Effects of Cu or Bi Additions on the Creep Properties of the Sn-3.5Ag Solder Alloys

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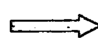
Introduction

- **Pb-Sn alloys**
  - Ideal for the soldering applications; low melting temperature, high electrical conductivity, good strength and good wettability

⟹ CONCERN OVER ENVIRONMENTAL PROTECTION

- **Sn-3.5Ag-Bi, Sn-3.5Ag-Cu alloy**
  - Most promising candidate alloys.
  - Rather high $T_{m.p.}$ and poor wettability compared to the 63Sn/37Pb solder.
  - Mechanical properties of these alloys are not known yet fully.

Package operating temperature ≈ 0.7 T_m



Creep and creep-fatigue properties of these alloys are important.

Experimental Procedure

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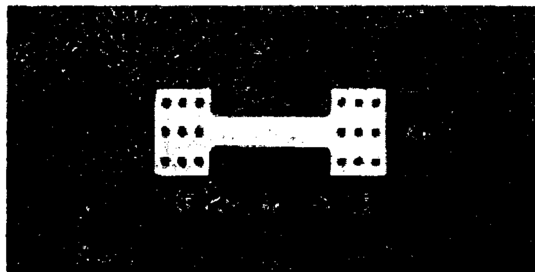
- **Solder composition (wt%)**
  - **Sn-3.5Ag-(0, 2.5, 4.8, 7.5, 10)Bi**
  - **Sn-3.5Ag-(0, 0.5, 0.75, 1.0, 1.5)Cu**

- **Specimen Geometry**



- As rolled + 120°C, 12hr heat treatment

Minimum Strain Rates

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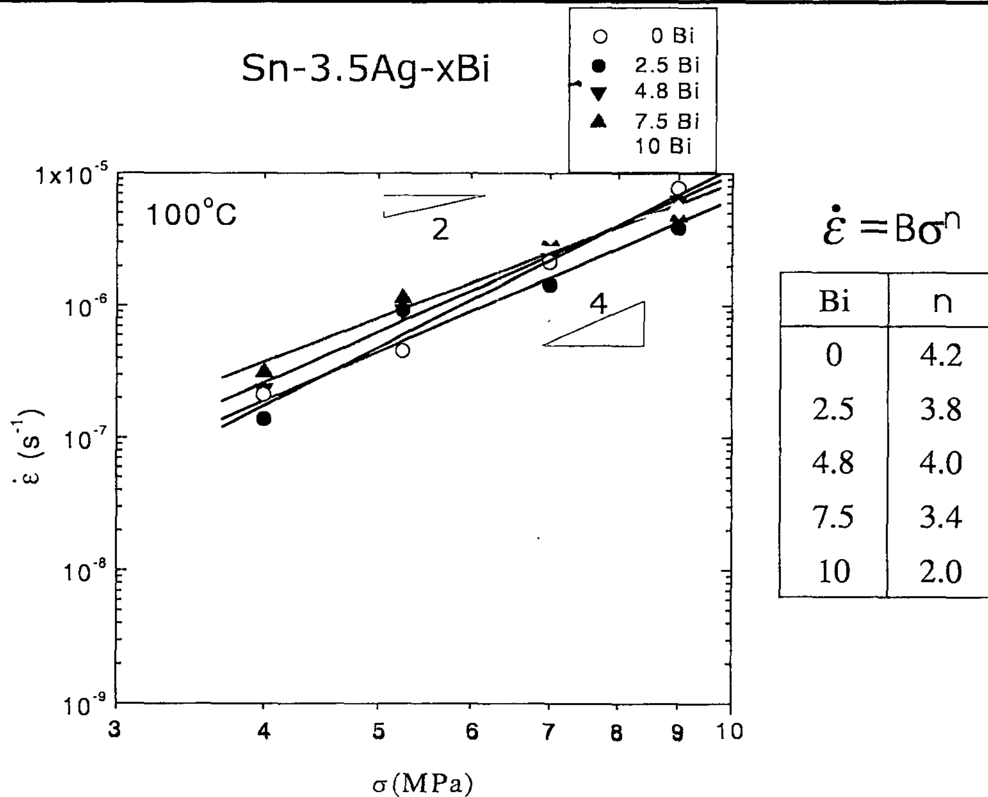

