MAGNETIC SUSCEPTIBILITY MEASUREMENTS OF SOFT-MAGNETIC METALLIC GLASSES UNDER ION BOMBARDMENT

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1. Introduction

Soft-magnetic metallic glasses are considered for magnetic cores of accelerator radio-frequency (RF)-cavities. In this particular application, they are exposed to ion radiation caused by the lost beam particles, which may alter their magnetic properties [1]. The spectrum of particle species, energies and fluences is rather complex because the irradiating ions origin from interaction of lost primary heavy ions with the beam-pipe wall. That is why a systematic study of the influence of ion bombardment on magnetic properties of the materials used for the magnetic cores of the RF-cavities is necessary.

Previous studies concentrated on light-ion part of the spectrum of irradiating particles, namely protons and nitrogen ions [2]. Recently, the studies have been expanded to heavy-ion part of the spectrum, Ta and Au. Unfortunately, the data obtained for light ions cannot be extrapolated to heavy ions, because the mechanism of radiation damage is qualitatively different for light vs. heavy ions [3]. That is why experimental studies are necessary in both cases. This paper presents the results of magnetic susceptibility measurements of VITROVAC®6025 [4] irradiated by Ta and Au ions.

2. Experimental Details

VITROVAC®6025 ($Co_{67}Fe_4Mo_2Si_{16}B_{11}$) was irradiated by Au ions at 11.1 MeV/u and Ta ions at 11.1 MeV/u (GSI UNILAC) and Ta ions at 250 MeV/u (GSI SIS-18). At these energies, the range is longer than the sample thickness (about 23 μm), as calculated by SRIM2010. Radiation damage profiles, as well as ionization (electronic stopping) profiles are rather flat [5]. Especially at very high energies, the radiation damage and ionization are almost uniformly distributed in the sample bulk, as shown in Figure 1 for 250 MeV/u Ta ions. Irradiation fluences from 1.0×10^{11} ions/cm^2 up to 1.2×10^{13} ions/cm^2 were applied.

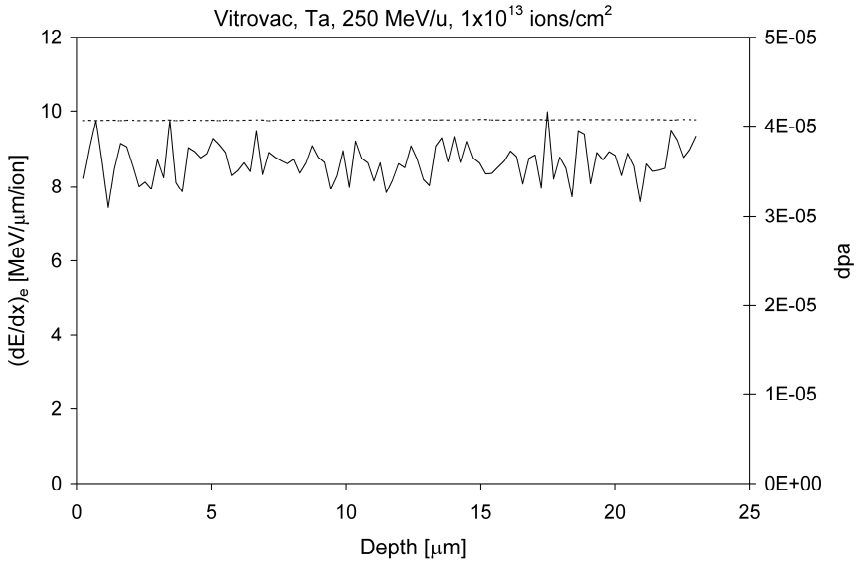

Fig. 1 *Ionization (dotted-line, left scale) and radiation damage (solid-line, right scale) profiles in VITROVAC irradiated by 1x10^{13} Ta ions/cm^2 at 250 MeV/u.*

The samples were analysed by magnetic susceptibility measurements performed with the aid of Kappabridge KLY – 2 [6]. In order to measure relative changes of magnetic susceptibility before and after irradiation, the samples where glued on a special sample-holder allowing for susceptibility measurements as well as ion irradiation without any direct manipulation with the sample in-between. In this way, mechanical manipulation with the sample was prevented and identical position of the sample in the Kappabridge measuring unit before and after irradiation was guaranteed. The measurement is based on inductivity changes in a measuring coil due to the presence of the measured sample inside the coil. This inductivity change is evaluated by a bridge-circuit. Figure 2 shows the principal scheme and view of the Kappabridge device. Although the Kappabridge allows for measurements of

temperature-dependence of magnetic susceptibility, we measured our samples at constant temperature of 311 K in order to exclude susceptibility changes due to temperature effects.

