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Research Article

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Recovery of Deformed 1070 Al alloy by PALT & XRD

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Abstract Positron Annihilation technique (lifetime) is one of the nuclear techniques used in material science. This technique study the electron density in material investigated (1070 al alloy). This work studies the behavior of deformed and annealed samples. The parameter of positron mean lifetime changes as a function of deformation and annealing. The positron annihilation lifetime technique is a probe test for recovery stage of defect (deformation) dislocation. The values of mean lifetime values change from the trapped state (deformed) to the bulk state (annealed). Values of mean lifetime in trapped state 202.9 ps while the value of mean lifetime in Free State is 165.6 ps. Aluminum 1070 alloy is a wrought alloy type with good corrosion resistance. It is an excellent brazing alloy. The variance of goodness of fit using the program analyses PATFIT is close to unity. The intensity of the lifetime component is varying around 75 %. The applications of the 1070 alloy General industrial components, Building and construction, Transport, Electrical material and Communication cables. Using two techniques to determine the grain size by PALT and XRD, it was found the values of the of the grain size by the two techniques (PATFIT and MAUD) have the same behavior.

Keywords Positron Annihilation Lifetime Technique, degree of deformation, trapped state, Free State, annealing process, 1070 alloy

1. Introduction

Information on the concentration, configuration and various microstructure characteristics of solids (and their lattice defects) can be obtained by positron annihilation technique. The positron lifetime, 2γ-angular correlation and Doppler broadening of the annihilation line was successfully used in defect studies especially in metals [1-2]. The clustering of vacancies in quenched metals was studied largely by resistivity measurements and electron microscopy [3]. Electron microscopy can provide information about defect clusters such as their concentration, size and spatial distribution however, because of the limit in resolution in the conventional electron microscope, vacancy clusters smaller than about 10Å in diameter cannot normally be detected. Positron annihilation spectroscopy has proved a useful alternative tool [4]. With the introduction of a sufficient concentration of open volume defects (e.g. about 10ppm vacancies) a large fraction of thermalized positrons can interact with electrons and become trapped in defects. A positron is strongly localized in a single vacancy and even more strongly in a vacancy cluster [5]. Grain boundaries in materials possess a more open structure than a perfect crystal as shown by seeger and schottky [6-9]. The potential energy of positrons will be lower in grain boundaries than in the bulk of the metal. Since in one dimension an attractive potential well gives rise to at least one bound state, no matter how shallow and narrow the well, e^+ can be localized in the grain boundaries. At sufficiently low temperature, grain boundaries in metals will, therefore, act as traps for thermalized e^+. Owing to the reduced electron density, the lifetime of positrons in grain boundaries τ_t is larger than the free lifetime τ_f of e^+ annihilating in a perfect environment. The mean lifetime should increase with decreasing mean grain size (1). This increase depends on the fraction of implanted e^+ that is capable of reaching the grain boundaries during their lifetimes. Therefore there is at least the possibility at least in principle, to deduce the e^+ diffusivity L_d, from the observed τ vs ℓ relationship. The first systematic data on the dependence of the e^+ lifetime on the mean grain size has been introduced by Lynn *et al.* [10] on polycrystalline cu which interpreted the results in terms of e^+ trapped in grain boundaries as did Leighly [11]. More detailed measurements of e^+ annihilation on fine-grained ZnAl alloys as a function of the mean grain size were also reported by [9,10]. For large grain sizes the mean lifetime τ varies linearly with the inverse grain size λ^{-1}, in agreement with most of the available experimental data [13]. Some measurements had been previous performed on alloys by Mackee *et al.* [12], Xiannyi *et al.*, [14], Weiming *et al* [15], Abdelrahaman [16] and Dupasquier *et al* [17]. The present paper shows use of the lifetime technique to study the change in grain size with degree of deformation and 1070 alloys.

2. Material properties

The following table 1 shows the chemical composition of aluminum/aluminum 1070 alloy.

Element	Content (%)
Aluminum, Al	$\geq$ 99.7
Iron, Fe	$\leq$ 0.25
Silicon, Si	$\leq$ 0.20
Zinc, Zn	$\leq$ 0.040
Vanadium, V	$\leq$ 0.050
Copper, Cu	$\leq$ 0.040
Titanium, Ti	$\leq$ 0.030
Magnesium, Mg	$\leq$ 0.030
Manganese, Mn	$\leq$ 0.030
Other(each)	$\leq$ 0.030

Physical Properties

The physical properties of aluminum/aluminum 1070 alloy are outlined in the table 2.

