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CREEP BEHAVIOUR OF A Sn – Ag – Cu – ALLOY NEAR ROOM TEMPERATURE

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PËRMBLEDHJE
Për të përshkruar deformimin ‘’creep’’ të materialeve metalikë përdoret kryesisht një ligj i dhënë sëpari nga Norton si dε/dt = A σn exp(-Q/R T). Sipas temperaturës së lëngjëve për këtë fazë ne mundë të arrijmë në përfundimin se ‘’creep’’ ndodh kryesishtë në tretësirën e ngurtë Sn. Vlerat e eksponentit të sforcos “n“ të deformimit “creep”, që ne kemi gjetur nga eksperimentet tona, janë në intervalin midis 1.8 dhe 2.9. Në bazë të vlerave të gjetura për “n“ mekanizmi kryesor i difuzionit është mekanizimi i dislokimeve. Vlerat experimentale të energjisë së aktivizimit janë midis Q/R=2363 and Q/R=5761. Vlera e parametrit A rritet me rritjen e sipërfaqes së kontaktit, me zvoglimin e energjisë së aktivizimit dhe me zvoglimin e exponentit të sforcos ”n” të deformimit “creep”.

SUMMARY
To describe the creep behaviour of metallic materials mainly a power law firstly given by Norton like dε/dt = A σn exp(-Q/R T) is used. According to the liquidus temperature of these phases we can conclude, that creep takes place mainly in the Sn-solid solution. The values of n we have found from our creep experiments amounts between 1.8 and 2.9. Based on the experimental values of n we can conclude that the main mechanisms of creep are dislocation mechanisms. The activation energies experimentally founded are in the range between Q/R=2363 and Q/R=5761. The A-parameter increases with the increase of the contact area, with the decrease of Q-activation energy and with the decrease of n-exponent creep stress.
Key words: Creep, SnAgCu, Norton law, activation energy, dislocation mechanisms.

1. INTRODUCTION

A Pb solder joint is fast becoming a reality in electronic manufacturing due to marketing and legislative pressures because Pb-material is harmful for healthy. The reliability of soldier joints is one of the most important factors when selecting a package for a particular application. The stiffness mismatch between the package and the board results in thermal stresses in solder joints during temperature and power cycling. The damage caused by these stresses accumulates as the electronic assembly is subjected to multiple cycles, ultimate causing failures of solder joints. Therefore reliability of Pb free solder joints is an important factor for selecting the proper replacement of the classic SnPb solder. Eutectic or near eutectic tin/lead (Sn–Pb) solder (melt-ing temperature*T*M= 183°C) has long been the predominant choice of the electronics industry due to itsoutstanding solderability and reliability. However, legisla-tion that mandates the removal of lead from electronics hasbeen actively pursued in the European Union and world-wide during the last 15 years due to environmental andhealth concerns regarding the high lead content in eutectic Sn–Pb solder.[4]
Based on expired collect a long time, the industry as a whole has converged towards SnAgCu solder alloy to replace SnPb solder from electronic assemblies and all applications. The

reliability of SnAgCu solder joints has been a subject of major research in electronic industry and a number of researches showing SnAgCu performs better or worse than SnPb solder, depending on the components tested and test conditions employed.

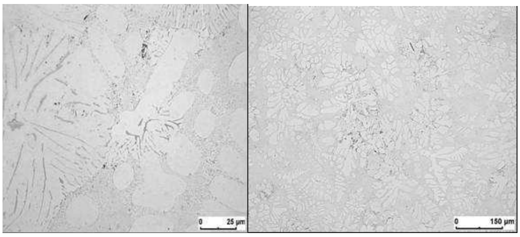


Figure 1: Show the microstructure of SnAg3.8Cu0,7

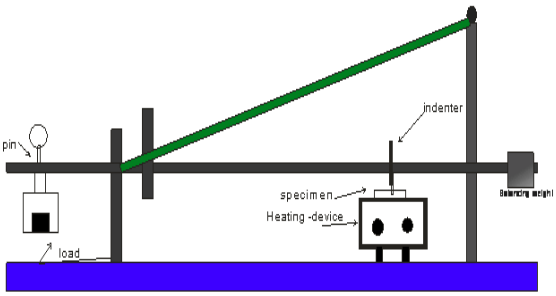


Figure 2: Schematic view of the construction equipment

The goal of the investigations was to determine the creep behaviour near room temperature. The experimental method used was the indentation creep test that has modified and used by Sastry in 2005.[8] This method is based on a penetration process of a cylindrical indenter Indentation creep test is an elegant test technique which offers the following advantages over the conventional creep testing:

- A small quantity of testing material is sufficient which provides an inexpensive method of developing new and advantages materials.

