The Effect of Structural Changes on Electrical and Mechanical Properties of Some Alloys

Thesis

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By

Milad Sobhy Megalaa Solaiman

(B. Sc. & Ed. - G. Deploma - Sp. Deploma)

537.5
M.S

u7991

To

Department of Physics
Faculty of Education
Ain Shams University
Cairo, Egypt

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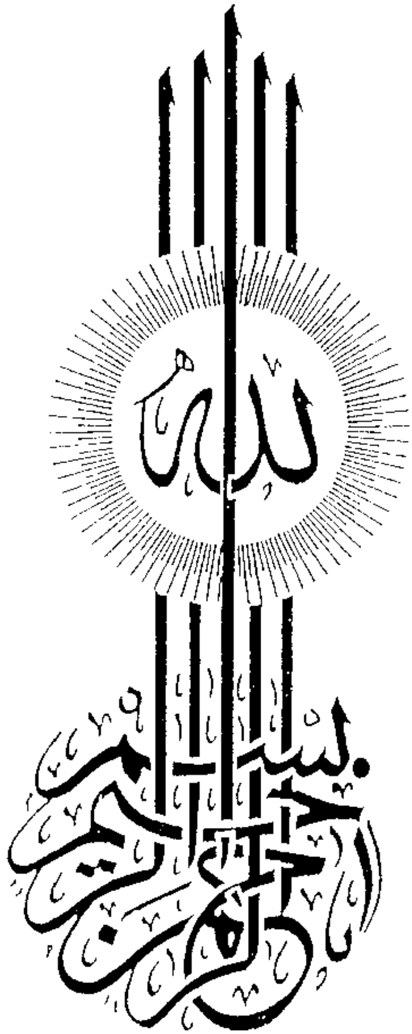

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ABSTRACT

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The present work mainly covers the study of the creep behaviour and the electrical resistivity of Al-10wt%Zn alloy in the form of wires 0.35 mm in diameter.

The thesis contains the study of the effect of:

1) Grain diameter on the transient and steady state creep behaviour in the high stress region $\sigma/G > 10^{-4}$, where σ is the applied stress and G is the shear modulus,

2) Ageing temperature on the transient and steady state creep behaviour in the temperature range below and above half of the melting temperature (T_m) of the alloy,

3) Ageing temperature on electrical resistivity in the temperature range below and above half of the melting temperature (T_m) of the alloy.

In the first part , creep properties of Al-10wt%Zn alloy were studied using specimens of different grain diameters (14, 20, 24 and 30 μm) in the high stress range 163 - 193.5 MPa. In the transient creep which follows the equation $\varepsilon_{tr} = K\, t^n$, where n and K are the transient creep parameters, it was found that the transient creep parameter n increases , whereas the parameter K decreases with increasing grain diameter. The effect of grain diameter on the steady state creep was also studied under the same conditions as mentioned above. It was found that, as the applied stress was kept constant,

$\dot{\varepsilon}_s$ decreases with increasing grain diameter whereas, the stress exponent m in the stress power law $\dot{\varepsilon}_s = a\,\sigma^m$, increases with increasing grain diameter, and has a value ranged from 8.4 to 12.5 . This was explained due to the transition in climb velocity of dislocation from a linear to an exponential function of stress.

The transient and steady state creep were correlated and a linear dependence of ln K versus ln $\dot{\varepsilon}_s$ for different grain diameters was obtained irrespective of the applied stress and the relation $K = K_o\,\dot{\varepsilon}_s^{\gamma}$ was proved to be valid with the exponent γ having an average value of 0.66.

In the second part, which devoted mainly to the study of the effect of the ageing temperature on the transient and steady state creep, specimens of average grain diameters (14, 20, 24 and 30 μm) were aged at 383, 403, 423, 443, 473 and 523 K . The creep tests were performed under a constant applied stress (163 MPa) at room temperature. It was found that, the transient creep parameter n ranged between 0.54 and 0.77 depending on the grain diameter and ageing temperature. The dependence of K on ageing temperature (T_a) was found to increase unitl it reaches a maximum at about 443 K then it decreases with further increase in T_a. This behaviour was observed for all grain diameters used. This was attributed to the formation and dissolution of Guinier - Preston G P zones and β-phase below and above

0.5 T_m respectively . The same feature was seen also for the dependence of the steady state creep rate $\dot{\varepsilon}_s$ on the ageing temperature.Activation energy calculations for both transient and steady start creep gave mean values of 0.44 eV and 0.33 eV repectively which are matching with those previously obtained for the vacancy-Zn pairs migration in Al-Zn alloys.

The third part, dealt with the effect of the ageing temperature, below and above 0.5 T_m on the electrical resistivity of the alloy specimens under consideration. With time of ageing,the resistometric study delineated two distinct stages, for specimens quenched from different temperatures , the first stage characterized by a decrease in resistivity, whereas an increase was observed in the second stage. The decrease in resistivity (ρ_t) with time (t) at the different ageing temperatures was interpreted as due to the formation and growth of G P zones, while the increase in (ρ_t) was attributed to the dislsoution of G P zones to form the rhombohedral transition phase which was emphasized by electron micrascope investigation . The activation energy of G P zone formation and growth was found to be 0.5 eV in accordance with that quoted in literature.

