Yana Mourdjeva, et. al. International Journal of Engineering Research and Applications
www.ijera.com
ISSN: 2248-9622, Vol. 10, Issue 7, (Series-V) July 2020, pp. 30-34

RESEARCH ARTICLE OPEN ACCESS

The Influence of Deformation Velocity and Temperature on High-Temperature Plasticity of Modified Alloys with Microcrystalline Structure.

Yana Mourdjeva, Nikolay Djulgerov,
Institute of metal science, equipment and technologies with hydro- and aerodynamics centre "Acad.A. Balevski" – Bulgarian Academy of sciences
Bulgaria, Sofia, 1574, 67 "Shipchenski prohod" str.

ABSTRACT: The aim of this research is to study behavior of the microcrystalline Al-Si alloys modified with antimony (Sb) and strontium (Sr) at high temperature deformation and the impact of the the deformation velocity and temperature. The plasticity of alloys is determined by the relative elongation.
Key words: eutectic modification, transmission microscopy, high temperature deformation, Al-Si based alloy.

Date of Submission: 06-07-2020 Date of Acceptance: 21-07-2020

I. INTRODUCTION:

Despite the good qualities of the Al-Si alloy, its use in the industry as a structural material is limited due to lack of plasticity. Its mechanical and technological qualities are determined by the crystallization velocity. The microstructure of Al-Si alloys consists primary phase (α-Al) and eutectic of Al matrix and Si particles. The amount of eutectic in the microstructure depends on the percentage content of Si. The morphology of the Si-particles is lamellar. Well-known method to improve mechanical properties is to add chemical modifiers that affect the formation of microstructures during crystallization [1, 2, 3, 4]. The morphology of Si from coarse plastic can be modified into fine fibrous, which has a beneficial effect on mechanical characteristics and plasticity. [3, 5, 6].

The general mechanism of chemical modification is not accepted to explain the significant microstructural changes when adding such small quantities of modifiers. One of the mechanisms suggests that modifier-Al-Si co-segregations promote twinning by changing the stacking sequences. Other mechanism suggests that modifier-Al-Si co-segregations inhibit and restrict growth of the eutectic Si phase and thus induces a morphological change in Si-phase (within the Si-phase at the re-entrant edges of growing surfaces). [3] Another known mechanism is based on the atomic adsorbing of modifier atoms at growth from Si crystal. The change in the sequence of arrangement forms new twins and locally enables growth in different directions [7, 8]. Although these mechanisms provide different characteristics of the growth of the eutetic Si-phase, they suggest multiple twinning reactions and formation of high density of twins.

The study of the mechanical properties of microcrystalline alloys provides useful and practical information about their load behavior and the influence of thermo-deformation factors. However proceeding microcrystalline alloys is inconceivable without studying the mechanical qualities of test samples with such structure in real size.

Research:

The influence of the temperature T and the deformation velocity έ at high temperature deformation evaluated by the relative elongation after fracture δ have been studied for ribbon samples and compacted samples of Al-11% Si alloy, modified with antimony (Sb) and strontium (Sr).

The ribbon samples with refined grains are obtained by selecting the crystallization velocity of the melt. Five-fold test specimens with a processing width of 5mm are mechanically cut from the ribbons. The tensile test is obtained on a solid kinematic test machine by heating the test specimens in a salt bath. The temperature is maintained with accuracy of ±2°C, the tempering time is 30 sec. High temperature deformation of the specimens is performed while temperature varies in the range of 450÷490°C and the deformation velocity varies in range of 1.10^{-4}÷1.10^{-2} s^{-1}. The plasticity is determined by relative elongation δ.

Compacting is performed in two stages: sealing of the ribbon samples and resulting compaction. The sealing of the microcrystalline

ribbon samples is performed by isostatic cold pressing. The specific pressure is in range of 600 ÷ 650 MPa. The resulting blanks are with diameter of ø40mm and 70÷75% density. The resulting compaction of blanks is carried out by hot extrusion in heating press form. Extrusion is performed at T=450°C and two degrees of reduction: 1/12 and 1/25. Five-fold cylindrical test specimens with a processing diameter of 5mm are made from the blanks. The tests at room temperature of compacted samples is carried out on the tensile test machine.