1-To determine the creep behaviour near room temperature.

2-These method is based on a penetration process of a cylindrical indenter, versus the load and the temperature.

- Constant compressive stress can be obtained by a constant load and the constant temperature until the experiment finished.
- The temperature and stress dependence of the steady-state creep rate can be obtained on a single specimen.
- Absence of tertiary stage of creep makes the deformation more stable and the test is better suited for investigating near brittle materials.
- Disadvantages are: no uniform deformation, no similarity of a deformation zone uses deformation dynamics.

Creep data are needed to quantify and understand deformation processes in different fields of research like mechanics [9], materials science [1,5] and geology [9]. In those fields it requires considerable experimental effort to obtain uniaxial creep data. Indentation creep testing has therefore been proposed as a technique which allows one to easily assess creep properties with small amounts of testing material [3].

2. MATERIALS AND METHODS

1- For the experiments we used quality of solder.SAC with density 7.5 (g/cm^3), liquid temperature 217°C< T_L ‹ 220°C and Brinell hardness 1.5HB

2-Microstructure of solder Sn-Ag-Cu(95.5% Sn,3.8%Ag,0.7Cu)

Phase	Symbol	Name	Type	Space group	Mode l
Bct	A5	(Sn),(b etaSn)	Beta Sn	14_1/a md	(Ag,C u,Sn)$_1$
Ag_3Sn	D0 alfa	Epsilo n	Beta Cu_3Ti	Pmmn	$(Ag)_{0.75}(Sn)_{0.25}$
Cu_6Sn_5	$B8_1$	Eta, Cu_6Sn_5 .h	NiAs	$P6_3$/m mc	$Cu_{0.545}$ $Sn_{0.455}$

Table 1: Is figured crystalline structure

Eutectic solder Sn-Ag-Cu(95.5% Sn,3.8%Ag,0.7Cu) is solder used in the following of this material.
In Table 1: Is figured crystalline structure.

In figure 1 we have shown the photo with magnification 25µm and 100 µm of solder SnAg3.8Cu0,7.
This device uses a simple lever to apply a steady impression force to a specimen. Loads are applied by hanging weight on the end of lever arm. The indenter arm is 10 mm while the arm of the applied force is 100 mm (Figure 2).
Indentation creep test (impression test) schematically was illustrated in figure 3 below.
A flat bottomed cylindrical punch of diameter '**A**' is pushed into the creep test specimen under an applied pressure **F.** The depth of penetration **h** of the punch is monitored as a function of time. Indentation creep test is derived by plotting **h** versus time. The punch diameter used was typically of 0.5mm smaller and larger 1mm was also employed depending on the application. They were made of stainless steel and were used for creep test at condition temperature.

Σ MPa	$\dot{\varepsilon}$ (30ºC)	$\dot{\varepsilon}$ (50ºC)	$\dot{\varepsilon}$ (80ºC)	$\dot{\varepsilon}$ (100ºC)
102	0.00038	0.002	0.0048	0.0048
102	0.0003	0.0015	0.002	
153			0.0048	
77	0.0002	0.0007	0.0015	0.0035
64	0.00008	0.00056	0.00085	0.002

Table 2: Results of the stress exponent

1/T	log (Rate min1)	log(Rate min2)	log(Rate min3)	log (Rate min4)
0.0033	2.525729	2.219203	3.135494	4.941642
0.003	5.010635	4.025352	4.248495	5.298317
0.0028	5.298317	4.442651	5.010635	6.173786
0.0026		5.298317	5.857933	

Table 3: Results of the activation enthalpy

The specimen is held at each end by a plain stainless steel indenter inserted through each loading stirrup. The moment due to the specimen stirrup and indenter is balanced by that of the weight hunger stirrup. The indenters are close fit to the holes at the end of the specimen.
Loads are applied by hanging weight on the end of the lever arm. A rest pin is provided to support the weight of the lever arm when loading the specimen prior to test. We used heater device to manually control and change the temperatures of the specimen during the test. This device is composed to heat the specimen during the creep experiment. The temperature during the test should be kept within ± 2˚C of the selected one.

