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SOME IRON-BASED METALLIC GLASSES STUDIED BY POSITRON ANNIHILATION

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ABSTRACT

The Fe_{40} Ni_{40} B_{16} P_4; Fe_{40} Ni_{40} P_{14} B_6; Fe_{80} B_{20}; Fe_{32} Ni_{36} Cr_{14} P_{12} B_6 iron-based glassy systems were investigated by positron annihilation methods. Regarding the parameters measured, a pronounced difference in the values referring to amorphous and crystalline phases respectively was found for Fe_{80} B_{20} only. The presence of trapping centres in the amorphous state of Fe_{40} Ni_{40} P_{14} B_6 is assumed on the basis of measurements studying the dependence of the annihilation parameters on the heat-treating temperature as compared with results for well-annealed and deformed crystalline pure metals.

АННОТАЦИЯ

С помощью используемых при измерении аннигиляции позитронов методом исследовались металлические стекла на основе железа Fe_{40} Ni_{40} B_{16} P_4; Fe_{40} Ni_{40} P_{14} B_6; Fe_{80} B_{20}; Fe_{32} Ni_{36} Cr_{14} P_{12} B_6. Отличие в параметрах относительно аморфной и кристаллической фаз было обнаружено только в Fe_{80} B_{20}. Сравнение результатов, полученных для термически обработанных и деформированных кристаллических металлов высокой чистоты, с параметрами позитронной аннигиляции, измеренными в зависимости от температуры термической обработки, позволяет предположить наличие центров захвата.

KIVONAT

A pozitron-annihilációs mérési módszerek segitségével vizsgáltuk a Fe_{40} Ni_{40} B_{16} P_4; Fe_{40} Ni_{40} P_{14} B_6; Fe_{80} B_{20}; Fe_{32} Ni_{36} Cr_{14} P_{12} B_6 vasalapu fémüvegeket. Az eredmények alapján csak a Fe_{80} B_{20} esetében találtunk az amorf, illetve kristályos fázisra vonatkozó paraméterekben határozott különbséget. Hőkezelt és deformált kristályos, nagytisztaságu fémekre vonatkozó eredményekkel összehasonlitva a Fe_{40} Ni_{40} P_{14} B_6-on hőkezelési hőmérséklet függvényében mért pozitron annihilációs paramétereket az amorf fázisban trapping-centrumok jelenlétére következtethetünk.

INTRODUCTION

Recently the investigation of glassy metals has witnessed increasing interest. This is due to the very promising technological properties of glassy metals and the many complex questions they have raised in physics. The structure of such amorphous metals is still a question open to discussion; a problem directly related to this is the existence /abundance, shape, volume, etc./ of "defects".

As from experiments on pure metals it is known and well demonstrated that positron annihilation is a sensitive and powerful tool for defect studies the application of this method seems to be more and more promising for the study of amorphous solids too [1-6]. The field of positron annihilation itself has been extensively reviewed in many books and articles, e.q. [7-9].

EXPERIMENTAL

Our measuring conditions were as follows:

a. The positron lifetime measurements were performed with the conventional fast-slow coincidence systems. The measured spectra were evaluated with the POSITRONFIT EXTENDED program [10] into one component, taking into account the source correction.

b. The measurements of the Doppler-boardening of the annihilation γ-line were carried out with an ORTEC high-purity Ge-detector. From the measured energy distribution the S lineshape parameter-defined as the ratio of the counts in a narrow central portion of the Doppler-broadened peak to the peak area - was calculated.

c. The 2γ-angular correlation measurement was realized on a long-slit geometry device. The measured angular distribution curves were decomposed into two and three components by the [11] PAACFIT program. As positron-source ^{22}Na was used for all measurements.

The most essential experimental characteristics of the above set-ups are summarized in Table 1.

Table 1

Method	^{22}Na source	Resolution	Laboratory
Angular correlation	5mCi, external	0.4 mrad	Budapest
Lifetime	10μCi. Al-foil /1mg cm^{-2}/	340ps/^{60}Co/	Budapest
Lifetime	3μCi, Hostaphan foil /0.33mgcm^{-2}/	320ps/^{60}Co/	Rossendorf
Doppler broadening	"	1.1 KeV at 514 KeV	Rossendorf

All measurements were performed at room temperature. The heat-treatment of the samples was carried out in vacou; the temperature was controlled to ± 5 K.

