Eötvös Loránd University

Faculty of Sciences

Doctoral School of Physics

PhD program: *Materials Science and Solid State Physics*

Investigation of mechanical and microstructural properties of ultrafine-grained Al-30Zn and Al-Zn-Mg-Zr alloys

4st Semester Report

Anwar Qasim Ahmed

Anwar.ahmed.qasim@gmail.com

Supervisor:

Prof. NGUYEN Quang Chinh

Introduction

Since supersaturated (7xxx series) of Al-4.8Zn-1.2Mg-0.14Zr (wt%) alloys have an important role in the technology fields so it is very important to examine their mechanical properties and their microstructure. The most two important factors for the alloys represent by ductile and strength over a wide range of temperature. Hence, these alloys behave as ductile at high temperatures and are with high strength at low temperatures. In recent times, severe plastic deformation (SPD) techniques were used to prepared samples of ultrafine grains alloys (UFG). Therefore, high-pressure torsion HPT and equal-channel angular pressing ECAP were exploiting in these experiments. Therefore, the ductility and the resultant strain rate sensitivity (SRS) for these UFG alloys are studied this semester at low temperatures and the results showed that the HPT technique has a priority over ECAP.

Summary of research work carried out in the previous three semesters

In the first semester high-pressure torsion (HPT) is used to produce ultrafine-grained (UFG) microstructure with average grain size of 200 nm in AlZnMgZr alloy. Stable UFG microstructures associated with a high value of (SRS) equals to 0.43 is obtained. Moreover, curve of stress strain for superplastic deformation shows 200% of elongation is achieved at 120 ^{0}C whereas a deformation higher than 500% is happened at 170 ^{0}C

During the second semester, many micro-pillars of ultrafine-grained Al-30Zn alloy were prepared with a unique size and compressed by different strain with different strain rates. However, the results of the experiment indicate a stable deformation process i.e. there is no breakdown in the pillars and indicate the flow stress of the UFG Al-30Zn alloy is sensitive to the deformation velocity. Additionally, a strain rate sensitivity of about 0.27 can be obtained, which is considered a high value

Research work carried out in the current semester

I have investigated of UFG Al-4.8Zn-1.2Mg-0.14Zr samples process by HPT and ECAP

1- HPT processed samples:
2- ECAP processed samples:

In the case of HPT- processed samples, I have continued the work which started in the first semester. We have analyzed the deformation process to study the strain rate sensitivity, activation energy, and ductility at low temperature by tension process with different strain rates and selected temperature lower than 0.5 Tm. The results show that a significant behavior is

achieved for the UFG over the traditional aluminum alloys in term of elongation and the homologous testing temperature (T_h). We have shown that conventional aluminum alloys which typically have Zr element as the grain-refining elements have the ability to be deformed super plastically at high temperature (over 0.7 of T_h). On the other hand, superplasticity is revealed at lower homologous temperature (0.5 to 0.7) when the grain size of ultrafine grain (UFG) is improved to 100-700nm. In the case of our UFG Al-4.8Zn-1.2Mg-0.14Zr samples processed by HPT, a maximum elongation of 500% is achieved in the ultralow temperature region which located exactly at a homologous testing temperature of 0.47 as shown by the blue region on the left side in Figure (1).

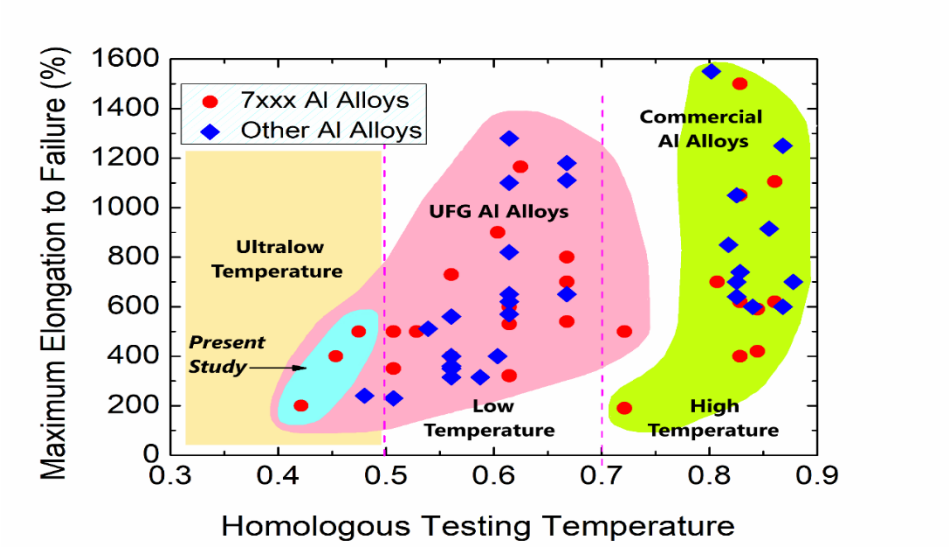

Figure (1) shows Temperature dependence of superplasticity of commercial Al alloys and UFG alloys

Activation energy, Q, during the deformation mechanism is calculated to illustrate the superplastic flow. This calculation is done by using the strain rate sensitivity (SRS) equal to 0.43 and considering the stress values at the same elongation values at 100% where strain is 0.69 for all testing temperatures. A figure is drawing for $\ln\sigma - 1/T$ and by mathematical calculations activation energy (Q) value is obtained as shown in Fig. 2, with a value of around 68 kJ/mole. This value of (Q) is considered a low value compare with the activation energy of self-diffusion and grain boundary diffusion in aluminium which ranging (142 kJ/mole) and (84 kJ/mole) respectively. Therefore, this low value of Q demonstrates the superplastic deformation for UFG is grain boundary sliding.

