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Mechanical, Electrical and Structural Properties of a Binary Alloy (Sn-4wt% Sb)

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MECHANICAL, ELECTRICAL AND STRUCTURAL PROPERTIES OF A BINARY ALLOY Sn-4wt% sb

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ABSTRACT

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The purpose of the present work is to investigate the effect of microstructural variations of Sn - 4 wt% Sb alloy during the phase transformation, on their mechanical and electrical properties.

Isothermal creep tests of Sn - 4 wt% Sb alloy have been studied under different constant stresses ranging from 10 MPa to 13 MPa near the transformation temperature. Transient and steady state creep of this alloy showed one transition point at 453 K. From the transient creep described by the equation $\varepsilon_{tr} = \beta\ t^{n}$, where ε_{tr} and t are the transient creep strain and time respectively. The parameter (β) was found to change with the applied stress from (3.3×10^{-2} to 120×10^{-2}) for Sn - 4 wt% Sb. The exponent (n) was found to change from (0.39 to 0.73) for this alloy. The parameter (β) was related to the steady creep rate $\dot{\varepsilon}_{st}$ through the equation $\beta = \beta_o(\dot{\varepsilon}_{st})^{\gamma}$,the exponent γ was found to change (0.6 and 0.7) in the low and high temperature regions respectively for Sn - 4 wt% Sb composition. The activation energies of the transient creep have been found to be (37.7 and 58.8 KJ/mole) in the low and high temperature regions (below and above 453 K), respectively thus, the atomic mechanisms of the transient creep are the grain boundary diffusion and the superplastic deformation, respectively.

The steady state creep of Sn - 4 wt% Sb alloy has been also investigated within the transformation temperature region. The strain rate sensitivity parameter (m) was found to change from (0.18 to 0.24) depending on the working temperature. The activation energies of the steady state creep of Sn - 4 wt% Sb were found to be (50.2 and 108.5 KJ/mole) in the low and high temperature regions respectively. These values refer to the superplastic mechanism and the self diffusion mechanism respectively.

The microstructure of the test alloy was also investigated. The average grain diameter of Sn - 4 wt% Sb increased from (0.12 to 0.32 mm), during creep tests. X-ray diffraction analysis showed that the residual internal strain was relatively recovered in the phase transformation temperature region. The stress-strain curves of the Sn - 4 wt% Sb alloy were found to be greatly influenced by the working temperature and the grain diameter. The yield stress (σ_y) and the fracture stress (σ_f) have been found to decrease with the increase of the working temperature. The temperature dependence of σ_y and σ_f showed that there is a transition point at (453K).

The fracture surface energy has been found to vary from (0.4 to 0.155 J/m^2) as the working temperature changed from

(393 to 473 K). Moreover, the dependence of the resistivity change of the Sn-4wt% Sb alloy on the aging temperature was studied the activation energies of the precipitation process was found to range from (0.05 to 0.17 eV), characterizing the binding energy between vacancy and Antimony-solute atom.

CHAPTER (I)
INTRODUCTION

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1- CREEP :

1.1) The Creep Curve

The deformation of material at constant stress is called "creep". To determine the engineering creep curve of metal or alloy , a constant load is applied to a tensile specimen at a constant temperature , and the strain of the specimen is determined as a function of time [1,2].An idealized creep curve is shown in Fig. (1).

The first stage (primary creep), represents a region of decreasing creep rate , primary creep is called (transient creep) in which the creep resistance of the material increases by deformation. For low temperature and stresses , as in the creep of lead at room temperature , from Fig.(1) ε_o ,ε_I are the creep strain at t=0 , $t=t_1$ respectively.

The second stage (steady state or secondary creep) shows that the creep rate is nearly constant, which results from a balance between the processes of strain hardening and recovery. The average value of the creep rate during secondary creep is called the minimum creep rate.

$$\dot{\varepsilon}_{st} = (\varepsilon_2 - \varepsilon_1)/(t_2 - t_1) \qquad (1)$$

The third stage (tertiary creep) , occurs in constant load creep test at high stresses and high temperature. Tertiary creep occurs when there is an effective reduction in cross sectional area either because of necking or internal void formation.

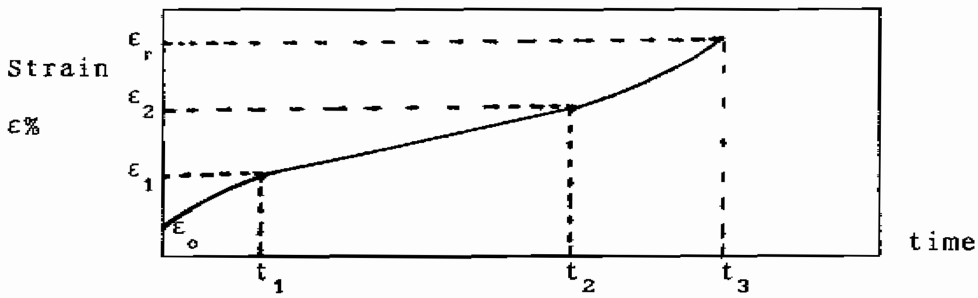

Fig (1) typical creep curve showing the three stages of creep at constant load test.

1.1.1) Logarithmic Creep

For value of ratio between T/T_m where "T" is the test temperature ,"T_m" is the melting temperature , in the range of (0.05 to 0.3 T_m) the time dependant creep strain (ε) varies linearly with the logarithm of the time (t) in case of simple tension creep

$$\varepsilon = \alpha \ln t + c \qquad (2)$$

where α and c are constants independent of time.This type of behaviour is called (logarithmic creep).

1.1.2) Parabolic and Secondary Creep:

From creep time relations for some metals and alloys in the range (0.2 to 0.7 T_m) it is observed that two relations fit data . The first decreasing primary creep is given by

$$\varepsilon = \varepsilon_o + \beta t^n \qquad (3)$$

where, (ε_o) is the strain upon loading and (β and n) are constants independent of time. This relation is called (parabolic creep) or β(flow). As stresses where secondary creep is observed a linear term is added to the equation (3) and takes the form

$$\varepsilon = \varepsilon_o + Bt^n + Kt \quad (4)$$

where K is the secondary creep rate , the value of (n) is in the range from (0.03 to 1 T_m) and seems to depend on temperature and stress. Combinations of equations (2,3) and (4) have been employed successfully in the range (0.3 to 0.4 T_m) [3].

1.1.3) Stress Dependence of Secondary Creep Rate :

For both metals and alloys in the annealed condition tested at constant temperature , the stress dependence of secondary creep rate ,($\dot{\varepsilon}_{st}$) at low stress level is given by the relation

$$\dot{\varepsilon}_{st} = A\,\sigma^n \quad (5)$$

where, (σ) is the stress and (A and n) are independent of stress.

For annealed metals and alloys (n) has been found to range from (1 to 7) and does not seem to depend on crystal structure [4-9]. A and n are constants dependent on temperature , under conditions where creep may be controlled by stress induced migration of vacancies.