# A study of quenched CuZnAl Alloy by positron

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**Abstract** Cu-23 at.%Zn-11 at.% Al alloy has been studied by positron annihilation technique. It is shown that the defects in the alloy induced by quenching from the temperature above $\alpha$-transformation are basically monovacancies, instead of other forms of defects.
**Keywords** Positron annihilation, Copper-based alloy, Vacancy

## 1 Introduction

CuZnAl alloy is one of most potentially functional materials showing shape memory effect. Because of their complicated microstructures and the problem of thermoelastic martensite stabilization, the alloys have been extensively studied by various techniques. The past publications show that positron annihilation technique (PAT) is able to give helpful information for the investigation of CuZnAl alloys' microstructures.[1~5]

As well known the first step, by which the shape memory effect could be attained, must be the quenching from high temperature where CuZnAl is in parent phase. And the microstructures (especially defects) created by the quenching is most important to the evolution of the alloy, for example, which may affect the properties of one-way or two-way shape memory elements and even result in thermoelastic martensite stabilization. However, the papers related to the quenching from high temperature by PAT were hardly seen in literatures. In this letter we shall show a result of the CuZnAl alloy quenched from high temperature using PAT.

## 2 Experimental procedure and results

Positron source was sandwiched $^{22}$NaCl with an activity of about $3.7\times10^5$ Bq. Doppler broadening measurements were performed by a highly pure germanium (EG&G ORTEC) which had an energy resolution (FWHM) of 1.8 keV at 1.332 MeV $\gamma$-ray of $^{60}$Co. Maximum of counts of each broadened 511 keV peak was $2\times10^4$. The peaks were characterized by a conventional $S$-lineshape parameter, which was defined as a ratio of counts in the central portion to the wings of the peak. Positron lifetime spectrometer was a fast-fast coincidence system with a time resolution (FWHM) of 250 ps. Total counts of each lifetime spectrum is more than $10^6$.

The shape memory alloy used was a sheet of Cu-23at.%Zn-10at.%Al with a thickness of about 1 mm. The examination with optical microscope found that the alloy's temperature of $\alpha$-transformation was below 600°C.

1) Six pairs of the samples were treated in a furnace at 900°C, 800°C, 750°C, 700°C, 650°C, 600°C for 5 min respectively. The samples were taken out of the furnace and quenched into the water at room temperature (RT) one by one. The last pair of the samples was furnace-cooled to RT. All the samples were taken out of water, dried with ethyl alcohol, and then measured immediately.

Table.1 shows the $S$-lineshape parameters for the samples at different quench tempera-

**Table 1** $S$-parameters of Doppler broadening peaks as a function of quench temperature for Cu-23at.%Zn-10at.%Al alloy

| Quench temperature/°C | $S$ parameter |
|---|---|
| RT | 1.060 |
| 600 | 1.080 |
| 650 | 1.098 |
| 700 | 1.120 |
| 750 | 1.141 |
| 800 | 1.160 |
| 900 | 1.190 |

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tures, including the pair furnace-cooled to RT.

2) Three pairs of samples, lifetime spectra were also measured and their quenching temperatures were RT, 700°C and 900°C, respectively. Computer program of fitting was "Extended-Positronfit". The spectra were decomposed into two lifetimes. The long lifetime $\tau_2$ represented the component from the annihilating of positrons at defects. The variances of the fitting were smaller than 1.5. The resolved lifetime parameters are listed in Table 2.

**Table 2** The resolved parameters of lifetime spectra for Cu-23at.%Zn-10at.%Al alloy

| Temperature/°C | RT | 700 | 900 |
|---|---|---|---|
| Mean lifetime/ps | $\bar{\tau}$=134 | $\bar{\tau}$=168 | $\bar{\tau}$=177 |
| Long lifetime/ps | | $\tau_2$=186 | $\tau_2$=185 |
| Intensity of long lifetime | | $I_2$=83% | $I_2$=95% |

## 3 Discussion

(1) The $S$-parameters of Table.1 are marked by black dots in Fig.1. Suppose that Cu-23at.%Zn-10at.%Al alloy only contains a kind of defects-vacancies trapping positrons. Based upon the positron trapping model[6~8], the $S$-parameter as a function of absolute temperature should be written as:

$$S = \frac{S_f \cdot \lambda_f + S_v \cdot \mu \cdot C_v}{\mu \cdot C_v + \lambda_f} = \frac{S_f \cdot \lambda_f + S_v \cdot \mu \cdot A \cdot^{-E/kT}}{\mu \cdot A \cdot e^{-E/kT} + \lambda_f} \qquad (1)$$

where $S_f$ is the $S$ from all positrons annihilating in perfect lattice, $\lambda_f$ the annihilation rate of free positrons, $S_v$ the $S$ from all positrons annihilating in vacancies, $\mu$ the specific trapping rate, and $C_v(=A \cdot e^{-E/kT})$ the vacancy concentration. It is evident that the $S$-parameters in Table.1 could be fitted by formula (1), as shown by the dashed line in Fig.1 (The quenching below 600°C was not done in this letter since the alloy will undergo the transformation of disorder-order at about 100~550°C).[9] The fact implies that after quenching from 600~900°C the defects remained in Cu-23at.%Zn-10at.%Al alloy consist of vacancies basically. Otherwise, it is impossible for the dependence of $S$-parameters on temperature $T$ to be well in agreement with formula (1).

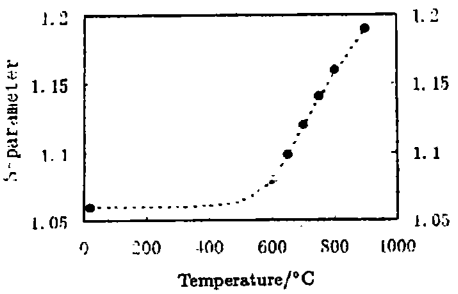


**Fig.1** The $S$-parameters of Cu-23at.%Zn-10at.%Al quenched from different temperatures
• the measured, ----the fitted

(2) Tabel 2 shows that the long lifetimes of the samples quenched from 700°C and 900°C are similar to the lifetime of vacancies in most metals. This further proves that the alloy quenched from high temperature includes lots of vacancies, instead of other forms of defects.

(3) Based on the fitting to Fig.1, the vacancy concentration $C_v$ of Cu-23at.%Zn-10at.%Al alloy after quenching from different temperatures has been estimated, as shown in Table 3.

**Table 3** The estimated vacancy concentration at different quench temperature for Cu-23at.%Zn-10at.%Al alloy

| quench temperature/°C | vacancy concentration |
|---|---|
| 600 | $7\times10^{-6}$ |
| 650 | $1\times10^{-5}$ |
| 700 | $3\times10^{-5}$ |
| 750 | $5\times10^{-5}$ |
| 800 | $8\times10^{-5}$ |
| 900 | $2\times10^{-4}$ |

## 4 Summary

Cu-23at.%Zn-10at.%Al alloy has been studied by PAT. The defects in the alloy induced by quenching from the temperature above $\alpha$ -transformation are basically monovacancies, whose concentrations were estimated, as listed in Table 3.

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