# Structure and properties of Al-Mg-Sc-Zr-Er alloy after nanoscale precipitation hardening

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The effect of magnesium content reduction and scandium, zirconium, manganese and chromium alloying on the structure, phase composition, strength and ductility, corrosion potential and current of Al-Mg and Al-Mg-Sc alloys made using a magnetohydrodynamic foundry was studied. The positive effect of magnesium reducing content and manganese on chromium replacing in Al-Mg-Sc alloys has been established.

**The aim of this work** is to investigate the effect of reducing the Mg content and doping (Sc, Zr, Mn, Cr) on the structural-phase state and mechanical and electrochemical characteristics of cast alloys of the Al-Mg system obtained by magnetohydrodynamic technology.

High characteristics of ductility, corrosion resistance and weld ability, as well as the lack of need for hardening heat treatment of Al-Mg alloys cause their widespread use in mechanical engineering, in particular in aerospace engineering. But their disadvantage is the low strength, which is increased by structural (grinding of structural elements) and solid-soluble or intermetallic hardening, in particular, doping with transition metals, among which one of the most effective is scandium. Scandium doping provides the formation of a dentate-free structure of castings with small crystals of solid aluminum solution in the form of cells and dispersed inclusions of intermetallics.

**Table 1. Chemical composition (mass. %) of investigated alloys.**

| № | Mg | Mn | Sc | Zr | Cr | Fe | Si |
|---|---|---|---|---|---|---|---|
| 1 | 6.28 | 0.39 | – | – | – | 0.12 | 0.18 |
| 2 | 5.96 | 0.40 | 0.24 | 0.09 | – | 0.28 | 0.16 |
| 3 | 4.61 | 0.43 | 0.28 | 0.12 | – | 0.31 | 0.17 |
| 4 | 4.60 | – | 0.26 | 0.13 | 0.47 | 0.14 | 0.10 |

**Note:** the average chemical composition is given; all alloys also contain ~ 0.03% Ti and ~ 0.003% Be, Al - the rest.

**Table 2. Mechanical properties of alloys**

| Property | № of alloy | | | |
|---|---|---|---|---|
| | 1 | 2 | 3 | 4 |
| $\sigma_{YS}$, MPa | 137 | 152 | 178 | 175 |
| $\sigma_{UTS}$, MPa | 213 | 234 | 284 | 280 |
| $\delta_5$, % | 8 | 11 | 14 | 15 |

The alloy of the Al-Mg-Zr system (variant № 8) contains 0.47% Cr instead of 0.43% Mn. Scandium, zirconium and chromium are recorded in the matrix, which may indicate the formation of dispersed strengthening phases of the $Al_3(Sc_{1-x}Zr_x)$ and $Al_7Cr$ type. As a result, doping with chromium instead of manganese provided the strength and ductility of alloy № 8 at the level of alloy № 3 (Table 2), but a significant positive effect on the corrosion resistance of the alloy was obtained.

The presence of scandium and zirconium in the alloy variant № 2 causes an increase in its mechanical characteristics compared to variant № 1 as a result of the formation in the matrix of the dispersed (nanoscale) reinforcing phase $Al_3Sc$ and intermetallics $Al_6(Fe, Mn)$ and $Al_3Fe$.

Variant № 3 shows a trend when with a decrease in magnesium content from 5.96% to 4.61%, the strength and ductility of the alloy increased markedly. This is due to a change in the nature of the matrix: zirconium appeared here, which indicates the formation of the dispersed phase $Al_3(Sc_{1-x}Zr_x)$ at the optimal ratio Sc / Zr ≈ 2/1.

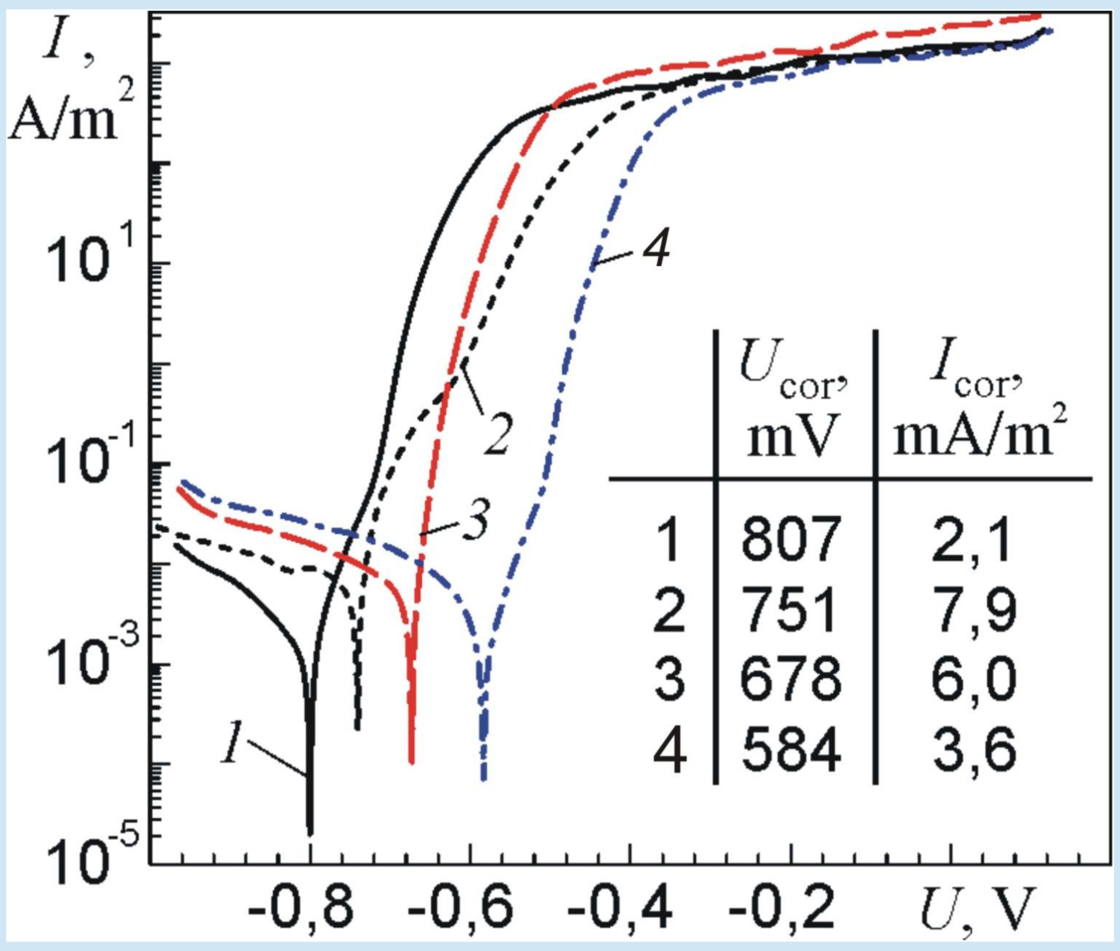


Fig. Polarization curves and electrochemical characteristics (in 3% NaCl) for the alloys according to its number in Table 1.

## Conclusions

In contrast to the known literature data, an increase in strength due to a decrease in the magnesium content in Al-Mg-Sc alloys obtained using magnetohydrodynamic mixing of the melt at 700 ℃ and its crystallization in a steel mold heated to 300℃ was recorded. It is established that chromium effectively replaces manganese in these alloys, providing their strengthening and a significant increase in their corrosion resistance.

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