Transient Field Measurements on Light and Heavy Ions in Amorphous Iron-Boron Compounds ◇

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Measurements of Transient Magnetic Fields (TF) were performed for the first time in the amorphous compounds of $Fe_{80}B_{20}$ and $Fe_{85}B_{15}$. The motivation for these experiments was to see, whether the strong ion beam induced attenuations of TF in crystalline Fe with a range of μm [1] are weaker in the amorphous alloys. It has been suggested, that the attenuation may be related to the excitation of spin-waves, which are expected to be strongly damped in an amorphous compound due to its disordered structure [2].

Light (^{24}Mg, ^{28}Si) and heavy (^{48}Ti, ^{56}Fe) ion beams were used. The first 2^+-state in the nuclei of all four beams served as the probe for calibration of TF. According to the empirical parametrization:

$$B_{TF} = B_{lin} = a \cdot Z \cdot v/v_0 \ (v_0 = c/137)$$

the strength parameter a has been determined. Many measurements have shown, that the attenuation depends on the stopping power of beam ions with a distinct threshold at about 8 MeV/μm [3]. Therefore we expect a full TF in the case of the light beam ions. For heavy beam ions any attenuations of TF with ^{48}Ti(2^+) and ^{56}Fe(2^+) probes can be neglected in spite of the high dE/dx because of the low velocity of probe ions (see [3]).

The targets used in the Mg- and Si-experiments consisted of two layers: Fe-B and Au. A minimum thickness of 2 μm of Fe-B can be obtained from 20 μm ribbons by polishing and etching techniques [4]. In these measurements Coulomb excitation (C.E.) was applied to beams to populate their first 2^+-state. Ion beams of 100 MeV ^{24}Mg^{+9} and 150 MeV ^{28}Si^{+11} with 2 pnA intensity on the target were provided by the tandem accelerators in Cologne and Munich. In both cases the beam ions were incident upon the Fe-B layer and scattered from the subsequent Au-layer, so that the Coulomb excited Mg- and Si-ions experienced the TF on their way through the amorphous layer to the annular Si-detector for registration. Precession angles Φ derived from double ratios of coincident counting rates with magnetization of the target in "up" and "down" directions are given by

$$\Phi_{TF} = g \cdot \frac{\mu_N}{\hbar} \int_{t_{in}}^{t_s} B_{TF} \cdot e^{t/\tau} \cdot d\tau$$

where τ lifetime, g g-factor, t_{in} entrance time, t_s stopping (exit) time.

In the measurements with ^{48}Ti and ^{56}Fe beams the targets consisted of three layers: Mg/Fe-B/Cu. ^{48}Ti beams of 130 MeV and ^{56}Fe beams of 150 MeV were provided by the Munich tandem accelerator with intensities of 2-3 pnA. C.E. occurred in collisions of the beam ions with Mg target nuclei providing probe ions of both beam and target nuclei: ^{24}Mg(2^+), ^{48}Ti(2^+), ^{56}Fe(2^+). The scattered ^{24}Mg ions were detected in a Si-detector at 0° to the beam direction. This allowed to measure in coincidence the γ-rays from the (2^+–0^+) transitions of the beam ion and the target nucleus simultaneously.

For the TF interpretation of the precessions of the ^{48}Ti(2^+) and ^{56}Fe(2^+) probe ions the measured values had to be corrected for static field (SF) contributions, as the ions were stopped in the ferromagnetic compounds. The measured precession is given by:

$$\Phi^{exp} = \Phi_{TF} + \Phi_{SF}$$

where $\Phi_{SF} = g \cdot \frac{\mu_N}{\hbar} \cdot B_{SF} \cdot e^{-t_S/\tau} \cdot \tau$.

The SF of Fe in amorphous Fe-B-alloys has been studied through the Mößbauer effect by various groups and it has been evaluated for both ^{48}Ti(2^+) and ^{56}Fe(2^+) ions. After correcting for the SF contributions the TF strength parameter was deduced [5]. For all four probe ions and both compounds one obtains a mean value:

$$< a >= 11.8(1.0)\ T$$

This result is very close to the value of pure crystalline Fe (a=12 T). Associating the strength parameter with the saturation magnetization in the ferromagnetic hosts one would have expected a smaller value [6].

From the measurements with the ^{48}Ti- and ^{56}Fe-beams the precessions of the ^{24}Mg(2^+) ions were:

$$^{48}\mathrm{Ti}(2^+):\ \Phi^{exp} = 6.5(1.0)\ \mathrm{mrad}$$
$$^{56}\mathrm{Fe}(2^+):\ \Phi^{exp} = 4.7(1.5)\ \mathrm{mrad}$$

The attenuation which is generally expressed by the ratio of the measured precession to its value calculated with the linear parametrization of the TF yields:

$$\mathrm{G}_{Ti-beam} = 0.50(08)$$
$$\mathrm{G}_{Fe-beam} = 0.46(15)$$

A comparison with crystalline Fe (G $\simeq$ 0.2) [3] supports our expectation, that the attenuation of TF is reduced in amorphous compounds

The only drawback which may have a strong impact on TF measurements with heavy ions, consists in dimensional changes of the Fe-B layer due to the ion bombardment. At high dE/dx of ion beams and low temperatures of the sample a reduction of the thickness of the bombarded layer occurs [7]. In our measurements an effect of about 5 % was tolerated.

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