Investigation of H^+ implanted Fe-Al alloys

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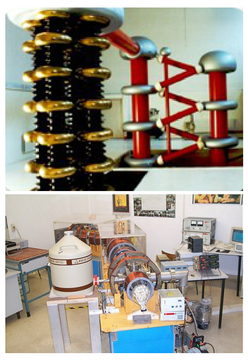
Introduction

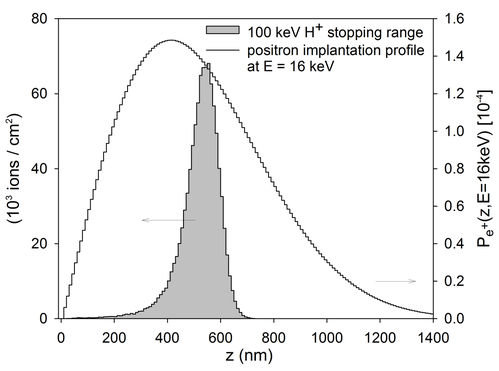
Iron aluminides are widely considered as perspective materials due to high specific mechanical strength and enhanced corrosion resistance at elevated temperatures. However, work machinability of these alloys suffers from poor ductility at room temperature. Since it has been shown that the ductility of Fe-Al alloys is remarkably improved in the absence of hydrogen and water vapor [1], environmental hydrogen embrittlement was suggested to take place in Fe-Al alloys. In addition to this, Fe-Al alloys are well known for a low vacancy formation enthalpy. As a consequence, the equilibrium concentration of vacancies in Fe-Al alloys is substantially higher compared to pure metals. Thermal vacancies formed at elevated temperatures in Fe-Al alloys can be relatively easily quenched to room temperature. Hydrogen interaction with vacancies could play very important role in the embrittlement process. The importance of hydrogen interaction with vacancies is further amplified by high mobility of hydrogen in Fe-Al lattice.

Experimental



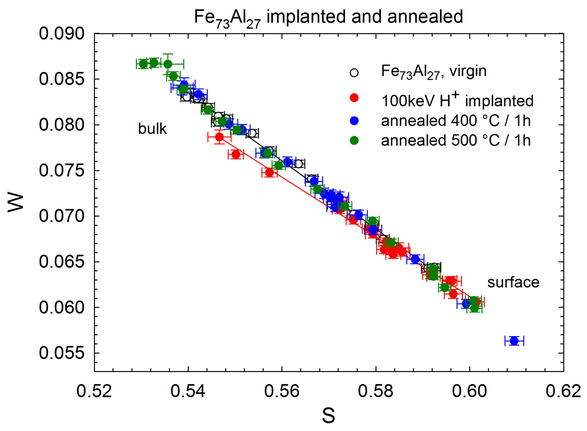
- Implantation by hydrogen ions with the energy of 100 keV up to fluence of 3×10^{18} at./cm^2 at room temperature at Slovak Technical University.
- Variable Energy Positron Annihilation Spectroscopy (VEPAS) at Helmholtz Zentrum Dresden Rossendorf, e^+ beam with positron energy from 30 eV to 35 keV; evaluated S-parameter of Doppler-broadened annihilation peak measured by HPGe detector with the resolution of (1.06 $\pm$ 0.01) keV (FWHM at 511 keV)