II. RESULTS:

The data for the obtained grain size at different composition (Tabl. 1) and the structure of the alloys (Fig. 1) are shown.

Alloy	Grain size [µm]
Al-11%Si	0,5
Al-11%Si-0,055%Sb	0,4
Al-11%Si-0,11%Sb	0,5
Al-11%Si-0,22%Sb	0,6
Al-11%Si-0,022%Sr	0,5
Al-11%Si-0,051%Sr	0,5

Tabl.1 The obtained grain size of tested non modified and modified alloys.

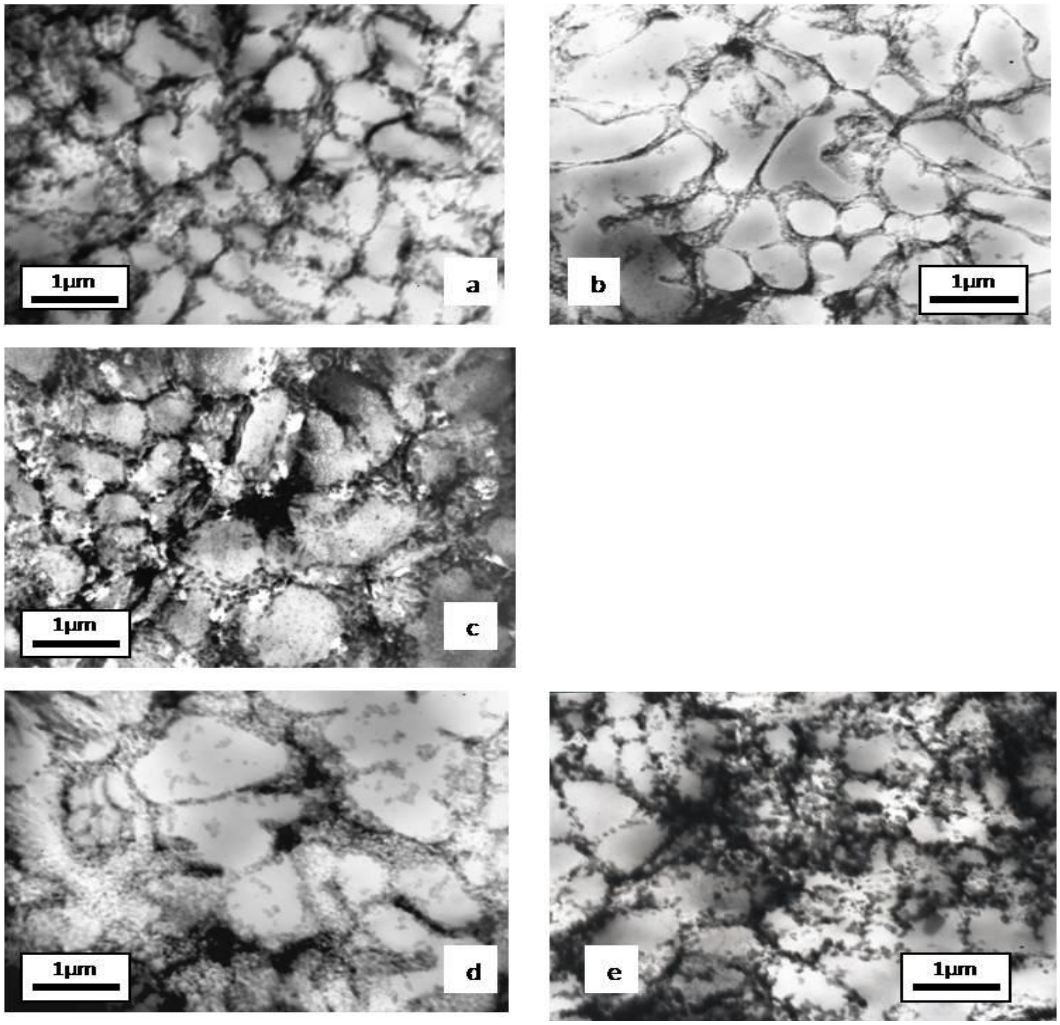

Fig. 1 Microstructure of ribbon samples (TEM): a) Al-11%Si-0,055%Sb, b) Al-11%Si-0,11%Sb, c) Al-11%Si-0,22%Sb, d) Al-11%Si-0,022%Sr, e) Al-11%Si-0,051%Sr.