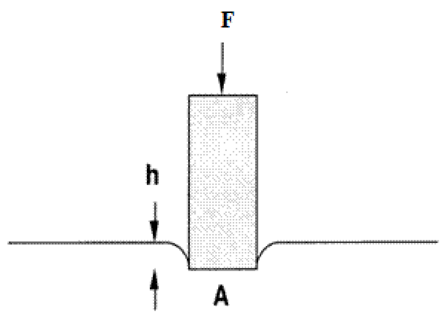


Figure 3: Schematic of the indentation creep test

3. RESULTS AND DISCUSSION

By using the equilibrium equation of the moments we have:

$$F_i = 10F_{af} \quad (1)$$

Where $\mathbf{F_i}$ the indenter force applied on the specimen and F_{af} applied force.
For all the experiments we have used the relations diffused below:

ε^I - Position of the specimen

$$\varepsilon^I = \frac{\varepsilon}{10} \quad (2)$$

h - Penetration

$$h = \frac{\varepsilon^I}{d} \quad (3)$$

$\dot{\varepsilon}$ - Creep rate

$$\dot{\varepsilon} = \frac{d\varepsilon}{dt} = \frac{dh}{dt} \cdot k \quad (4)$$

In crystalline materials, such as metals, creep mechanism is linked to diffusional flow of vacancies and thermal dislocation movement. However the equation of Norton power law for creep behavior can be expressed as:[10]

$$\dot{\varepsilon} = A\sigma^{n} \exp\left(-\frac{Q}{RT}\right) \quad \text{(Norton law)} \quad (5)$$

Where $\dot{\varepsilon}$ is the creep rate, **A** is the constant parameter of material, **n** is the stress exponent, **σ** is the applied stress; **Q** is the activation enthalpy, **R** is the universal gas constant and **T** is the absolute temperature in Kelvin.

n	2.9	2.6	2	1.8
B	6E-10	1E-08	2E-07	1E-06
σ (MPa)	102	77	64	102
d (mm)	0,5	1	1	1
Q/R	5761	4273	3871	2363
A (min^{-1})	7E-12	8.4E-11	1E-10	3E-08

Table 4: Results of the material parameter

A characteristic parameter describing the steady state creep is the stress exponent.
It can be expressed as:

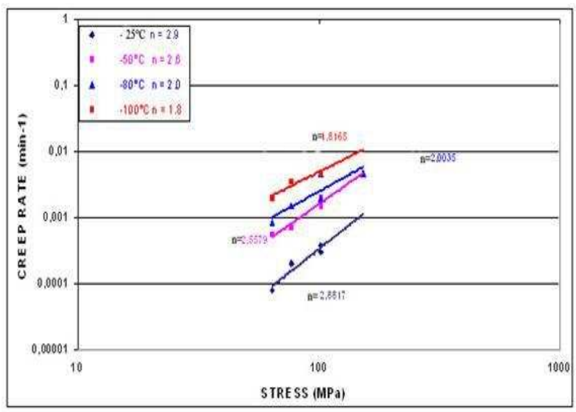
$$n = \frac{d\ln\dot{\varepsilon}}{d\ln\sigma} \quad (6)$$

In this manner we conclude to found stress exponent which is different for the different temperature. Table 2 and the graph 1 give the value of stress exponent for high temperature impression creep of SnAgCu. This data establish a straight line whose slope is given by "**n**".
The Norton exponent n strongly depends on the metal and on the creep mechanism.[6] At lower temperatures core diffusion become dominant. The Norton exponent at RT exceeds this exponent at high temperatures – by 2. The value of n that we have found is between 1.8 and 2.9.

