Journal of Mining and Metallurgy, 39 (3‡4) B (2003) 499-507

MODEL OF FRACTURE MICROMECHANISM OF Cu-Cr-Zr SYSTEM BY "IN-SITU TENSILE TEST IN SEM"

M. Besterci[1], J. Ivan[2], P. Kulu[3], D. Arensburger[3] and O. Velgosova[4]

[1] Institute of Materials Research of SAS, Watsonova 47, 04353 Kosice, Slovakia
[2] Institute of Materials and Mechanics SAS, Račianska 75, 83008 Bratislava, Slovakia
[3] Institute of Materials Technology, Tallinn, Technical University, Ehitajate tee 5, 19086 Tallinn, Estonia
[4] Technical University, Department of Non-ferrous Materials and Waste Treatment, Latna 9/A, 04001 Košice, Slovakia

(Received 15 February 2002; accepted 5 May 2003)

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 affinal 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‰model of fracture mechanism.

1. Introduction

In our previous works [1-8] 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. Monitoring of straining in the electron microscope revealed changes in the microstructure and the progress of fracturing, through it should be kept in mind that it is influenced by the very small thickness of the test piece.

2. Experimental

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

Special very small 0.lmm thin tensile specimens, Fig.l, 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<lμm. 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 $\varepsilon=6.6 \cdot 10^{-4}s^{-1}$. 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 AI category particles was observed at the relative deformation of $\varepsilon=0.11$, Fig.6.

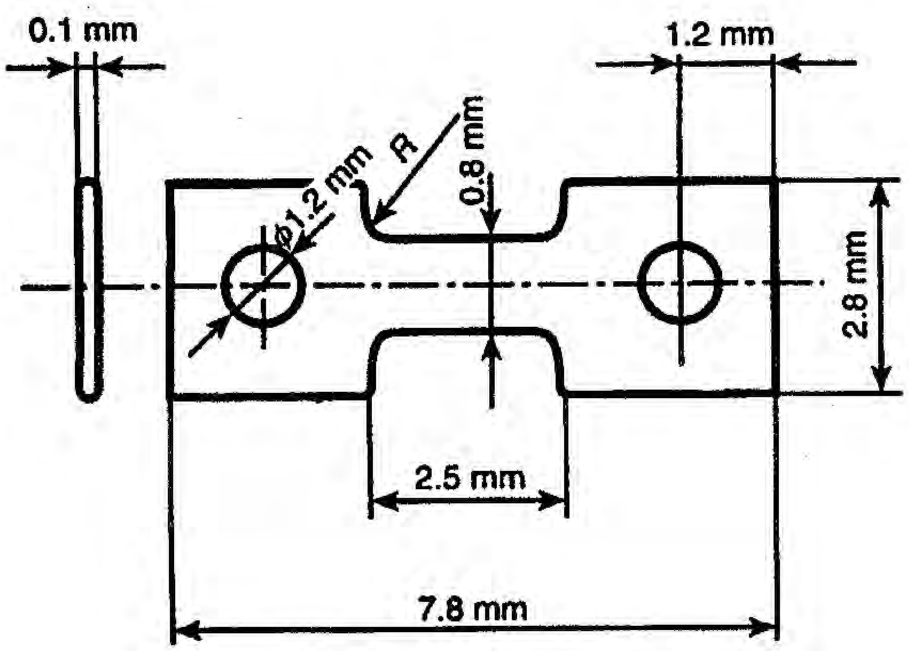


Figure 1. Shape and dimensions of a specimen

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 $\varepsilon=0.116$, Fig.9.

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 CujZr 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.

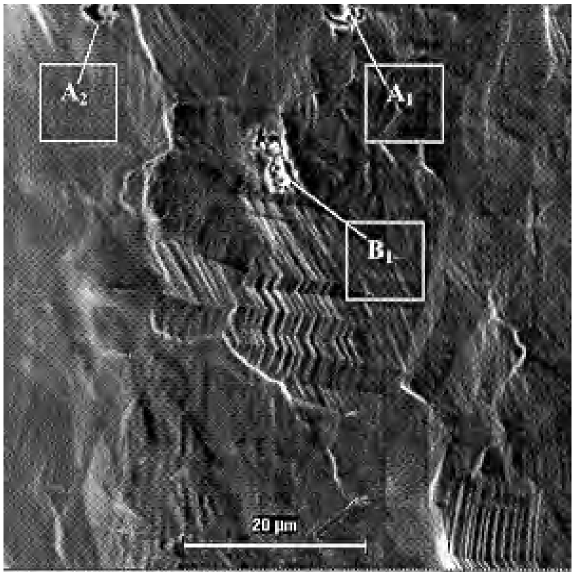


Figure 2. Cr particles in two size categories A_1, A_2 and fine Cu_5Zr (B_1)

