

Thickness and substrate dependent structural and magnetic properties evolution in Mn_2GaC MAX phase films.

Marek Wójcik,¹ Ewa Jędryka,¹ Jaydeb Day,¹ Roger Kalvig,¹ Piotr Dłużewski,¹ Einar B. Thorsteinsson,² and Fridric Magnus²

¹*Institute of Physics, Polish Academy of Sciences,
Al. Lotników 32/46, 02-668 Warsaw, Poland*

²*Science Institute, University of Iceland,
Dunhagi 3, 107 Reykjavík, Iceland*

Inherently nanolaminated Mn_2GaC films from MAX phase family with hexagonal crystal structure and comprising Mn-C-Mn layers interleaved by Ga-layers along hexagonal c-axis grown epitaxially on MgO(111) substrate and non-epitaxially on Si(100) substrates were studied. The evolution of structural and magnetic properties as a function of film thickness and substrate was systematically investigated. Thickness dependent zero field (ZF) ^{55}Mn NMR studies performed on $\text{Mn}_2\text{GaC}/\text{MgO}$ films carried out at 4.2 K revealed a significant change in magnetic properties upon crossing a critical thickness of approximately 100 nm. This is reflected in the reduction of the number of magnetically nonequivalent Mn positions from 4 to 3. Structural characterization confirms that the epitaxial stacking of layers is preserved below this threshold, whereas films thicker than 100 nm exhibit non-uniformly grown polycrystalline grains. Notably, the $\text{Mn}_2\text{GaC}/\text{Si}$ films show structural and magnetic features analogous to those of $\text{Mn}_2\text{GaC}/\text{MgO}$ films above this critical thickness. External field dependent ^{55}Mn NMR experiments at 4.2 K, with external field applied in film plane, reveal a helical spin configuration of ferromagnetically coupled Mn-C-Mn “supermoment” layers in $\text{Mn}_2\text{GaC}/\text{MgO}$ films below the critical thickness, originating from a competing exchange interaction between supermoment layers [1]. In contrast, $\text{Mn}_2\text{GaC}/\text{MgO}$ films showing nonepitaxial crystal structure above critical 100 nm thickness and $\text{Mn}_2\text{GaC}/\text{Si}$ films exhibit ferrimagnetic ordering. These findings established that the effect of epitaxy and substrate critically influence exchange interaction between supermoment layers, thereby governing the magnetic structure of Mn_2GaC MAX phase compound.

References:

[1] J. Dey et al. Phys. Rev. B 108, 054413 (2023)