FRACTURE MICROMECHANISM OF CU-CR-ZR SYSTEM BY "IN-SITU TENSILE TEST IN SEM"

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MECHANIZMUS PORUŠOVANIA SYSTÉMU CU-CR-ZR METÓDOU "IN-SITU TENSILE TEST IN SEM"

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Abstrakt

V predloženej práci bol na základe metódy "in-situ tensile test in SEM" hodnotený mechanizmus porušovania sústavy Cu-Cr-Zr.

Na základe "in-situ" pozorovania zmien štruktúry sústavy Cu-Cr-Zr v procese deformácie metódou SEM sme navrhli mechanizmus lomu:

a) v priebehu zaťaženia do hodnoty pomernej deformácie $\varepsilon = 0{,}08$ sme v štruktúre nepozorovali žiadne trhliny

b) pri zaťažení a nasledujúcej deformácii $\varepsilon = 0{,}11$ vznikajú prvé trhliny v okolí veľkých Cr častíc dekohéziou ako aj praskaním

c) trajektória lomu je usmerňovaná pod uhlom 67° k smeru namáhania koalescenciou trhlín

d) pri konečnej pomernej deformácii $\varepsilon = 0{,}116$ vznikne lom

Analýza lomového povrchu ukazuje, že lom je transkryštalický tvárny, charakterizovaný jamkovou morfológiou. Jamky sú dvoch veľkostných kategórii vznikajúcich na veľkostne rôznych časticiach iniciáciou, rastom a koalescenciou dutín.

Abstract

In the present work fracture mechanism of the Cu-Cr-Zr system was studied by "in-situ tensile test in SEM". It has been shown, that during tensile strain over the critical deformation the first cracks appeared due to the decohesion of matrix - large Cr particles interphase or by Cr particles failure. The further stress increase causes the cracks formation on matrix - small Cr particles interfaces and in the clusters of Cu_5Zr intermetalics. The trajectory of final fracture was formed preferably by coalescence of cracks oriented about 67° to the loading direction. The model, presenting fracture mechanism in the investigated system was suggested.

Keywords: fracture mechanism, in-situ tensile test in SEM, PM copper alloys

1. Introduction

In our previous works [1-6] we have investigated the deformation process in the dispersion-strengthened materials using an in-situ tensile test in scanning electron microscope and proposed a model for the mechanism of fracture.

2. Experimental materials

Cu-0.5Cr-0.3Zr system prepared by powder metallurgy technology is used as a material for welding electrodes. Technology of material preparation consists of powder mechanical homogenisation, cold pressing, sintering in H_2 at 900°C, quenching and extrusion. Aging of material followed for 10 min at 100°C.

Fig.1 Shape and dimensions of a specimen

Special very small 0.1mm thin tensile specimens Fig.1 were produced and fixed into a special loading device inside the JEM 100C scanning transmission electron microscope. The microscope allowed both, to monitor the microstructure and measure in-situ the deformation of the specimen during loading until the fracture by means of the ASID-4D device.

3. Results and discussion

Microstructure of the material is from the point of view of quality and phase distribution heterogeneous. Cr particles of two size categories A_1, A_2 and fine Cu_5Zr (B_1) intermetallic compounds, Fig.2, are present in copper matrix. The EDX analyses diagrams of particles are on Figs.3, 4 and 5. Size categories of noncoherent Cr particles are A_1>5μm, A_2<1μm. Cu_5Zr particles are of nanometric size arranged in clusters. Due to the extrusion, all particles are distributed in bands, direction of which is identical to the direction of extrusion.

Samples were deformed by tension at room temperature with constant strain rate of = $6,6.10^{-4}s^{-1}$. Up to the relative deformation of $\varepsilon = 0,08$ no cracks formation was observed during the sample straining. The initiation of first microcracks in vicinity of Cr A_1 category particles was observed at the relative deformation of $\varepsilon = 0,11$, Fig.6.

The cracks were formed mainly by decohesion on the particle-matrix interface, Fig.7, or by the cleavage of the particles, Fig.8. Further increase of load involved into the deformation process smaller Cr particles of A_2 category as well as the clusters of Cu_5Zr (B_1) intermetallic particles. The failure line is directed by coalescence of small local cracks. The fracture is formed under the angle about 67° to the direction of the tensile load and was completed at the relative deformation of ε = 0,116, Fig.9.

Fig.2 Cr particles in two size categories A_1 A_2 and fine Cu_5Zr (B_1)

Fig.3 EDX analyse diagram of A_1 particles

Fig.4 EDX analyse diagram of A_2 particles

Fig.5 EDX analyse diagram of B_1 particles

Fig.6 Initiation of first microcracks

Fig.7 Cracks formed by decohesion

The reasons of decohesion are the different physical properties of system phases. Cu matrix has significantly higher coefficient of the thermal expansion and lower Young modulus as Cr and Cu_5Zr phases. After the hot extrusion of the system, due to the differences in mentioned factors the interphase stress occurred, which contributed to the interphase decohesion failure during the tensile deformation. Cracking of large Cr particles (A_1) is caused by their shape factor and notch effect.

Analysis of the fracture surface showed the transcrystalline ductile fracture mechanism, characterized by the dimples morphology. The dimples are of two size categories due to their forming on large and small particles by initiation, growth, and coalescence, Fig.10.

Fig.8 Cracks by the failure of the particles

Fig.9 The final fracture forming

Fig.10 The fracture surface

Fig.11 Model of failure mechanism

4. Conclusion

On the basis of in-situ deformation processes results of the Cu-Cr-Zr system and observed microstructural changes by method of SEM we suggested the following mechanism of fracture.

During the straining up to the value of relative deformation of $\varepsilon = 0,08$ no cracks were observed. By further straining at relative deformation of $\varepsilon = 0,11$ first cracks formed on interface of large Cr particles and matrix by decohesion as well as by cleavage of these Cr particles. Fracture trajectory was directed under about 67° degree to the direction of straining by coalescence of cracks, which were formed in particles, on the particles-matrix interface as well as in the clusters of Cu_5Zr intermetallic particles. The final fracture of transcrystalline ductile mode was completed at relative deformation of $\varepsilon = 0,116$.

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