CHAPTER I

INTRODUCTION

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INTRODUCTION

The perfect crystals so far considered is built up by repeated translation of basic unit along the three crystallographic axes . In practice , however , the real crystals are not quite this regular and there are a variety of imperfections or defects present in all crystals. These imperfections play a major role in explaining many of the physical phenomena exhibited by solid.

1.1 Lattice imperfections in crystalline solids.

Lattice imperfections can be broadly classified into:

1.1.1 Point defects.

A Frenkel[1] type of point defect is formed in perfect crystal when an atom leaves its usual site and goes into the space between two normal atom positions, and the lattice site left vacant is called a vacancy. The number of vacancies in a metal increases rapidly with temperature. By rapid quenching from high temperature it is possible to trap-in a number greater than the equilibrium number of vacncies at room temperature.

Schottky[2] pointed towards the possibility that atoms might be found in places other than lattice sites and these are called interstitials.

It should be noted that vacancies and interstitials are created by cold-working[3-6]. A vacancy and interstitial atom usually combine to annihilate each other, two vacanies might combine to form a divacancy which is more mobile than a single vacancy[3,7].

1.1.2 Line defects "Dislocations"

The dislocation is a disturbance in regular packing of the atoms forming the crystal. There are two basic types of dislocation in crystalline material , viz. the edge dislocation and the screw dislocation[8,9]. Edge dislocation in which the displacement corresponding to the Burger's vector is directed perpendicularly to the dislocation line. If many point defects are generated they can form or remove dislocation lines in the following way. For example, a large number of interstitial atoms which form into an interplaner "raft", Fig.(1), may bond as a normal atomic plane in the middle of the raft. However, the edge of the plane cannot match the surrounding lattice so an edge dislocation forms . Similarly , a raft of vacancies may collapse over the central region which again produces an edge dislocation. The size of the loops can change as interstitials or vacancies migrate in the solid.

Screw dislocation in which the displacement vector is parallel to the dislocation line. Compound dislocation of screw and edge dislocations may also exists if they have the same Burger's vector .

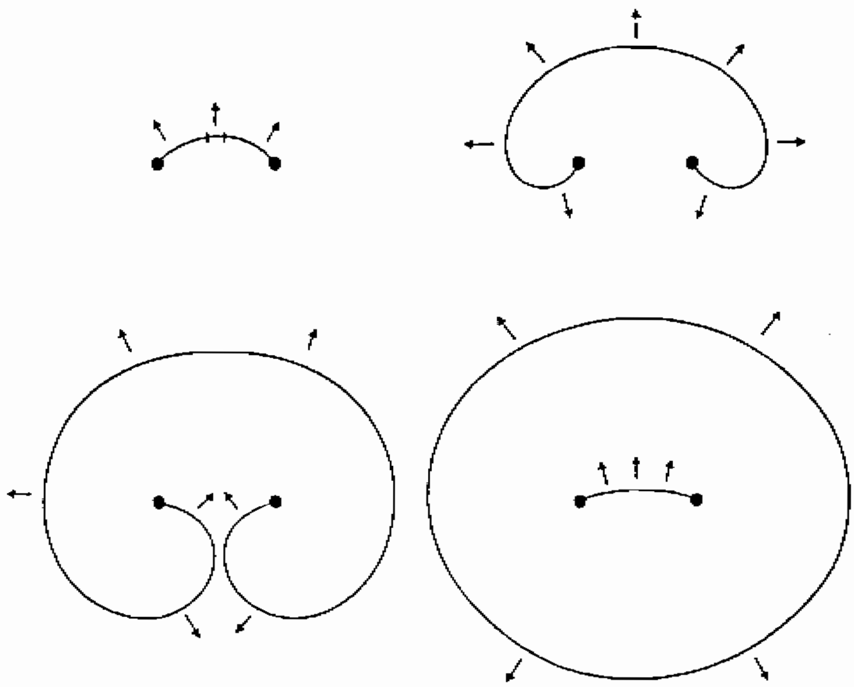

Fig. (1) A mechanism proposed by Frank and Read for a strongly pinned region of a dislocation line to act as a source for dislocation loops.

For several decades, motion of dislocation was adopted as a tool through which the plasticity of metals was studied[10]. The sideways motion of dislocations is termed slip and the plane in which it moves is the glide plane. As a general rule, slip occurs on the plane of densest atomic packing. If the dislocation moves parallel to the extra atomic plane it is called climb. This is only possible if the dislocation is a source or a sink for point defects.

Not all parts of the dislocation line are equally mobile and the line may be pinned at nodes where dislocation lines intersect. These points may then act as sources of vacancies or interstitials if the line is forced to bow through the crystal whilst anchored at fixed points. Pinning may also occur by the presence of impurity atoms. The strain field around a dislocation makes dislocation lines favoured sites for the accretion of lattice impurities.

If a segment of a dislocation line is strongly pinned then applied stresses may made it the source of dislocation loops. Such a mechanism has been suggested by Frank and Read[11] and is illustrated in Fig.(2). Here the pinned segment bows under the stress across the slip plane and expands by the inclusion of more material. Once the line reaches a semicircular shape it will expand beyond the pinning points so as to enclose them. Loops formed from a Frank-Read source will be inhibited once the outer loop pile