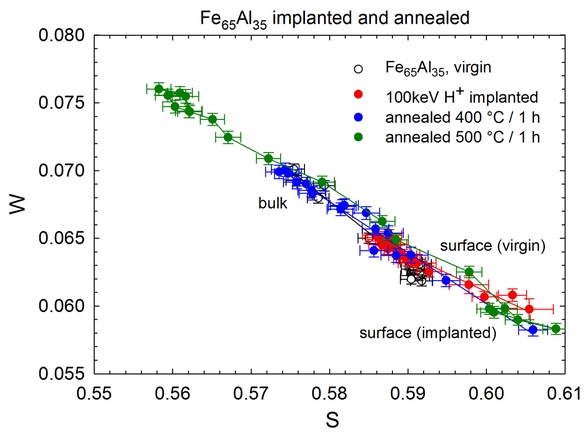
Implantation profiles

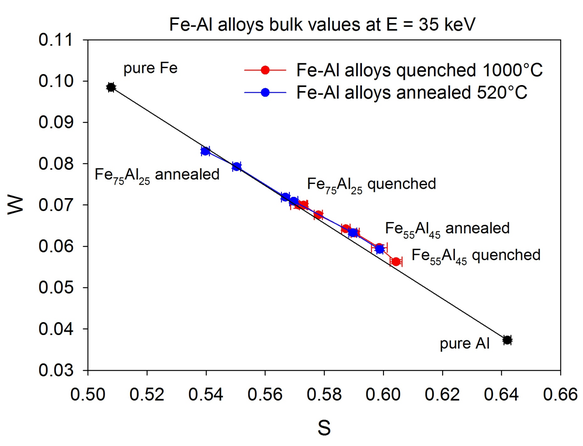


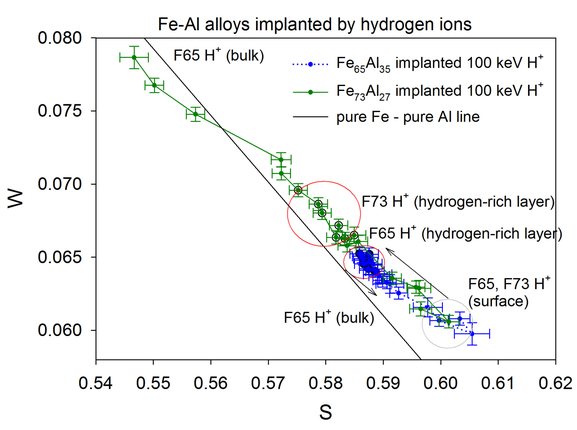
Mean implantation depth for 100 keV H^+ is $\bar{z}_{H^+} \approx 520$ nm and FWHM of H^+ stopping range distribution ≈ 130 nm.
Positron implantation profile is Makhovian curve with the mean implantation depth at 16 keV positron energy $\bar{z} \approx 510$ nm

