CHARACTERISTICS OF THE BULK POSITRON LIFETIME IN Cu-Zn ALLOY

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ABSTRACT:

Experimental characterization of positron lifetimes spectroscopy for ulk states are considered in Cu-Zn binary alloys system with concentrations of 5%, 15%, 23%, 37% and 52% weight percent of Zn for the first time. The general trend exhibits the same behavior in all cases, in which the bulk positron lifetimes vary little with alloys composition. The bulk annihilation rates of the Cu-Zn alloys cannot be represented by a linear relationship throughout the entire concentration range including all phases. The positrons are not equally likely to be anywhere in the crystal, but there is a preferential positron trapping at Zn site rather than Cu sites.

1 -INTRODUCTION

In metals, positrons may be trapped by lattice defects, such as, vacancies, vacancy clusters and dislocations. Positrons being localized at these defects experience a lower electron density than the average, which results in distinct increases of trapped positrons lifetime.

In a binary alloys system, when the concentration of one constituent atom is varied, the alloy passes through a number of different crystal structures. Positrons annihilation in such alloys will generally not take place with the electrons of each sort of atom in proportional to the concentration, but it will be significantly affected by the relative positron affinity of the constituent atoms [1].

Polly-crystalline of Co-Si alloy samples with different Si content were studied by positron annihilation lifetime [2]. The results were interpreted in terms of the average electron density over the entire range of Si-concentration including various phases.
Ortega and del Rio [3] have studied the precipitation process of Mg-Ca by positron lifetime and Doppler broadening . They showed that the positron affinity at a cell in a binary alloy depends on the two types of cells. In the case of positron preference for one type of atoms, the annihilation parameter values are biased toward that type of atom. The theoretical calculations have showed that the positron density enhancement effect [4,5,6] should be small where solute atoms are well dispersed, but when enhancement effect are more pronounced. This means that they have arisen from clustering or segregation effects. The appearance of long clustering of one constituent atom may lead to additional complications [7].
The present work was undertaken to study the positrons lifetime in Cu-Zn alloy system as a function of zinc concentration. It may provide some information about the characteristics of

the bulk lifetime of positrons when the aforementioned; binary alloy is passing through different phases.

2-EXPERIMENTAL PROCEDURE

Polly-crystalline rods of Cu-Zn alloy of 5%, 15%, 23%, 37%, and 52% wt percent of Zn with a diameter of 20 mm were cut into sets of discs each with 3 mm thickness. The samples were polished and their contents were checked quantitatively by Energy Dispersion x-ray Spectroscopy (EDS), and then were annealed in an evacuated quartz tub at 750 C° for six hours. They were then heat-treated at 200 C° for 24 hours. The surfaces of the samples were mechanically polished and cleaned by alcohol and then dried.

The positron lifetime was measured for each of the samples by a conventional fast slow-timing coincidence system with RCA-photo-multiplier and KL236 plastic scintillation. The resolution function was approximated by a Gaussian function having (FWHM) of 418ps for ^{22}Na energy window using ^{60}Co at 40% energy window. The time window for the coincidence of the start and stop in the triggering circuit was established by simple cable delay (~5m) [8]. A positron source of ^{22}Na with activity of about 21μCi was prepared by evaporating a few drops of NaCl on aluminum foil of 5 microns thickness and was covered with another Al foil of the same thickness. The source was sandwiched in between the two Al-foils. More experimental details are described in ref. [9]. The positron lifetime spectrum was analyzed by POSITRONFIT computer program [10]. All positron lifetimes' measurements were performed at room temperature.

