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STRUCTURE AND PROPERTIES OF EFFECTIVE AL-ZIRCONIUM ALLOYS FOR ELECTRONICAL PURPOSES

The structure and properties of effective Al-Zr alloys for electrical purposes were studied in the article. The effect of heating temperature on the structure of mechanical properties of three types of Al-Zr alloys wires was evaluated. Thus, the study evaluated the influence of heating temperature on the structure and properties of Al-Zr alloy. The studies proved wire samples with composition of 0,2-0,3 % Zr alloys to have higher thermal stability (up to 400 °C temperature). As well as, the amount of zirconium does not have significant influence on the line broadening ratio assessment.

Key words: Al-Zr alloys, structure and properties, mechanical tests, heating temperature.

Actuality of theme. Improvement of electro-technical properties or proper maintenance of alloys for electrical purpose and other electric wiring working under definite heating and electric loading is a matter of current interest **[**1**]**. In this regard Al based Zr alloys and working out efficient production regiemes are of great importance **[**2**]**. AI-Zr based A5E and ABE alloys were used to conduct a research. Their chemistry was shown at Table 1 **[**3**]**.

Typical microstructure of A5E alloy wire produced under pressure was indicated at Tables 1 and 2. The alloy infrastructure contains mixture of Fe and Si phases in aluminium based matrix. In the initial phase grain structure of alloy is unrecrystallized (fiber structures) and it is in the form of recrystallization after annealing (equal grain arrow) (picture 2.b).

Results. In the thickening form ABE alloy typical microstructure of wire obtains phases consisting of FE and Si mixtures against aluminium matrix.

Their amount is significantly higher than in A5E alloys (picture 3).

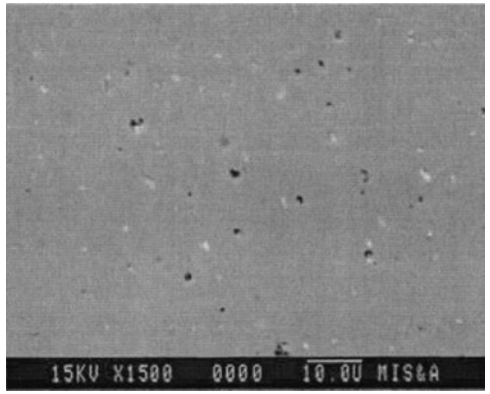
Table 1. Chemistry of alloys

Alloy grade	Main elements, mass%			
	Fe	Si	Al	Zr
A5E	0,12-0,14	0,07	base	0,34
ABE	????	0,45-0,60	base	0,55

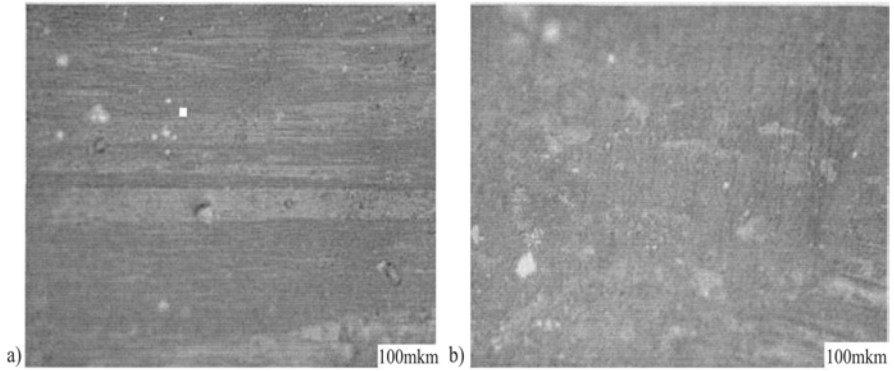
In the primary form grain structure is recrystallized (fiber) (picture 4.a), after annealing it is in the form of recrystallization (picture 4.b). In the primary form A5E and ABE alloy wires mechanical testing for tensioning proved typical properties relevant to these materials, although decrease in firmness was noticed after one hour annealing at 300° C. Thus, for instance, yield strength of these materials decreases more than 5 times (table 2).