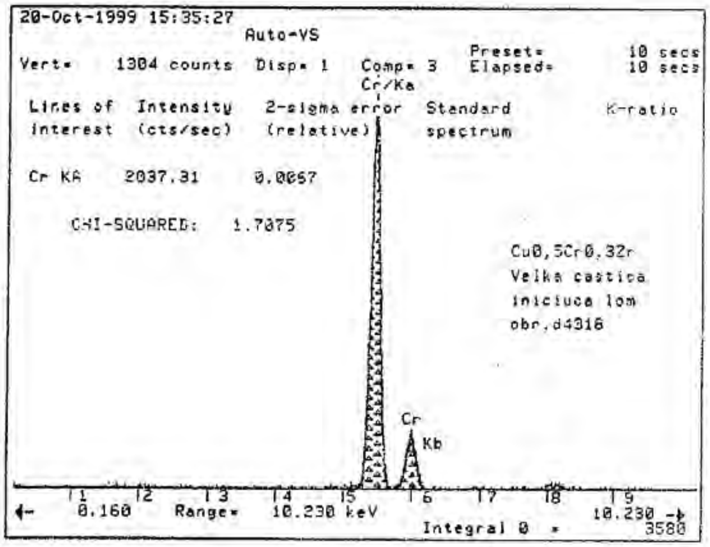
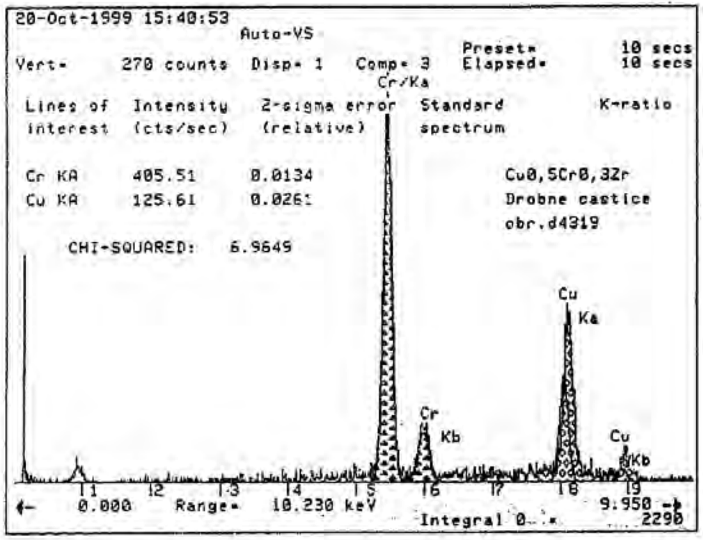


Figure 3. EDX analyse diagram of A_1 particles

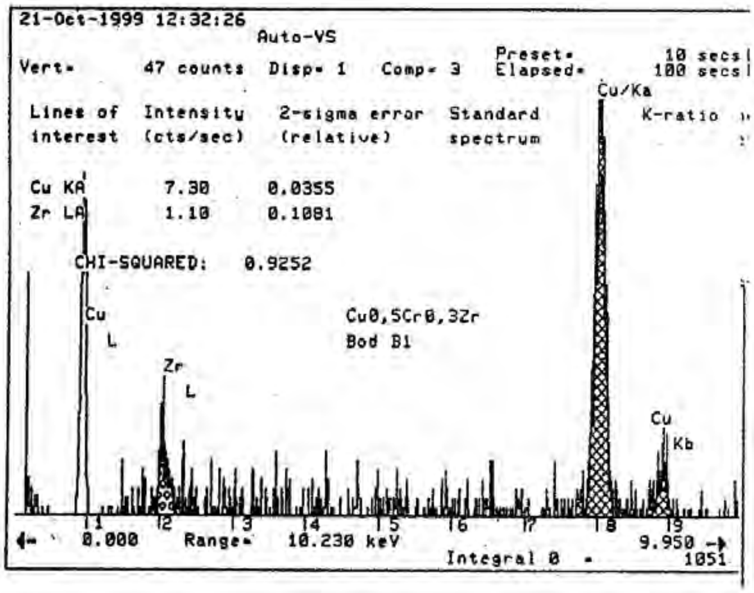


```
20-Oct-1999 15:40:53
                              Auto-VS
                                                  Preset=        10 secs
Vert=      270 counts  Disp= 1    Comp= 3   Elapsed=       10 secs

 Lines of   Intensity   2-sigma error  Standard          K-ratio
 interest   (cts/sec)   (relative)     spectrum

 Cr KA      405.51      0.0134                  Cu0,5Cr0,3Zr
 Cu KA      125.61      0.0261                  Drobne castice
                                                obr.d4319
    CHI-SQUARED:    6.9645
```