The conventional sandwich-type source-sample arrangement was utilized for the positron lifetime and Doppler-boadening measurements. The three-layer thick metallic glass samples were prepared by point-welding pieces of ribbon to a stainless steel frame. The iron-based metallic glasses studied by the above methods were $Fe_{80}B_{20}$; $Fe_{40}Ni_{40}P_4B_{16}$, $Fe_{40}Ni_{40}P_{14}B_6$; and $Fe_{32}Ni_{36}Cr_{14}P_{12}B_6$ from Allied Chemicals or produced in Hungary and in the GDR.

RESULTS, DISCUSSION AND CONCLUSIONS

2γ-angular correlation measurements were performed on $Fe_{80}B_{20}$ and $Fe_{40}Ni_{40}P_{14}B_6$ amorphous alloys. A typical result for $Fe_{40}Ni_{40}P_{14}B_6$ is shown in Fig. 1.

From the computer analysis of the measured curves it was found that only ill-fitting of the curves is achievable following the conventional assumption that they consist of two components, one of Gaussian form, originating from positron annihilation with core electrons, and one of parabolic shape, resulting from annihilation with valence electrons. No better fit was obtained when assuming a third component representing a localization of the positron before annihilation as in the case of pure metals containing defects. This fact indicates a substantial difference in the electronic structure of amorphous alloys compared with that of materials of crystalline structure.

In order to establish the most sensitive part of the distribution of the annihilation γ-line for producing the S-parameter, a difference of the annihilation γ-lines referring to $Fe_{40}Ni_{40}P_{14}B_6$ and Fe single crystal respectively was evaluated and is shown in Fig. 2. On base of this result for the calculation of the S-parameter a narrow central portion /corresponding to ± 1.5 mrad in the angular correlation measurements/ was selected.