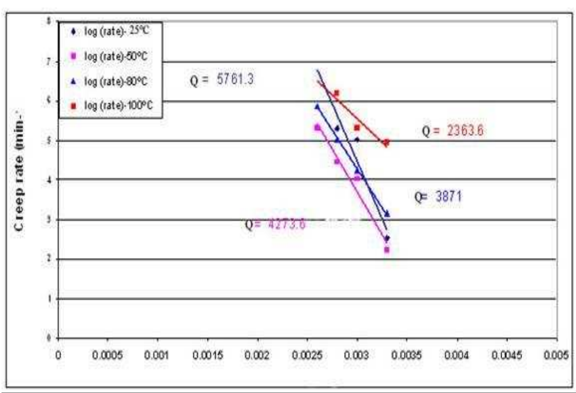
We see that at room temperatures we are in dislocation mechanisms, while with increasing of the temperature we have diffusion mechanism.
Other important activation parameters that aid in the identification of the rate controlling creep mechanism is the activation enthalpy which can be expressed as:[2]

$$\frac{-Q}{R} = \left(\frac{\partial \ln\dot{\varepsilon}_{min}}{\partial\, 1/T}\right)_{\sigma=const}$$

The results that we found are accumulated on the table 3 and in the graph 2 we can see the value of activation enthalpy.



Graph 1: Minimum creep rate vs. applied stress at30°C, 50°C, 80°C and 100°C



Graph 2: Minimum creep strain rate versus reciprocal of temperature for temperature 30°C, 50°C, 80°C, 100°C.

This graph shows that the increase of the temperature causes the decrease of Q. Therefore the **Q** value in room temperature is bigger than **Q** in 100°C. The grain in (RT) needs a big **Q**-activation energy to move. This means that it's more difficult to deform a specimen in (TR) than in a higher temperature. Increasing the diameter of the specimen has also a role in the value of **Q**. From the experiments we see that for the same stress under the same conditions but for different diameter we get different values of Q-activation energy. To check that this is not a mistake, but that is a true relationship between the diameter and the activation energy we have made some experiments putting the specimens of different diameters under the same stress. The **Q**-activation enthalpy is larger for the sample with the bigger r (d=1mm) than for the one with smaller diameter (2r=0.5mm).

The parameter of creep behavior is A which is called the parameter of material. From the experiment above we have all value that can help us to calculate this material parameter. We know now the power law creep strain rate and with this law we can calculate A- parameters. When we found **n**, together with we have found and **B**. **B** is a function of temperatures. We can use this formula to find parameter A that can be expressed as: [7]

$$A = \frac{B}{\exp\left(\frac{-Q}{RT}\right)} \tag{8}$$

The results that we have found A-parameter are shown on the table 4 below.

These are all experimental result found for creep behaviour of the solder alloy 95.5Sn3.8Ag0.7Cu.

Summarizing very interesting result was the dependence of creep strain rate from the diameter size. Our results show that for tests performed with large diameter indenters the creep strain rate increase. Obtained results are compared with data reported in the literature using conventional testing and both sets of data are found to be in good agreement. The validity of the impression creep test technique is clearly demonstrated in spite of some differences, due to experimental errors.

For the same punching stress, the impressing velocity varies inversely with the punch diameter in the bulk diffusion regime, inversely with the punch area in the surface diffusion regime, and proportionally with the punch diameter in the dislocation regime. The last statement is experimentally confirmed. These characteristics can be used to differentiate between mechanisms.

REFERENCES

1. Cadek, J. Creep in Metallic Materials.Elsevier, Amsterdam (1988).
2. Evans R. W. and Wilshire B., Introduction to Creep, The Institute Of Materials, London (1993) 1-75
3. Evans B.J. Geophys. Res 89,4213-4222 (1984). for electronic packaging Springer Science + Business Media, LLC 2009.
4. Hongtao MaÆ Jeffrey C. Suhling, A review of mechanical properties of lead-free solders
5. Kassner M.E, M.T.Perez-Prado, Fundamentals of Creep in Metals and Alloys ELSEVIER 2004 New York
6. Nabarro F.R.N Creep in commercially pure metals.Elsevier, Acta Materialia,2005 Hirth, J.P and J.Loethe: Theory of Dislocation. McGraw-Hill.New- York.1968
7. Nabarro, F.R.N and Villiers, H.L. The Physics of creep,Taylor and Francis, London (1995).
8. Sastry D.H. . Impression creep technique—An overview, Materials Science and Engineering, volume 409, Issues 1-2, 15 November 2005, Micromechanics of Advanced Materials II.
9. Webster, G.A. and Ainsworth, R.A. High Temperature Component Life Assessment. Chapman & Hall, London (1994).
10. Yue Z.F. Probst-Hein M. and Eggeler G. Determination of creep parameters from indentation creep experiments: a parametric finite element study for single phase materials.