Figure 4. EDX analyse diagram of A_2 particles



```
21-Oct-1999 12:32:26
                              Auto-VS
                                                  Preset=        10 secs
Vert=      47 counts   Disp= 1    Comp= 3   Elapsed=      100 secs

 Lines of   Intensity   2-sigma error  Standard          K-ratio
 interest   (cts/sec)   (relative)     spectrum

 Cu KA        7.30      0.0355
 Zr LA        1.10      0.1081

   CHI-SQUARED:    0.9252

                                 Cu0,5Cr0,3Zr
                                 Bod B1
```

Figure 5. EDX analyse diagram of B_1 particles

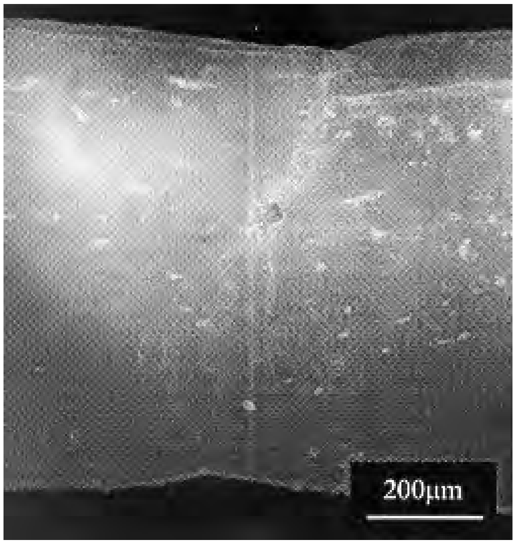


Figure 6. Initiation of first microcracks

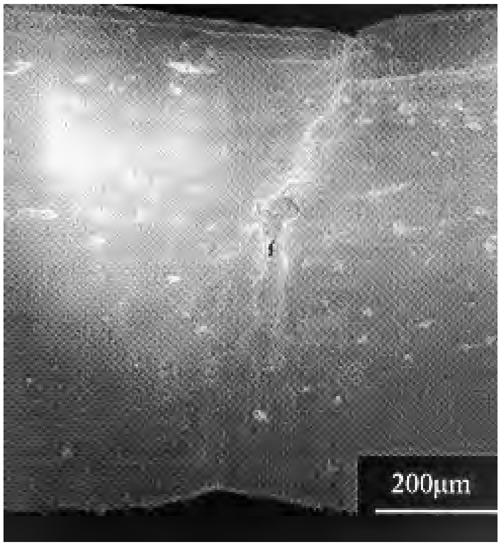


Figure 7. Cracks formed by decohesion

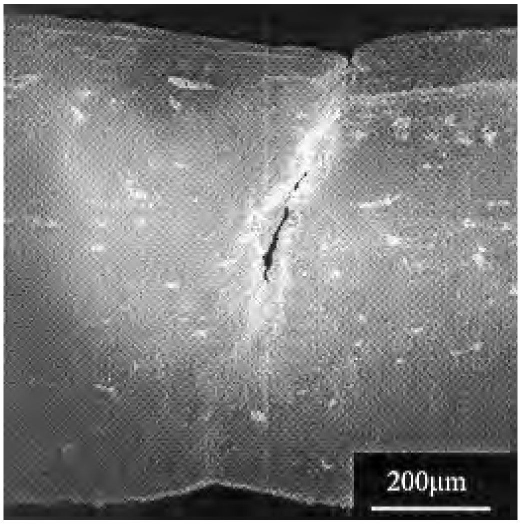


Figure 8. Cracks by the failure of the particles.