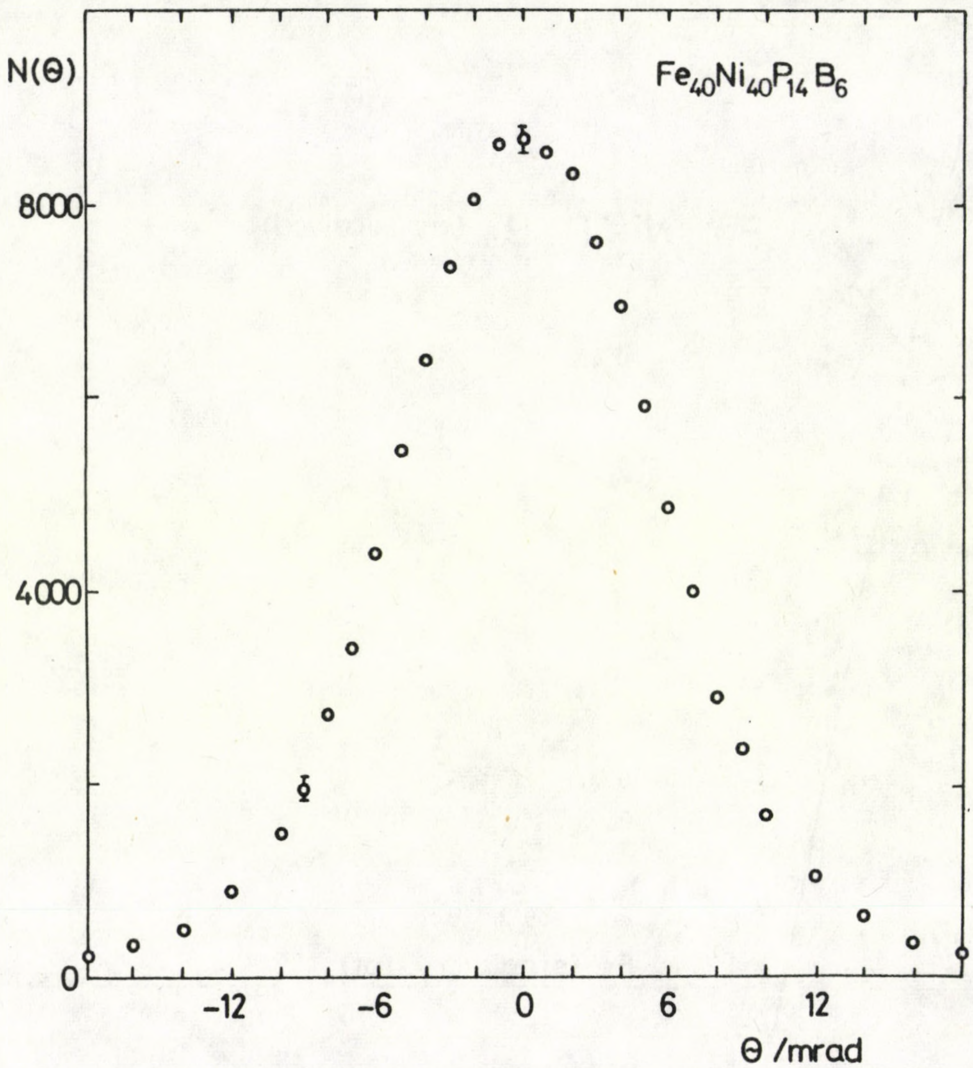

Fig. 1. 2γ-angular correlation spectrum measured for Fe_{40} Ni_{40} P_{14} B_6.

Measurements of the positron lifetime and Doppler-broadening of the annihilation γ-line were also used to investigate the effect of crystallization on the positron annihilation parameters. The results are summarized in Table 2.

A pronounced difference in the values referring to amorphous and crystalline phases respectively was found only for $Fe_{80}B_{20}$.

As earlier results indicated temperature dependent positron annihilation characteristics in the amorphous state of some metallic glasses it was decided to carry out measurements on one metallic glass in a broader temperature range.

Fe_{40} Ni_{40} P_{14} B_6 was selected because of sample-preparing considerations /it was a ~ 15 mm wide ribbon/.

