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# STRUCTURAL AND MECHANICAL PROPERTIES OF SOME ALUMINUM-BASED BINARY ALLOYS

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**Abstract**

*The purpose of this study is to investigate structural and mechanical properties of some aluminum-based alloys. Microstructures of the Al-Sn and Al-Zn binary alloys were examined using optic microscopy. The mechanical properties -Vickers hardness and micro hardness tests were investigated according to standard procedure.*

***Keywords:*** *aluminum alloys, binary systems, Al-Sn, Al-Zn, structural properties, mechanical properties*

## 1. INTRODUCTION

Aluminum is one of the most adaptable of the common foundry metals and the proportion of company that produced aluminum alloy is growing mostly because of the larger amounts being used for automotive and other application. Due to their good tribological and antifriction properties [1-3], and improvement of mechanical properties with additional alloying elements [4], engineering application of the Al-Me (Me=Sn,Zn) alloys is extensive. These alloys are usually related to plain bearing and smart materials, internal combustion engine pistons, cylinder liners [1, 3, 5, 6], but also as advanced lead-free materials [7].

Concerning the Al-Sn alloys, it should be mentioned that tin as alloying element to aluminum casting alloys have the purpose of reducing friction in bearing and bushing applications [8], because tin phase in those alloys melts at a very low temperature (227.7 °C) and can exude under emergency conditions to provide short-term liquid lubrication to rubbing surfaces if such bearings/bushings severely overheat in service [8,9].

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On the other hand, Zn-Al alloys and other Zn-Al-based alloys are promising materials for the development of high temperature solders. The main applications for high-temperature (Tm ≥ 230°C) solders within the electronics industry are for advanced packing technologies, e.g. die-attach and BGA (Ball Grid Array) solder spheres, chipscale package (CSP) and multi-chip modelling (MCM).

The phase diagrams of Al-Zn and Al-Sn are shown in Fig.1, according to Ref. [10].

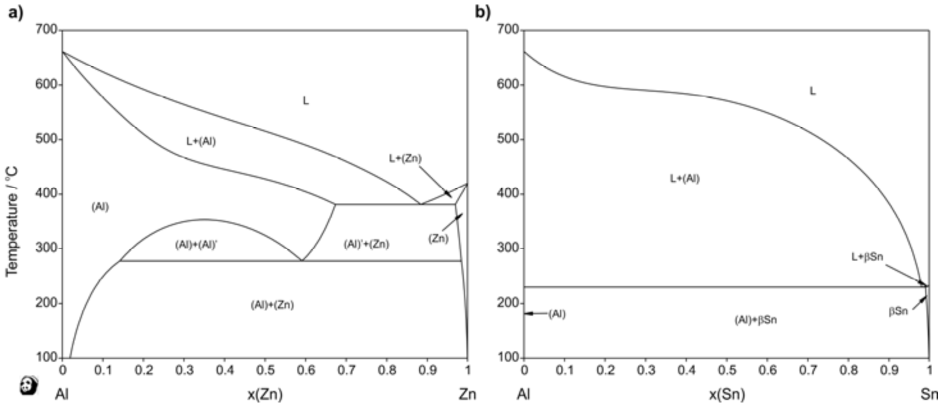


**Fig. 1.** *Phase diagrams of Al-Zn (a) and Al-Sn (b)*

The results of structural and mechanical properties investigation for binary Al-Zn and Al-Sn alloys are presented in this paper as a contribution to better knowledge of these aluminum-based materials characteristics.

## 2. EXPERIMETAL

The samples were prepared by induction melting of pure metals (purity higher than 99.99%) under protective atmosphere. The alloys were melted and cooled repeatedly to improve homogeneity. The total mass losses of the prepared ingots were less than 1 mass%.

The composition and masses of investigated samples are presented in Table 1.

