Mössbauer Experiments on $^{57}$Fe in the Giant Moment System Ni$_{75-x}$Fe$_x$Ga$_{25}$

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Mössbauer experiments on $^{57}$Fe on the giant moment system Ni$_{75-x}$Fe$_x$Ga$_{25}$ were performed. For various Fe concentrations $x$ the hyperfine fields, the isomeric shift, and the quadrupole splitting were measured. A saturation hyperfine field of 223 (2) kOe at the Fe atom substituting a Ga site and of 200 (2) kOe at the Fe atom substituting a Ni site were found.

I. Introduction

The system of iron in Ni$_3$Ga is one with the strongest exchange enhancement known so far. Susceptibility measurements [1] have shown that for less than 0.1 % iron in this host the magnetic moment per iron atom is around 40 $\mu_B$ and the Curie temperature is still between 10 and 20 °K. Extensive Mössbauer experiments in external magnetic fields with sources of $^{57}$Co diffused into Ni$_3$Ga which also had an iron content of 20 and 250 ppm have recently been made by Maletta [2]. In this study the hyperfine field at the iron site as a function of external field and temperature could be fitted with a Brillouin function; with $g=2$ for the most dilute sample a magnetic moment of the iron atom of 60 $\mu_B$ was obtained and a saturation hyperfine field for iron of 223 kOe.

The study of strongly exchange enhanced systems is one line of approach for the investigation of the properties of magnetic moments in metals. Especially for those magnetic metallic systems which seem to have considerable itinerant character for the magnetic electrons, like e.g. Ni, the investigation of their precursors is a very important task. The combination of Ni and Ga presents in this respect an intuitively very appealing approach. Ni as such is a ferromagnet, with indications of some itineracy of the $d$ electrons. From measurements of the density of states it is known that the slope of the $d$ density of states at the Fermi energy is very steep. Ga on the other hand has a $d$ band more than 10 eV below the Fermi energy, and near the Fermi energy there are only the $s-p$ bands. The addition of Ga to Ni can then be thought of in a crude way as shifting slightly the Fermi energy of the Ni, thus destroying the condition for spontaneous magnetic order, but leaving a relatively
high \( d \) density of states at the Fermi energy, which is responsible for the high exchange enhancement.

We have performed Mössbauer effect experiments with absorbers of \( \text{Ni}_{75-x}\text{Fe}_x\text{Ga}_{25} \) with \( 0.06 \leq x \leq 2 \) at 4.2 K and at room temperature in zero external field. In part II the preparation and analysis of the samples will be described. The experimental results are given in part III. Finally in part IV the concentration dependence of the observed hyperfine fields is discussed and compared with a simple model given by Craig et al. [3], which describes the concentration dependence of the hyperfine field in an exchange enhanced lattice and was applied to the giant moment behavior of iron in palladium. In addition the radial extension of the conduction electron polarization around the iron atom is estimated.

II. Sample Preparation and Analysis

The crystal structure of Ni\(_3\)Ga is cubic [4] (fcc) with Ga atoms at the corner and Ni atoms at the faces of the cubic unit cell (Fig. 1). The phase diagram [5] shows that the cubic Ni\(_3\)Ga phase exists for a Ga concentration between 24 and 28 at\%. This phase is stable in the temperature range below the melting point of about 1200 °C. It should be mentioned that in that range of concentration the system goes from weakly ferromagnetic to strongly paramagnetic without change of crystal structure.

The starting materials for the alloys were Ni and Ga metal with a purity of 99.998 \% and 99.999 \%, respectively and Fe metal enriched to about 80\% \(^{57}\)Fe. First a master alloy was prepared with 1 at\% Fe by melting the corresponding amounts in an induction furnace in an Ar/H\(_2\) atmosphere at about 1500 °C for a few minutes. The loss of weight of about 1\% could mainly be attributed to Ga as shown by a chemical analysis of the evaporated deposite. Therefore a small excess in weight