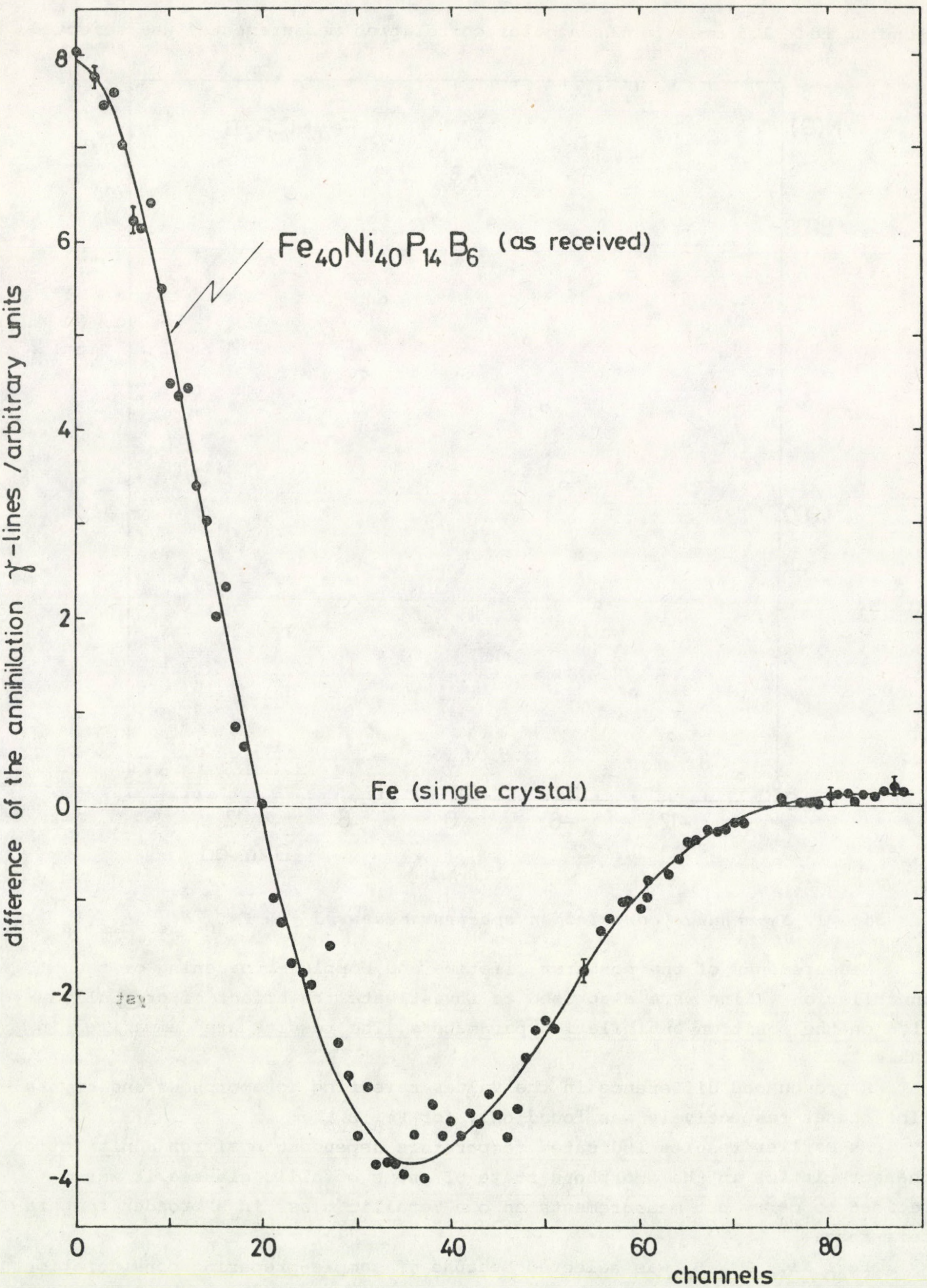

Fig. 2. The difference of the annihilation γ-line for Fe_{40} Ni_{40} P_{14} B_6 as referred to the one measured for Fe single crystal.

Table 2

	$Fe_{80}B_{20}$	$Fe_{40}Ni_{40}B_{16}P_4$	$Fe_{40}Ni_{40}P_{14}B_6$	$Fe_{32}Ni_{36}Cr_{14}P_{12}B_6$
$\frac{S_c-S_a}{S_c}$ /%	-2 ± 0.5	0 ± 0.5	0 ± 0.5	0 ± 0.5
$\tau_c-\tau_a$/ps	-8 ± 3	2 ± 3	2 ± 3	-2 ± 3

Table 2. Difference between amorphous and crystalline phase of some metallic glasses measured by positron annihilation methods. The index c and a denote the crystalline and amorphous state respectively.

Figure 3/a presents the results of the Doppler-broadening measurements compared with those of pure, crystalline and polycrystalline, well-annealed and deformed Fe-samples.

The S-parameter values for the metallic glass considerably exceed those of the pure Fe even after substantial deformation.

Regarding the effect of heat-treatment of the S-parameter an increase of ~ 1% is observed at ~ 380 K which disappears at ~ 480 K; above this temperature the value of the S-parameter remains constant, independent of phase.

The results of lifetime measurements are shown in Fig. 3/b. The τ-values do not present such a conclusive picture as given above and a trend similar to that in Fig. 3/a is not observable.

The complexity of the amorphous state is indicated by the positron annihilation parameters measured in the amorphous and crystalline state of metallic glasses producing a significant difference in some, while in others no such difference is observed.

The higher mean values of the S-parameter and lifetime compared with values related to well annealed Fe-samples might show the presence of trapping centres /possible holes/ in the amorphous state of $Fe_{40}Ni_{40}P_{14}B_6$.

The temperature dependence of the S-parameter values might indicate a change in structure or in the trapping process in the temperature range 350-450 K.

