Materials Science Forum Vols. 304-306 (1999) pp. 711-716
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A Technique to Study the Granular Flow during Superplastic Deformation

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Keywords: SEM, Granular Flow, Zn-Al-Cu Alloy, Tension Test, Microstructure

Abstract. A new technique for Scanning Electron Microscopy (SEM), which provides a mesoscopic coordinate system inscribed on the surface of the center of a tension test specimen, and relates this system to another fixed at rest in laboratory it is developed. Such technique allows to establish in a repeatable way any angle relative to any axis of any coordinate system, or distances between grains, or to measure local or global true deformation in parallel or perpendicular direction relatives to the tension axis. This technique was applied to give some results on a Zn-20.2% All - 1.8% Cu Alloy tension test specimen with 412 μm length.

INTRODUCTION

In principle, the study of superplastic deformation of materials requires the development of special methods of investigation which allows to study the plastic deformation at three different microstructural levels: *i.e.* macroscopic (the entire deformated volume); mesoscopic (at the level of movement of many grains) and the microscopic level (to study the grain boundary sliding between individual grains). Relative to grain boundary sliding there is no exist, until now, a technique which allows to obtain, simultaneously, information on the three levels above mentioned.

The present paper deals with the development of a new technique (to be used in Scanning Electron Microscopy) which provides the possibility of quantitative measurements about the superplastic flow at the three different microstructural levels before described. The new techniques provides a mesoscopic coordinate system inscribed on the surface of the center of the samples, in order to be capable to put a pair of sets of numbers that determines the location of any material point of interest on the surface of the sample under plastic deformation. The origin of this coordinate system centered on the sample under deformation is related with another coordinate system which is fixed on rest at laboratory. And also any coordinate system that we create at microscopic level in any point of interest can be related to the mesoscopic coordinate system. Our technique, allow us to establish in a repeatable way any angle relative to any axis of any coordinate system, or distances between distant particles or grains, or to measure local or global deformations in parallel or perpendicular directions relatives to the tension or compression axis.

The technique schematically described was applied to the case of structural superplastic Zn-20.2% Al- 1.8% Cu alloy deformated at room temperature. This alloy was chosen for this investigation because: *i)*.- the superplastic behavior of a similar alloy (Zn - 22% Al) is well studied [1-9]. *ii)*.- The near room temperature thermal and mechanical properties of Zn-20.2% Al- 1.8% Cu has been recently studied [10] and for room temperature this material can be tested at conditions near to superplastic behavior, with significant contribution of grain boundary sliding to the plastic deformation of the sample.

Experimental procedure and results

Tension test samples with length of 412 μm parallel to the rolling direction were prepared. The geometry and size of the specimen designed for tension test in SEM is shown in Fig. 1. The coordinate system inscribed on the sample surface is shown in Fig. 2. The length size of the tension test specimen is delimited by the two sets formed each by five diamond pyramidal figures. The experiments were performed at constant cross head velocity, $v = 0.1 mm/min$, giving a nominal macroscopic initial strain rate of $4.0 * 10^{-3} s^{-1}$. The tension test were conducted until fracture, see Fig. 3, and during all the deformation stages the coordinate system (inscribed initially on the sample) could be observed, see Fig. 4.

With this technique is easy to chose any place on the surface of the sample to study the grain configuration on local basis. For example in Figs. 5 and 6 the emergence (surgence?) of new material on the free surface can be observed in a certain region

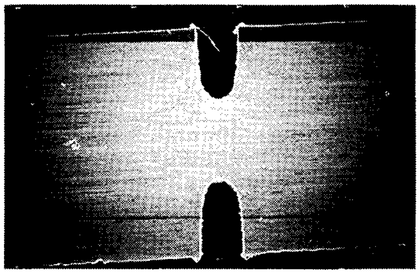


Fig.1.Tension test specimen for SEM. Length 412 μ m.

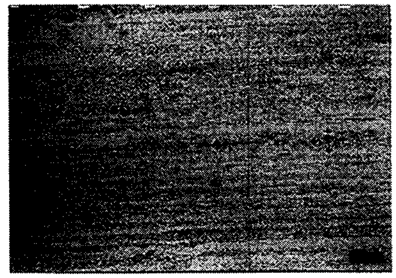


Fig.2. Initial Mesoscopic aspect of microsture of the Zn-20.2%Al-1.8%Cu alloy. The length size of the tensile sample is delimited by the two trapezoidal figures.

