

# SEMINARIUM Z MAGNETYZMU I NADPRZEWODNICTWA

Uprzejmie zawiadamiamy, że w **środę**  
**18 października 2023 r., o godz. 10:00**

odbędzie się seminarium w sali 203, budynek I

na którym

**mgr Dey Jaydeb**

(Instytut Fizyki PAN)

wygłosi referat na temat:

## **“Magnetic ordering in nanolaminated Mn<sub>2</sub>GaC MAX Phase thin film: NMR Study”**

Magnetic M<sub>n+1</sub>AX<sub>n</sub> (MAX) materials, composed of transition metals (M), IIIA or IVA group elements (A), and carbon or nitrogen (X) in one to three layers (n), have been a decade-long focus of research. Among these, Mn<sub>2</sub>GaC, synthesized as a nanolaminated thin film, stands out as the first magnetic MAX phase with a single M-element species at its M-sites. This reduces chemical disorder compared to previous quaternary MAX phases, which featured two atomic species at these sites.

Mn<sub>2</sub>GaC possesses hexagonal symmetry (P6<sub>3</sub>/mmc space group) and consists of atomically laminated Mn-C-Mn slabs stacked along the hexagonal c-axis, interleaved with gallium atomic layers. Its magnetic order-disorder transition temperature has been reported as 507 K, with a magneto-structural phase transition at around 214 K, below which the magnetic structure has not been fully defined. Theoretical studies indicate complex magnetic structures involving competing ferromagnetic (FM) and antiferromagnetic (AFM) interactions. Experimental evidence from unpolarized neutron reflectometry suggests fully compensated long-range AFM order (*AFM*[0001]<sub>4</sub>) in Mn<sub>2</sub>GaC films, while macroscopic magnetic measurements indicate the presence of remanent magnetization.

To solve these ambiguities, <sup>55</sup>Mn Nuclear Magnetic Resonance (NMR) studies were conducted at 4.2 K on a 100 nm thin film of MgO (111)/Mn<sub>2</sub>GaC under zero-field (ZF) conditions and various in-plane magnetic field values. ZF <sup>69,71</sup>Ga NMR data revealed a large effective field at Ga (~15.75 T) due to uncompensated magnetic moments from neighboring Mn atoms, indicating a non-collinear magnetic structure [1]. ZF <sup>55</sup>Mn NMR detected magnetically non-equivalent Mn positions, with an average magnetic moment of  $\cong 2 \mu_B$  / Mn-atom. In-field NMR experiments showed a continuous distribution of magnetic moment orientations from 0° to 180°, representing a helical magnetic structure along the c-axis (perpendicular to the film plane). This helical structure, deduced from NMR data analysis, arises from competing ferro-antiferro exchange interactions between supermoment layers and features an incommensurate pitch with up to 14 crystal lattice period [2].

[1] J. Dey, M. Wójcik, E. Jędryka, R. Kalvig, U. Wiedwald, R. Salikhov, M. Farle, and J. Rosén, *Non-collinear magnetic structure of the MAX phase Mn<sub>2</sub>GaC epitaxial films inferred from zero-field NMR study (CE-5: L05)*, *Ceram. Int.* 49, 24235 (2023).

[2] J. Dey, E. Jędryka, R. Kalvig, U. Wiedwald, M. Farle, J. Rosen, and M. Wójcik, *Helical magnetic structure of epitaxial films of nanolaminated Mn<sub>2</sub>GaC MAX phase*, *Phys. Rev. B* 108, 054413 (2023).

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**Wykład będzie prowadzony w języku angielskim w sali 203, dostępna będzie również transmisja ZOOM - link podany jest na stronie IF PAN.**

**Serdecznie zapraszamy**  
**Roman Puźniak / Andrzej Szewczyk / Henryk Szymczak**