High-pressure torsion and magnetic-field annealing of meteorite-derived FeNi alloys: structural and magnetic analysis

Mieszko Kołodziej,[1,2] Jean-Marc Grenèche,[3] Sandy Auguste,[3] Jozef Marcin,[4] Jozef Kovač,[4] Bogdan Idzikowski,[1] and Zbigniew Śniadecki[1]

[1] *Institute of Molecular Physics, Polish Academy of Sciences, M. Smoluchowskiego 17, Poznań 60-179, Poland*

[2] *NanoBioMedical Centre of Adam Mickiewicz University, Wszechnicy Piastowskiej 3, Poznań 61-614, Poland*

[3] *Institut des Molécules et Matériaux du Mans (IMMM, UMR CNRS 6283), Le Mans University, Avenue Olivier Messiaen, CEDEX 09, Le Mans 72085, France*

[4] *Institute of Experimental Physics, Slovak Academy of Sciences, Watsonova 47, Košice 040 01, Slovakia*

The $L1_0$ FeNi phase naturally occurs in meteorites, and is regarded as the holy grail of rare-earth-free permanent magnets due to its exceptional magnetic potential [1]. Despite decades of effort, synthesizing this ordered phase in bulk form remains a persistent challenge. Even though numerous research groups worldwide continue to explore new processing routes [2-3] to overcome the major issue - the sluggish Fe–Ni diffusion kinetics [4]. In this context, meteorite-derived alloys offer a unique platform for studying pathways toward $L1_0$-type ordering. In this work, we investigate the structural and magnetic evolution of an equiatomic FeNi alloy based on the Morasko meteorite. The alloy was produced by arc-melting and melt-spinning, followed by high-pressure torsion (HPT) to enhance defect density and promote atomic mobility. Subsequent isothermal annealing at 296° C — performed both without and under a 14 T external magnetic field — was applied to stimulate Fe–Ni interdiffusion and assess the potential formation of the tetragonal $L1_0$ FeNi phase. X-ray diffraction confirmed a single-phase fcc-FeNi structure for all samples, with a slight lattice expansion after HPT. Mössbauer spectroscopy revealed subtle changes in the local atomic environment of Fe, indicating enhanced diffusion and partial chemical segregation after annealing. Although no definitive signatures of $L1_0$ ordering were detected, minor spectral features suggest its potential development. Moreover, magnetic-field annealing increased Fe–Ni segregation, a key requirement for $L1_0$ formation. The combined HPT and magnetic-field-assisted annealing approach improves the conditions required for $L1_0$ FeNi at sub-transition temperatures, adding a meaningful step toward the long-standing goal: synthesis of bulk $L1_0$ FeNi under laboratory conditions.

References:

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