# Structure-Magnetism Correlations and Chemical Order-Disorder Transformations in Ferrous $L1_0$-Structured Compounds

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Understanding chemical order-disorder transformations and their effects on structural and magnetic properties of ferrous $L1_0$ intermetallic systems has been a longstanding problem in materials science and solid state chemistry. Herein, the kinetics of ordering and disordering of the $L1_0$ structure in the FePd and FeNi systems will be explored in correlation with their magnetic and structural properties. In many systems, the chemically ordered $L1_0$ structure forms through an ordering transformation from a chemically disordered parent phase, which is often a face-centered cubic (fcc, A1) solid solution of the two elements (see unit cells of both structures in Figure 1). $L1_0$ FeNi (a.k.a. tetrataenite) is only found naturally in meteorites that form over 4.5 billion years; to date, it has not been produced in bulk by laboratory methods. The challenge for manufacturing $L1_0$ FeNi is that it has a critical temperature of 320 °C, below which the fcc chemically disordered phase transforms into the $L1_0$ chemically ordered phase [1]. Below this critical temperature, the atomic mobilities of Fe and Ni are extremely low (1 atomic jump per 2,600 years [2]) therefore the atomic movement necessary for chemical ordering is limited. On the other hand, the $L1_0$ structure forms readily in FePd making it a useful model system in which to study the order-disorder transformation [3] (it is noted, however, that the high cost of palladium makes FePd an impractical material for bulk industrial applications). In this dissertation, laboratory-synthesized $L1_0$ FePd was used as a test-bed system while a variety of meteorites were used as natural sources of $L1_0$-structured FeNi. The effect of the cooling rate on the $A1 \rightarrow L1_0$ chemical ordering transformation in FePd is investigated to elucidate the mechanism of chemical ordering. The effect of the heating rate on the $L1_0 \rightarrow A1$ chemical disordering transformation in FeNi is investigated to gain understanding of the phase's stability and order-disorder transformation mechanism. Analysis of the magnetic properties of $L1_0$ FeNi and $L1_0$ FePd indicates that the materials have theoretical magnetic energy products comparable to those of today's best permanent magnets; thus, results from this work may aid future synthesis efforts for advanced permanent magnet applications.

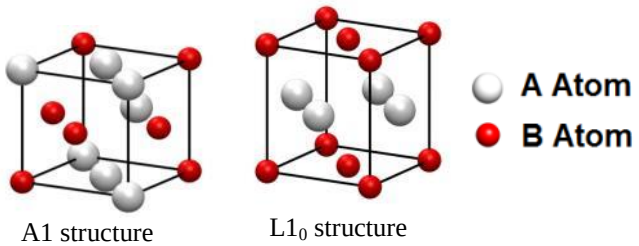


**Figure 1: Unit cells of binary alloy AB with (a) the chemically disordered fcc (A1) structure and (b) the chemically ordered $L1_0$ structure.**

* Supervised by Laura H. Lewis

[1] C. W. Yang, D. B. Williams, and J. I. Goldstein, "A revision of the Fe-Ni phase diagram at low temperatures (<400ºC)," *Journal of Phase Equilibria*, vol. 17, pp. 522-531, 1996.

[2] J. Yang and J. I. Goldstein, "Magnetic Contribution to the Interdiffusion Coefficients in Bcc (a) and Fcc (g) Fe-Ni Alloys," *Metall and Mat Trans A*, vol. 35A, pp. 1681-1690, 2004.

[3] T. Klemmer, D. Hoydick, H. Okumura, B. Zhang, and W. A. Soffa, "Magnetic hardening and coercivity mechanisms in L10 ordered FePd ferromagnetics," *Scripta Metallurgica et Materialia*, vol. 33, pp. 1793-1805, 1995.