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THE EFFECTS OF NEUTRON IRRADIATION ON THE MAGNETIC PROPERTIES OF AMORPHOUS Fe—B ALLOYS[1])

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The Mössbauer spectroscopy was used to study the changes in the local atomic structure of neutron irradiated amorphous $Fe_{80}B_{20}$ alloys. The observed broadening of hyperfine field distribution is discussed in terms of the possible irradiation induced structural and chemical changes in the short range order around the Fe atoms.

I. INTRODUCTION

Investigations of the sensitivity of magnetic properties of metallic glasses to radiation damage clearly demonstrate that structural changes caused by irradiation modify various characteristic magnetic parameters such as exchange interactions and Curie temperature [1, 2], magnetic permeability [3], low field a.c. susceptibility [4], temperature dependence of spontaneous magnetization and hysteresis loop parameters [5]. However, little is known about the nature of the irradiation-induced structural and chemical changes at the atomic level. Because of this the mechanism of radiation damage and the determination of the local atomic arrangement in irradiated amorphous alloys are today a matter of considerable interest. In order to obtain the above mentioned information, it is necessary to investigate their properties at atomic level by appropriate techniques such as the Mössbauer or the NMR spectroscopy in addition to bulk magnetic and related properties.

The aim of the present work was to obtain information about the changes in short range order of neutron irradiated $Fe_{80}B_{20}$ amorphous alloys by help of the Mössbauer spectroscopy. Our interest was focused on the hyperfine field distribution because of its sensitivity to local environments.

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II. EXPERIMENTAL

The as-received samples of the investigated alloys were prepared by rapid quenching from melts by means of the melt spinning technique. The ribbon samples were about 20 μm thick and 6 mm wide.

The neutron irradiation was performed in the WWR-S-10 nuclear reactor at Řež. The specimens were exposed to a neutron spectrum with a flux of $\Phi = 2.78 \times 10^{13}$ neutrons. $cm^{-2} s^{-1}$ to a total fluence of 5×10^{18} neutr. cm^{-2}. The neutron energy spectrum used for the analysis of our irradiation experiments was measured by the activation method [6]. The intensity ratio of fast to thermal neutrons was 12 : 10. The irradiation temperature was monitored and never exceeded 70 °C.

The atomic displacement level for the investigated alloys produced by neutron irradiation was evaluated approximately as a 0.08 displacement per atom (calculation similar as in [7]). It may be noted that nearly all displacement damage is caused by a $^{10}B(n, \alpha)$ Li + 2.3 MeV reaction. This reaction results in the production of about 200 at. ppm of Li and the same amount of He as impurities at the end of the irradiation. The effects of radiation-induced chemical changes of other elements contained in samples were evaluated as negligible.

III. RESULTS AND DISCUSSION

The room temperature Mössbauer spectra of irradiated and as-quenched samples were taken at a standard transmission geometry with a constant acceleration drive using a $^{57}Co/Cr$ source. The obtained spectra exhibit typical broadened six line patterns and line width and line intensity asymmetries, as can be seen in Fig. 1.

The broadening of the lines in the magnetic hyperfine spectra of amorphous alloys is generally attributed to a distribution of hyperfine fields. Such broadening reflects the distribution of nonunique sites and the spread in inter-atomic distance. In order to obtain the hyperfine field distribution $P(H)$ the measured spectra were fitted by the modified histogram fitting program with the additional constraint $P(H) \geqslant 0$ [8]. The least-squares computer fitting was carried out by the MINUIT procedure [9]. To account for the asymmetry in the shape of the line pairs we introduced a linear relation between the hyperfine field and the combination of isomer shift and quadrupole splitting, similarly as in [10].

The obtained hyperfine field distributions are shown in Fig. 2. The corresponding parameters calculated from these distributions as well as the values of the angle Θ between the average direction of the magnetic moment and the γ-ray direction and the values of χ^2 for the best fit are in Table 1.

It can be seen that the values of the mean hyperfine field $\bar{H}$ are nearly the same for the irradiated and the unirradiated samples. Small changes of the value of the angle Θ derived from the relative intensity of the Mössbauer absorption lines were observed.