Properties	Metric	Imperial
Density	2.70 g/cm^3	0.0975 lb/in^3

Mechanical Properties

The mechanical properties of aluminum / aluminum 1070-O alloy are in table 3.

Properties	Metric	Imperial
Tensile strength	95 MPa	13778 psi

3. Experimental

Four samples of alloys, which have the composition as shown in the table 1, were homogenized at 673 K for 12 hours then slowly cooled to room temperature.

Table 1 shows the chemical limits for the samples under investigation.

As shown schematically in figure 1, the positron source was sandwiched between two identical samples. The ^{22}Na source was deposited from aqueous (sodium chloride) solution on a thin Kapton foil. The source sample configuration was wrapped in a thin Al foil.

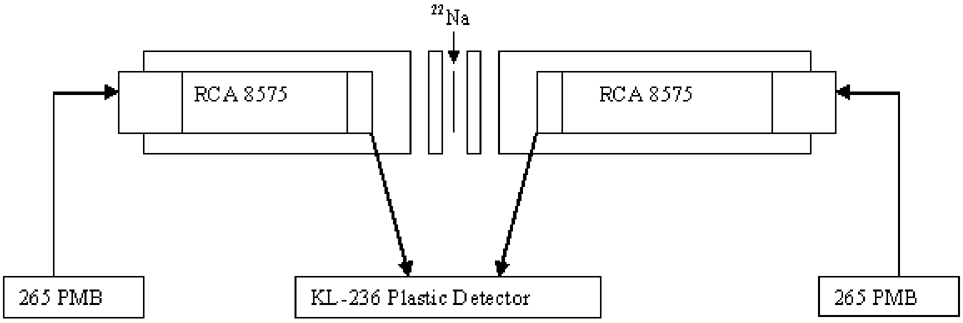

Figure 1: Schematic diagram of the source sample arrangement

The block diagram of the system used in measuring lifetimes is described elsewhere [9,10,16,17]. The positron lifetime was recorded by a time spectrometer using a fast/fast coincidence method. The time resolution of the system using ^{60}Co source was approximately 290 Ps (FWHM). The coincidence counts rate was accumulated in each spectrum for all samples during a period of 7200 s. The lifetime spectra were analyzed with computer program POSITRONFIT [16].

3.1. Positron Annihilation Lifetime Spectroscopy (PALS)

The circuit consists of a pair of scintillates and photomultipliers (PMTs) rigidly mounted. Positive high voltage power supply provides power to the PMTs via voltage divider which allows one to vary the potential applied to the two tubes. The 1.274 MeV γ-ray was taken as a start signal for the time to pulse height converter (TPHC), while one of the 0.511 MeV annihilation quanta was chosen as the stop signal. Thus, the time interval between the above 2γ-rays was the lifetime of the positron in the material. The signal from the TPHC was fed to the computer multichannel analyzer (CMCA) for storage. The resolution of the system is 290 ps as measured using the coincidence as given by ^{60}Co.

A very thin radioactive ^{22}Na was used as a source of positron in this study, so that only a small percentage of the positrons annihilate in the source. The positron source is sandwiched between two identical samples [20]. The thickness of the samples is adequate to absorb emitted positrons. The source-sample configuration was then wrapped in a thin aluminum foil. Each spectrum was collected for a period of 3 hours during which about 5×10^5 coincidence counts were accumulated. The lifetime spectra were analyzed using PATFIT program [21].

3.2. X-ray Diffraction

Continuous scanning was applied with a slow scanning rate (1^o/min) and a small time constant (1sec) using a JEOL X-ray diffractometer (XRD) (Model JSDX-60PA) prepared with a Cuk α-radiation (λ= 0.145184 nm), X-ray source at 40 kV and 35 mA. A range of 2θ (from 30 to 90^o) was scanned, so that the required diffraction peaks for phase identification could be detected. XRD was performed for the phase identification and preferred orientation determination.