***Table 1.*** *Composition (at. %) and masses (in g) of the investigated samples*

*a) Al-Sn alloys*

| Alloy | xAl | xSn | mAl | mSn | $m_{total}$ |
|---|---|---|---|---|---|
| H1 | 0 | 1 | 0 | 7.3 | 7.3 |
| H2 (eut) | 0.0202 | 0.9798 | 0.034 | 7.208 | 7.242 |
| H3 | 0.2 | 0.8 | 0.359 | 6.327 | 6.687 |
| H4 | 0.4 | 0.6 | 0.785 | 5.178 | 5.963 |
| H5 | 0.6 | 0.4 | 1.295 | 3.798 | 5.093 |
| H6 | 0.8 | 0.2 | 1.919 | 2.110 | 4.030 |
| H7 | 1 | 0 | 2.7 | 0 | 2.7 |

*b) Al-Zn alloys*

| Alloy | xAl | xZn | mAl | mZn | $m_{total}$ |
|---|---|---|---|---|---|
| F1 | 0 | 1 | 0 | 7.14 | 7.14 |
| F2 (eut) | 0.1165 | 0.8835 | 0.340 | 6.242 | 6.582 |
| F3 | 0.2 | 0.8 | 0.579 | 5.610 | 6.188 |
| F4 | 0.4 | 0.6 | 1.137 | 4.133 | 5.270 |
| F5 | 0.6 | 0.4 | 1.676 | 2.708 | 4.384 |
| F6 | 0.8 | 0.2 | 2.197 | 1.331 | 3.528 |
| F7 | 1 | 0 | 2.7 | 0 | 2.7 |

Microscopic analysis of investigated samples was performed by light optical microscopy (LOM), using a Reichert MeF2 microscope with max magnification x500. Before chemical etching by Keller's reagens - 2.5 mL HNO3, 1.5 mL HCl and 1.0 mL HF, grinding using coarse abrasives and subsequent polishing of the surface using fine abrasives, were done in the frame of standard metallographic procedure.

Hardness measurements were done using standard procedure according to Vickers, with a diamond indenter, in the form of a square-based pyramid with an angle of 136 between the opposite faces at the vertex and load of 10 kg for Al-Zn and 5 kg for Al-Sn alloys. Vickers micro hardness was measured using instrument PTM-3 with 50 grams load force, depending on a phase. The time for the initial application of the force is 2 to 8 seconds, and the test force is maintained for 10 to 15 seconds.

## 3. RESULTS AND DISCUSSION

The results of microstructural analysis of investigated Al-Sn and Al-Zn samples (Tab.1), obtained by optical microscopy, are shown in Fig.2 and 3, respectively.

As can be noticed, (Al+βSn) eutectic structure is shown in Fig.2 (H2), while structure in Figs.2 (H3-H6) consists of light primary aluminum crystals in gray tin-based reach base, with dark etched tin grain boundaries. Such obtained results are in agreement with phase diagram given in Fig.1b, confirming that crystallization of Al-Sn alloys goes with aluminum crystals formation below liquidus temperatures, forming a mixture consisting of solid aluminum and tin-reach solution.

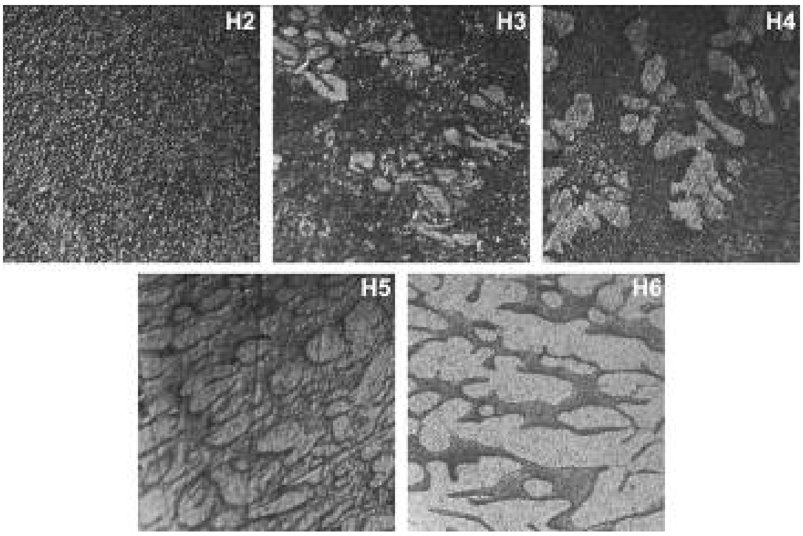


**Fig. 2.** *Characteristic optic microphotographs of Al-Sn alloys: H2 (eut) (xAl=0.0202), H3 (xAl=0.2), H4 (xAl=0.4), H5 (xAl=0.6) and H6( xAl=0.8) - magnification 500x*

Concerning the Al-Zn alloys, typical microstructures of examined alloys are shown in Fig 3 (F3-F6), while in Fig. 3 (F2) characteristic (Al)+(Zn) eutectic structure is shown, which is in accordance with the most recent research of these binary alloys in [11].

