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# INVESTIGATION OF EFFECT OF ANNEALING THE $Fe_{78}Si_9B_{13}$ AMORPHOUS ALLOY USING THE EELS METHOD AND THE HALL EFFECT

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The effect of structural relaxation on the electronic structure of $Fe_{78}Si_9B_{13}$ metallic glass was investigated by means of the Hall effect, electrical conductivity and EELS methods. The effect of the structural relaxations was observed by four-hour annealing of the samples in argon atmosphere at temperatures 573, 673, 723, 773 K. The most distinct changes in the measured quantities were observed for samples annealed at 773 K. The differences in EELS spectrum, a decrease in the electrical and the Hall resistance are specific to these samples. X-ray diffractometry confirmed that the samples annealed at this temperature show recrystallization.

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## 1. Introduction

Freshly produced ribbons of amorphous alloys do not exhibit long-range ordering of the atomic structure. Annealing of metallic glasses at temperatures characteristic of a given composition leads to intense atomic rearrangement with a final result being a crystal state [1, 2].

The aim of this work was to investigate the influence of relaxation processes, caused by annealing of metallic glasses at various temperatures, on their electronic properties.

## 2. Results

Influence of annealing temperature on characteristic electron energy losses (EELS), the Hall effect and resistivity was investigated on samples of amorphous alloy $Fe_{78}Si_9B_{13}$ annealed isothermally for 4 hours at temperatures 573, 673, 723 and 773 K in argon atmosphere.

EELS studies were performed using four-grid retarding potential analyser type OPR-304 RIBER. Energy of electron beam was 200 eV [3]. EELS spectra are shown in Fig. 1. Analysis of the spectra allowed to determine characteristic losses related to excitation of volume plasmons $\Delta E_v$ in particular samples, which are presented in Table.

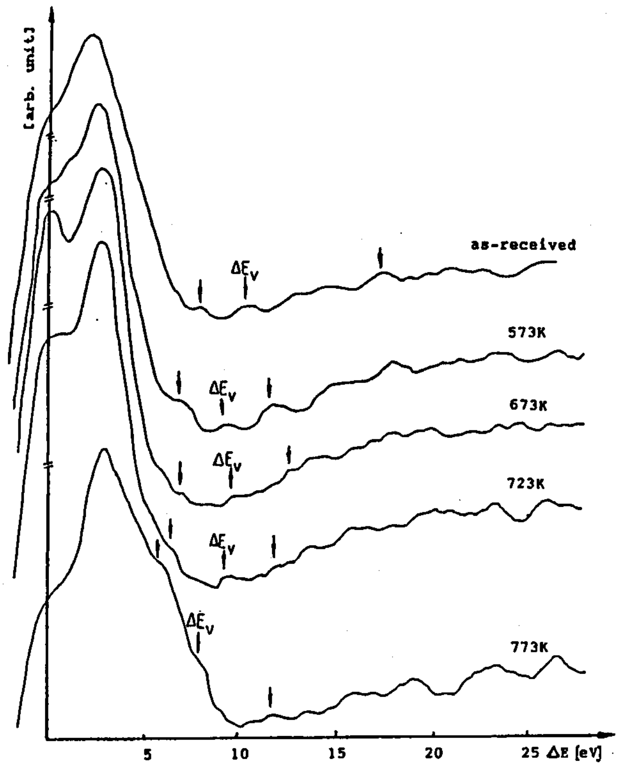


Fig. 1. Spectra of EELS for the $Fe_{78}Si_9B_{13}$ alloy: as-received and annealed at various temperatures.

TABLE

Values of volume plasmon loss energy $\Delta E_v$, ordinary Hall coefficient $R_H$ and electrical resistivity $\rho$ for $Fe_{78}Si_9B_{13}$ alloy annealed at various temperatures and non-annealed.

| | as-received | 573 K | 673 K | 723 K | 773 K |
|---|---|---|---|---|---|
| $\Delta E_v$ [eV] | 10.8 | 9.0 | 9.2 | 9.0 | 8.4 |
| $R_H$ [n$\Omega$ m/T] | 4.21 | 6.22 | 5.00 | 5.06 | 1.28 |
| $\rho$ [$\mu\Omega$ m] | 1.37 | 1.30 | 1.40 | 1.30 | 0.82 |

The Hall effect was investigated at constant magnetic field and constant current in the sample [4]. Results for annealed and non-annealed samples are given in Fig. 2 in the form of the Hall voltage $U_H$ and the Hall resistivity $\rho_H$ dependence on the external magnetic field $B_0$. Using least squares method the slope of the function $\rho_H = f(B_0)$ (for $B_0 > \mu_0 M_s$; $M_s$ — magnetization of saturation), i.e.

the ordinary Hall coefficient [4] was determined. The values of the ordinary Hall coefficient $R_H$ are given in Table. For both annealed and non-annealed samples electrical resistivity was determined and the results are gathered in Table.

