Abstract: The magnetic properties of Fe grains were studied by Mössbauer spectroscopy in three different nanocomposite systems: Fe-Zr-B-Cu nanocrystalline alloys prepared from melt quenched amorphous precursors, and Fe/B and Fe/Ag multilayers prepared by vacuum evaporation. It is shown that non-equilibrium alloying plays an overwhelming role in the deviation of the value of the Fe hyperfine field in small particles and in the bulk. On the other hand, a grain boundary phase with distinct magnetic properties cannot be separated. With decreasing grain size the superparamagnetic behaviour of the Fe grains becomes more dominant and a coexistence of ferromagnetic and superparamagnetic particles can be observed. Multilayer deposition is shown to be a flexible tool for preparing magnetically heterogeneous nanocomposite structures with narrow size distributions, offering new possibilities to study the magnetic interactions between nanosize objects.

1. INTRODUCTION

Nanocrystalline Fe (nc-Fe) has been the subject of many studies since the eighties when different technologies were developed to prepare it either as a single phase material or as a part of a nanocomposite. Many of its peculiar properties were attributed to a special grain boundary structure which is very different from that of the usual grain boundaries in polycrystalline materials. The Gleiter model of nanocrystalline materials [1] depicted them as essentially perfect fine grains with wide disordered grain boundaries of significantly reduced density. Mössbauer spectroscopy gave an essential contribution to this model, providing measurements on nc-Fe prepared by the inert gas condensation technique [2]. The results were described by two hyperfine components: a sharp sextet with parameters of pure bcc-Fe (crystalline component) and a broad sextet (grain-boundary component) with different parameters. The temperature depend-
ence of the broad sextet and the sharp lines was found to be different and an increased magnetic moment (i.e. low temperature hyperfine field) of the grain boundary component was also observed. However, more recent Mössbauer effect studies on nc-Fe prepared by other methods could not reproduce this feature and a component in the Mössbauer spectra corresponding to grain boundary atoms could not be identified [3]. Studies of nc-Fe in polycrystalline Fe/B multilayers [4] led to the conclusion that the perturbation which can be found in the hyperfine field due to changes of the Fe coordination numbers and distances in bcc-grain boundaries is of the order of the experimental linewidth (i.e. below 1 T). In this work we will study three nano-composite systems, where the grain size is sufficiently small for superparamagnetic behaviour of the grains. We will also examine questions concerning the grain boundary phase and interaction between nanosize particles.

2. EXPERIMENTAL

2.1. Fe-Zr-B-Cu nanocrystalline alloys

NANOPERM type Fe_{92-x}Zr_{7}B_{x}Cu_{1} nanocrystalline alloys (nc-Fe_{92-x}Zr_{7}B_{x}Cu_{1}) were prepared from melt quenched amorphous ribbons by heat treatment in a differential scanning calorimeter (DSC) to a well defined stage of the crystalline transformation.

![Figure 1. Composition dependence of the bcc-Fe grain size in nc-Fe_{92-x}Zr_{7}B_{x}Cu_{1}](image)

The average grain size of the bcc-Fe phase was measured by X-ray diffraction [5]. The composition dependence of the grain size after a heat treatment to the end of

![Figure 2. Mössbauer spectrum of the nc-Fe_{92}Zr_{7}B_{x}Cu_{1} composite measured at 12 K. The fitted subspectra (see text) are also shown. The evaluated hyperfine field distribution of the residual amorphous phase is shown in the right panel](image)