

## **Project 4.20. Magnetic order in nanolaminated MAX phases based on $\text{Mn}_2\text{GaC}$ .**

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www: <http://www.ifpan.edu.pl/sdvs/en/on3.html>

### **Background:**

Inherently nanolaminated compounds described by a general formula  $\text{M}(\text{n}+1)\text{AX}_\text{n}$  (where M is transition metal, A- atom from the A group elements and X stands for carbon (C) or nitrogen (N) ) are known in the literature as MAX phases. Hexagonal  $\text{M}(\text{n}+1)\text{X}_\text{n}$  layers separated by a monatomic A layers create a natural layer system in atomic scale. Due to a combination of exceptionally good mechanical and electrical properties these materials have been studied for a long time. Delamination of layered MAX phase structures leads to the formation of 2D graphene-like transition metal carbides  $\text{Mn}(\text{n}+1)\text{X}_\text{n}$ , known as MXenes. In 2013 a breakthrough achievement has been made by obtaining a magnetic representative of MAX phase in form of epitaxial thin film showing critical temperature for magnetic ordering above the room temperature. This discovery introduces a new direction in functionalities and thus many directions of applications including spintronics, magnetocaloric etc. have been listed in the literature. Verification of these predictions and practical realization of potential application requires a deep understanding of their magnetic properties. To date the only reported experimental data pertain to macroscopic magnetization measurements using VSM/SQUID techniques. For a deeper understanding of their performance it is, however, necessary to investigate their microscopic properties, using the techniques that allow to determine their magnetic structure. Considering the nanoscopic sizes of epitaxial films the only experimental technique that can provide this kind of information, is the Nuclear Magnetic Resonance (NMR). Preliminary data obtained in the NMR laboratory at IF PAN indicate the presence of competing ferro- and antiferromagnetic interactions, leading to a complex, non-trivial magnetic structure (e.g. a spiral structure). We propose an extensive study of magnetic interactions and magnetic structure in a number of MAX phase thin films derived from  $\text{Mn}_2\text{GaC}$  by means of NMR technique. NMR experiment in ferromagnetic materials belongs to the advanced characterization methods and there are only few laboratories in the world, equipped with spectrometers capable of performing this kind of research. NMR laboratory in the Division of Physics of Magnetism of IF PAN is recognized as the worldwide leading group using this technique to investigate the magnetic materials with nanoscopic sizes. It is equipped with very sensitive spectrometers, based on the automatic data accumulation, making it possible to register even very weak signals. They cover a wide frequency range, suitable for all potentially interesting magnetic materials.

### **Aim:**

This project aims at defining the magnetic structure in a number of MAX phase thin films derived from  $\text{Mn}_2\text{GaC}$ . To determine the type and strength of magnetic interactions within the magnetic M(Mn, Cr, V) layers and between them (across the A and X layers, respectively) the Nuclear Magnetic Resonance (NMR) experiment will be performed in zero field and in presence of the external magnetic field up to 6 T applied in different orientations with respect to the film geometry.

### **Requirements:**

M.Sc. degree in Physics (solid state physics). Good command of the English language, ability and interest to work in a team, knowledge of the programming C language. Some experience of working in experimental laboratory environment will be welcome.

### **Funding source:**

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