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Investigation of Defects in Al-si$_{10}$ Alloy Using Electrical Measurements

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Abstract: The measurement of electrical resistance at room temperature for Al- Si$_{10}$ sample before and after quenching at different temperature has been carried out. Also, electrical resistance has been measured for a sample deformed up to 40% of thickness reduction. The effect of annealing on the deformed sample has also studied. The activation energy for formation the thermal vacancies was evaluated and found around 0.79 eV.

Key words: Al-Si alloy, Quenching Temperature, Annealing Temperature, Formation energy, degree of deformation.

INTRODUCTION

Aluminum is the third most abundant element in the Earth's crust and constitute 7.3% by mass. In nature, it is only exists in very stable combinations with other materials. Aluminum–silicon casting alloys have numerous applications in the automotive industry because of a specific feature involving high strength-to-weight ratio, thereby increasing mechanical performance and decreasing fuel consumption (Ammar, 2008). The grains rotate and elongate during deformation causing certain crystallographic directions and planes to become aligned. Consequently, preferred orientations develop and cause anisotropic 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 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 (Ashour, 2002). Information on concentration, configuration and various microstructure characteristics of solids and their lattice defects can be obtained by positron annihilation technique (Badawi, 2000; Hautojarvi, 1979; Siegel, 1980). The clustering of vacancies in quenched metals was studied largely by resistivity measurements and electron microscopy (Cotterill, 1972). This paper aims to discuss the availability of using electrical measurements to detect defects in a plastically deformed Al-Si$_{10}$ sample. The annealing of the defect induced by plastic deformation was successfully studied by measuring the change of resistivity of the sample as a function of annealing temperature.

2. Experimental:

Al-Si sample has been subjected to heating for 1 hour at different temperatures and then quenched in a cold water. Then, deformation has been carried out in the of range of 1% to 40% of thickness reduction.

The electrical resistance of the sample has been measured using the two-point probe method. The electrodes are brought into contact with the sample surface. A known current is passed through the electrodes, while the voltage readings is made between the two surfaces of the sample. Both the potential difference, V, and current, I, were measured using a digital multimeter.

RESULTS AND DISCUSSION

3.1. *Determination of the Activation Energy for Formation Thermal Vacancies:*

The I-V curves for Al-Si sample before and after quenching at different temperatures are shown in Fig. (1). The electrical resistance as a function of quenching temperature is shown in Fig. (2). It is clear from these curves that the resistance of the sample increases with increasing quenching temperature. This can be attributed to formation of thermal vacancies. The activation energy for formation of this thermal vacancies can be estimated by using the empirical equation (1) which is called threshold method (Schulte, 1969).

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Correlation Between T_c and Activation Energy E_{1v}^f:

Kuribayashi et al. (Schulte, 1978) were the first to point out explicitly a further correlation between the E_{1v}^f obtained from conventional analyses of vacancy trapping curves and the threshold temperatures T_c at which the onset of the vacancy trapping effects is first apparent. As has been demonstrated analytically by Kim and Buyers (Kuribayashi, 1973) and by Nanas et. al. (1977) which can be given from the relation

$$E = (-0.098 \pm 0.057) + (15.2 \pm 0.7) x 10^{-4} T_C \tag{1}$$

The temperature at which the onset of the defect occurs was depicted in fig.(2). The activation energy for defect formation was found to be around 0.79 eV**.** The change in the value of resistivity reflects the characteristic of the defect formation as shown below. While the recovery processes as a function of the annealing temperature also was studied below.

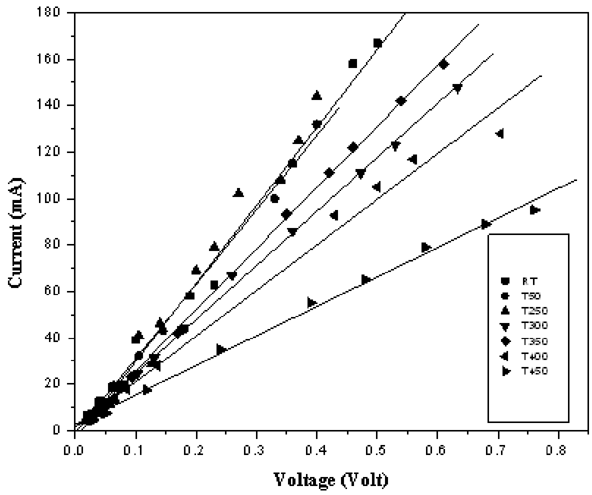

Fig. 1: I-V curve for Al-Si sample quenched at different temperatures.

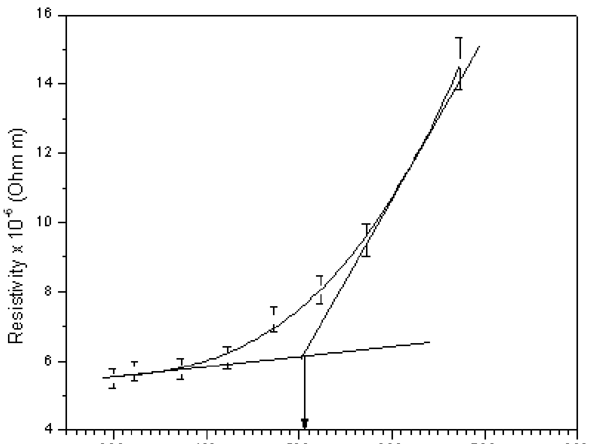

Fig. 2: The resistance as a function of quenching temperature.

