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Z. KAJCSOS
G. BRAUER

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METALLIC GLASSES STUDIED BY POSITRON ANNIHILATION

Z. Kajcsos, G. Brauer*

Central Research Institute for Physics
H-1525 Budapest 114, P.O.B. 49, Hungary

*Zentralinstitut für Kernforschung, Rossendorf
8051 Dresden, Pf. 19, DDR

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АННОТАЦИЯ

Методом позитронной аннигиляции изучались металлические аморфные сплавы $Fe_{40}Ni_{40}B_{16}P_4$, $Fe_{40}Ni_{40}P_{14}B_6$, $Fe_{80}B_{20}$, $Fe_{32}Ni_{36}Cr_{14}P_{12}B_6$. Согласно измеренным параметрам только в случае $Fe_{80}B_{20}$ найдено значительное различие аморфной и кристаллической фаз. На основе измерений, в ходе которых изучалась зависимость аннигиляционных параметров от температуры термообработки, сравнивая при этом с результатами, полученными для термически хорошо обработанных и деформированных кристаллических чистых металлов, в аморфном состоянии металлического стекла $Fe_{40}Ni_{40}P_{14}B_6$ предложено наличие центров захвата.

KIVONAT

Pozitron annihilációval 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. Ami a mért paramétereket illeti, csak a $Fe_{80}B_{20}$ fémüveg esetében találtunk jelentős különbséget az amorf és kristályos fázisok jellemzői között. A $Fe_{40}Ni_{40}P_{14}B_6$ amorf állapotában csapdahelyek jelenlétét tételezzük fel azon mérések alapján, amelyek során az annihilációs paraméterek hőkezelési hőmérséklettől való függését vizsgáltuk, összehasonlitva a jól hőkezelt és deformált kristályos tiszta fémekre vonatkozó eredményekkel.

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.

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 [1-5]. The field of positron annihilation itself has been extensively reviewed in many books and articles, e.g. [6-8].

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 into one component, taking into account the source correction.

b. The measurements of the Doppler-broadening 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 /corresponding to ± 1.5 mrad in the angular correlation measurements/ 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 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 vacuum; the temperature was controlled to ± 5 K.

The conventional sandwich-type source-sample arrangement was utilized for the positron lifetime and Doppler-broadening 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 $Fe_{80}B_{20}$;$Fe_{40}Ni_{40}P_{4}B_{16}$;$Fe_{40}Ni_{40}P_{14}B_{6}$; and $Fe_{32}Ni_{36}Cr_{14}P_{12}B_{6}$. Some of the samples were purchased from Allied Chemicals,some of them were produced in different laboratories.

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. 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.

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/.

Figure 1/a presents the results of the Doppler-broadening measurements compared with those of pure, crystalline and polycrystalline, well-annealed and deformed Fe-samples.

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 letters c and a denote the crystalline and amorphous state, respectively.

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 on 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.1/b. The τ-values do not present such a conclusive picture as given above and a trend similar to that in Fig.1/a. is not observable.

The complexity of the amorphous state is indicated by the positron annihilation parameters measured in the amorphous and crystalline states 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.

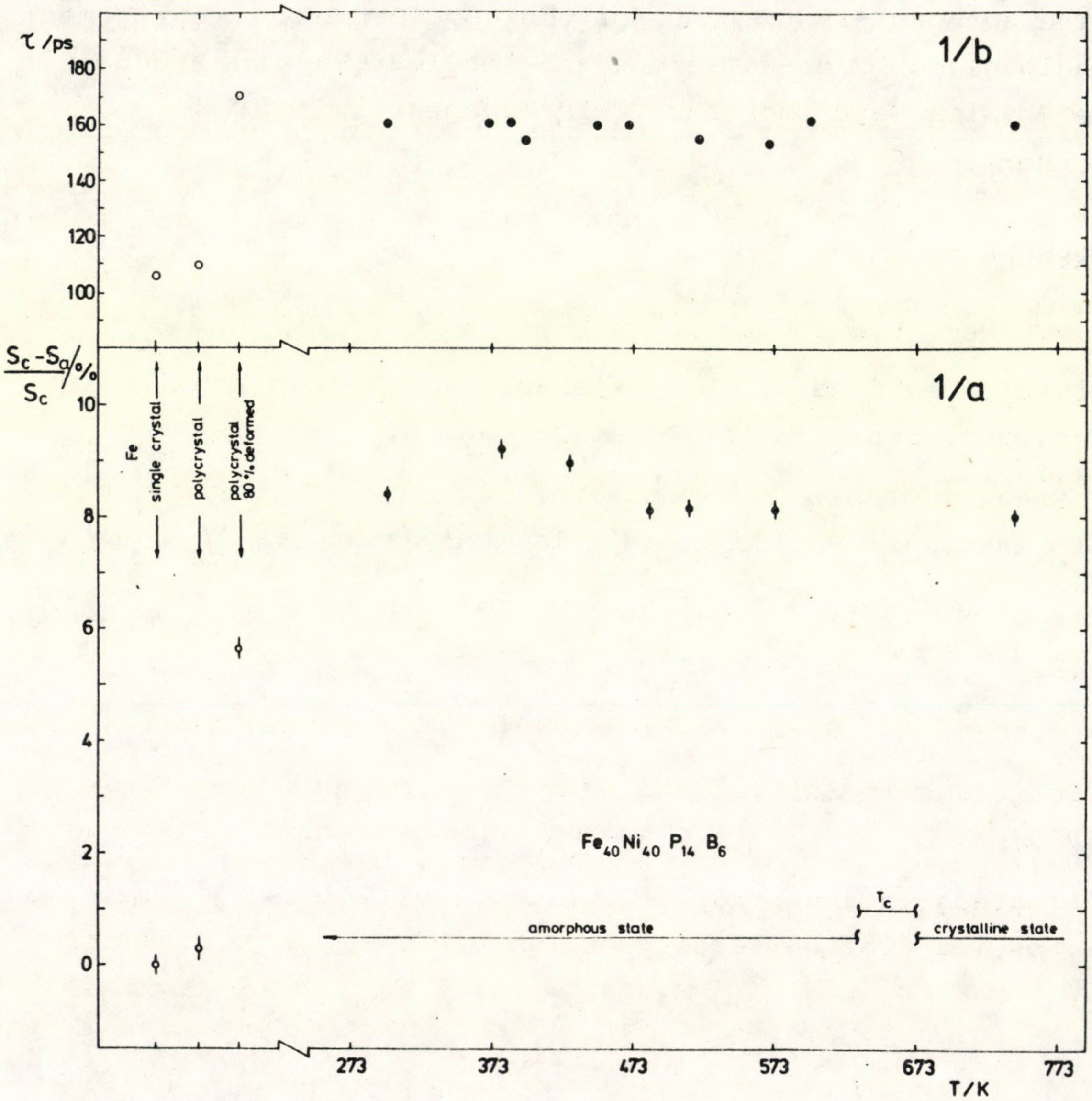

Fig.1/a. S-parameter values referring to Fe and $Fe_{40}Ni_{40}P_{14}B_6$ *in dependence on heat-treating temperature;*
Fig.1/b. The positron lifetime values as measured in Fe and in $Fe_{40}Ni_{40}P_{14}B_6$ *in dependence on heat-treating temperature.*

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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