Are the stacking faults in Cu-Zn-Al able to trap positrons

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Abstract The phase transformation of Cu-23 at.%Zn-11 at.% Al alloy from about 5°C to 25°C has been studied by means of the positron annihilation and transmission electron microscope. It is shown that the stacking faults in the alloy have no remarkable effect on the trapping of positrons.

Keywords Positron annihilation, Transmission electron microscope, Copper-based Alloy, Stacking faults

1 Introduction

It is well known that up to now nearly all of metallic materials and their microstructures have been studied using the positron annihilation technique (PAT). The examination of various microstructures by PAT is an important field in materials science because it can be used as references for many other experimental and analytical methods. Especially, PAT is sensitive to microdefects in metals, such as vacancies, dislocations, vacancy clusters, fine particles (grains), as well as gas, impurities, fine precipitates, phase transformations, order-disorder transitions and so on.[1] Any small departure from perfect lattices may result in a remarkable change in the annihilated parameters of positron-electron pairs.

Stacking fault is also a kind of defects that is often encountered in metals. However, information that whether or not stacking faults trap positrons is very little in the literature. Although as early as 1979 Dlubek *et al.*[2] suggested that the positron method does not respond to interstitial atoms and stacking faults, the direct experimental evidences for it have not been found.

This letter gives the experimental results of the effect of stacking faults in material on the trapping of positrons by PAT and the transmission electron microscope (TEM).

2 Experimental procedure and results

2.1 Instruments

The solid state detector used for measuring Doppler energy spectra was a high purity germanium (EG&G ORTEC). The measuring system's energy resolution (FWHM) was about 1.8 keV at 1.332 MeV of γ-ray from ^{60}Co. The top count of each 0.511 MeV broadened peak was 2×10^4. The measured peaks were characterized by the S-lineshape parameter which was defined as a count ratio of the central part to the wings of each peak. The positron source was sandwiched ^{22}NaCl with an activity of 0.37 MBq. TEM (H-700) was used, which operated at a voltage of 200 kV.

A conventional fast-fast coincidence system (EG&G ORTEC) was employed for measuring lifetime spectrum. Its time resolution (FWHM) was 253 ps. The total count of each spectrum exceeded 10^6. The lifetime spectra were fitted by using a " Extended-positronfit" program. All the spectra were resolved into four components, in which τ_2 was attributed to the annihilation from defects, τ_3 and τ_4 were associated with the annihilation from positron source and surfaces of specimens and were not dealt with in the following due to the their small intensity.

2.2 Alloy

The alloy used in this experiment was a strip of Cu-23at.%Zn-11at.%Al. The strip was treated at 750°C for 5 min then, quenched and manufactured into the elements showing two-way shape memory effect through training. As well known, the elements offer thermoelastic martensite transformation containing stacking faults. Observations by an optical microscope

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showed that the elements consisted of martensite at room temperature.

2.3 Experimental procedure

The specimens were electric-spark-cut from the elements. The size of the specimens for PAT measurements was 8 mm wide and 10 mm long. The foil used for TEM observation was prepared by thinning with sand papers and then twin jet.

Doppler energy peaks were measured at about 5°C and 25°C, respectively. The same measurements were made three times and their *S*-parameters were listed in Table 1, which shows that *S*-parameters do not change with temperature within the measurement error of the instruments.

Table 1 *S*-parameters for Cu-23at.%Zn-11at.%Al alloy

No	5°C	25°C
1	1.074	1.069
2	1.068	1.075
3	1.073	1.075

The lifetime spectra at about 5°C and 25°C of the above specimens also measured. The results obtained by fitting the measured data were shown in Table 2 and Table 3, respectively.

It can be seen from Tables 2 and 3 that the lifetime parameters ($\overline{\tau}$, τ_i, and I_i) at the two temperatures are basically the same. The long lifetimes τ_2 are very close to the typical lifetime of vacancies in metals, indicating that the specimens used may contain a small quantity of vacancies.

Table 2 The results of the lifetime spectrum about 5°C

Average lifetime/ps	$\overline{\tau}$=140	
Lifetime component/ps	τ_1=131	τ_2=192
Intensity of lifetime component/%	I_1=85	I_2=15

Table 3 The results of the lifetime spectrum at about 25°C

Average lifetime/ps	$\overline{\tau}$ =141	
Lifetime component/ps	τ_1=132	τ_2=195
Intensity of lifetime component/%	I_1=86	I_2=14

Fig.1 and 2 show the TEM micrographs of Cu-23at.%Zn-11at.%Al alloy at about 5°C and 25°C, respectively. For comparison, the TEM observations were made under exactly the same conditions — the same field and the same magnification. After taking the micrograph of Fig.1, the same foil was heated in situ by electron beams, leading to a temperature rise of about 20°C and a corresponding change in microstructure. Fig.2 was the micrograph taken from the heated foil.

