Turk J Phys
26 (2002) , 453 – 457.

Monitoring the Effect of Recrystallization and Quenching in AlMg$_x$ Alloy by Pat

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Received 31.10.2000

Abstract

Positron annihilation technique (PAT) lifetime measurements have been carried out on AlMg$_x$ samples (x = 0.23, 0.85, 1.27 and 1.4 at %) with point defects and dislocations introduced by plastic deformation at room temperature. Clustering of vacancies was observed by quenching using PAT. The samples were annealed at 573 K for 12 hours to homogenize and divided into two sets. The first set of AlMg$_x$ (x = 0.23, 0.85 and 1.4 at %) was deformed to 10, 25 and 35% thickness reduction. Isochronal annealing was studied in the range of 300-550 K. In the second set of measurements, AlMg$_x$ (x = 1.27 Mg at %) was deformed to 31.25% thickknes reduction. Variation in the mean lifetime with annealing time (Isothermal annealing at 323 K) was studied. On the other hand, the effect of the degree of deformation on change of the value of the mean lifetime with different concentration of Mg was studied. This work is able to distinguish the state of sample with different concentration of impurities. The deformed samples reach the bulk state at higher temperature. Grain growth occurred with increasing temperatures as shown by lifetime value. The effect of quenching from various temperatures range (373-823 K) was studied.

Key Words: Isothermal and Isochronal annealing; Deformation; Grain size; Quenching; Recrystallization.

1. Introduction

The grains rotate and elongate during deformation causing certain crystallographic directions and planes to become aligned. Consequently, preferred orientations develop and cause anistropic behavior. When the metal is heated above the recrystallization temperature, rapid relaxation eliminates residual stresses and produces the polygonised dislocation structure. At still higher annealing temperatures, both relaxation and recrystallization occur rapidly, producing a fine recrystallized grain structure. A number of factors also influence the size of the recrystallized grains. Lowering the annealing temperature, or shortening the annealing time will reduce the grain size by minimizing the opportunity for grain growth. Information on the concentration, configuration and internal structure of lattice defects in solids can be obtained by positron annihilation. Thus, the positron lifetime, 2γ angular correlation and Doppler broadening of the annihilation line have been successfully used in defect studies, especially in metals [1-3]. Positron annihilation spectroscopy has proved to be a useful alternative tool. In a near-to-perfect lattice, a thermalized positron exists in–and annihilates from–a delocalized state in which it experiences the bulk, non-local properties of the metal. With the introduction of a sufficient concentration of open-volume defects (e.g. about 10 ppm vacancies) a large fraction of thermalized positrons can interact with and become trapped in defects.

Grain boundaries in metals possess a more open structure than the perfect crystal. Seeger and Schottky [4] found a simple relationship between the volume expansion of a large-angle grain boundary in a metal and the specific grain-boundary energy. At sufficiently low temperatures, grain boundaries in metals will therefore always act as traps for thermalized positrons (e^+). The first systematic data on the dependence of the positrons (e^+) lifetime on the mean grain size appear to have been those of Lynn et al. [5] on polycrystalline Cu, which where interpreted in terms of positrons trapping in grain boundaries by Leighly [6]. Similar measurements have been done in previous work in Al-alloys and others [7-12]. This paper describes the lifetime technique measurements used to study the concentration of Mg in Al alloy.

2. Experimental Details

Figure 1 represents the experimental arrangement for sample configuration. The positron source was ^{22}Na, deposited from an aqueous solution of sodium chloride solution on a thin Kapton foil. The AlMg$_x$ samples with various Mg impurities of 0.23, 0.85, 1.27 and 1.4 at % were annealed at 573 K for 12 hours. After annealing, the temperature was gradually decreased to room temperature to produce a homogenous volume. The ^{22}Na positron source was sandwiched between two identical samples of AlMg$_x$, (x = 0.23, 0.85, 1.27 and 1.4 at %) alloy. Then, the sandwiched source was wrapped in a thin Al foil. The bundle was placed between two 2.54 cm x 2.54 cm KL-236 plastic scintillators. Two 8575 photomultiplier tubes (PMT) and two 265 photomultiplier bases (PMB) were used. The positron lifetime was then determined as usual by measuring the time interval between the detection of the 1.274 MeV γ-ray emitted almost simultaneously with the emission of the positron, and the detection one of the two 0.511 MeV annihilation photons [13]. The positron lifetimes were recorded by a time spectrometer using a fast fast coincidence method. The time resolution of the system using a ^{60}Co source was approximately 280 ps (FWHM). Figure 2 shows a block diagram of the electronic circuitry used in lifetime measurement. The pulses were taken from the anodes of the photomultiplier tubes, and fed to constant fraction differential discriminators (CFDD). The output pulses from the linear gate were fed to the computerized MCA for sorting and storage. The coincidence counts rate was accumulated in each spectrum for all samples over a period of 1h. The lifetime spectra were analyzed with a computer program [14].