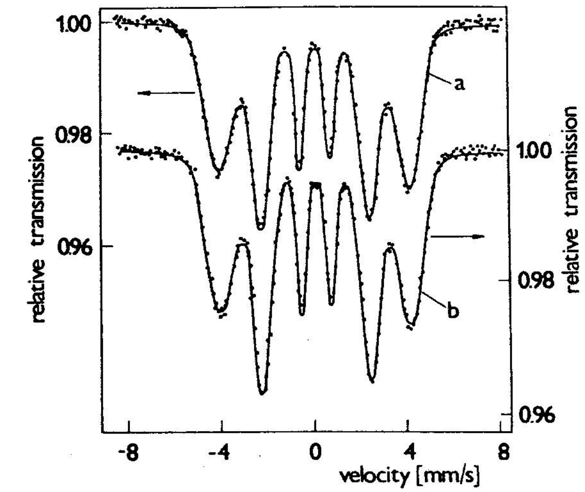

Fig. 1. Mössbauer spectra of amorphous $Fe_{80}B_{20}$ alloys a) before irradiation b) after irradiation with a fluence of 5×10^{18} neutr. cm^{-2}

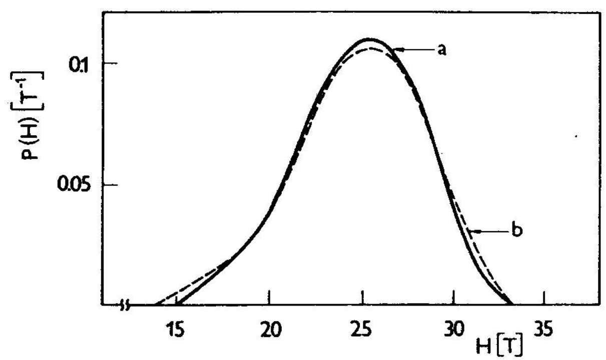

Fig. 2. Hyperfine field distribution of amorphous $Fe_{80}B_{20}$ alloys obtained from the fitting procedure a) before irradiation b) after irradiation with a fluence of 5×10^{18} neutr. cm^{-2}

The irradiation leads to an increase of the value of the standard deviation σ_H from 3.19 T to 3.37 T. The above increase can represent iron atoms having a greater variety of arrangements of neighbourhoods in irradiated alloys than that

Table 1

Parameters calculated from Mössbauer spectra of Fig. 1

fluence (neutr. cm^{-2})	$\bar{H}$ [T]	σ_H [T]	Θ	χ^2
0	24.9 (±0.1)	3.19	62° (±0.5°)	2.08
5×10^{18}	24.8 (±0.1)	3.37	64.5° (±0.5°)	2.13

of the unirradiated ones. The hyperfine field is sensitive mainly to the local metalloid neighbourhood of the iron atoms [11]. Hence the observed broadening of the hyperfine field distribution can be attributed to the radiation induced increase in the population of Fe atoms with a large, resp. small, number of boron nearest neighbours against the Fe atoms contributed to the central part of the $P(H)$ distribution (2 and 3 boron nearest neighbours).

The reason for the redistribution of boron atoms after irradiation may be the process of selective displacements of the lighter atom species from the central part of the displacement cascades to their peripheral parts, which becomes important in alloys with a large mass difference between the alloying elements [12]. However, a possible explanation can also be the concept of an irradiation-induced boron decomposition into boron-depleted regions and boron enriched clusters suggested in ref. [13] for neutron irradiated amorphous $Fe_{40}Ni_{40}{}^{10}B_{20}$ alloys.

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ДЕЙСТВИЕ НЕЙТРОННОГО ОБЛУЧЕНИЯ НА МАГНИТНЫЕ СВОЙСТВА АМОРФНЫХ Fe—B СПЛАВОВ

При изучении изменений локальной атомной структуры аморфных $Fe_{80}B_{20}$ сплавов, которые были облучены нейтронами, была использована спектроскопия Мессбауэра. Наблюдаемое расширение распределения сверхтонкого поля обсуждается с точки зрения возможных структуральных и химических изменений, обусловленных облучением