3.2. ***Resistance Behaviour Probing by Plastic Deformation on the Sample under Study:***

Al-Si_{10} sample under investigation were plastically deformed in the range of 1% to 40% degree of thickness reduction. Fig.(3). shows I-V curves for the deformed sample at different degree of deformation. The resistance of the deformed sample as a function of thickness reduction is shown in Fig(4).

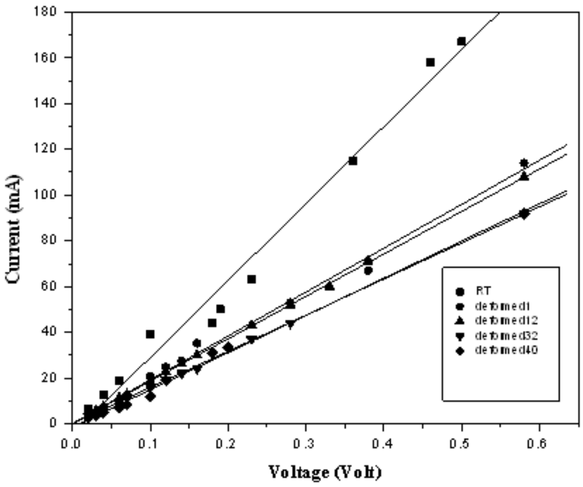

Fig. 3: I-V curves for the deformed sample.

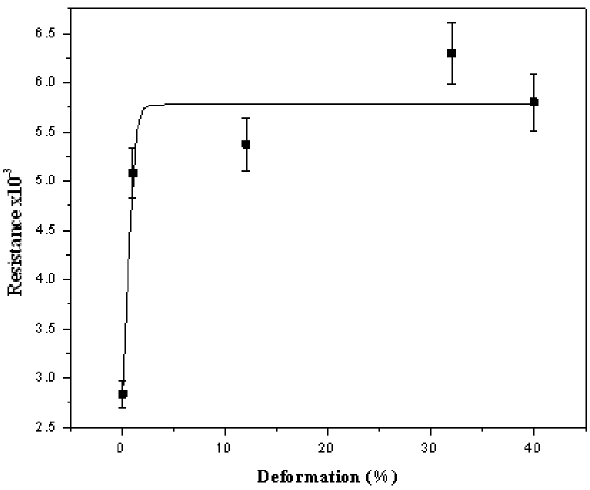

Fig. 4: Electrical resistance as a function of deformation.

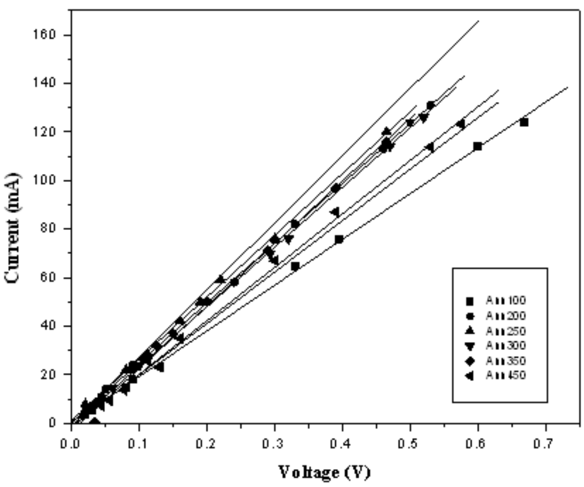

Fig. 5: I-V Curves for Al-Si deformed sample annealed at different temperatures.

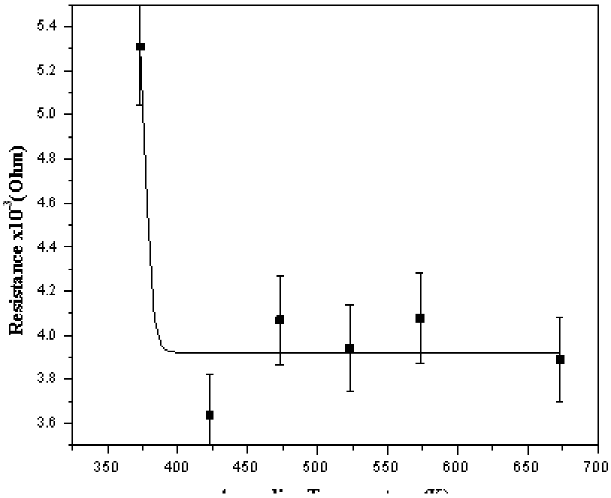

Fig. 6: The electrical resistance of the deformed Al-Si sample as a function of annealing temperature.

It can be observed that the resistance of the sample increases with increasing the degree of deformation up to 12% thickness reduction, then, the resistance is almost constant. This is in consistent with the work were done previously for close sample of AlSi11:35Mg0:23 using positron annihilation technique (ABDEL-RAHMAN, 2004).

3.3. *Recovery of Plastic Deformation:*

In order to recover the plastic deformation, The deformed sample was subjected to subsequent annealing for 1 hour at different temperatures. The I-V curves of the annealed sample is shown in fig(5) while the resistance as a function of annealing temperature is depicted in Fig(6). One can notice that the electrical resistance decreases with increasing annealing temperature. This decrease can be attributed to the migration of vacancies and dislocation with increasing annealing temperature (Badawi,).

Conclusions:

Based on the obtained results from the electrical measurement technique on sample of Al-Si_{10} one can conclude the following

1- An increase of the electrical resistance is observed with increasing quenching temperature.
2- The activation energy for formation of the thermal vacancies was calculated for the sample using the so called threshold temperature method and found to be around 0.79 eV.
3- The electrical resistance increases with increasing the degree of deformation (thickness reduction) up to 12% thickness reduction , after that the resistance is almost constant.
4- Annealing of the deformed sample decreases the electrical resistance.

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