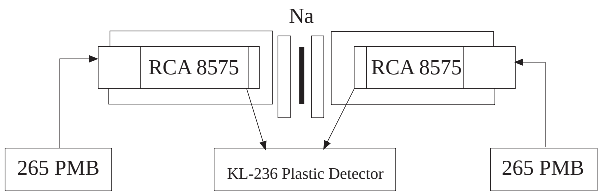

Figure 1. The experimental arrangement for sample configuration.

3. Results and Discussion

Positron mean lifetimes were measured three times for the samples of Al and AlMg alloy with 0.23, 0.85, 1.27 and 1.4 at % Mg concentration. All the samples were annealed at 573 K for 12 hours and homogenized. Samples were divided into two sets. The first set contained samples with concentration x = 0.23, 0.85, and 1.4 at % Mg, and deformed to 10, 25 and 35% thickness reduction, respectively. Isochronal annealing for the first set was studied in the range 300 to 550 K.

Figure 3 shows the mean lifetime for the first set as a function of the annealing temperature. In the second set of measurements, AlMg$_{1.27}$ samples were deformed by 31.25% thickness reduction. The variation of the mean lifetime for the second set as a function of different annealing times (Isothermal annealing at 323 K) is shown in Figure 4. The general observation from Figures 3 and 4 are that the deformed samples reach bulk state due to grain growth at higher temperatures. This structural behavior can be interpreted according to the release of the acceleration process during increasing temperatures at the grain boundaries [15].

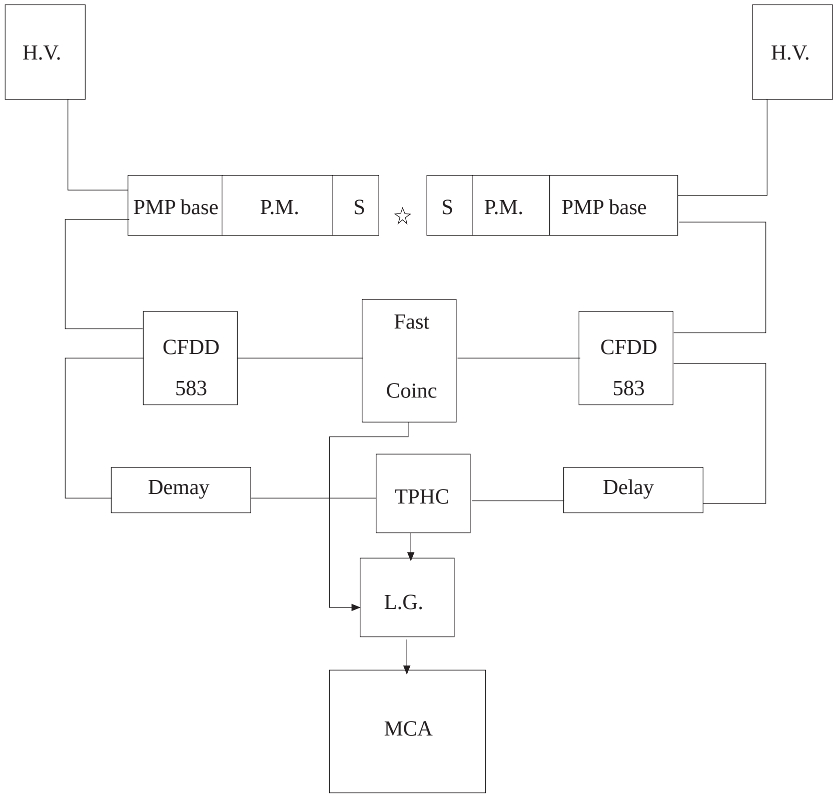

Figure 2. The block diagram of the electronic circuitry used in lifetime measurement.