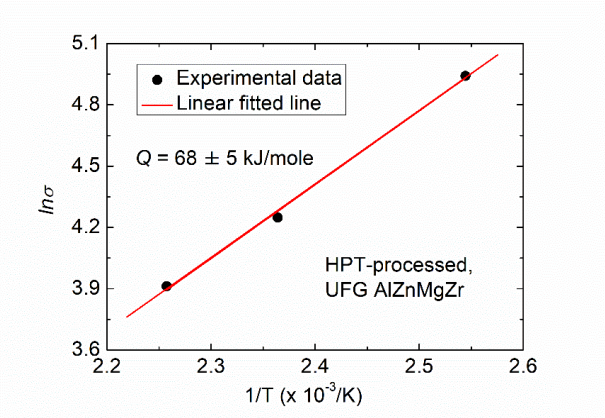

Figure 2: Determination of the activation energy (Q) for UFG Al-Zn-Mg-Zr alloy at ultralow-temperature

The ultralow superplasticity of the HPT-processed AlZnMgZr sample can be explained by the diffusion-enhancing effect of the segregation of Zn and Mg at the grain boundaries.

A manuscript on these results has been submitted to Material Research Letter (MRL)

Chinh NQ, Murashkin MYu, Bobruk EV, Lábár JL, Gubicza J, Kovács Zs, Ahmed AQ, Maier-Kiener V, and Valiev RZ, *Ultralow-temperature superplasticity and its novel mechanism in ultrafine-grained Al alloys*. Submitted to MRL, 2021

2- ECAP-processed samples:

Al-Zn-Mg-Zr samples were also processed by Equal-Channel Angular Pressing (ECAP) technique. In the technique, an average grain size of about 260 ± 30 nm was observed. ECAP-processed samples were also deformed by a tensile test at 150 ^{0}C, and the maximum elongation was about 200% as shown in figure (3)

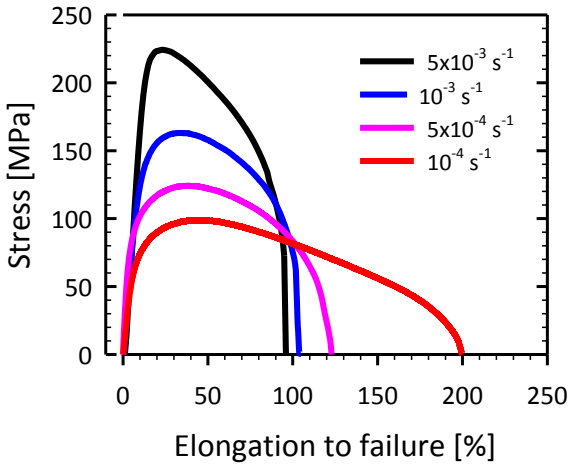

Figure (3): *Stress-strain (σ – ε)* curves of UFG Al-Zn-Mg-Zr alloy which showing a total elongation about of about 200%

From the tensile date, a strain rate sensitivity (SRS) of about 0.2 was obtained as in figure (4) which seems to below for the maximum elongation of 200%. In order to clarify this problem, we have prepared also impression creep tests in the temperature region between 140 ^{0}C and 160 ^{0}C. Both the realistic SRS and activation energy was determined by taking into account the role of threshold stress.

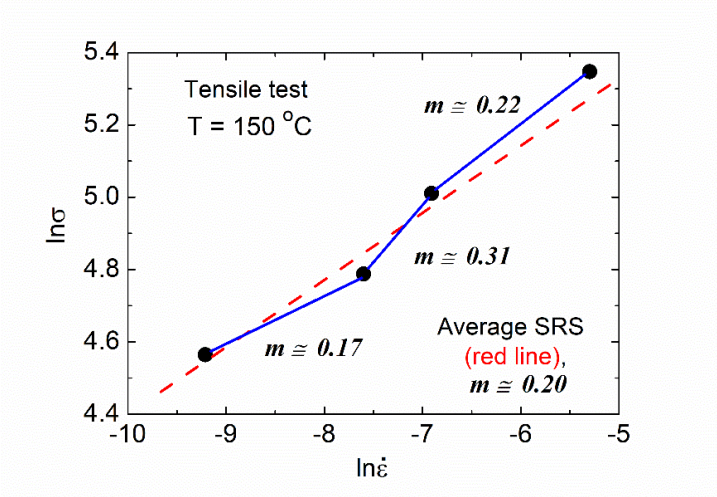

Figure (4) shows the estimated value of local and average apparent strain rate sensitivity

A manuscript on these results has been submitted to Journal of Materials Science (JMS).

Boldizsár B, Jenei P, Ahmed AQ, Murashkin MYu, Valiev RZ and Chinh NQ *Low-temperature super-ductility and threshold stress of an ultrafine-grained Al-Zn-Mg-Zr alloy processed by equal channel angular pressing.* Submitted to JMS, 2021

Other activities through this semester:

Through this semester I performed also Differential scanning calorimetry(DSC) experiments and micropillar-compression tests on both Al-30Zn and UFG of Al-Zn-Mg-Zr samples.

During this semester two courses were taken:

Lattice defect 2

Material physics 1