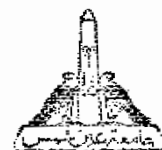


**Ain shams University**  
Faculty of Education  
Physics Department



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

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Submitted to Ain Shams University  
in Partial Fulfilment of the Requirements  
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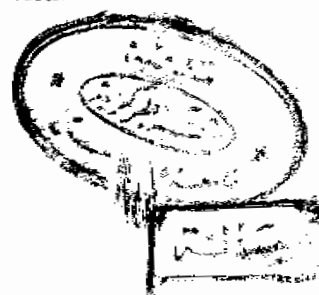
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Ain Shams University



**1994**

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

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# CONTENTS

PAGE

ACKNOWLEDGEMENT

ABSTRACT.....1

CHAPTER(I) INTRODUCTION.....1

1) Creep.....1

1.1) The Creep Curve.....1

1.1.1) Logarithmic Creep.....2

1.1.2) Parabolic and secondary Creep.....2

1.1.3) Stress dependence of secondary creep rate...3

1.2) Temperature dependence of creep.....4

1.2.1) Low temperature creep.....4

1.2.2) Intermediate temperature creep.....5

1.2.3) High temperature creep.....6

1.3) Modes of deformation in creep.....7

1.3.1) Intragranular creep deformation.....8

1.3.2) Role of grain Boundaries during creep  
deformation.....9

1.4) Creep theories.....9

1.4.1) Nabarro-Herring mechanism.....9

1.4.2) Recovery theory.....11

1.4.3) Weertman climb theory.....11

1.4.4) Other possible dislocation mechanisms in  
high temperature creep.....13

1.4.5) Creep at intermediate temperature.....14

1.4.6) Creep at low temperature.....14

1.4.7) Effect of temperature on tertiary creep.....15

1.4.8) Effect of stress on tertiary creep.....16

1.5) The importance of creep.....16

2) Plastic deformation.....17

2.1) Origins of plastic deformation.....18

2.2) Structural plasticity deformation.....19

3) Stress -Strain curves.....20

3.1) Mechanisms of work hardening.....22

3.2)	Hardening in FCC crystal .....	23
4)	Electric Resistivity .....	25
4.1)	Change of resistivity with temperature .....	25
4.2)	Electrical reesistivity of structural sensitive property .....	26
4.3)	Theory of the resistivity in alloys during (GP) zone formation .....	28
5)	Phase transformation.....	29
5.1)	Verious kinds of phase transformation .....	30
5.2)	Characteristices of nucleation and.....	30
5.3)	growth transformation .....	33
5.4)	Sn-Sb Phase diagram .....	33
6)	Literature review .....	35
CHAPTER (II).....		41
Aim of the present work .....		41
CHAPTER (III).....		42
Experimental Tehniques .....		42
3.1)	Experimental details .....	42
3.2)	Preparation of alloy .....	42
3.3)	Preparation of metallographic sample .....	43
3.4)	Measurement of grain diameter .....	46
3.5)	The creep testing machine .....	46
3.6)	Creep measurements .....	48
3.7)	Stress-strain measurements .....	50
3.8)	Electrical resistivity measurements .....	50
3.9)	X-ray diffraction measurements .....	52

CHAPTER (IV).....56

Experimental results .....56

4.1) Creep observation .....56

4.1.1) Effect of stress ( $\sigma$ ) .....56

4.1.2) Effect of temperature (T) .....58

4.1.3) Transient creep .....58

4.1.4) Transient creep parameters .....60

4.1.5) The steady state creep .....62

4.1.6) Activation energy of the steady state creep .....62

4.1.7) Microstructure investigations .....67

4.2) Stress-strain characteristics .....74

4.1.1) Stress-strain curves .....74

4.2.2) Fracture surface energy .....74

4.3) Electrical resistivity .....78

CHAPTER (V).....84

Discussion and Conclusion .....84

5.1) Transient creep .....84

5.2) Steady state creep .....85

5.3) The Microstructure of Crept sample .....86

5.4) Work hardening characteristics .....86

5.5) Electrical resistivity .....88

Conclusion .....90

REFERENCE .....92

ARABIC ABSTRACT

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# ABSTRACT



## ABSTRACT

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  $\epsilon_{tr} = \beta t^n$ , where  $\epsilon_{tr}$  and  $t$  are the transient creep strain and time respectively. The parameter ( $\beta$ ) was found to change with the applied stress from ( $3.3 \times 10^{-2}$  to  $120 \times 10^{-2}$ ) for Sn - 4 wt% Sb. The exponent ( $n$ ) was found to change from (0.39 to 0.73) for this alloy. The parameter ( $\beta$ ) was related to the steady creep rate  $\dot{\epsilon}_{st}$  through the equation  $\beta = \beta_0 (\dot{\epsilon}_{st})^\gamma$ , the exponent  $\gamma$  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  $\mu\text{m}$ ), 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 ( $\sigma_y$ ) and the fracture stress ( $\sigma_f$ ) have been found to decrease with the increase of the working temperature. The temperature dependence of  $\sigma_y$  and  $\sigma_f$  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<sup>2</sup>) 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**

## CHAPTER (I)

### INTRODUCTION

#### 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)  $\epsilon_0$  ,  $\epsilon_1$  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.

$$\dot{\epsilon}_{st} = (\epsilon_2 - \epsilon_1)/(t_2 - t_1) \quad (1)$$

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.

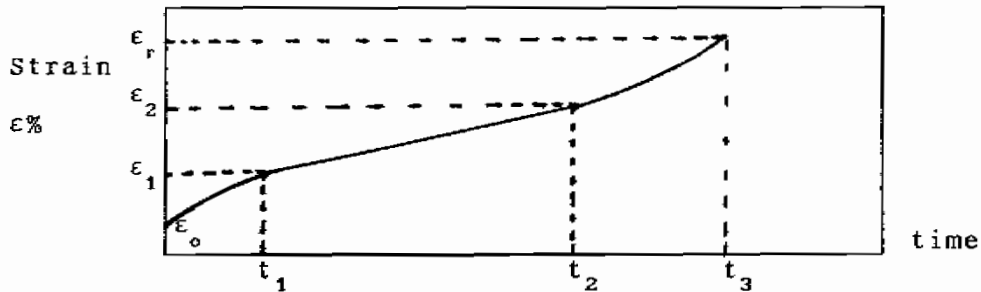


Fig (1) typical creep curve showing the three stages of creep at constant load test.

#### 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  $(0.05 \text{ to } 0.3 T_m)$  the time dependant creep strain ( $\epsilon$ ) varies linearly with the logarithm of the time ( $t$ ) in case of simple tension creep

$$\epsilon = \alpha \ln t + c \quad (2)$$

where  $\alpha$  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  $(0.2 \text{ to } 0.7 T_m)$  it is observed that two relations fit data. The first decreasing primary creep is given by

$$\epsilon = \epsilon_0 + \beta t^n \quad (3)$$

where,  $(\epsilon_0)$  is the strain upon loading and  $(\beta \text{ and } n)$  are

constants independent of time. This relation is called (parabolic creep) or  $\beta$ (flow). As stresses where secondary creep is observed a linear term is added to the equation (3) and takes the form

$$\epsilon = \epsilon_0 + Bt^n + Kt \quad (4)$$

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, ( $\dot{\epsilon}_{st}$ ) at low stress level is given by the relation

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

where, ( $\sigma$ ) 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.