point here is the physical realization of qubits with low noise and decoherence. The search for the material platform for qubit implementation is the main task for the material science side of the QC problem. The promise of fault-tolerant QC resulted in nearly a decade of intensive research devoted to building qubits based on topological superconductors. However, only several material systems of topological insulators and III-V semiconductors were thoroughly studied. Recently it was realized that after years of development, the level of the disorder is still too high for qubit implementation. A solution to this problem is a realization of qubits using monochalcogenide semiconductors that have all the necessary ingredients for qubit implementation, namely high spin-orbit coupling and a reduced role of charge disorder due to a high dielectric constant.

Aim:

Aims of the project: to establish a new material platform based on monochalcogenide materials for the successful fabrication of semiconductor qubits.

First, we fabricate high quality epilayers, heterostructures, quantum wells and nanowires of chalcogenide materials using molecular beam epitaxy (MBE). This technique allows the controllable growth of single-crystalline nanostructures with monolayer precision. Further, the decoherence processes will be reduced through growth optimization with fine-tuned composition, reduced defect amount, carrier density and enhanced carrier mobility. Such a procedure would require thorough structure and composition investigations with modern techniques as well as magnetotransport measurements to obtain electrophysical parameters.

Second, we will induce superconductivity (SC) in grown structures by the SC-proximity effect. In this step, the quality of the interfaces which is crucial for Cooper pair injection will be optimized. The interfaces will be characterized by structural and transport means. Also, the role of band alignment and bending at superconductor-semiconductor interface will be investigated by angle-resolved photoemission spectroscopy (ARPES). The problem will be addressed also in a parallel approach, where SC is already integrated by the network of misfit dislocations at the heterostructure interface with a large lattice mismatch. The microscopic mechanism of such SC stays not very clear despite previous studies. In this work, we will also elucidate it by studying superconducting transition as a function of electrophysical parameters.

Finally, we will fabricate the gate using atomic layer deposition of hafnia and alumina on the chalcogenide semiconductor surface and test the gating effect. Thus at the end of the project, we expect that a fully tested material system suitable for the fabrication of semiconductor qubits will be provided.

Requirements:

- Ukrainian citizenship, having the status of employee at a recognized scientific institution of Ukraine (universities or institutes of the National Academy of Sciences of Ukraine);
- MSc in Physics (or equivalent in related fields, such as e.g. materials engineering and electronics, is required);
- sufficient proficiency in English;

The good candidate should have expertise at least in one of the following field:

- MBE growth of semiconductor nanostructures;
- structural characterization of semiconductor nanostructures by SEM, AFM, XRD, TEM, etc.;
- processing of nanostructures by electron beam and optical lithography;
- low temperature magneto-transport;
- ARPES measurements

Funding:

Scholarship: grant funding of 7120 PLN per month, before subtracting obligatory employer and employee social security contributions (~15%), for 24 months, which gives approx. 5500 PLN net/month in years 1-2, and (after passing mid-term. exam) approx. 4739 PLN net/month in years 3-4.

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