$$\dot{\varepsilon} = B\sigma^n$$

Bi	n
0	4.2
2.5	3.8
4.8	4.0
7.5	3.4
10	2.0

Strain rate vs. Bi content

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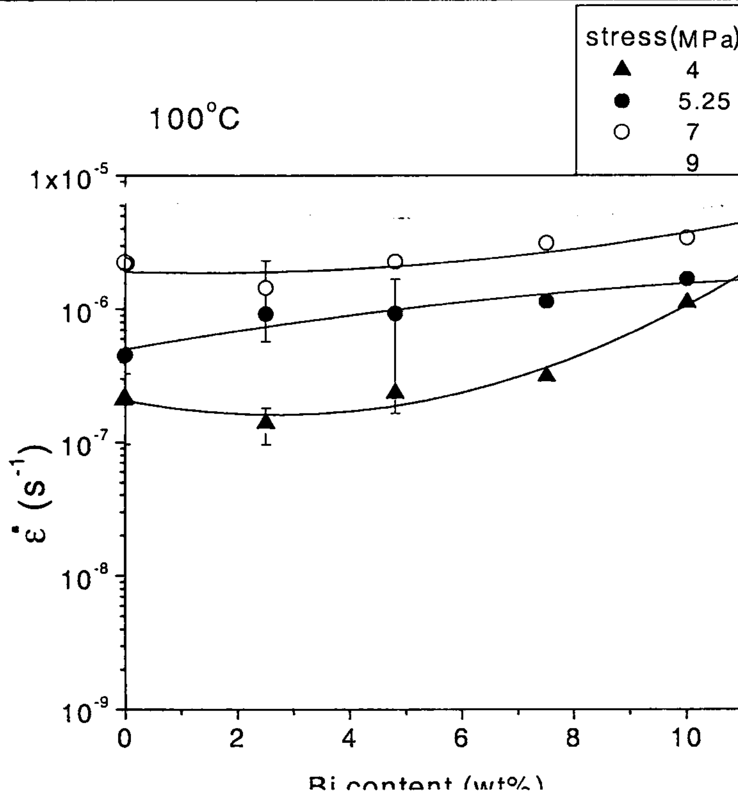

Rupture time

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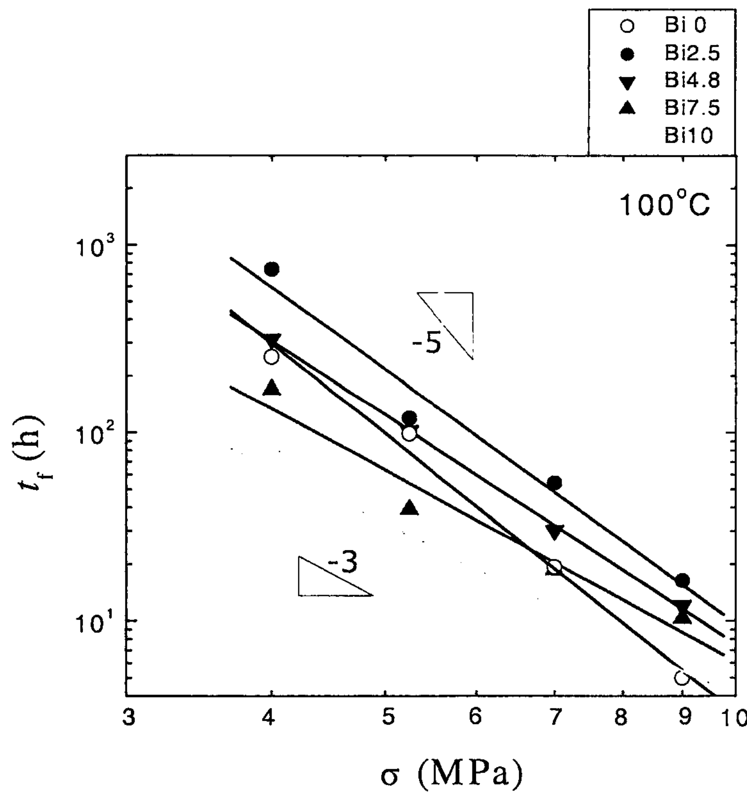