The data shows that modifiers don't change significantly the size of the grains of the alloys. But when samples are tested at high temperature deformation, modified alloys showed significantly better mechanical properties.

The TEM studies of the alloys shows that compared with the eutectics of the non modified alloy Al-11%Si the modification significantly refines the eutectic. In modified alloys Si-crystals have a significantly finer structure than the lamelar structure in the unmodified alloy.

In Fig. 2 is shown the dependence of the relative elongation on the deformation velocity and the temperature for test samples of the studied alloys.

For all alloys the maximum values for δ are at T= 490°C and ἐ = 1.10-3 s-1. The figure also shows that the Al-11%Si-0,11%Sb alloy shows the highest plasticity. δ increasing as the antimony content increases. The influence of Sr is similar because of the increase of the content of Sr plasticity increases.

The tests at room temperature of compacted samples is carried out on the tensile test machine. The results are shown in Tabl. 2.

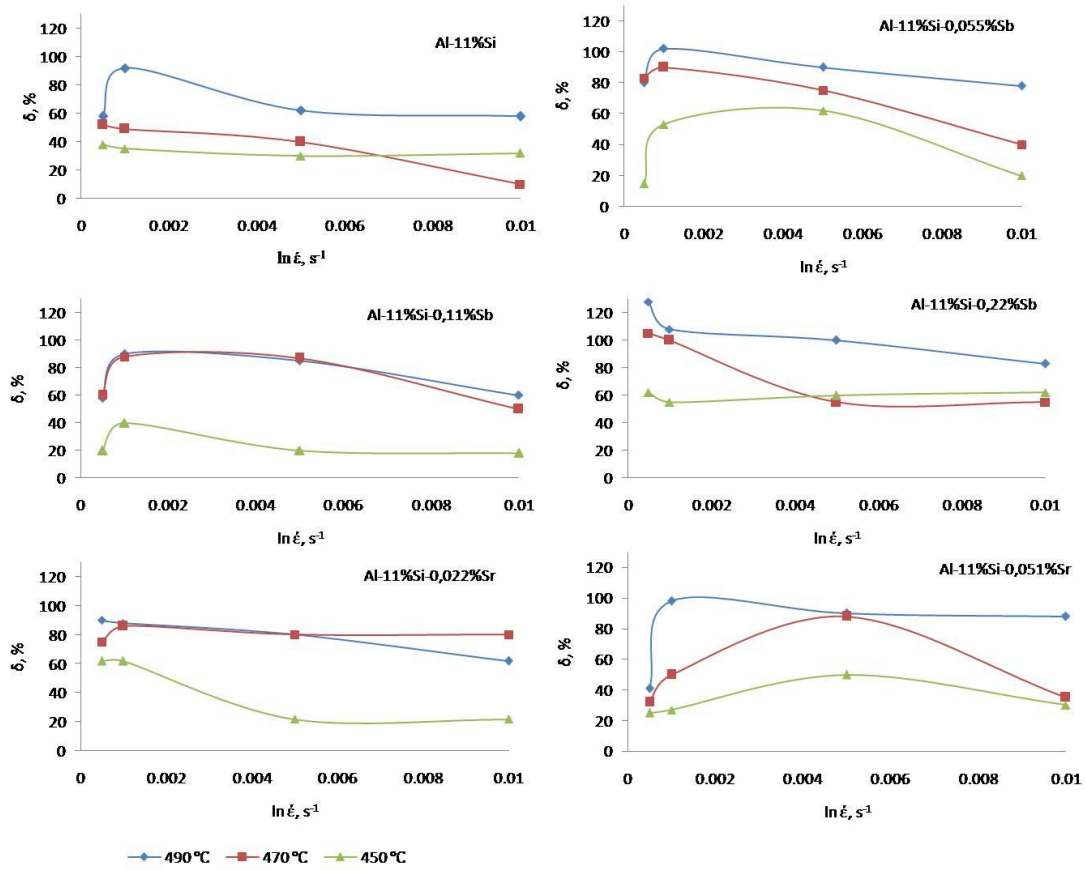

Fig. 2 The dependence of the relative elongation on the deformation velocity and the temperature.