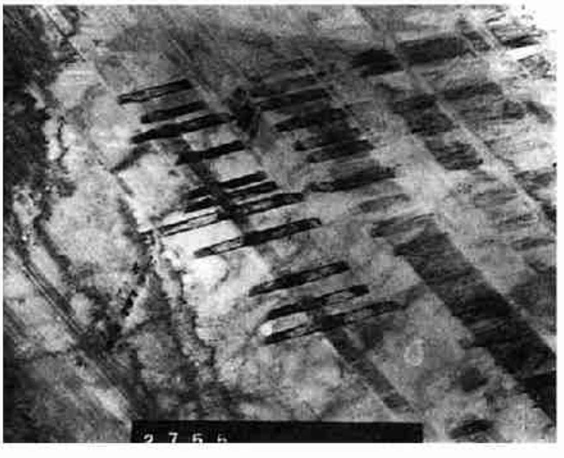

Fig.1 TEM micrograph of Cu-23at.%Zn-11at.%Al alloy at about 5°C(×12000)

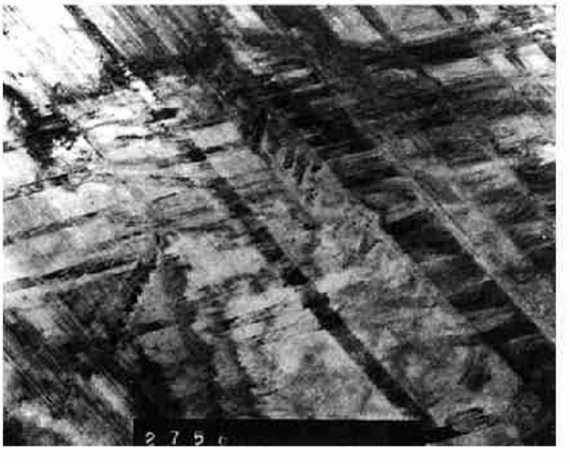

Fig.2 TEM micrograph of Cu-23at.%Zn-11at.%Al alloy at about 25°C(×12000)

3 Discussion

It has been known that Cu-Zn-Al alloy is complicated in compositions and phase transformations. Before discussing the influence of stacking faults on positron annihilating, we should first have a clear understanding of the sampling sites of positrons in the alloy. In most cases, the following aspects are required to be considered when phase transformations in metals are studied by PAT: (1) a trap at the defects induced by phase transformations such as vacancies and dislocations; (2) a trap at the interfaces between new phase and parent phase; (3) a stronger affinity of positrons to the region rich in some kind of atoms; (4)a localization of positrons at a new phase with different composition or structure.

First, Cu-Zn-Al shape memory alloys generally contain a large number of quenched vacancies. But the supersaturated vacancies induced by quenching must have been substantially eliminated because the specimens have been annealed at low temperature during the preparations of the elements prior to positron annihilation measurements. Since the intensities of the long lifetimes in Tables 2 and 3 account for 14%~15% of the total intensity only, the vacancies in the specimens are not main sampling sites.

Second, from Figs.1 and 2, it can be seen that the sizes of the martensite variants are larger than the positron diffusion length, implying that the interfaces between martensite and parent are not the centers of trapping positrons.

Third, Figs.1 and 2 show no precipitates in the Cu-Zn-Al alloy (yet, there were precipitates of $Ti_{11}Ni_{14}$ in Ti-Ni shape memory alloy) and, therefore, there is no region rich in some kind of atoms.

Now, the only factor affecting positron annihilation is stacking faults. So they must be the major sites of positrons annihilation.

By comparing Figs.1 with 2, it is found that with the rising of temperature both the microstructure and the stacking faults of the alloy changed greatly, but the parameters (Tables 1, 2, and 3) of positron annihilation dominated by the stacking faults basically remain unchanged. Obviously, it may be said that the stacking faults in Cu-23at.%Zn-11at.%Al alloy have no positron trapping effect. The authors think that this is because although stacking faults are a kind of detects, they result from alternation of arrangement of atom planes instead of absence of atoms, in which there are not centers of negative and thus not trapping efffect.

4 Summary

Stacking faults are a kind of defects often observed in metals and alloys. Whether or not stacking faults trap positrons and affect the annihilating of positrons is important for practical applications of PAT. The present letter gave the direct experimental evidence that the stacking faults in Cu-23at.%Zn-11at.%Al alloy have no remarkable effect of trapping positrons.

References

1 West R N. In:Hautojarvi ed. Positron in solids. London:Springer-Verlag, 1979.89

2 Dlubek G, Brummer O, Alam Ashraful. Phys Stat Sol, 1979, **52**(a):217