$$t_f = B\sigma^{-m}$$

Bi	m
0	4.9
2.5	4.5
4.8	4.0
7.5	3.4
10	3.0

Rupture time vs. Bi content

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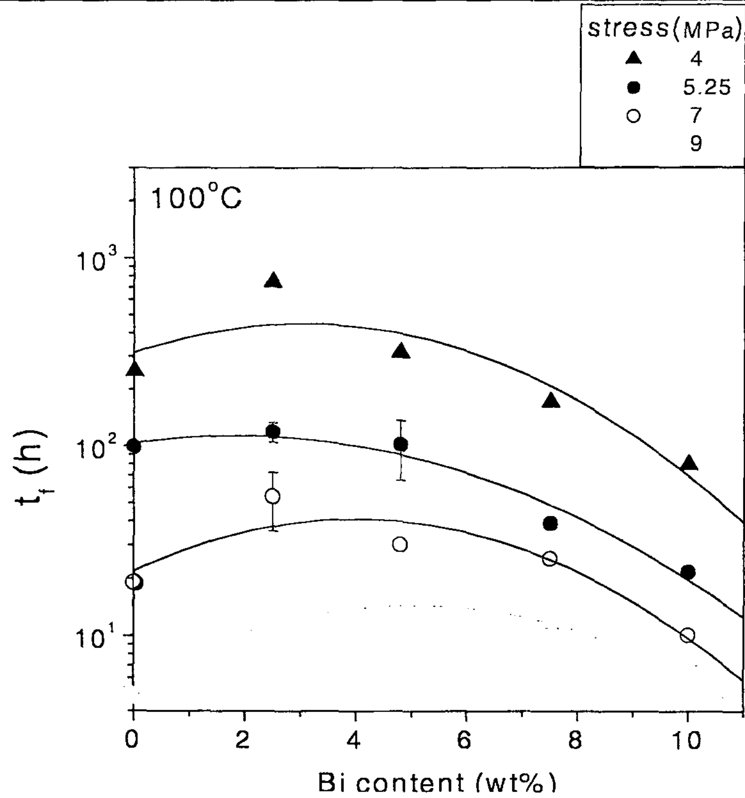

Ruptured Specimen

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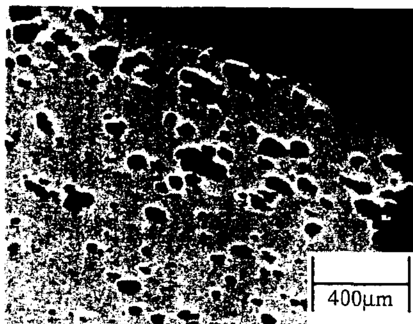
σ = 7 MPa

Before Etching | After Etching

0 Bi



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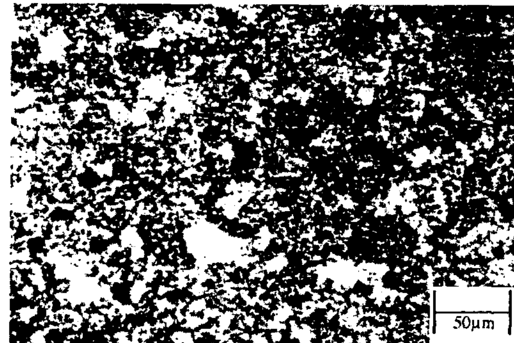
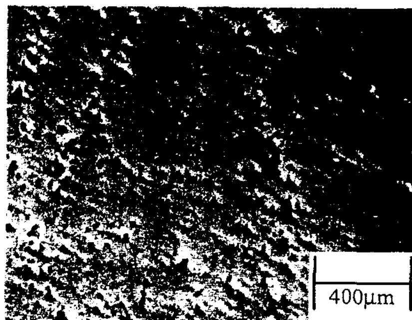