4. Results and Discussion

Positron annihilation studied

The mean lifetime τ is given by ($\tau_1 I_1 + \tau_2 I_2$) where τ_f and τ_t are the free and trapped lifetime, and I_f and I_t are their respective intensities. The mean lifetime (values from the average of three measurements) as obtained experimentally is plotted in Figure. (2) as a function of annealing temperature. As shown in figure 2. were

4.1. Lifetime measurements

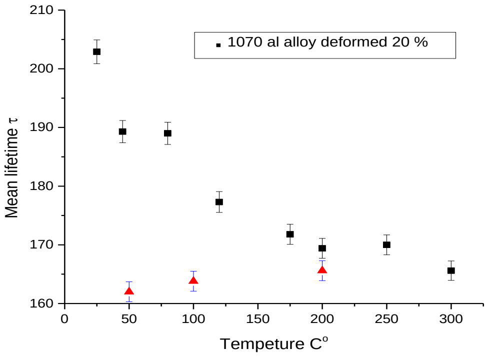

Figure 2: The mean lifetime as a function of annealing Temperature

From our measurements of lifetime as a function of annealing temperature for the samples Al1070 deformed at 20 % degree of deformation. By using the positron annihilation lifetime parameters. We could observe the variation of the lifetime as a function of the annealing temperature as shown in figure 2. While figure 3. Shows the values of the variance of the goodness of fitting nearby close to the unity. That is related to the trended of the results with the accuracy of the calculation. Also figure 4 indicated that the lifetime components (intensity) varying around 75 % while the rest is the value of the intensity trough the Kapton foil (source contribution) as it is close from the references.

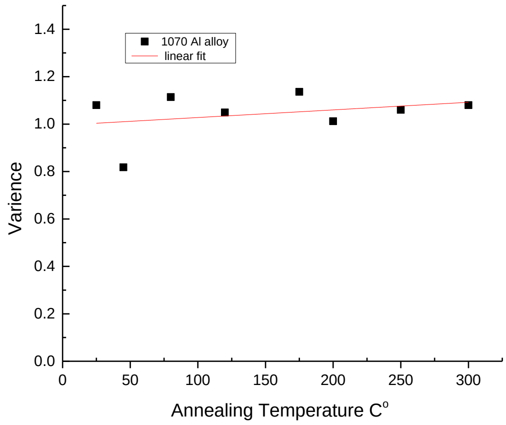

Figure 3: The variance of goodness of fit as a function of annealing Temperature

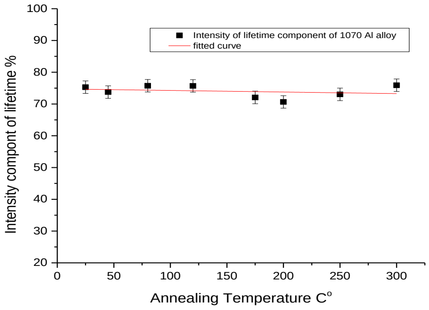

Figure 4: The intensity of the lifetime component a function of annealing Temperature.

4.2. XRD measurements

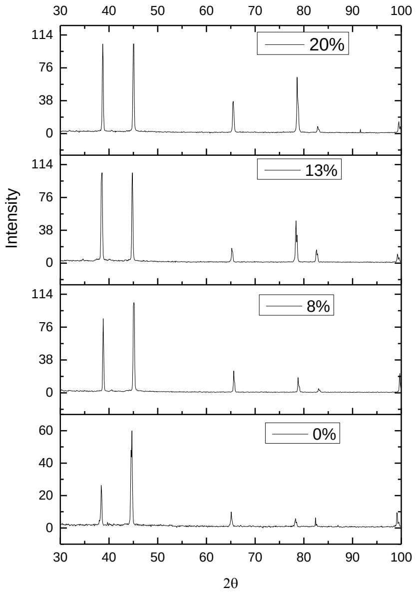

Figure 5: Spectrum of XRD at different deformation of sample Al 1070

Figure 5 explains the relation between the XRD Intensity as a function of degree of deformation for the 1070 Al alloys.

4.3. Study effect of plastic deformation on the mean crystal size

The comparison between results from positron annihilation lifetime spectroscopy and XRD results of Al1070 alloys. First Positron annihilation data where the mean crystal size L and the mean lifetime t is related to t_f and t_t by a simplified model which leads to the relationship, as reported by Hidalgo and de Diego [19].

$$\tau = \tau_f + \left[\left(\tau_t - \tau_f\right) \frac{L_d}{\ell} \right] \qquad (1)$$

Where l_d is the mean diffusion length of positron in metal (Al): l_d =1500 A. By substituting for l_d , t_t and t_f in the equation the grain size was calculated.