As at present, there is no general description of positron annihilation in the amorphous solid state further systematic studies in a much broader temperature range - also below room temperature - under well-controlled conditions are necessary and are in progress.

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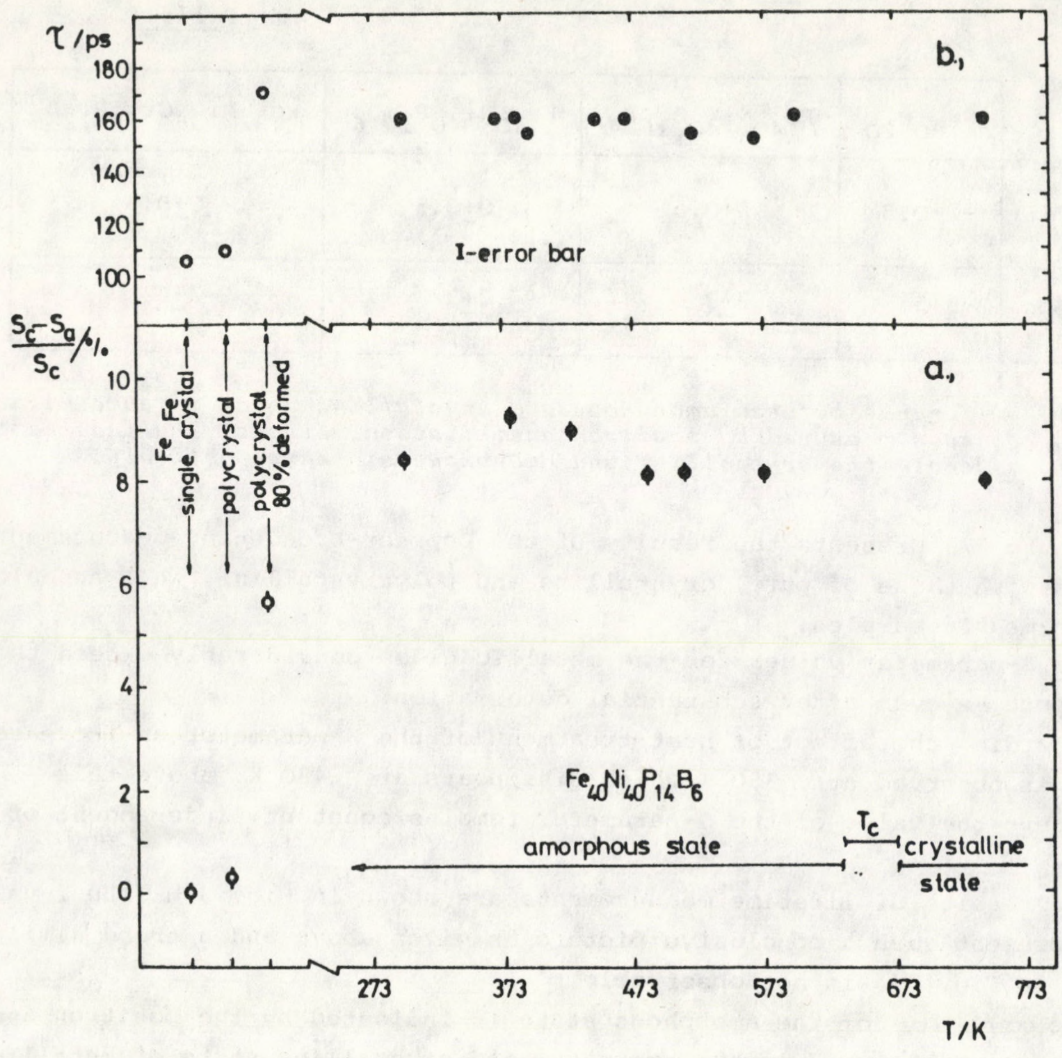

Fig. 3/a S-parameter values referring to Fe and $Fe_{40}Ni_{40}P_{14}B_6$ in dependence on heat-treating temperature

Fig. 3/b The positron lifetime values as measured in Fe and in $Fe_{40}Ni_{40}P_{14}B_6$ in dependence on heat-treating temperature

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