VEPAS



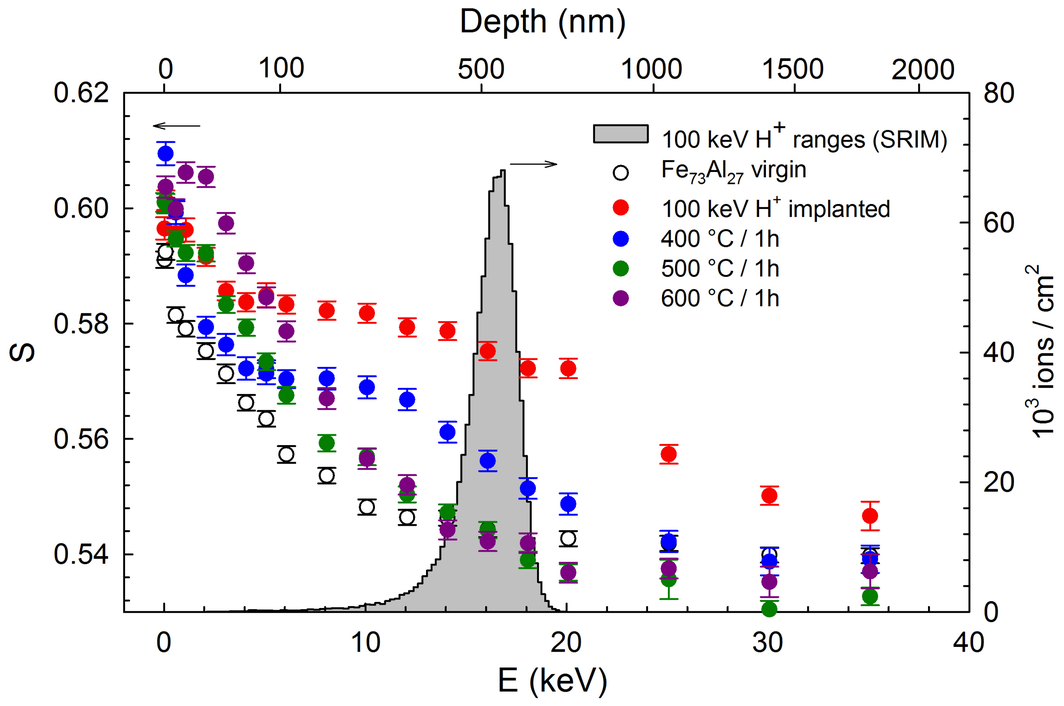




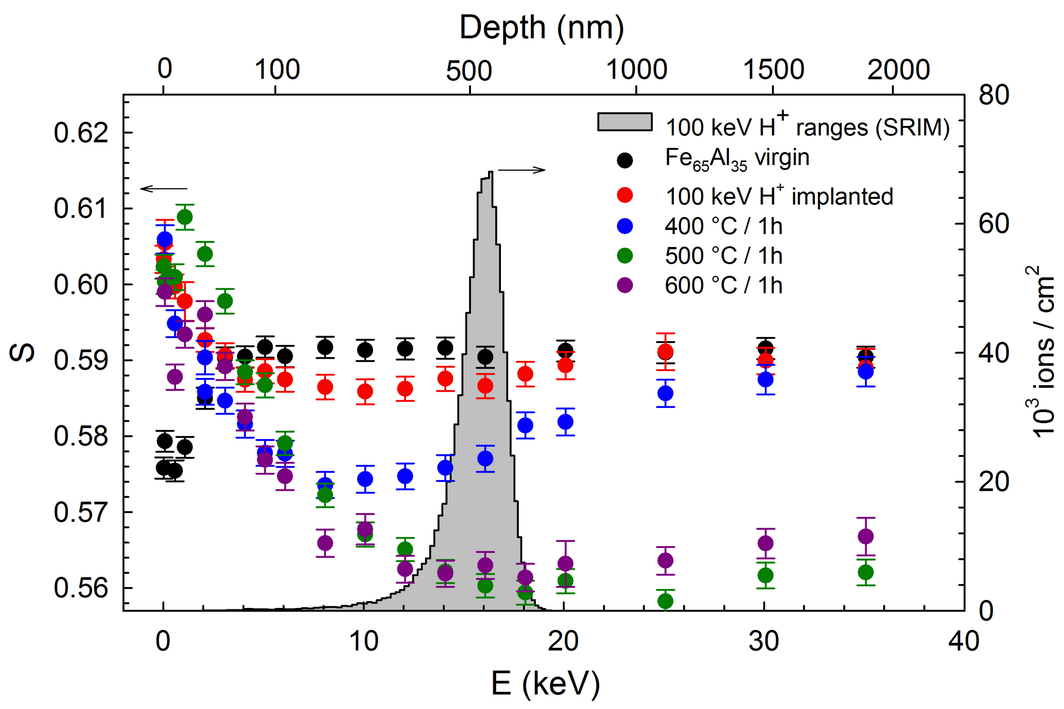


Hydrogen implantation

- $Fe_{73}Al_{27}$ alloy with the low initial vacancy concentration $c_V \approx 4\times10^{-6}$