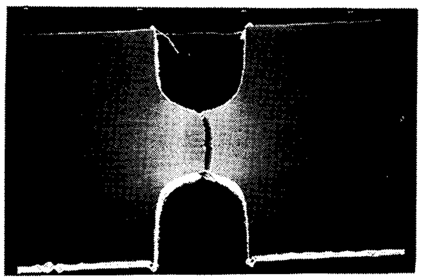


Fig.3. SEM microphotograph at macroscopic level of the tension specimen after a real deformation ε=0.68 at fracture condition.

Fig.4. Mesoscopic coordinate system on the sample at fracture condition.

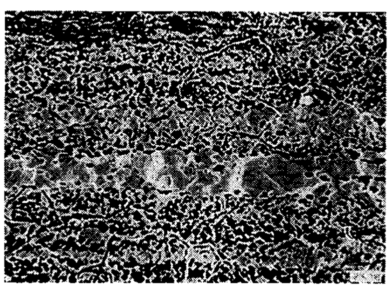


Fig. 5.Sliding grains on the surface.

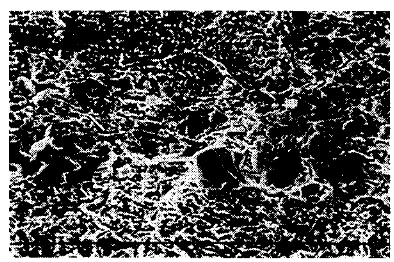
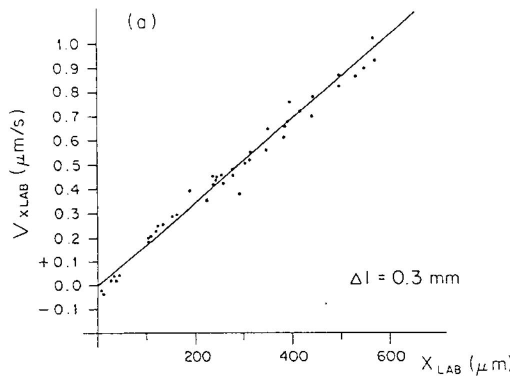


Fig.6. Material below surface is appearing as new surface in the same region as shown in Fig.5.

of the structure formed by alternated bands riches on Al and Zn on the deformated sample. Figure 7 illustrate the experimental data for velocity of specific material objets (grains) choosed on the surface of the sample under deformation as a function of the distance existing between the grains and the rest side of the sample under deformation. From Fig. 8 the average real deformation ε_x versus time at mesoscopical scale is presented, also is presented macroscopical ε_x versus time denoted by open square points. For times between 120 and 240 seconds the mesoscopical data gives a constant rate $\bar{\dot{\varepsilon}}_{x\ mes} = (1.72 \pm 0.38) * 10^{-3} s^{-1}$, which is statistically indistinguishable from the macroscopic value $\dot{\varepsilon}_{macro} = 1.61 * 10^{-3} s^{-1}$ in the same interval of time.



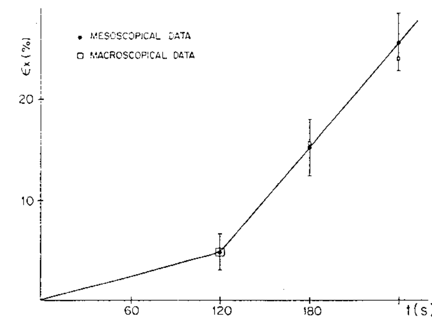


Fig. 7. Linear relationship between velocity of material points on the sample surface and distance along tension axis as measured from coordinate system at rest in Laboratory, after a real deformation of 54.7%.

Fig.8. Average real deformation ε_x versus time at mesoscopical scale denoted by black dots with error bars as indicated. Macroscopical ε_x versus time curve denoted by open square points.

Conclusions

1) The proposed technique allows to study the grain boundary sliding process at three levels: macroscopic, mesoscopic and microscopic.

2) Our technique allows to measure rotation, translation and velocity of each grain on the sample surface and also the local deformation of each grain all these measurements relatives to a coordinate system fixed at the laboratory.

3) As our technique allows to locate every grain in the surface of the sample during deformation gives the possibility to make mapping of the granular flow during superplastic deformation as suggested by Ashby and Verrall [11].

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