Second XRD data as shown in figure 5, where the X-ray spectrum of the sample was analyzed by MAUD program [22,23] show the experimental data and calculated data and give the results as shown below table (4). The lattice parameter for the sample deformed presented as shown in figure 6.

1070 al alloys	Lattice parameters	Grain size by MAUD (XRD)	Grain size by (PALT)
Deformed 20%	4.02945 Å	0.13285 µm	0.1318 µm

We noted that the grain size decrease with increasing deformation , increasing the value of the grain size is a same in the two techniques but its value at not deformed differs by a factor (10), lattice constant decrease which make decrease of d-spacing.

Table 5 shows the results of the (hkl) planes values for non-deformed and deformed 1017 Al alloys.

h	k	l	d for non-deformed sample	d for 20% deformed sample
1	1	1	2.343Å	2.326Å
2	0	0	2.029Å	2.014Å
2	2	0	1.435Å	1.424Å
3	1	1	1.223Å	1.214Å
2	2	2	1.171Å	1.163Å

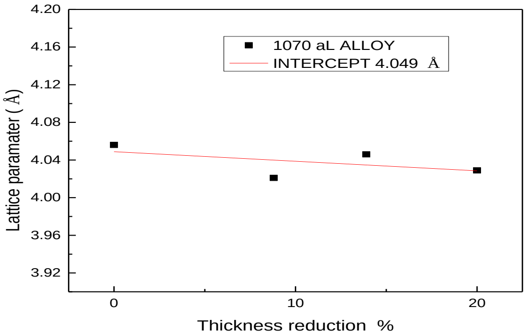

Figure 6: Lattice parameter as a function of thickness reduction of 1070 al Alloy

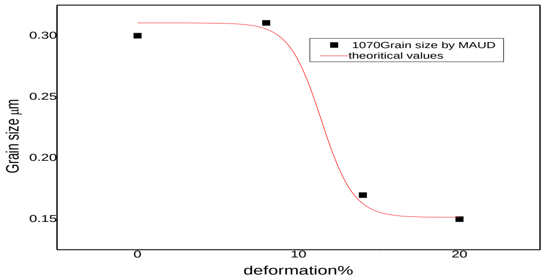

Figure 7: Grain size as a function of deformation of 1070 Al alloy

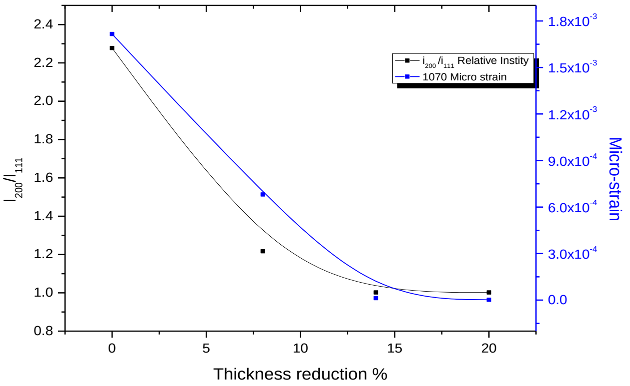

Figure 8: $I_{(200)}/I_{(111)}$and Micro strain as a function of Thickness reduction of 1070 Al alloy

Figure 7 refers to the relation between the grain sizes as a function of degree of deformation of 1070 al alloy. While figure 8 refers to the ratio of the intensity and the macro-strain as function of thickness reduction, it is clear from this figure the relation between both ratio and macro-strain are coincidence with the thickness reduction.

5. Conclusion

From our measurements concerning to the 1070 al alloys using positron annihilation lifetime technique and X-ray diffraction (material analyzes Using X-ray diffraction (MAUD). We could observe the values of the grain size of both deformed material nearly the same values using the both techniques PAT & XRD only for deformed samples. Also we could observe that the (hkl) as a function of the 2tehta for non-deformed and deformed 1070 al alloys slightly decrease. Values of mean lifetime in trapped state 202.9 ps while the value of mean lifetime in Free State is 165.6 ps. The lattice parameter for 1070 Al Alloy as a function intercept value from the figure is 4.049 Å. While the h k l values is higher for the non-deformed 1070 Al Alloy as shown in figure. It is clear from figure 8. The values of h k l in both cases of non-deformed and deformed samples nearly close to each other at the same 2 theta. The conclusion there is no change of the macro strain could be observed as a function of the deformation.

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