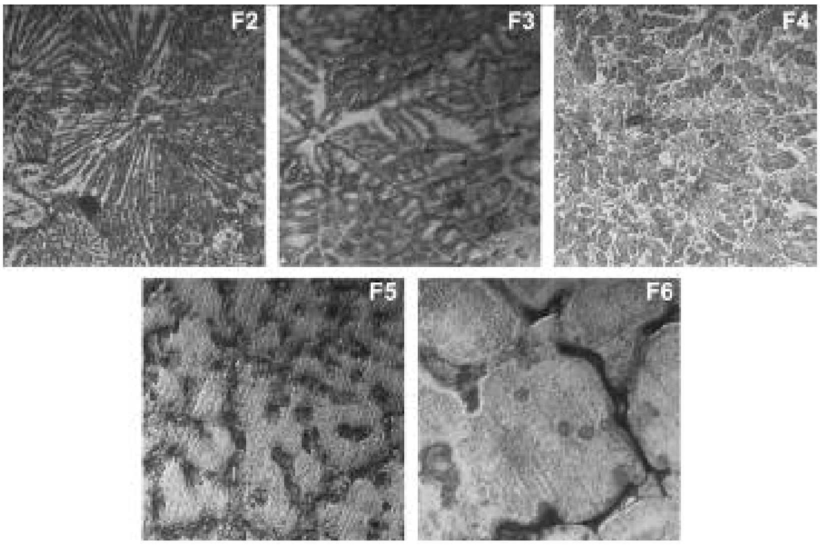


**Fig. 3.** *Characteristic optic microphotographs of Al-Zn alloys: F2 (eut) (xAl=0.1165), F3 (xAl=0.2), F4 (xAl=0.4), F5 (xAl=0.6) and F6 (xAl=0.8) - magnification 500x*

The values, measured for hardness and microhardness of investigated Al-Sn and Al-Zn sample, are presented in Tab.2 and in Figs.4 and 5, respectively.

***Table 2.*** *Measured values of hardness and microhardness of investigated samples: Al-Sn (a) and Al-Zn (b)*

*a) Al-Sn alloys*

| Alloy | xAl | xSn | $HV_{\square 50}$ | $HV_5$ |
|---|---|---|---|---|
| H1 | 0 | 1 | / | / |
| H2 (eut) | 0.0202 | 0.9798 | 15.68 | 10.35 |
| H3 | 0.2 | 0.8 | 20.02 | 13.08 |
| H4 | 0.4 | 0.6 | 19.89 | 14.78 |
| H5 | 0.6 | 0.4 | 25.73 | 16.65 |
| H6 | 0.8 | 0.2 | 29.76 | 19 |
| H7 | 1 | 0 | / | / |

*b) Al-Zn alloys*

| Alloy | xAl | xZn | $HV_{\square 50}$ | $HV_5$ |
|---|---|---|---|---|
| F1 | 0 | 1 | / | / |
| F2 (eut) | 0.1165 | 0.8835 | 94.06 | 56.58 |
| F3 | 0.2 | 0.8 | 103.44 | 72.42 |
| F4 | 0.4 | 0.6 | 95.76 | 75.42 |
| F5 | 0.6 | 0.4 | 96.54 | 88.32 |
| F6 | 0.8 | 0.2 | 132.03 | 97.8 |
| F7 | 1 | 0 | / | / |

