A brief outline of experimental results of NMR studies of ternary systems Fe$_{3-x}$T$_x$Si are presented. The observation of transition metal site selectivity, which correlates with electronegativity and atomic size, enables one to develop a quantitative model relating specific B sites and their corresponding near-neighbor moments. Brief reference is made to recent work on amorphous metals, short-range ordering, and the initial NMR studies of multilayer systems.

1. Introduction

Ever since the first observation of nuclear magnetic resonance (NMR) in a metallic ferromagnet by Gossard and Portis [1], there has been a great interest in understanding the detailed excitation process for nuclei in domains and domain walls [2], and in the application of this spectroscopy to the study of hyperfine fields [3] and relaxation times [4] in magnetically ordered alloys. The relation of the results of hyperfine field studies by both Mössbauer and NMR to the promising neutron studies of the magnetic disturbance about an impurity in Fe by the Harwell group [5] provided an opportunity to construct a rather high-resolution picture for the effect of an impurity and for the relationship, on a very local scale, between hyperfine fields determined at specific near neighbors (NN) to the impurity [6] and the corresponding neutron deduced spatial variation of the local magnetization. Here one has the very complex theoretical problem of determining the separate long-range spin-up and spin-down polarizations produced by an impurity; a problem, similar to that of the conduction electron polarization oscillations in a paramagnetic host [7], treated by Friedel and by the Ruderman, Kittel, Kasuya, and Yoshida approaches. For a review, see ref. [8].

Generally, the assignment of results of experimental data to a specific near neighbor has been complicated by the fact that in a binary disordered alloy one must
be able to unambiguously assign spectral results to a specific near-neighbor configuration, not easily separable in many spectra taken on these systems. When it is possible to combine the resolution of the NMR experiments with the reliable intensity information from a Mössbauer spectrum, extremely precise assignments of hyperfine fields to specific NN configurations results.

Earlier, from NMR experiments on both binary [9] and ternary [10] alloys, some evidence for clustering and short-range order was available. Similar evidence was deduced from Mössbauer studies [11]. The occurrence of short-range order in some systems and the complexity of the NMR excitation process in the ferromagnet cast some doubt on the conclusions which have been drawn for some systems.

The unexpected observation [12] that substituted transition metal impurities select between the two inequivalent Fe sites in the Fe$_3$Si alloys provided a system in which some of the difficulties mentioned above could be reduced. From these studies of site selectivity, we concluded that Fe$_3$Si and its pseudobinary alloys are ideal alloy systems in which to study hyperfine fields and the relationships of these fields to crystallographic, metallurgical, and magnetic properties. A summary of the spin-echo NMR data and its analysis for Fe$_{3-x}$T$_x$Si alloys, where T are dilute amounts of transition metal impurities, is contained in ref. [13]. Reference [14] is a review of the local environment description of hyperfine fields and atomic moments over the entire composition range of the 3d substitutions. An outline of some of our results is presented here.

2. **Hyperfine fields, crystallographic, and magnetic properties of some systems based on Fe$_3$Si**

Fe$_3$Si is a long-range ordered alloy which is ferromagnetic. Its crystal structure, the face centered cubic DO$_3$ type, is shown in fig. 1. This structure has four sites A, B, C and D, with the specific neighbor configurations summarized in table 1. The Fe atoms are located in two different sites [A,C] and [B] which are both chemically and magnetically inequivalent. The Fe[A,C] sites have 4 Fe[B] and 4 Si[D] as first near neighbours (1NN) and magnetic moments of 1.35 $\mu_B$, while the Fe[B] have 8 Fe[A,C] 1NN and carry a magnetic moment of 2.2 $\mu_B$ and the Si[D] sites have the same neighbors as Fe[B] but essentially a zero moment. The measured hyperfine fields at 1.4 K are $-218(2)$ kG, $338(2)$ kG and $37$ kG for the Fe[A,C], Fe[B] and Si[D] sites, respectively. It should be pointed out here that Fe[B] resembles Fe in bcc Fe metal in that both are surrounded by eight Fe 1NN and carry a moment of 2.2 $\mu_B$. The ratio of the moments of the two Fe sites in Fe$_3$Si is 0.61 compared to a ratio of 0.67 for their hyperfine fields.

In Si-rich off-stoichiometric alloys about the composition Fe$_3$Si, excess Si replaces Fe in the B sites producing Fe[A,C] sites with three and two Fe[B] 1NN, while in the Fe-rich alloys, Fe is found on the Si[D] sites producing Fe[A,C] sites...