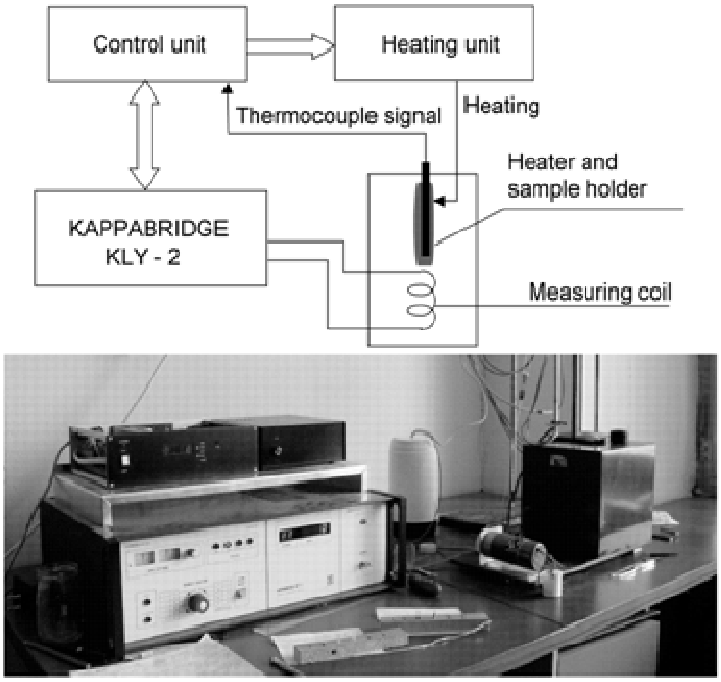

Fig. 2 Kappabridge principal scheme (upper panel) and photo (lower panel).

3. Results, discussion and conclusions

Relative change of magnetic susceptibility as a function of irradiation fluence is shown in Figure 3 for Ta and Au ions at 11.1 MeV/u.

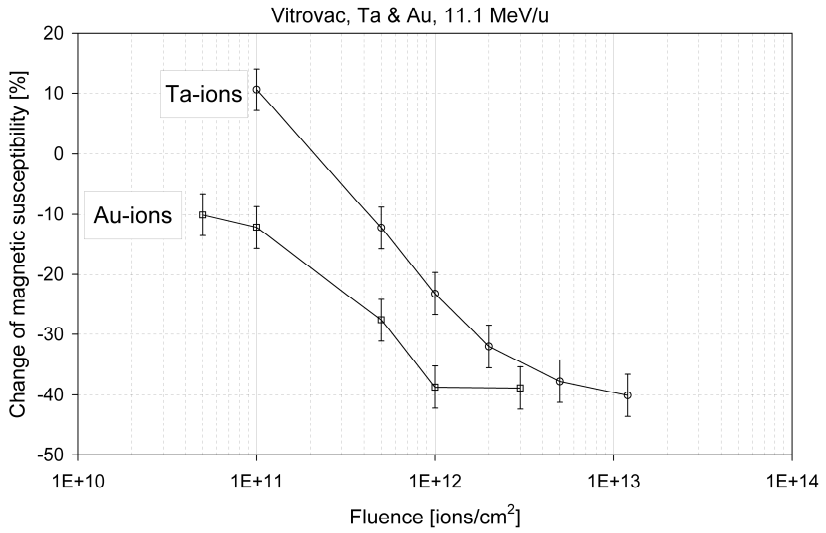

Fig. 3 *Magnetic susceptibility as a function of fluence, VITROVAC, Ta, Au, 11.1 MeV/u*

It can be seen that magnetic susceptibility of VITROVAC starts decreasing at irradiation fluences of $1x10^{11}$ ions/cm^2 that is a value consistent with other studies [7]. There is a saturation tendency starting at fluences over $1x10^{12}$ ions/cm^2, but there is a lack of data-points in this region to make a definite conclusion. The saturation tendency occurs at about 40% drop-level of original magnetic susceptibility. The changes induced by Au ions are larger in comparison with the changes induced by Ta ions, which may be related to the mass-difference between these two ion species.

Samples irradiated by 250 MeV/u showed no remarkable changes of magnetic susceptibility because of lower electronic stopping compared with the 11.1 MeV/u.

Our irradiation experiments showed that magnetic properties of soft magnetic metallic glasses are significantly affected by heavy-ion irradiation at relatively low fluences of $1x10^{11}$ ions/cm^2.

Acknowledgement

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