3-RESULTS AND DISCUSSION

The positron lifetimes corresponding to the bulk states for different alloys phases are given in Table (1). In free positron annihilation limit, the annihilation rates for Cu-Zn binary alloys should be expressed by the annihilation rates for Cu and Zn components as [11];

$$\lambda^{Cu\text{-}Zn} = \lambda^{Cu} + (\lambda^{Zn} - \lambda^{Cu})\, C^{Zn} \qquad \text{------------------------} \quad (1)$$

Where $\lambda^{Cu\text{-}Zn}$ λ^{Cu} , λ^{Zn} and C^{Zn} are the bulk annihilation rates of the binary alloy, the Cu, the Zn annihilation rates of pure metals and the concentration of Zn in the alloy sample respectively. The observed relationship was assumed to be linear and was fitted to the equation:

$y = a + bx$

Using the measured values of the positron rates in pure copper and zinc [9].

$\lambda^{Cu} = 7.576 \pm 0.115\ ns^{-1}$

$\lambda^{Zn} = 6.330 \pm 0.040\ ns^{-1}$

The best fit of the data points in the α-phase region yielded:

$\lambda^{Cu} \quad = 7.579 \pm 0.005\ ns^{-1}$

$\lambda^{Zn} - \lambda^{Cu} = -1.195 \pm \qquad ns^{-1}$

The linear interpolation slop between the two pure metals is $\lambda^{Zn} - \lambda^{Cu} = -1.247 ns^{-1}$ and the measured annihilation rate of copper $\lambda^{Cu} = 7.576\ ns^{-1}$ is in good agreement with the fitted values. The data points in α–phase region can therefore be represented well in terms of the free positron annihilation limit as shown in Fig. (1). This result indicates that the positrons are sampling all the region of the crystal equally. If all experimental points with various phases are considered as showing in Fig. (2), the fit yielded:

$b = -0.784 \pm 0.100\ ns^{-1}$
$a = 7.546 \pm 0.029\ ns^{-1}$

The result shows that the experimental slope is deviated from the interpolation slope between the two pure metals by 0.453 ± 0.152. This indicates that the experimental point of the various phases cannot be represented in terms of the free positron annihilation limit. The latter suggest that positrons are not equally likely to be any where in the crystal, but it avoids the core region. It is expected that positrons may prefer one sort of the two atoms Cu or Zn.
Stott and Kobica [12] postulated that the lifetime of the bulk state in binary alloys containing two sorts of atoms A and B in relation of the bulk positron lifetime for the two pure metals constituent is given by:

$$\tau^{AB} = \frac{\tau^A \tau^B}{C^A \phi^A \tau^B + C^B \phi^B \tau^A} \qquad (2)$$

Where C^A and C^B are the atomic fraction of the constituent cells A and B respectively, ϕ^A and ϕ^B are the positron affinity factors such that:

$\phi^A + \phi^B = 2$ and $\phi^A > 1$ implies that positrons prefer atom A. In terms of the annihilation rates, equation (2) becomes;

$$\lambda^{AB} = \lambda^A \phi^A + C^B(\lambda^B \phi^B + \lambda^A \phi^A) \qquad (3)$$

The fitting of the data according to equation (3) with all the experimental points including different phases of the alloy shows that the value of ϕ^{2n} is 1.040 ± 0.020, where a value of 0.960 ± 0.020 was assigned to ϕ^{cu} .This result indicates that the positrons prefer Zn sites on Cu sites.
It may be concluded that in terms of the free positron annihilation limit, the annihilation rates for Cu – Zn alloys of different phases cannot be described by a straight line throughout the full range of Zn concentration, but the linear behavior of λ_f appears for the Cu–rich α-phase only .In the view of the pseudo-potential theory, the annihilation rates of Cu – Zn alloys of different phases concentration of Zn can be represented by a linear Relationship throughout the full concentration range including different phases. The bulk lifetime of the positrons in Cu–Zn alloys of different Zn concentration was measured and found to be from 133 ± 1 ps for Cu – 5 atomic percent of Zn alloy to 140 ± 2 ps in the case of Cu – 52 atomic percent of

Zn. Therefore, it was concluded that the bulk positron lifetime is not sensitive to the Zn concentration changes in this alloy. Since the affinity factor for Zn is longer than of Cu.

It can be also concluded that the positrons are not equally likely to be anywhere in the crystal and they prefer Zn sites on Cu sites.