This effect is connected with full disappearance of thickening as a result of annealing (process of recrystallization). On the other hand, recrystallization of contraction in the structure of annealing results in the significant growth of grains. In other words, main compounds in the size of nanograins are gathered on the aluminium based matrix and their aggregation occurs. The analysis of fractrograms in the fracture of initial samples (picture 5) shows the existence of tenacious fracture characteristic to low-alloy aluminium wire.

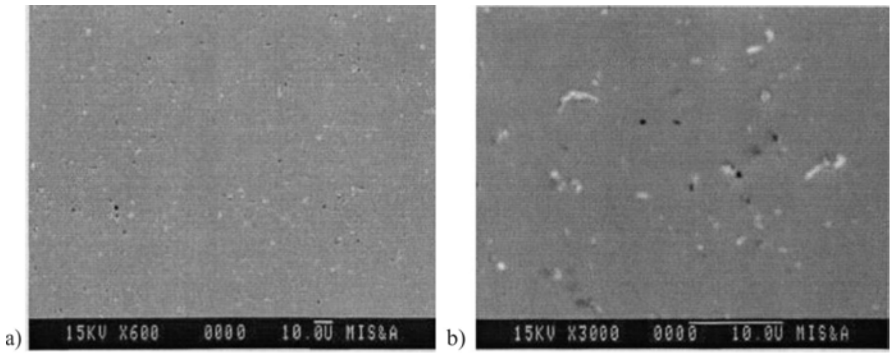
But fractograms of deformed samples (picture 6) show some change in the character of fracture. Thus, fractured spaces crumbled and the depths of fracture were shallower than the ones observed in the primary aluminium.



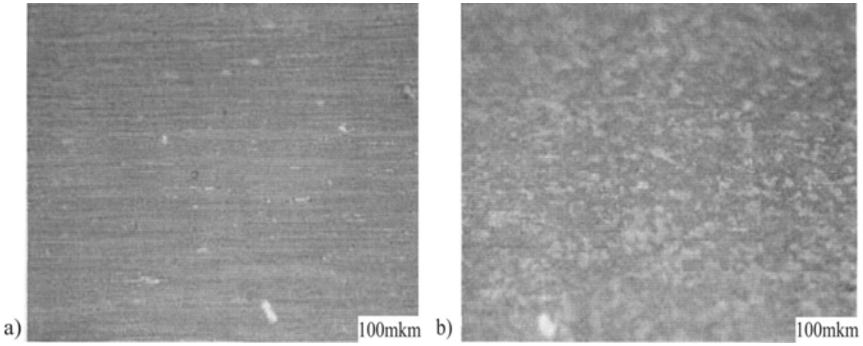
Picture 1. Microstucture of primary A5E alloy wire (SEM)



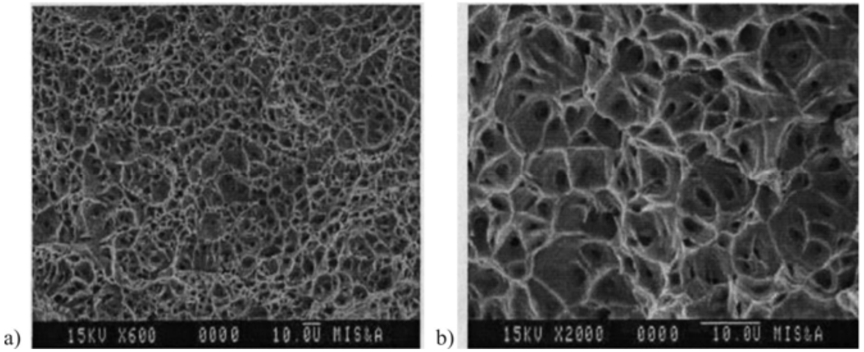
Picture 2. Microstructure of A5E alloy wire (lengthwise):
Hardened (a) and after one hour annealing at 300 °C (b)