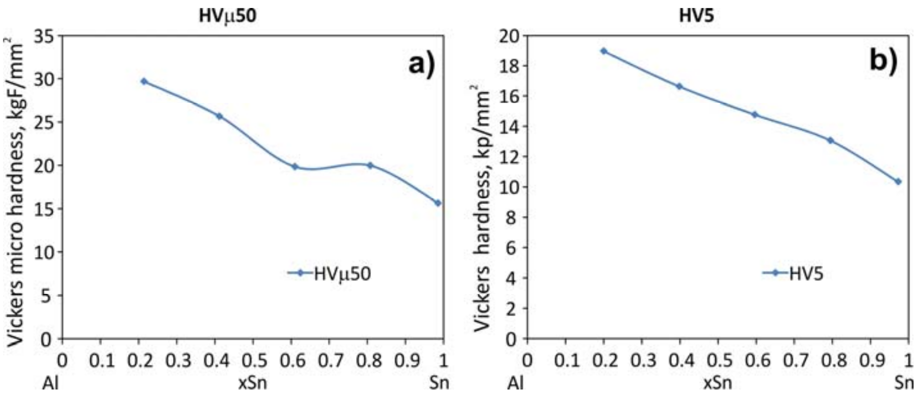


**Fig. 4.** *Graphical presentation of microhardness (a) and hardness (b) measured values for Al-Sn alloys*

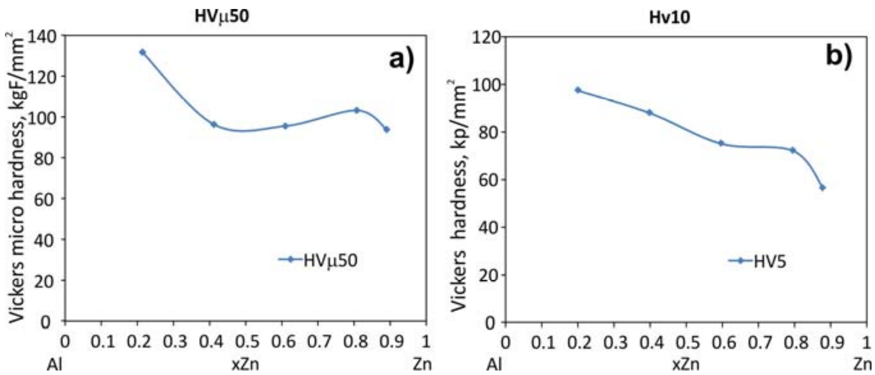


**Fig. 4.** *Graphical presentation of microhardness (a) and hardness (b) measured values for Al-Zn alloys*

As can be seen in the case of Al-Sn alloys, obtained values for hardness and microhardness show that both parameters decrease with tin content increase in the alloys, while similar trend can be seen in the case of Al-Zn alloys – decreasing of both examined mechanical properties with increasing of zinc content.

## CONCLUSION

The results of metallographic investigations using light optic microscopy, hardness and microhardness investigations for two aluminum-based systems, Al-Sn and Al-Zn, were presented in short in this work.

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## REFERENCES

[1] G. Yuan, X. Zhang, Y. Lou, Z. Li, Tribological characteristics of new series of Al-Sn-Si alloys, Trans. Nonferrous Met. Soc. China, 13 (4) (2003), pp. 774-780.

[2] S. Abis, G. Barucca, P. Mengucci, Electron microscope characterization of Al-Sn metal-metal matric composites, J.Alloy & Compd., 215 (11) (1994), pp. 309-314.

[3] S. Abis, G. Onofrio, New bearing aluminum-based alloys, Proceedings of Advanced Materials, Milano (Italy), 1989, pp. 511-513.

[4] R. Schouwenaars, J.A. Torres, V.H. Jacobo, A. Ortiz, Tailoring the Mechanical Properties of Al-Sn-Alloys for Tribological Applications, Materials Science Forum, 317 (2007), pp.539-543.

[5] I. Keijiti, M. Zoshimi, F. Kenichiro (Toyota, Japan), Al-Sn Base bearing alloy and composite, United States Patent 4296183 (http://www.freepatentsonline.com/4296183.html)

[6] A. Milosavljević, A. Kostov, R. Todorović, Smart Materials: Shape Memory Alloys, Bakar/Copper, Vol. 36, 1 (2011), pp. 39-44.

[7] M. Kitajima, T. Shono, Development of Sn-Zn-Al lead-free solder alloys, Fujitsu Sci.Tech.J., 41 (2) (2005), pp. 225-235.

[8] D. Apelian, Aluminum Cast Alloys: Enabling Tools for Improved Performance, North American Die Casting Association, Wheeling, Illinois (USA), 2009.

[9] Gaber, Mechanical and resistometry studies on Al-Zn alloys, Journal of Materials Science: Materials in Electronics, 1 (3)(1990), pp. 137-142.

[10] A.J. McAlister, in: Binary Alloy Phase Diagrams, T.B. Massalski (ed.), Metals Park, Ohio: Am. Soc. Met. 1986.

[11] Ž. Skoko, S.Popović, G.Štefanić, Microstructure of Al-Zn and Zn-Al alloys, Croatica Chemica Acta, 82 (2) (2009), pp. 405-420.