Nanostructural Materials: Production, Structure, High Strain Rate Superplasticity

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Abstract – The structural and mechanical behavior of rods of Al-Li alloys subjected to the intensive plastic deformation (IPD) was studied. A nanostructural state in alloys has been shown to form by IPD. It has been found that the ductility was up to 2000%. Multistage high strain rate of superplastic (SP) strain has been shown (Fig. 1). Evolution of structure in the process of SP flow was studied (Fig. 2). The data showing intra-grain sliding during the hardening stage and grain boundary sliding during the softening stage have been obtained.

The structure of rods subjected to the equal-channel angular (ECA) pressing has been studied by X-ray diffraction, transmission and scanning electron microscopy, back electron scattering diffraction and orientation image microscopy. A fine-grained structure has been shown to form in the process of pressing. A largest number of grains demonstrate the formation of a dislocation substructure and subgrains.

A mechanical behavior has been studied for ECA pressed samples having different structural states. Temperature and strain rate conditions to attain ultimate strains to failure have been defined for samples of each structural state. It has been shown that samples with a developed substructure are subject to a superplastic (SP) straining. Contrary to the expectations the ductility of finest-grained samples turned out low. It has been found that the ultimate SP straining to failure is characteristic of samples subjected to 10-pass ECA pressing at 370°C. It complies with the strain rate of 10^{-2} s^{-1} at 370°C. Its greatest value was ~2000%.

Mechanical behaviour of the alloy has been studied in SP straining conditions. Multistage high strain rate of SP strain has been shown. Dependencies of the true strain rate on temperature, the true stress and true strain for the straining during hardening stage and softening stage have been established. The activation energies and the coefficients of strain rate sensitivity of stress (m), which characterize these stages, have been determined. It has been shown that the strain up to ~2000% corresponds to this alloy and m = 0.45 for both stages. These parameters correspond to SP flow.

It has been established that the hardening stage deformation has the strain rate ~10^{-2} s^{-1} and is controlled by volume self-diffusion. This is typical for SP deformation by intra-grain sliding. Dynamical recrystallization on sub-grain level corresponds to this stage. It has been established, that during the softening stage the strain rate is ~10^{-4} s^{-1} and is controlled by grain boundaries self-diffusion. This is typical for SP deformation of fine-grain materials, which is caused by grain boundary sliding.

Structural behavior by SP straining conditions has been studied. The data showing intra-grain sliding during the hardening stage and dynamic recrystallization with participation of grain boundary sliding and migration during the softening stage have been obtained.

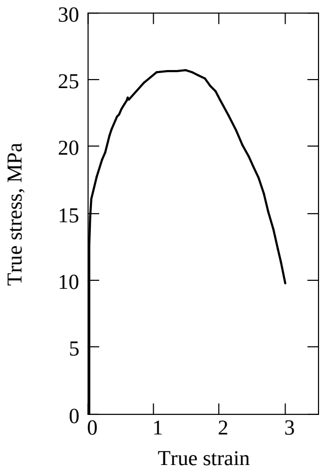

Figure 1: True stress vs true strain. Al-Sc-Li-Zr alloy.

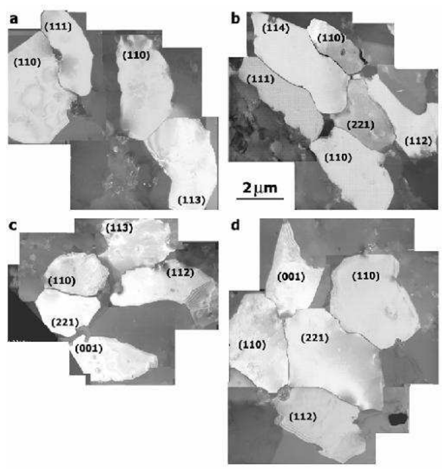

Figure 2: Dark field TEM image of grain structure in Al-Sc-Li-Zr alloy. Tension at 370℃. Strain – 110% (a), 300% (b), 900% (c), 1200% (d). Indexes of zone axes for some grains are indicated.