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HIGH TEMPERATURE MECHANICAL PROPERTIES OF UNIRRADIATED DISPERSION STRENGTHENED COPPER

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Tensile and creep results of oxide dispersion strenghtened copper are presented. The most important features of ODS copper high temperature behaviour are the high strength corresponding to low creep rates, high stress creep rate dependence , a poor ductility and a brittleness wich result in a premature creep fracture at high applied stress.

INTRODUCTION

Oxide Dispersion Strenghened (ODS) copper material, due to its excellent thermal conductivity associated with a high temperature strength is a candidate material for structural applications as divertor plasma facing components of thermonuclear fusion reactor. Moreover the material must retain good mechanical properties subsequent to elevated temperature thermal cycles as brazing operations.

This paper presents the tensile and creep properties at elevated temperature of an commercial alumina dispersion strenghened copper : tradename glidcop Al25 in the as received condition and after high temperature thermal cycle.

The commercial dispersion strengthened copper Al25, containing 0.5Wt% alumina (Al_2O_3), was purchased in 20mm diameter rods. This industrial material : tradename Glidcop Al25 is produced by internal oxidation of copper-aluminium powder [1]. The dilute solid solution alloy of aluminium in copper is melted and atomised in powder. The oxygen produced by copper oxide dissociation, diffuses and oxidises aluminium into alumina oxide (Al_2O_3). These reduced powder is consolidated into bars or rods by hot extrusion.

The microstructure consists of fine highly elongated grains : about 5µm length and 0.5µm in diameter) which have a fiber type shape. A strong {200} and {111} texture is observed in the transverse direction of the as received rods. The fine alumina particles (average size in the range [5-10nm]) identified as tetragonal j or n' alumina by indexing ring pattern appear relatively homogeneous dispersed in the grain. In addition a few larger platelets : size 0.1µm looking for α alumina are observed. There is a high dislocation density in the grains or subgrains in the as received material. The effect of short term annealing (15 mn at 980°C) on the grain structure is little pronounced. The main effect observed after long term annealing (1000h at 700°C) is the increase of density of large particles analysed as mixed oxide $9Al_2O_3.2B_2O_3$ located in the grain boudaries.

Tensile tests at different temperatures (up to 980°C) and creep tests at 450°C and at 300°C were performed. Without room temperature tensile tests all the tests were carried out under vacuum (2.10^{-5} Torr). Specimen for high temperature tests were mechanically polished and then electropolished to produce a defect free surface. This is an important step for creep tests since surface flaws are source of crack initiation which may result in a shorter creep time.

RESULTS OF TENSILE PROPERTIES

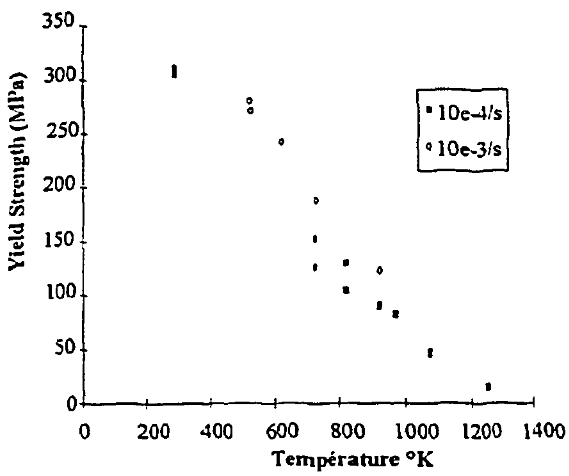

Figure 1 : Temperature effect on yield stress.

The results presented on figures 1 and 2 show the good behaviour at room temperature with an ultimate tensile strength and total elongation reaching 410MPa and 20% respectively.

The ultimate tensile strength and the yield strength decrease linearly with temperature and the total elongation present a drop in the temperature range [450°C-750°C].

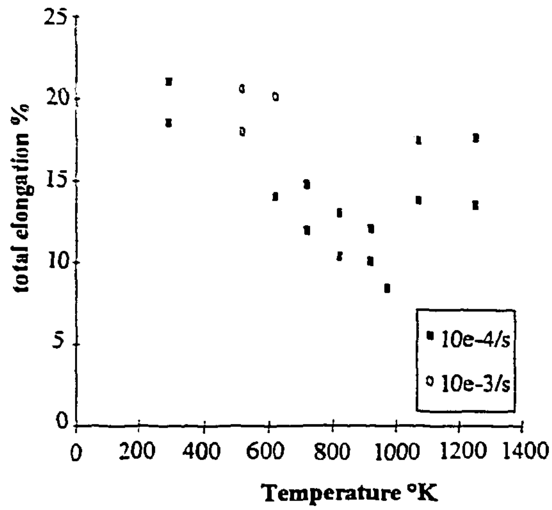

Figure 2 : Temperature effect on total elongation.

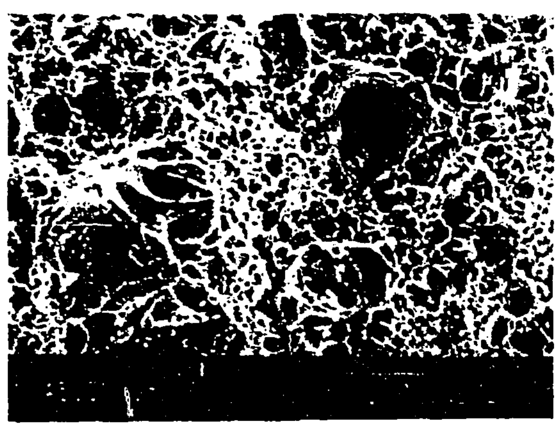

Figure 3 : SEM micrography of fracture surface. Sample tested of room temperature.