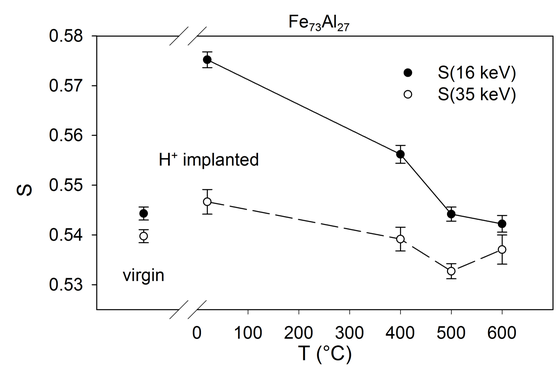


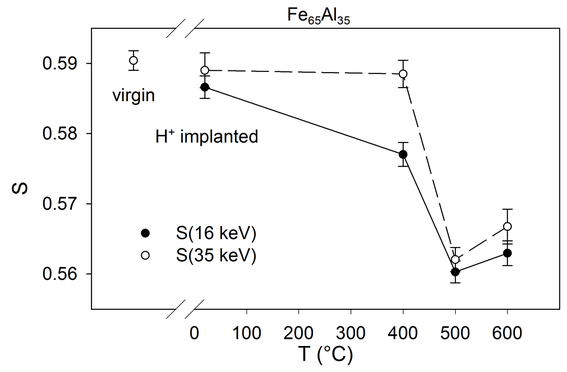
- $Fe_{65}Al_{35}$ alloy with the high initial vacancy concentration $c_V \approx 5\times10^{-3}$

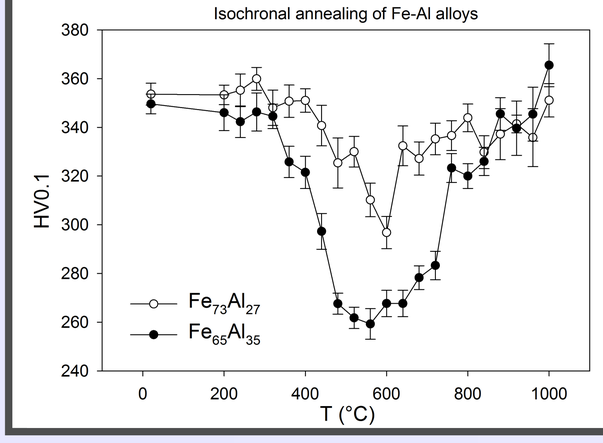


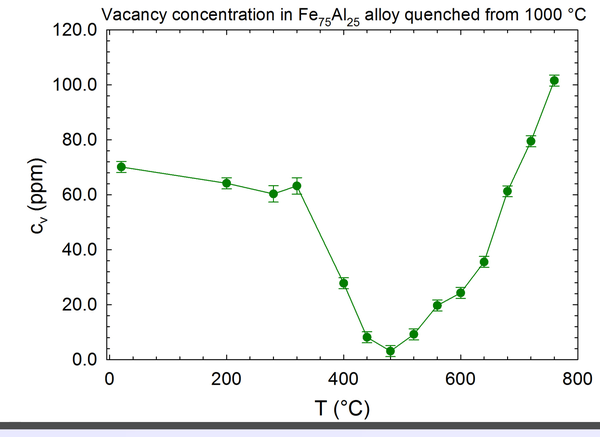
Implanted hydrogen diffuses at 400 °C from implantation region into the sample and fills vacancies which decreases the S parameter due to decreased positron localization. Vacancies anneal out at the temperature 500 °C.

Discussion









Conclusions

Fe-Al alloys implanted by H^+ ions with the energy of 100 keV were studied by VEPAS technique. It was found that H^+ implantation creates vacancy-hydrogen complexes in a sub-surface region. Moreover, trapping of hydrogen at vacancies existing already in sample was observed. The investigation of the thermal stability of defects in H^+ implanted alloys revealed that hydrogen diffusion is activated by annealing at 400 °C leading to a spread of hydrogen concentration profile. Vacancies are annealed out by further annealing at 500 °C.

Acknowledgments

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References

[1] N. Stoloff, et al. *Intermetallics* **2** 75 (1994)