DIMAG: Electrically controlled ferromagnetism in 2-dimensional semiconductors

Main area: Synthesis and characterization of layered materials beyond graphene
Keywords: 2D materials; ferromagnetism; spintronics; density functional theory; ARPES; XMCD
Duration: 36 months
Total project funding: € 782.990

Abstract

The DIMAG project is dedicated to establishing a new type of 2D magnetic materials, which not only exhibits a fundamentally new type of ferromagnetic behavior, but also has optimal characteristics for spintronics applications. This 36-month project, brings together 5 academic laboratories: (1) the Laboratory for Semiconductor Physics (KU Leuven, Belgium), (2) the Institute for Nuclear and Radiation Physics (KU Leuven, Belgium), (3) the Physics Department of the Hamburg University (Germany), (4) the Laboratoire de Physique des Solides (CNRS, France), and (5) Laboratory of Quantum Optics of the University of Nova Gorica (Slovenia). Each group brings highly specialized expertise, and advanced experimental and density functional theory methods that are key to achieving the goals of DIMAG, which in turn are beyond the state of the art. DIMAG will be coordinated by Prof. Michel Houssa, from KU Leuven. The total requested budget is 993 k€.

The general goal of DIMAG is to induce and study Stoner-type ferromagnetism in 2D semiconductors exhibiting a Van Hove singularity in the density of states (DOS), as predicted for GaSe, InSe, and SnO. First we will develop the synthesis of high-quality 2D materials with a controlled number of layers, by exfoliation from commercially available single crystals, as well as by molecular beam epitaxy. We will optimize the number of layers in order to maximize the DOS at the Van Hove singularity, as a compromise between low number of layers and high layer quality. In parallel, we will develop the control of the Fermi level in the vicinity of the Van Hove singularity (by acceptor doping and electrical gating), which is predicted to result in a Stoner instability and induce a ferromagnetic state. We will study these effects in depth, using state-of-the-art techniques: scanning tunnelling microscopy and spectroscopy to probe structural, electronic and magnetic properties at the atomic scale; angle resolved photoemission spectroscopy and inverse photoemission spectroscopy (static and time-resolved) to fully characterize the electronic structure below and above the Fermi level; X-ray magnetic circular dichroism and magneto-optical Kerr effect to establish the intrinsic origin of the ferromagnetic behavior. Based on this detailed understanding, we will optimize the materials synthesis (number of layers, structural quality, doping…), aiming to: (i) increase the ordering temperature and the carrier spin-polarization up to the highest achievable values; (ii) reversibly switch between ferromagnetic and non-ferromagnetic states with voltage bias.

The DIMAG project directly addresses key goals of the Flagship work program, namely division 1 (Enabling Science and Materials), work packages 1 and 2 (WP1 - Enabling research; WP2 - Spintronics). In addition to its underlying fundamental nature, the project is highly application-oriented, as it aims to deliver new functionality that is device-compatible (room-temperature operation and voltage control). Taking the Flagship's WP1 and WP2 beyond graphene, into new 2D materials, DIMAG will have a tremendous impact, opening a broad new area of fundamental and applied research on new materials with device-compatible properties and functionality.

Consortium

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