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Table (1) Positron lifetimes corresponding to the bulk states for different alloys phases.

Zn %	τ_f (ps)	λ_f (ns^{-1})
0.0	132	7.576 ± 0.114
5.0	133	7.519 ± 0.057
15.0	135	7.407 ± 0.550
23.0	137	7.299 ± 0.107
37.0	137	7.299 ± 0.107
52.0	140	7.042 ± 0.102
100.0	158	6.329 ± 0.036

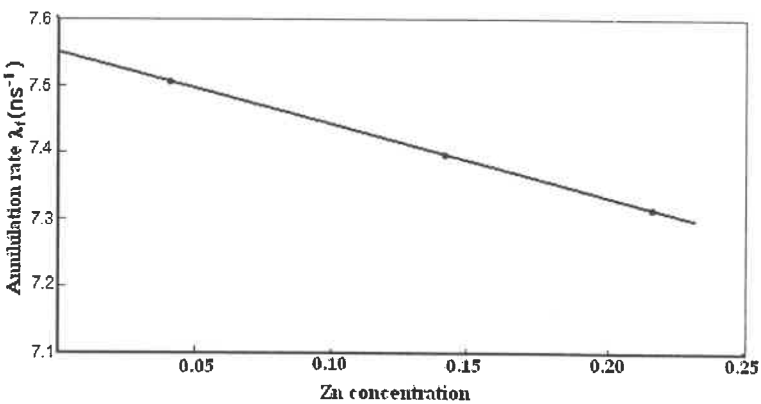

Fig (1) : The annihilation rate λ_f as a function of Zn concentration in the α-phase region of Cu-Zn alloys

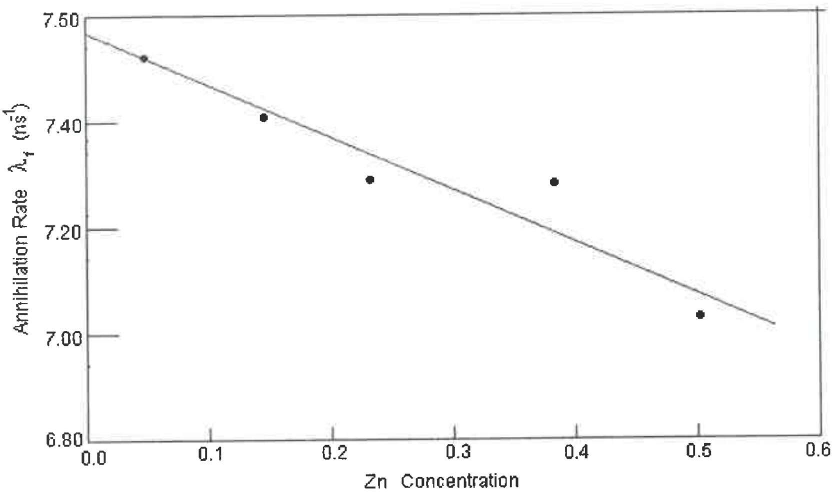

Fig (2) : The annihilation rate λ_1 as a function of Zn concentration in Cu-Zn alloys of different phases

الخلاصة

درست خواص طيف الفناء الحر للبوزترونات في سبائك النحاس- الزنك لمنظومة سبائكية ثنائيه تحتوي على 52wt%, 37wt%, 23wt%, 15wt%, 5wt% من الزنك وقد وجد أن السلوك العام لطيف الفناء متشابه في جميع الحالات وأن عمر الفناء الحر يتغير بمقدار قليل تبعا لاختلاف نسبة الزنك في السبيكة. كما وجد أن معدل الفناء الحر للبوزترونات لهذه السبيكة كدالة لتركيز الزنك لا يمكن تمثيله بدالة خطية خلال جميع أطوار السبيكة ،وأن البوزترونات لا تتوزع بصورة متساوية وعشوائية ضمن التركيب البلوري بل تألف الزنك أكثر من النحاس.