Alloy	Tensile strength σ_B [MPa]	Relative elongation after fracture δ_5 [%]
Al-11%Si	190	11,94
Al-11%Si-0,055%Sb	220	10,95
Al-11%Si-0,11%Sb	210	8,6
Al-11%Si-0,22%Sb	170	14,08
Al-11%Si-0,022%Sr	140	10,49
Al-11%Si-0,051%Sr	180	11,26

Table.2 Data from tensile test of compacted samples of non modified and modified alloys

After compacting, the average grain size is enlarged twice when comparing with the average grain size of the ribbons. It varies between 1÷1,5μm, but it still obvious that alloys are microcrystalline. In Fig.3 is given microstructure of Al-11%Si-0,022%Sr alloy.

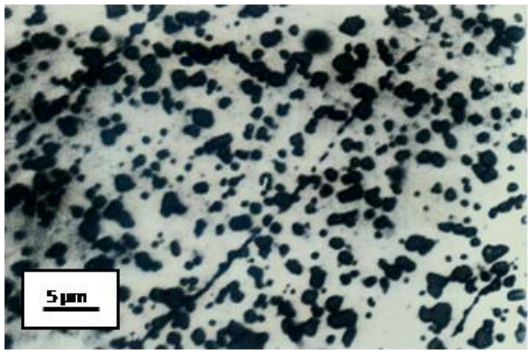

Fig. 3 Microstructure of compacted sample from Al-11%Si-0,022%Sr

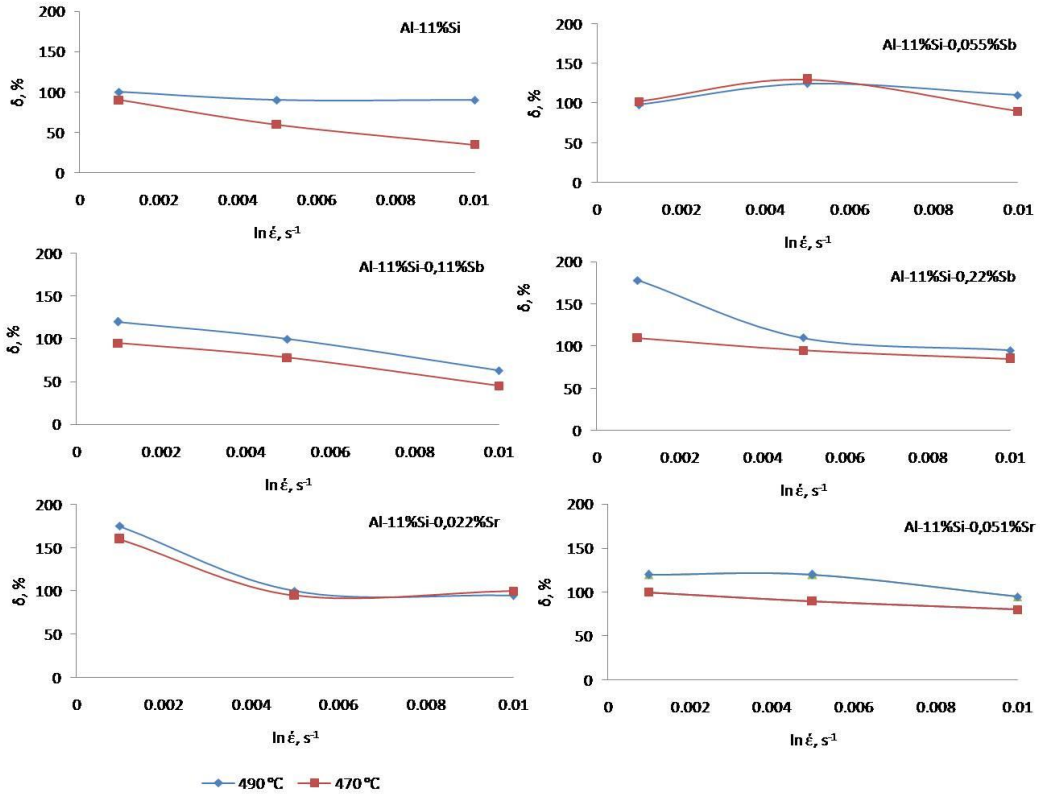

Fig.4 The dependence of the relative elongation on the deformation velocity and the temperature at high temperature deformation tests for all tested alloys.