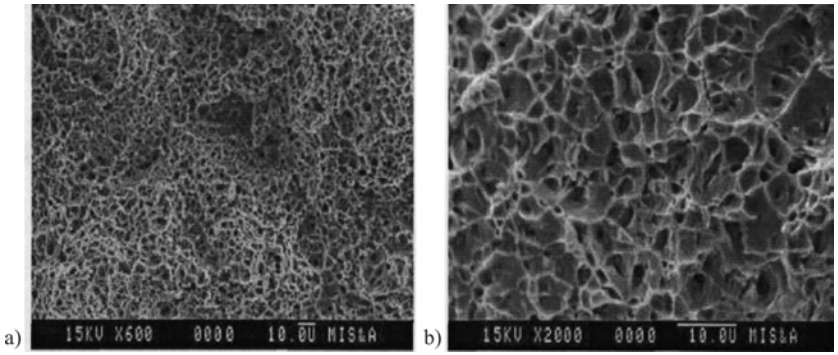
Picture 3. Microstructure of primary ABE alloy wire (SEM):
'a' and 'b' are similar as in picture 3.2



Picture 4. Microstructure of ABE alloy wire (lengthwise):
primary (a) and after one hour annealing at 300 °C (b)



Picture 5. Fractograms of primary form of A5E alloy wires after pulling tests (CEM)



Picture 6. Fractograms of the hardening form of ABE alloy wire after pulling tests (CEM)

Table 2. Influence of heating on mechanical properties of A5E and ABE alloy wires

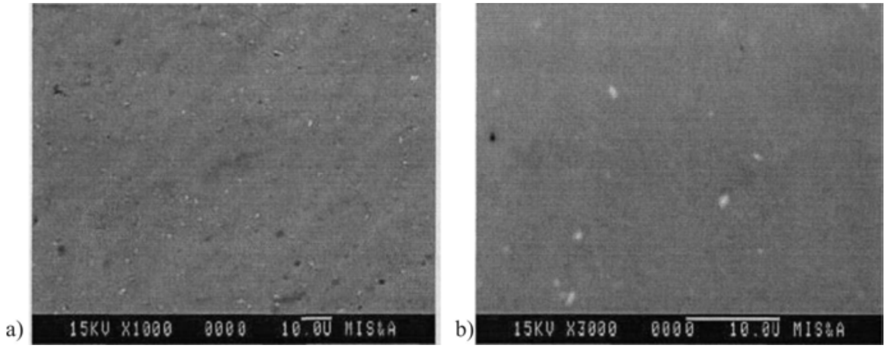
Alloy	Form	σ_b, MPa	$\sigma_{0,2}$, MPa	δ, %
A5E	Primary	177	159	5
	300° C, 1 hour	80	36	44
ABE	Primary	306	266	8
	300° C, 1 hour	110	48	30

This, certainly, complies with general regularities, the second category distortions occur in the crystal lattice due to deformation. Grains are directed and their sizes change in different directions and subsequently anisotropy strengthens as well.

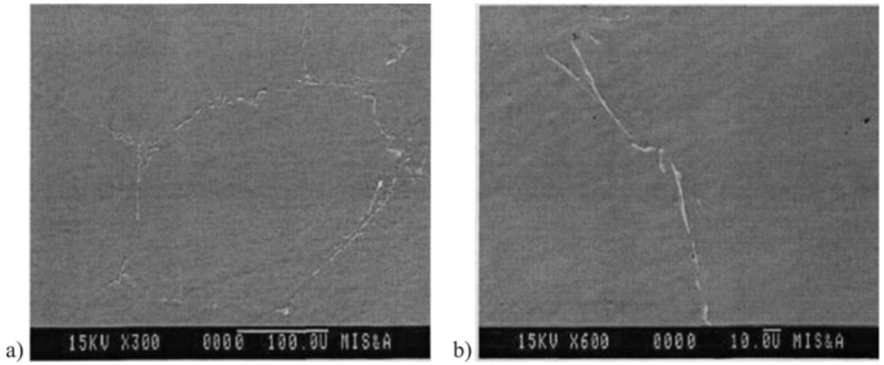
Microstructural analysis of the studied samples did not find out significant derivations between them and standard A5E (picture 7) alloy structures, thus there were observed eutectic small pieces of FE phase in the aluminium based hard liquid.

Big crystals of FE phase (Al_3Fe) were observed as part of microstructure after remelting at 800 °C and low cooling speed in the furnace, but primary Al_3Zr phase crystals were not observed (picture 8.a). Besides, the second separations of the current phase were not observed after primary heating of the wire at 600 °C (picture 8.b). This enables to suggest that the amount of zirconium is less in this alloy. Chemical analysis is required to define the exact amount of zirconium.