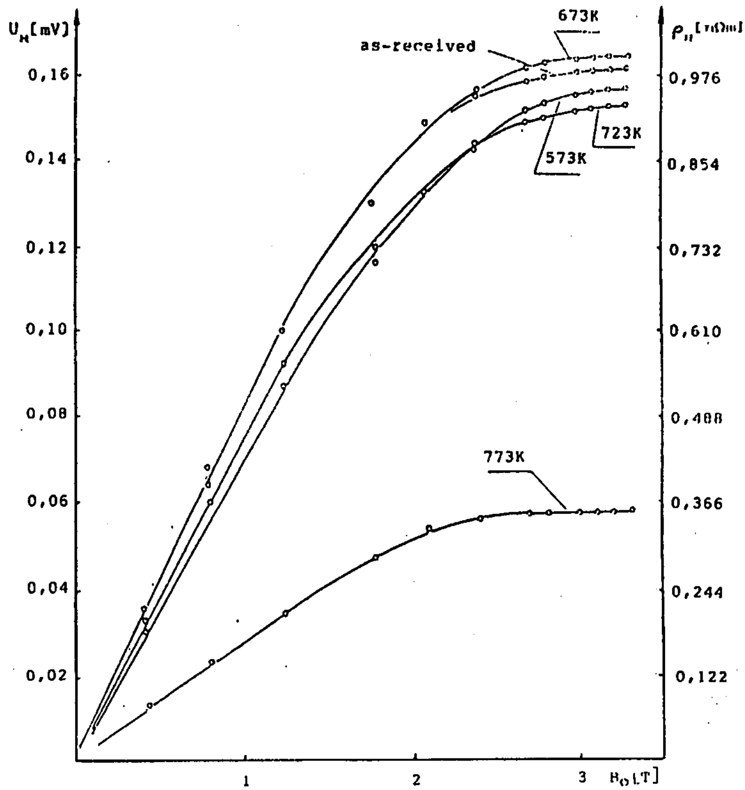


Fig. 2. The dependence of the Hall voltage $U_H$ and the Hall resistivity $\rho_H$ on the applied magnetic induction $B_0$ for the $Fe_{78}Si_9B_{13}$ alloy. 573, 673, 723 and 773 K — annealing temperatures.

The measured quantities show changes caused by annealing and the particularly pronounced effect is observed for sample annealed at 773 K.

In order to evaluate changes in atomic structure induced by annealing, X-ray diffraction studies of annealed and non-annealed samples were performed using a DRON-2.0 diffractometer. The samples were irradiated by $\lambda = 0.071069$ nm radiation from a molybdenum tube. Diffraction patterns for both types of samples are shown in Fig. 3. Diffraction pattern for a sample annealed at 573 K was identical with that for non-annealed sample, thus it is not shown in the picture [5].

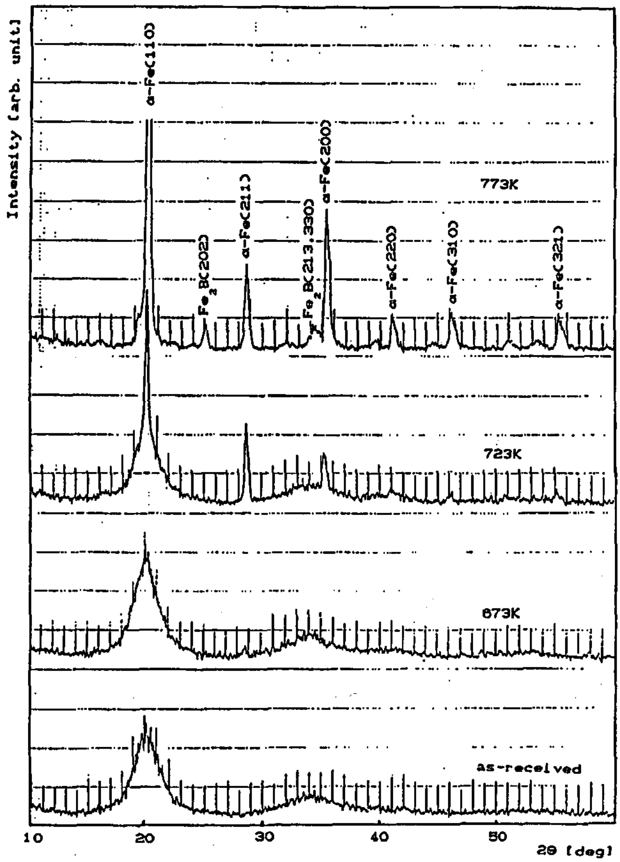


Fig. 3. X-ray diffraction patterns for as-received and submitted to 4 hour annealing samples of amorphous $Fe_{78}Si_9B_{13}$ alloy. 573, 673, 723 and 773 K — annealing temperatures.

## Conclusions

Considerable changes of the measured quantities observed in the annealing temperature range $723 \div 773$ K may be assigned to differences in the atomic structure which, as it was shown in diffraction patterns at these temperatures, show a long-distance ordering. Pronounced changes of the measured electrical quantities for samples annealed at 773 K (in comparison to samples annealed at 723 K) must be related to further crystallization of considerable amount of $\alpha$-Fe phase with a bcc structure and a new phase $Fe_2B$ with a tetragonal structure ($\alpha$-Fe phase starts to arise already at lower annealing temperatures in the range $673 \div 723$ K). Changes of electrical quantities for samples annealed below 723 K may be related to structural relaxations which, as it was shown by the measurements, influence electronic properties of the alloy.

## References

[1] A. van den Beukel, S. Radelaar, *Acta Metall.* **31**, 419 (1983).
[2] M.R.J. Gibbs, J.E. Evetts, J.A. Leake, *J. Mater. Sci.* **18**, 278 (1983).
[3] H.B. Kołodziej, J. Olesik, U. Madałkiewicz, *Acta Phys. Pol. A* **59**, 443 (1981).
[4] E. Jakubczyk, B. Całusiński, *Acta Univ. Lodziensis* **10**, 87 (1987).
[5] J. Filipecki, B. Całusiński, D. Gaudyn, G. Antosik, *Phys. Lett. A* **130**, 52 (1988).