VARIABILITY OF ATOMIC ORDER AND MAGNETIC MOMENTS DISTRIBUTION NEAR Fe₃Al*)

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Atomic order and magnetic interactions of the Fe—Al alloys near the Fe₃Al stoichiometry vary strongly among the A2, B2 and DO₃ types of order due to the composition and heat treatment. The type and degree of atomic order of alloys with ca. 20, 24 and 26 at. % Al and various thermal history were gained from the room temperature $^{57}$Fe Mössbauer spectra. From the calculated magnetic moments distributions, the average moments were inferred and compared with the measured magnetic polarizations. Structural causes of the magnetization variations were drawn.

1. INTRODUCTION

The Fe—Al alloys represent a basis of perspective special soft magnetic alloys. To apprehend their magnetic properties, the knowledge of their structure, its changes and structural causes of the macroscopic characteristics is needed. The Fe—Al phase diagram is particularly complicated in the region near the Fe₃Al stoichiometry and the temperatures up to ca. 600°C (fig. 1), i.e. exactly where the used compositions and heat treatments range. Here the multiple ordering transitions between the A2, B2 and DO₃ structures and the magnetic transformation take place.

![Phase diagram](https://example.com/fig1.png)

Fig. 1. Eclectic phase diagram near Fe₃Al (after Inden [1]). Investigated alloys and their states are marked with ●.

The $^{57}$Fe Mössbauer spectroscopy, by its dual nature — being both the structure and magnetic measuring technique — may serve as a promising method for solving the above questions, especially when combined with suitable macroscopic measurements. From the Mössbauer spectrum, the (discrete) distribution of hyperfine fields

*) Dedicated to Academician Vladimir Hajko on the occasion of his 65th birthday.
at $^{57}\text{Fe}$ and hence the statistics of local surroundings in the crystalline lattice can be gained with respect to the 1st (n.n.) and 2nd (n.n.n.) neighbour occupations around the central iron. This yields the picture of the atomic short range order — its type and degree and their changes due to the composition variations and thermal (or mechanical) history of the alloy.

On the other hand, when knowing the dependence of the (time average) iron atomic magnetic moment in given surroundings, e.g. from the neutron diffraction data, one could derive the iron moment distribution, i.e. the magnetic structures of ordered Fe-Al lattices. By averaging the moments (together with the zero Al moments) throughout the lattice, the alloy magnetization can be calculated. The comparison with the directly measured macroscopic data leads then to conclusions on their structural causes.

Much work has been done on the part of the Fe-Al system in question — structural, magnetic and Mössbauer. The structural data of the b.c.c. part of the Fe-Al phase diagram have recently been reviewed by Inden [1]. An early Mössbauer work on the DO$_3$ ordered Fe-Al alloys was done by Cser [2, 3]. Some magnetic data were published by Rassmann and Wich [4] and Okamoto and Beck [5]. The neutron diffraction data on the local Fe magnetic moments in Fe$_{0.7}$Al$_{0.3}$ are known from Cable et al. [6].

In our previous papers, we have shown the transformation of hyperfine field into magnetic moment distributions and from the matching calculated and measured magnetic polarizations concluded on the localized character of iron magnetic moments [7]. The changes in the local order in the Fe-26·1 at. % Al alloy and their magnetic consequences were discussed in [8]. The aim of this work is to summarize the results of the Mössbauer study of various ordered states of the Fe-Al alloys from ca. 20 to 26 at. % Al after different heat treatments along with the corresponding measured and re-calculated magnetizations and to conclude on the regularities of the magnetic structures of ordered b.c.c. lattices near the A$_3$B stoichiometry.

2. METHODS OF SOLUTION

In our study, Fe-Al alloys with 20·2 at. % (alloy A), 23·7 at. % (B), 26·1 at. % Al (C) were used. The carbonyl iron with a low carbon content (0·03 wt. %) and the aluminium of the 0·9999 purity were melted in the induction furnace in argon atmosphere. The bar-shaped ingots of the mass of about 100 g were hot rolled to the ca. 0·1 mm thick strips. The cold rolling followed by the chemical polishing yielded the universal samples for the Mössbauer and other measurements: 40 µm foil strips approximately 60 mm long and 20 mm wide.

All samples were homogenized at 1000 °C for 1 h and cooled down in the furnace. One strip of each material was plastically deformed by 40% by cold rolling in order to destroy the atomic order as much as possible, and one was briefly (1 h) annealed at 700 °C and then cooled at a rate of 10 K/h to reach the highest DO$_3$ atomic order.