Moreover at the strain rate concerned $\varepsilon = 10^{-4}\ s^{-1}$, the fracture surfaces exhibit :

-a transgranular aspect with dimples at room temperature (figure 3)

- an intergranular aspect above 450°C (figure 4).

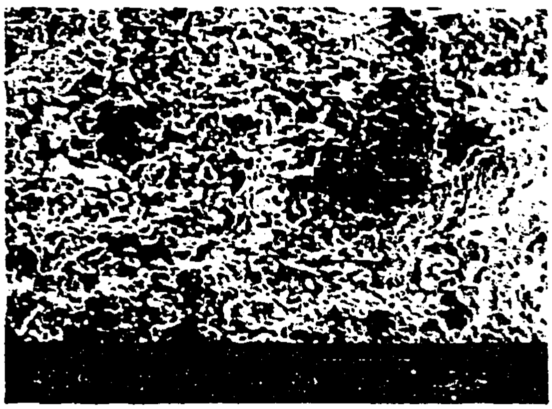

Figure 4 : Fracture surface of sample tested at 650°C. As received DS copper copper glidcop Al25.

The short heating treatment induce a weak softening but no significant difference of the behaviour.

CREEP RESULTS

The creep tests were carried out at 450°C in the stress range [100-150MPa] and at 300°C in the stress range [175- 190MPa]. All the creep curves observed present a very short tertiary stage with a sharp transition from the secondary to the tertiary stage leading in a very short time to failure with a creep elongation being typically less than 4%. Correlation of creep elongation with time to rupture indicates clearly the limited ductility amount at low strain rate. The creep properties (life time, creep elongation and strain rate) present a large scatter.

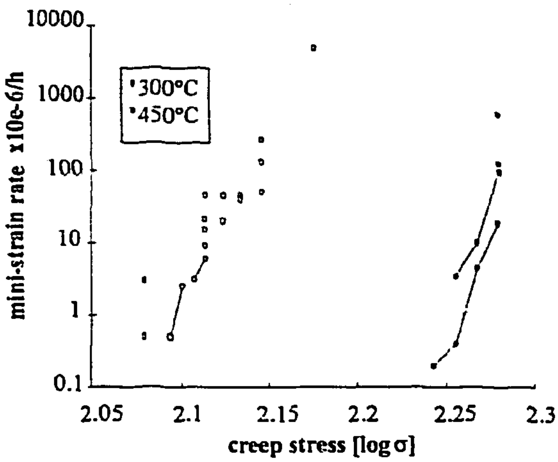

Figure 5 : Stress dependance of creep strain. Creep tests at 450°C and 300°C.

The figure 5 reveals the stress dependence of the minimum creep rate, the stress dependence n of the creep rate reaches 40 at 450°C and 60 at 300°C. Scaning Electron micrograph and optical analysis of the gauge sections and fracture surfaces of the specimens indicated the following aspects :

- a brittle fracture on the great area on the surfaces and characterized by intergranular rupture The figure 6 indicates clearly the fiber shape grains and some little cavities.

- a ductile morphology on a little area with dimples.

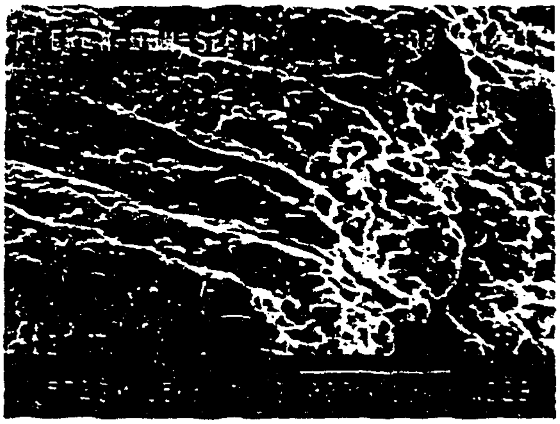

Figure 6: SEM micrograph of creep fracture surface. Creep test at 450°C under 120MPa.

DISCUSSION

The most important features of ODS copper high temperature behaviour are the high creep strength (120MPa at 450°C and 180MPa at 300°C) corresponding to low creep rate : $\varepsilon < 1.10^{-6}\ h^{-1}$ compared to dispersion free material but the poor creep ductility and the brittleness which result in a premature creep fracture at high applied stress. The large scatter may be explained by a large dispersion density differential between some grains. The anomalously high stress dependence of the creep rates and the dispersion-dislocation is not now explained. In this temperature range, about 0.5Tm (Tm melting temperature) and for for this low deformation rates corresponding to diffusional creep at the boundaries (coble creep) grain boundary sliding contributes at creep deformation. The intergranular brittleness is closely linked to the respective contributions of matrix and grain boundaries to deformation, the damage rate increasing as the grain boudary contribution inceases. The fine alumina dispersion effect on cross slip capacities in the copper matrix, the climb control at high temperature or the attractive dislocation-dispersoid interaction is now insufficiently understood [2]. The high dislocation densities effect on creep behaviour and the fine elongated grains may be accentuated the growth and coalesence of cavity during creep and lead to failure of the material.

CONCLUSION

DS copper Al25 exhibit a high strength at high temperature but a limited ductility at low strain rate. Stress exponents of 40 and 60 were measured at 450°C and 600°C. The fracture surfaces are intergranular for most of the surface. The intergranular brittleness is probably due to the strengthening effect of particles and initial dislocation substructure in the matrix.

REFERENCES

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[2] J.H. Schroder, E. Artz, "Weak beam studies of dislocation/dispersoïd interaction in an ODS superalloy", Scripta Met. 19, Vol 19, p.1129-1134.