Temperature dependence on tensile properties of Cu-40mass%Fe dual phase alloy

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Cu - Fe binary alloy shows less mutual solubility.

**Cu(fcc) + Fe(bcc)**

dual phase structure
Dependence of temperature on tensile property

Polycrystalline Cu or Fe single phase material


- Fe (Bcc) High yield stress
- Cu (Fcc) Low yield stress
- Fe (bcc) Low elongation
- Cu (fcc) High elongation

At low temperature
Fcc + Bcc dual phase materials tensile property?

Liquid nitrogen 77K
Room temperature 293K

Pure Iron (C + N < 70 ppm)
Tensile properties, deformation and fracture behavior of the cold rolled Cu-40mass%Fe alloy at low temperature had been evaluated in order to reveal the temperature dependence on tensile property in fcc + bcc dual phase structure.
Materials: Cu – 40%Fe alloy

Heat treatment:

Commercial cold rolled plate in 2.0 mm thickness → 850°C for 1.8ks → Water cooling

Tensile test at 293 K, 77 K and 8 K.
OM and SEM observation, EDS, EBSD, DIC analysis
1. Microstructure

2. Tensile property

3. Deformation and fracture behavior
OM image and analysis of inclusion

OM image

Inclusion

Cu layer

Fe layer

Width of layer is approximately 3 μm

EDS analysis

Inclusions (iron oxide)

Cu + Fe layer structure
Each phase has **ultra fine grains** (\(<1\mu m\))

Fe and Cu layer have **precipitates** of Cu and Fe
1. Microstructure

2. Tensile property

3. Deformation and fracture behavior
Tensile property at each temperature

- Nominal stress, $\sigma_n$/MPa
- Nominal strain, $\varepsilon_n$/-

Increasing

8 K

77 K

293 K

Total elongation is almost same

strength - elongation balance is improved as lowering temperature
Work hardening rate in each temperature

Uniform Elongation is almost same

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Uniform Elongation</th>
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<tbody>
<tr>
<td>293 K</td>
<td>22.3%</td>
</tr>
<tr>
<td>77 K</td>
<td>24.0%</td>
</tr>
<tr>
<td>8 K</td>
<td>21.7%</td>
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</tbody>
</table>

Work hardening rate increase as lowering temperature
Dependence of temperature on tensile property

Polycrystalline Fe or Cu single phase material

Cu(fcc) + Fe(bcc) dual phase structure is effective to improve strength – elongation balance at low temperature

At low temperature
Bcc + Fcc dual phase materials tensile property?

Fe(bcc) High yield stress
Cu(fcc) Low yield stress

Fe(bcc) Low elongation
Cu(fcc) high elongation
1. Microstructure

2. Tensile property

3. Deformation and fracture behavior
Strain distribution in 5 % tensile deformed at 293 K, 77 K, 8 K

Strain was inhomogeneously distributed regardless of phases at 8 K

Strain tends to concentrate on Fe layer at 293 K

→ is one of the reason for high work hardening at 8 K
SEM images at uniform deformation and necking region

SEM images in fractured specimen at 8 K

Uniform deformation region

Necking region

Fe layer

Cu layer

Tensile direction

ND
RD
2μm

No Voids or cracks

There are crack and a lot of voids inside only Cu layer

Fine grain or Cu precipitates may suppress brittle fracture

Fe layer has enough ductility even at 8 K
Fracture surface at 293 K, 77 K and 8 K.

There are a lot of coarse voids generated from inclusions.

These voids easily connect each other, and then the specimen is broken.

This alloy has a possibility of improvement of the tensile property by removing these inclusions.

Inclusions degrade elongation.
The annealed cold-rolled Cu-40%Fe alloy formed layer structure macroscopically and each layer had fine grains and Fe or Cu precipitates.

Yield stress, tensile stress and work-hardening rate continuously increased as lowering temperature though elongation was hardly changed.

Strain was inhomogeneously distributed at low temperature regardless of Cu and Fe layer, and voids and cracks tended to generate inside Cu layer at low temperature.
Thank you for your kind attention