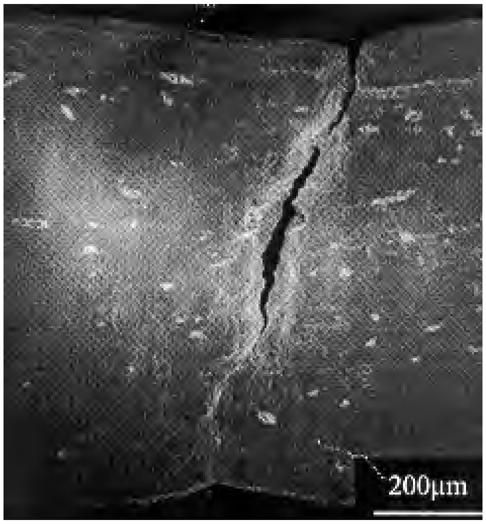


Figure 9. The final fracture forming

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.

Figure 10. The fracture surface

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 fracture mechanism of the material show in Fig.11.

4. Conclusion

On the basis of deformation process we suggested the following conclusions.

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 $\varepsilon = 0.116$.

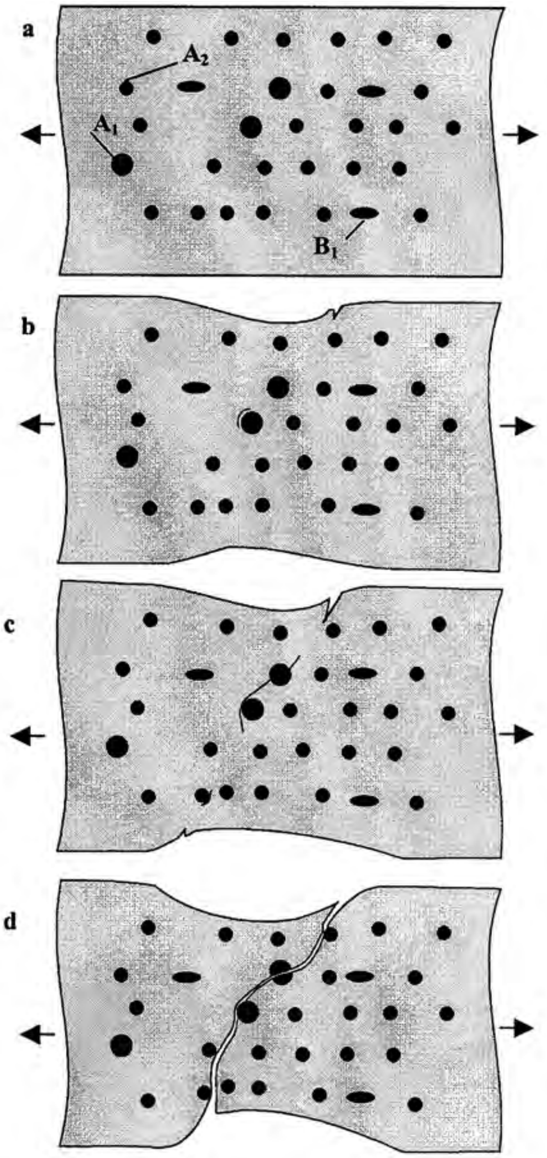


Figure 11. Model of failure mechanism

References

1. A. Mocelina and all, *Mater. Sci.*, 28,1993, pp.4855
2. R. Velisek and J. Ivan, *Kovove Mater.*, 32, 1994, pp.531
3. M. Besterci, and J. Ivan, *Journal of Materials Science Letters*, 15, 1996, pp.2071
4. M. Besterci, and J. Ivan, *Journal of Materials Science Letters*, 17, 1998, pp.773
5. M. Besterci, and J. Ivan, *Acta Metallurgica Slovaca*, 4,1998, 3, pp. 12
6. M. Besterci, at al. *Materials Letters*, 38, 1999, pp. 270
7. M. Besterci, and J. Ivan, *Kovove Mater.*, 4,1997, pp. 278
8. M. Besterci, and J. Ivan,, and L. Kovac, *Kovove Mater.*, 1,38, 2000, pp.21