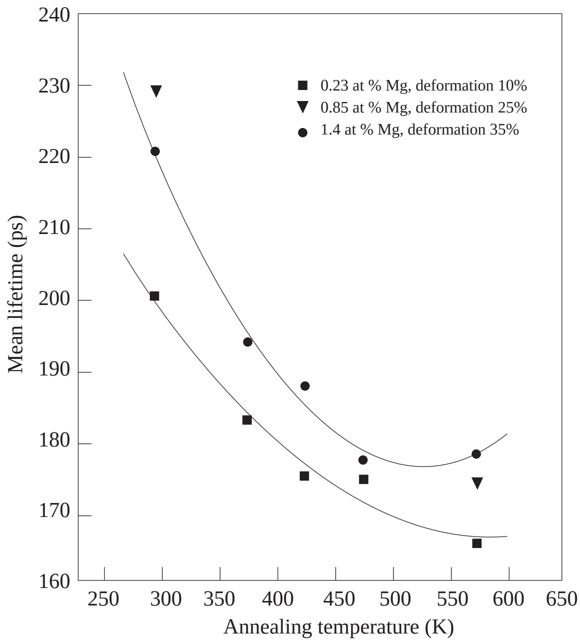

Figure 3. Mean lifetime as a function annealing temperature for different values of deformation.

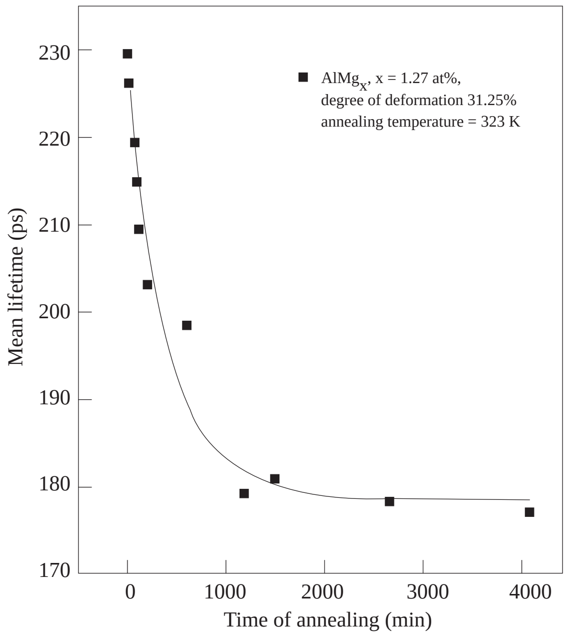

Figure 4. Mean lifetime as a function of time of annealing for $AlMg_x$ sample deformed at room temperature.

On the other hand, the sample $AlMg_{1.4}$was heated (between 300-823 K) before quenching into water while the other $AlMg_{0.23}$ sample was heated directly to 823 K. The mean lifetime of positron behavior and temperatures of both samples before quenching is illustrated in Figure 5. In both samples, the mean lifetime changes from 171 ps to 220 ps as the quenching temperature increases from 373 to 823 K (see Fig. 5). This indicates that the Mg vacancy swelling is attributed to positron traps. The lifetime values for $AlMg_{1.4}$ and $AlMg_{0.23}$ are in a good agreement with Boileau et al. [16].

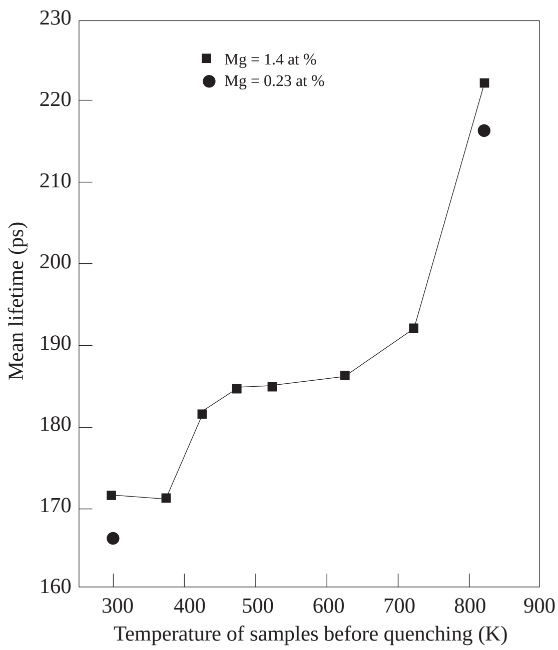

Figure 5. Mean lifetime as a function of quenching temperature for $AlMg_x$ alloy.

4. Conclusion

The characteristics of positron annihilation have been measured for the AlMg samples with different Mg concentrations. Experimental data shows a strong inverse correspondence between grain-size and positron lifetime in $AlMg_x$. The observations indicated that the deformed samples reach to the bulk state at higher temperature (isochronal annealing), and long annealing time (isothermal annealing). The stability of positron lifetime in AlMg alloy has been presented at room temperature, indicating the presence of impurities concentration.

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