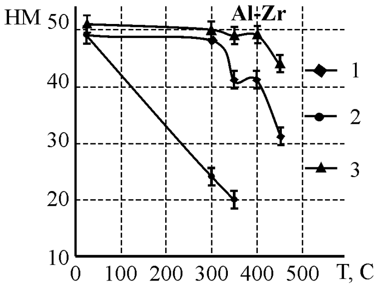
As small sizes of foreign made Al-Zr alloy samples do not allow to define their chemical composition directly, there was prepared dissolved alloy 10 times as many as in comparison with content of the primary alloy (one portion from sample 3 and 9 portions A99 aluminium). Shown at Table 3 and the results of chemical analysis got by back-calculating the amount of zirconium in the alloy show to be at the rate of 0.26 mass %.



Picture 7. Microstructure of primary foreign made Al-Zr alloy wire no. 3



Picture 8. Microstructure of foreign made Al-Zr alloy after repeated wire alloying (a) and slow cooling speed (b)



Picture 9. Influence of heating temperature (within an hour) on microhardness (MPa) of three types foreign made Al-Zr alloy wires

Further, influence of thickening temperature on the microhardness of Al-Zr alloy wire was studied (Picture 9). The tests proved samples No.1 and No.3 to be of higher thermal stability (up to 400 °C temperature).

Table 3. Chemical composition of foreign made Al-Zr alloy (sample no. 3) according to the findings of spectral analysis

Al	Zr	Fe	Si	Cu	Mg	Zn	Mn	Ti
99,30	0,26	0,18	0,09	0,015	0,005	0,04	0,007	0,023

Note: main alloying elements and mixtures (as a whole, 25 elements were analyzed).

Comparative study of line broadening ratio of foreign made wires of Al-Zr alloy and ASE type of alloy wire was conducted in the interval of 350 °C. The study showed the amount of zirconium not to have significant influence on the line broadening ratio assessment.

Conclusion. Thus, the study evaluated the influence of heating temperature on the structure and properties of Al-Zr alloy. The studies proved wire samples with composition of 0.2-0.3 % Zr alloys to have higher thermal stability (up to 400 °C temperature). As well as, the amount of zirconium does not have significant influence on the line broadening ratio assessment.

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***Ібрагімов Хаяль Алішах огли.* Структура та властивості ефективного алюмінієво-цирконієвого сплаву в електронних цілях**

Досліджено структуру та властивості алюмінієво-цирконієвих сплавів. Оцінено вплив підвищення температури на структуру механічних властивостей трьох типів дротів з алюмінієво-цирконієвого сплаву. Оцінено вплив температури нагрівання на структуру та властивості алюмінієво-цирконієвих сплавів. Доведено, що зразки дротів із вмістом 0,2-0,3 % цирконієвих сплавів мають більш високу термостійкість (температура до 400 °С). Також встановлено, що кількість цирконію не має істотного впливу на оцінку коефіцієнта розширення ліній.

Ключові слова: алюмінієво-цирконієві сплави, структура і властивості, механічні тести, температура нагрівання.

***Ибрагимов Хаяль Алишах оглы.* Структура и свойства эффективного алюминиево-циркониевого сплава в электронных целях**

Рассмотрены актуальные проблемы усовершенствования электротехнических свойств и оптимального состава сплавов для электрических сетей, работающих под определенной температурой и электрическими нагрузками. В связи с этим исследована структура и свойства алюминиево-циркониевых сплавов. Проанализировано влияние повышения температуры на структуру механических свойств трех типов проводов из алюминиево-циркониевого сплава. Оценено влияние температуры нагрева на структуру и свойства алюминиево-циркониевых сплавов. Исследование показало, что образцы проводов с содержанием 0,2-0,3 % циркониевых сплавов имеют более высокую термостойкость (температура до 400 °С). Также установлено, что количество циркония не имеет существенного влияния на оценку коэффициента расширения линий.

Ключевые слова: алюминиево-циркониевые сплавы, структура и свойства, механические тесты, температура нагрева.