PhD Scholarship

Synthesis and Characterization of Two-Dimensional Boridenes Exfoliated from Single Crystals of Laminated Borides

Laboratory and researchers:
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Doctoral school:
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Key words:
nanolamellar materials, two-dimensional systems, chemical etching, surface functionalization, transport properties, environmental stability

Summary:
Two-dimensional materials are fostering the development of new concepts for advanced electronic and optical technologies. In this contest the search for novel 2D materials is of fundamental and practical importance. MAB phases is a family of nanolaminated materials, where M is an early transition metal, A is an "A" group element and B is boron, which is interleaved with mono- or bilayers of the A element (Fig.1 as an example of Fe_2AlB_2). This assembly of layers crystalizes in orthorhombic, tetragonal, or hexagonal symmetries. In 2021, the first 2D boridene $(Mo_{4/3})B_{2-x}T_z$ (T_z – surface functional groups) was experimentally realized by employing chemical exfoliation of the Al-layer in acid based environment from the parent chemically ordered MAB phase. The produced 2D boridene flakes are on average of 50 nm in size with ordered vacancies on the metal sites, which serve as electrochemical active centers and have already demonstrated high catalytic performance for the hydrogen evolution reaction. These results stimulate to perform further studies on the discovery of new chemistry of 2D boridenes that were theoretically predicted to have high potential for energy storage and magnetism-based applications in case of Mn_2B_2 and Fe_2B_2.

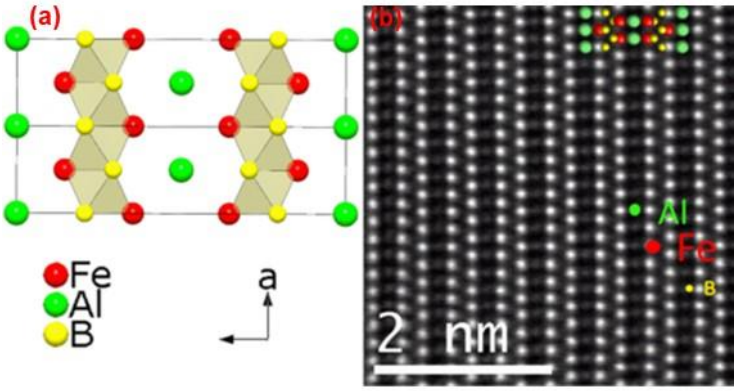

Fig.1 $AlFe_2B_2$ unit cell. (b) High-resolution HAADF STEM image of $AlFe_2B_2$ taken along the [101] zone axis along with a projection of a unit cell represented with Fe (red), Al (green), and B (yellow) spheres [Phys. Rev. Materials 2, 084408 (2018)].

This PhD project aims to develop advanced strategies for the synthesis of new 2D boridenes derived from MAB phase single crystals, in particular from MoAlB and Fe_2AlB_2 composition. Different chemical based approaches will be used to selectively etch away Al-layer, including wet chemistry in acid and base environments as well as molten salt assisted synthesis. The obtained 2D boridenes will be examined by advanced materials characterization, in particular X-Ray diffraction, electron microscopy, and raman spectroscopy using large scale instruments for detailed structural and surface chemistry investigation. Discovery of electronic and magnetic transport properties of exfoliated flakes will bring insight into their anisotropic behaviour. The results of the proposed project will contribute into expanding the chemical diversity of 2D materials, pushing forwards their use in such applications as energy production and storage, spintronics, and biomedicine. The project will be carried-out in NanoMat research group at Laboratoire des Matériaux et du Génie Physique, which is unique due to the ability to

grow high-quaity MAX and MAB phase single crystals and has a strong background in the MXene synthesis, characterization, and their application for gas sensors and solar cells.

Requested profile and competences:
We are looking for highly motivated students with master's degree in inorganic and materials chemistry, materials science, or related fields. Main scientific aspects are synthesis of two-dimensional materials from nanolaminated precursors using chemical based approaches and performing their comprehensive characterization. Excellent communication skills and ability to work in a team as well as good oral and written skills in English language will be highly appreciated.

Collaboration:
LMGP benefits from an extensive number of connections to other well-known research teams in the MAX phase and MXenes field, incorporating international collaborations with Forschungszentrum Jülich (Germany), Institute PPrime (France) and Nagoya University (Japan).

Application: Curriculum vitae, a cover letter, a summary of the master thesis and the email address of academic researchers who can recommend the applicant must be sent to Hanna Pazniak (hanna.pazniak@grenoble-inp.fr) and Thierry Ouisse (thierry.ouisse@grenoble-inp.fr).

Starting date: 1st October, 2022.