MAGNETIC HYPERFINE FIELD IN X_2MnZ (X = Co, Fe; Z = Al, Ga, In, Ge, Si) HEUSLER ALLOYS

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ABSTRACT

Heusler alloys, particularly those belonging to the full-Heusler X_2MnZ family, have garnered significant attention in the fields of advanced magnetic materials and spintronics due to their predicted half-metallic ferromagnetic behavior and high Curie temperatures [1,2]. Understanding the microscopic origins of their magnetism is crucial for optimizing these materials for future technological applications. This work investigates the local magnetic properties, specifically the Magnetic Hyperfine Field (MHF), in the X_2MnZ (X = Co, Fe; Z = Al, Ga, In, Ge, Si) Heusler alloy family, using the nuclear physics technique Time-Differential Perturbed Angular Correlation (TDPAC).

The alloy samples are synthesized via arc-melting under an inert argon atmosphere, followed by specific thermal treatments in a tubular vacuum furnace to promote the strict ordering of the $L2_1$ cubic crystalline phase, which is a prerequisite for their high spin polarization. Structural characterization is performed using X-Ray Diffraction (XRD) and detailed Rietveld refinement to confirm phase purity, determine lattice parameters, and evaluate anti-site atomic disorder. To probe the local magnetic interactions at the atomic scale, TDPAC spectroscopy is employed using radioactive probe nuclei, such as ^{111}In/^{111}Cd and ^{181}Hf/^{181}Ta, which are incorporated into the crystalline lattice as dilute impurities to measure the hyperfine fields acting on specific atomic sites [3]. The application of TDPAC provides an exquisite, site-specific sensitivity that macroscopic techniques cannot attain, making it an invaluable tool within the realm of nuclear instrumentation applied to condensed matter physics. Preliminary room-temperature TDPAC measurements on Co_2MnGe using ^{111}Cd probes yielded a magnetic hyperfine field of B_{hf} = 4.1(1) T, strongly indicating probe occupation at the Ge site, as suggested by Delyagin *et al.* [4], who reported a low value of 1.05 T for B_{hf} at ^{119}Sn probes located at Ge sites.

By systematically varying the transition metal (X) and the main group element (Z) across the alloy series, we aim to correlate the MHF behavior with structural modifications, variations in interatomic distances, and the total number of valence electrons. The experimental TDPAC data, complemented by conventional macroscopic magnetic measurements, enables further progression in understanding the dominant mechanisms governing the hyperfine interactions. Specifically, this approach facilitates a more comprehensive exploration of the interplay between local magnetic moment contributions and conduction electron polarization (CEP) effects, laying a solid experimental and theoretical groundwork for future investigation. Furthermore, this comprehensive study highlights the robust application of nuclear techniques and methodologies in elucidating complex, strongly correlated magnetic phenomena in emerging quantum materials. The insights gained not only clarify the fundamental physics underlying the magnetic exchange interactions in Heusler alloys but also pave the way for tailoring their electronic properties for next-generation spin-based devices.

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