Fig.4 shows results of high temperature deformation tests for all tested alloys. It is apparent that all alloys have higher plastic performance than the non modified alloy Al-11%Si. The samples of all modified alloys show higher δ values at T=490°C and $\dot{\varepsilon}=1.10^{-3}$ s^{-1} (Only alloy Al-11%Si-0,055%Sb shows maximum plasticity at $\dot{\varepsilon}=5.10^{-3}$ s^{-1}). For alloys containing Sb, the antimony content increases and the values of the relative elongation δ_5 also rises. Only alloy Al-11%Si-0,022%Sr shows higher plasticity at $\dot{\varepsilon}=1.10^{-3}$ $s^{-}1$.

The data shows that the test samples from compacted blanks showed higher plastic performance despite their larger-grained structure. It is due to the influence of the large-scale factor, more important than the structural factor in the high temperature deformation of samples with a microcrystalline structure. It is also apparent that the

values of δ_5 are characteristic of deformation occurring mainly by grain boundary sliding, i.e. the tested materials show superplastic properties.

III. CONCLUSIONS

1. Modifying the Al-11%Si alloy with Sr and Sb improves the mechanical performance of the no modified alloy.
2. These modifiers mainly affect on the largeness of the eutectics and lead to Si-crystals with a finer fibrous structure compared to the lamellar structure of Si-crystals in the base alloy Al-11%Si.
3. Ribbon samples of all modified alloys show the highest values of relative elongation in high temperature deformation at temperature T = 490 °C and deformation velocity $\acute{\varepsilon} = 1.10^{-3}\ s^{-1}$.
4. Compacted samples of all modified alloys show the highest values of relative elongation in high temperature deformation at temperature T = 490°C and deformation velocity $\acute{\varepsilon} = 1.10^{-3}\ s^{-1}$.
5. After compacting, the mechanical performance at high temperature deformation at temperature T=490°C and $\acute{\varepsilon} = 1.10^{-3}\ s^{-1}$, the samples of all modified alloys show higher values of relative elongation δ_5 than the compacted samples of the base alloy, despite their larger grain structure compared to the structure of the ribbon samples. This is mainly due to the influence of the large-scale factor, that is more important than the structural factor at the high temperature deformation of microcrystalline structure samples.
6. It is also apparent that the values of the relative elongation δ_5 are characteristic for deformation occurring mainly by grain boundary sliding, i.e. the tested materials exhibit superplastic properties.

REFERENCES

[1]. N. Fatahalla, M.F. Hafiz, M Abdulkhalek, Effect of microstrokture on the mechanical properties and fracture of commercial hypoeutectic Al-Si alloy modified with Na, Sb and Sr, Journal of material science, 1999, 34, p 3555-3564, in English.
[2]. M. F. Hafiz, T. Kobayashi, N. Fat-Hallat, Role of microstructure in relation to the toughness of hypoeutectic Al-Si casting alloy, CASI Metals Journal, 1994, 7, p 103-111, in English
[3]. M. Timpel, N. Wanderka, R. Schlesiger, T. Yamamoto, N. Lazarev, D. Isheim, G. Schmitz, S. Matsumura, J. Banhart, The role of strontium in modifying aluminium-silicon alloys , Acta Materialia, 2012, 60(9), p 3920-3928, in English
[4]. G. K. Sigworth, The modification of Al-Si alloys:Important practical and theoretical aspects, International Journal of Metalcasting, 2008,2, p 19-40, in English.
[5]. L. F. Mondolfo, Aluminum Alloys: Structure and Properties,1st Edition, Butterworth-Heinemann, London, 1976, in English
[6]. S. Z. Lu, A. Hellawell, The mechanism of silicon modification in aluminum –silicon alloys: impurity induced twinning, MTA, 1987, 18, p 1721-1733, in English.
[7]. D. R. Hamilton, R. G. Seidensticker, Propagation Mechanism of Germanium Dendrites, Journal of Applied Physics,1960, 31 (7), p.1165-1168, in English
[8]. S. Prakask, Probing the local atomic structure of Sr modified Al-Si alloy, Acta Materialia, 2014, 64(2), p185, in English.