4.8 Bi



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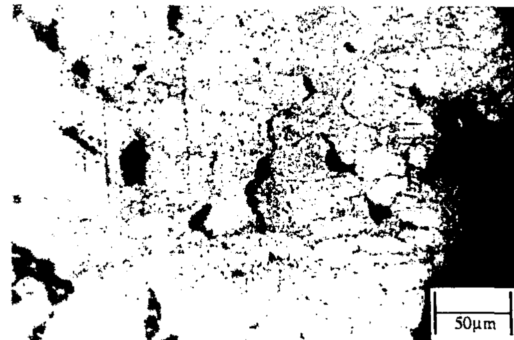


EDS

Ag3Sn

2.5Bi

Acc.V Spot Magn Det WD Exp 10 µm
20.0 kV 3.0 2000x SE 7.5 640

Bi

Ag3Sn

7.5Bi

Acc.V Spot Magn Det WD Exp 10 µm
20.0 kV 3.0 2000x SE 5.4 766

Ag3Sn

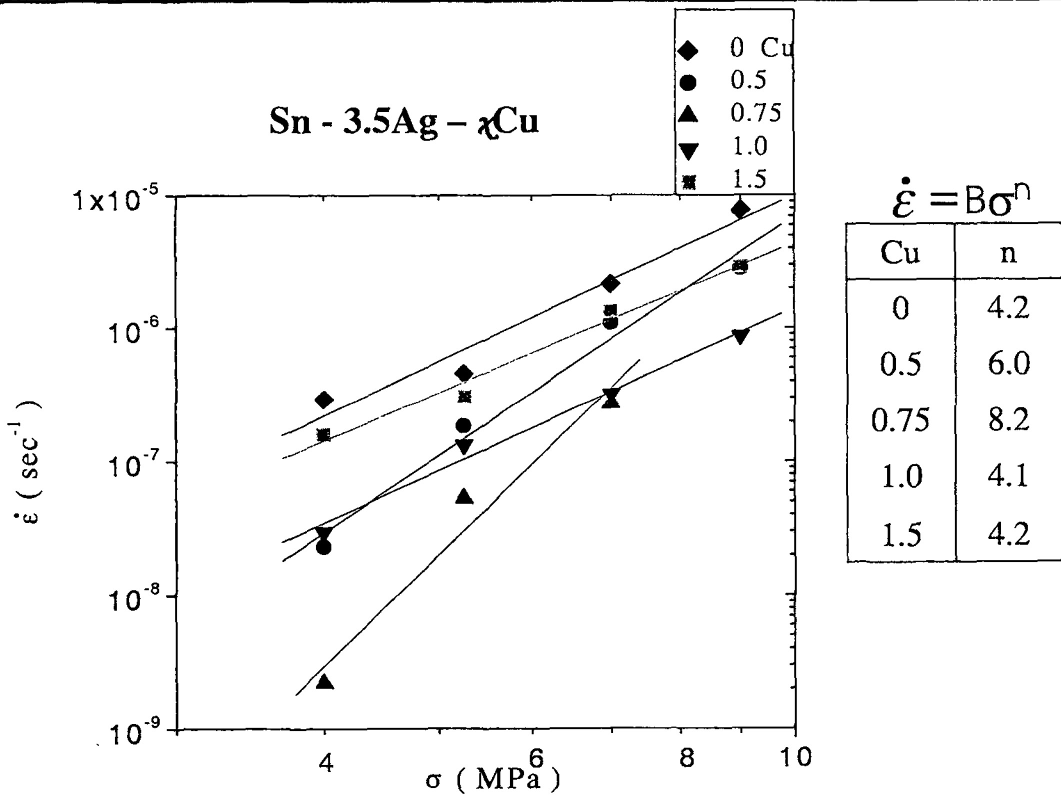
Ag3Sn Bi

4.8Bi

Acc.V Spot Magn Det WD Exp 10 µm
