Neutron irradiation effect on the complex permeability in RPV materials

Seung Sik Park a, W. W. Na a, and H. T. Kim a
a TCNC, Korea Atomic Energy Research Institute, Yuseong P.O. Box 105, Daejeon 305-600, Korea

1. Introduction

Impedance spectroscopy has been used mostly for the magnetic characterization of the amorphous alloys. However, complex susceptibility spectroscopy has not been tried for the radiation effects on steel, either. In the present study, we present the effects of neutron irradiation on the complex susceptibility spectrum, which are related to the magnetic permeability. The variation of the quasi-static susceptibilities and the relaxation frequencies associated with the domain wall dynamics were determined from the measured spectra with the neutron dose and discussed in terms of the pinning sites induced by the neutron irradiation.

2. Experimental and Results

2.1 Experimental

Specimens used in this investigation were taken from the surveillance program in one of the commercial LWRs for various fuel cycles. They were extracted from the broken Charpy specimen weldments exposed to a fluence of $1.23\times10^{19}\,n/cm^2$ and $3.94\times10^{19}\,n/cm^2$ (*E*> 1.0 MeV, 288 °C), respectively. The permeability spectra samples were prepared in a rectangular form of 2x10x0.1 (mm^3). The frequency spectrum of the initial complex susceptibility, $\chi^* = \chi' - j\chi''$ was measured by a HP 4192A impedance analyzer. Frequency ranges were between 100 kHz and 10 MHz

2.2 Results

Fig. 1 shows the frequency spectra of the imaginary μ'' as a function of the neutron fluences. Our samples exhibited the typical features of a domain wall relaxation dispersion. The corresponding relaxation frequency, f_r was extracted from the plots of the imaginary permeability as a function of the frequency. Under the lower frequencies of the wall relaxation, the magnetization follows the applied field. However, the magnetization lags behind the applied field with its maximum at the relaxation frequency. The wall relaxing frequency depends on the wall restoring force, α and the viscous damping factor, β [1]. Typically the restoring force can be ascribed to the wall pinning on the defects, and the wall pinning due to the demagnetization fields [2]. The decrease of μ' and μ_r'' was attributed to the strongly pinned wall introduced by the neutron irradiated defects, resulting in an increase of the relaxation frequency. It agrees well with other papers where the initial permeability decreased due to the domain wall motion [3]. Both μ' and μ'' decreased with a neutron irradiation. Their rate of decrease is up to 10% and 12% at a dose of $3.94\times10^{19}\,n/cm^2$, respectively. A summary of the permeability results is given in Table 1.

Table 1 Summary of the magnetic properties for the specimens; amplitude of the real permeability: μ_r' (Amp), relaxation frequency of the imaginary permeability: f_r, Amplitude of the imaginary permeability: μ_r'' (Amp).

Samples	Dose*	μ_r' Amp (arb. unit)	μ_r'' f_r (kHz)
Uir.	0	0.41	398
Ir1 (3rd)	1.23	0.38	457
Ir2 (5th)	3.94	0.37	501

(*: $\times 10^{19}\,n/cm^2$)

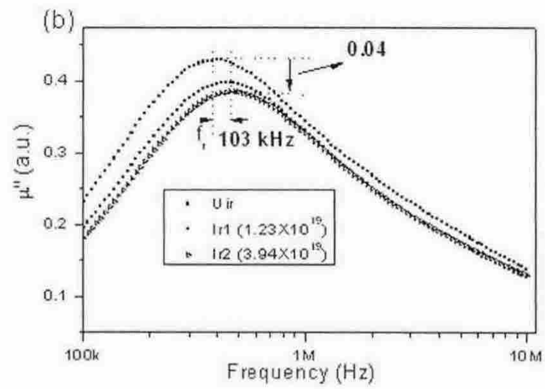

Figure 1. Imaginary parts of the permeability spectra as a function of the frequencies of the same three samples; Uir is unirradiated, Ir1 and Ir2 are samples irradiated with the dose of 1.23×10^{19} and 3.94×10^{19} n/cm2, respectively

3. Conclusion

The permeability spectra were studied by an impedance analyzer. μ' and μ'' decreased at the relaxation frequency as the neutron dose increased. Relaxation frequencies increased with a neutron irradiation. This result agrees with permeability changes caused by the neutron irradiated degradation which were referred to other magnetic measurements in a large literature.

REFERENCES

[1] C. Aroca, E. Lopez and P. Sanchez, Phys. Rev. B 30, 4024 (1984).

[2] H. C. Kim, S. C. Yu, C. G. Kim, H. S. Han, W. K. Cho, Matl. Sci. and Eng. A 304-306, 1030 (2001).

[3] H. C. Kim, S. C. Yu, C. G. Kim, H. S. Han, W. K. Cho, J. Magn. Magn. Mater. 215-216, 355 (2000).