MSc Thesis:
MXene/2D TMO heterostructures for high-rate electrochemical energy storage

Publishing date: JANUARY 2021
Number of positions: 2 MSc students are welcome.
Starting date: As soon as possible

2D nanomaterials are defined as one or few atoms thick materials (**Fig. 1**) with lateral dimensions in the nano- to micro-scale [1]. They have opened up new perspectives in energy storage due to their exceptional properties and variety of new chemistries [1]. Families of special interest for energy storage include graphene [2, 3], **transition metal oxides (TMOs)** [1], 2D transition metal dichalcogenides (TMDs) [4, 5], and **MXenes**, a family of **2D transition metal carbides and nitrides *discovered in 2011*** [6].

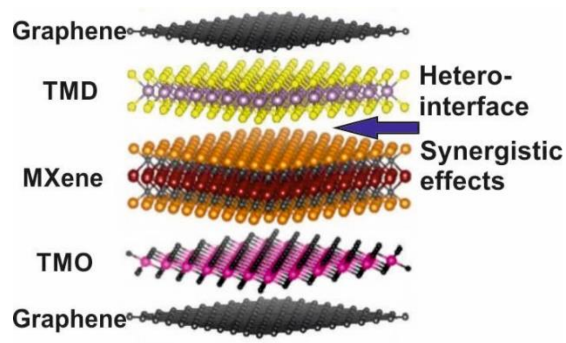

Fig. 1. A model of a **2D heterostructure**

2D nanomaterials have shown a high potential for applications in **supercapacitors** and **high-rate batteries.** 2D nanomaterials have an intrinsic high surface area, can be chemically functionalized, have a capacity for ion-intercalation, and **unlike state-of-the art traditional battery materials**, can perform at strikingly high rates. Moreover, 2D nanomaterials are mechanically strong [6] and have high packing densities [7, 8], which makes them ideal candidates for **flexible, miniaturized and ultrathin energy storage devices for application in wearable electronics**. This is the ultimate application pursued in this project.

The MSc project focuses on exploiting the energy storage properties of individual 2D nanomaterials in **novel predesigned heterostructures,** defined as the stacking of two or more chemically different 2D nanomaterials with an intimate face-to-face contact (**Fig. 1**) [9-11]. Unlike, common composites, the intimate face-to-face contact (**heterointerface**) enables **synergystic effects**, defined as en enhancement of a physical or chemical property beyond a simple addition of properties of the individual components [12]. The synergystic effects achieved depend on the particular materials combination and include new improved electrical properties, enhanced energy storage capacity and cycling stability via new hetero-interface enabled chemical/electrochemical pathways, enhanced mechanical properties, e.g. mechanically stronger electrodes, and many others.

The MSc student(s) undertaking this project will focus on the development of MXene/2D TMO heterostructures. The project will include:

(1) **Synthesis of MXenes**. **Novel MXene chemistries** will be approached. A student is expected to engage in one chemistry choice. Established etching and delamination methods will be utilised.
(2) **Synthesis of transition metal oxide**s. Focus on a single chemistry. Established hydrothermal and/or liquid phase exfoliation methods will be utilised.
(3) **Characterisation by X-Ray diffraction** (XRD) and **scanning electron microscopy** (SEM). The student will engage in XRD. SEM will be performed by the leader of the project.
(4) **Manufacture of heterostructures** via a **spray deposition technology** [2, 13].
(5) **Electrochemical characterisation**. This will involve the investigation of best electrolytes for energy storage.

A **background** in inorganic chemistry and/or materials science is ideal for development of this project. The student will be strongly supported on everyday basis on synthesis. The student will acquire experience on XRD, electrode manufacture, and electrochemical characterisation.

If you are interested in the project, please contact:

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References

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