10.0 kV 3.0 2000x SE 10.3 763

σ = 7 MPa

Minimum Strain Rates



$$\dot{\varepsilon} = B\sigma^{n}$$

Cu	n
0	4.2
0.5	6.0
0.75	8.2
1.0	4.1
1.5	4.2

Strain rate vs. Bi content

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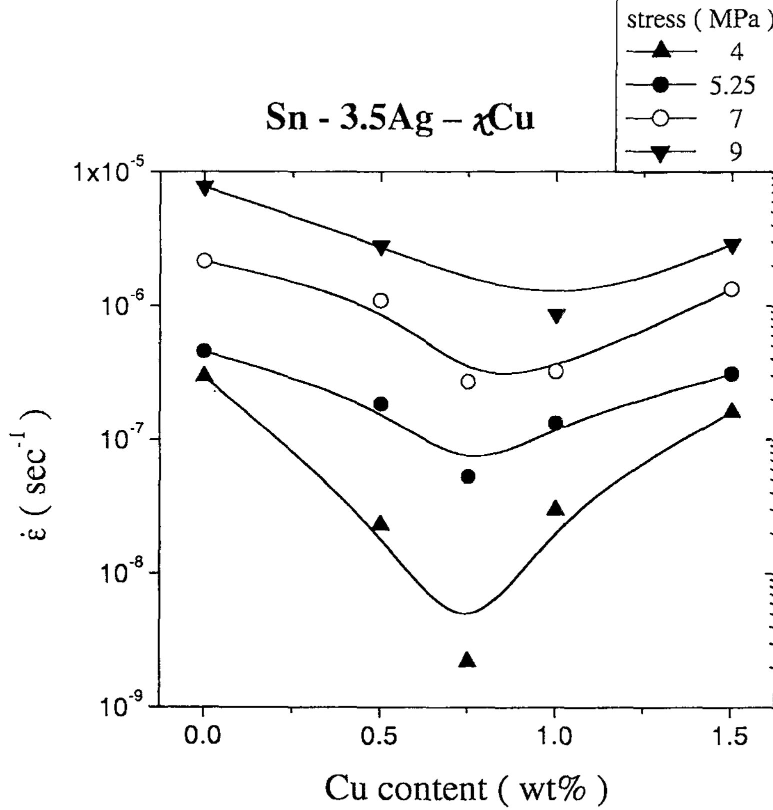

Rupture Time

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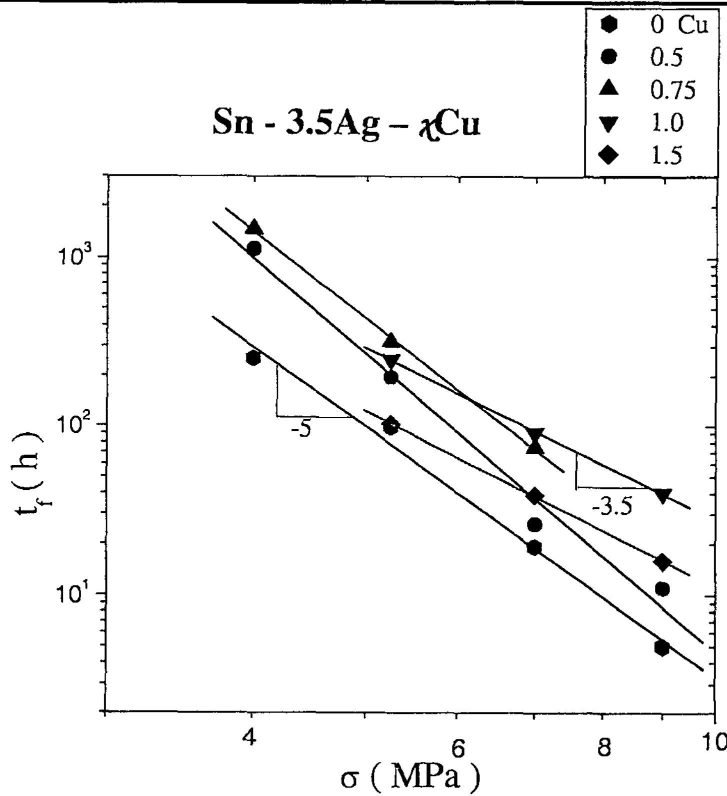

$$t_f = B\sigma^{-m}$$

Cu	m
0	4.9
0.5	5.9
0.75	5.3
1.0	3.4
1.5	3.5

Rupture time vs. Bi content

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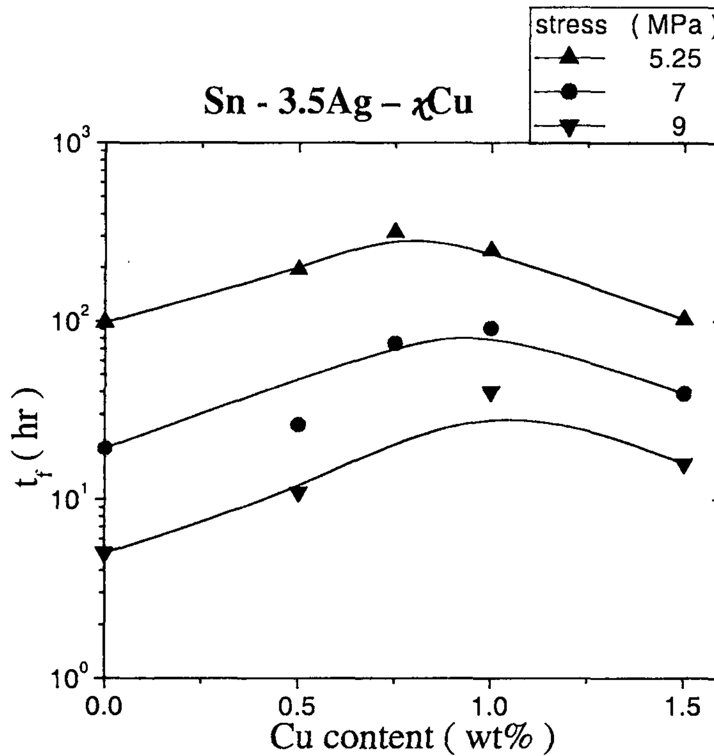

Ruptured creep specimen

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0.5 Cu

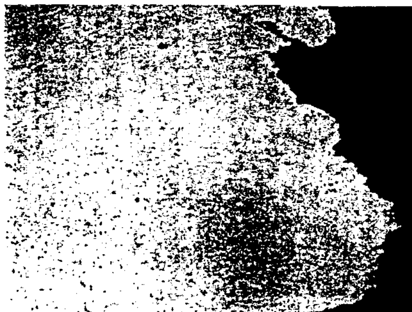
σ: 9 MPa

0.75 Cu

σ: 7 MPa

1.0 Cu

σ: 9 MPa



1.5 Cu

σ: 9 MPa

Ruptured creep specimen

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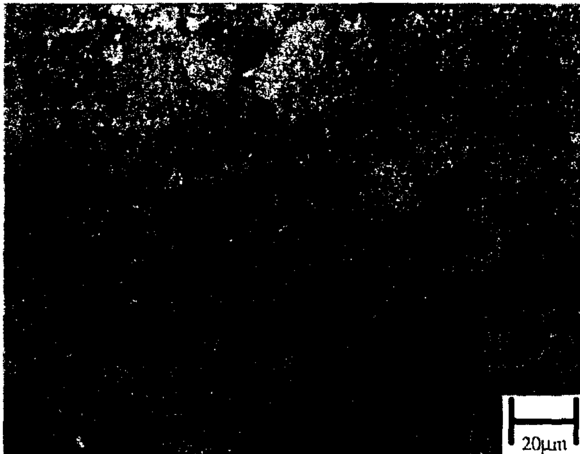

0.75 Cu, σ: 5.25 MPa, t_f: 249hr

1.5 Cu, σ: 7 MPa, t_f: 39hr

Conclusions

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1. Additions of Bi generally deteriorated creep properties while those of Cu were beneficial.
2. Optimum Bi content in terms of $\dot{\varepsilon}_{min}$ were 2.5%, while the Cu addition was optimal at 0.75%
3. Stress exponents of $\dot{\varepsilon}_{min}$ were generally 4.0 ± 0.6. However, an unusually small stress exponent (n=2) was found in the Sn-3.5Ag-10Bi, while the opposite was true (n ≥ 6) in the Sn-3.5Ag-0.5Cu and Sn-3.5Ag-0.75Cu alloys.
4. Creep ruptures in Bi containing alloys were assisted by the nucleation, growth, and inter-linkage of grain boundary voids, while the Cu containing alloys showed only ductile voids in the matrix.