INVESTIGATION OF POLYTHERMAL SECTIONS OF THE Mg-Zn-Ce SYSTEM IN THE Mg-RICH REGION

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At the present time, in order to improve mechanical and technological properties of deformable Mg alloys, their alloying with rare-earth metals, for instance Ce, is used [1]. The present work presents investigation results of polythermal sections in the Mg-rich region of the Mg-Zn-Ce system.

In the Mg-Zn binary system, the $Mg_{51}Zn_{20}$ compound, i.e., the one richest in Mg, has a rhombic elementary cell with parameters a = 1.4083, b = 1.4486, and c = 1.4025 nm [2]. That compound takes part in the eutectic equilibrium $L \rightleftharpoons \alpha + Mg_{51}Zn_{20}$ at 343°C and undergoes a eutectoid decomposition, $Mg_{51}Zn_{20} \rightleftharpoons \alpha + MgZn$, at 330°C [3]. The Mg-Ce phase diagram, on the Mg side, presents a eutectic-type diagram. The temperature of the eutectic transformation $L \rightleftharpoons \alpha + Mg_{12}Ce$ was determined to be 590°C. The cerium concentration at the eutectic point is 20.5% [5]. The compound $Mg_{12}Ce$ (I) of $ThMg_{12}$ structural type with lattice parameters of a = 1.033; c = 0.596 [5]; and $CeMg_{12}$ (II) with a = 1.033 and c = 7.75 nm [5], whose lattice parameter is 13 times greater than $Mg_{12}Ce$ (I). The compound richest in Ce in the Mg-Ce system is $Mg_{10.3}Ce$, whose structural type is Th_2Ni_{17}, and whose parameters are a = 1.0333 and c = 1.025 nm [6].

The Mg-Zn-Ce system has previously been investigated [1,7,8]. It was established in [7] that there is a nonvariant equilibrium at 341-343°C, at the composition of 50% Mg+47.5% Zn+2.5% Ce, without explaining its reaction or mentioning the phases taking part in it.

The authors of [7,8] investigated alloys of the Mg-Ce-Zn system in the solid state. Using X-ray spectrometric analysis, the authors of [1] established that the α solid solution is at equilibrium with the $Mg_{12}Ce$-based solid solution $(Mg,Zn)_{12}Ce$, the compound $Mg_{15}Zn_{20}$, the ternary compound $Mg_7Zn_{12}Ce$ (hexagonal lattice, a = 0.880 nm [8], and also the compound with a wide homogeneity region on the isoconcentration line corresponding to 0.1 at fraction of Ce, which, according to [9], has the $(Mg_{0.9-0.5}Zn_{0.1-0.5})_{10.1}Ce$ composition and the Th_2Ni_{17} crystalline structure, with parameters respectively changing within the homogeneity region: a = 1.010 - 0.960 and c = 0.997 - 0.947 nm. It is possible that, at higher temperatures, that compound gradually and continuously transforms into the binary $Mg_{10.3}Ce$ compound, which exists in the Mg-Ce system in a narrow temperature range, 611-621°C [5]. Thus Zn, while dissolving in that compound, stabilizes it in a wide temperature and concentration region. Taking into account the complexity of the system and the discrepancy of data reported, the authors carried out some additional investigations which helped to establish phase interactions in alloys of the Mg-Ce-Zn system.

The phase diagram was investigated, using the methods of differential thermal, X-ray spectrometric, and microstructural analyses. The following original materials were used: magnesium MG-95 (99.5% Mg), cerium TseM (99.8% Ce), and zinc TsO (99.92% Zn). The alloys were melted in corundum crucibles under a layer of VI-2 flux. Thermal analysis was carried out, using an NTP-64 low-frequency thermographic recorder, at specimens cooling rates of 2-5°C/min in the crystallization temperature range. The temperature was measured with a chromel-alumel thermocouple. X-Ray spectrometric analysis used an MS-46-type X-ray microanalyzer, of "Kameka" make, and a JSM-U3 scanning electron microscope with an X-ray microspectrometer attachment. Diffractograms were recorded, using a DRON-2, 0 powder diffractometer (in Fe-K_α emission). Microstructure was determined on mechanically-polished cross sections, etched in a 30% H_3PO_4 solution in alcohol.

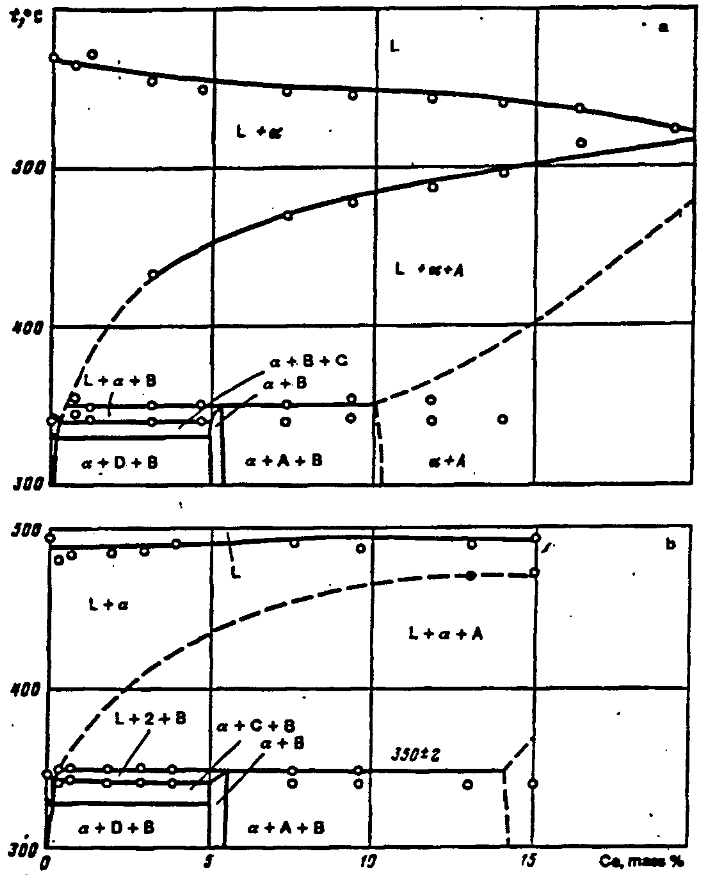

Fig. 1. Polythermal sections of the Mg-Zn-Ce system at constant Zn concentrations of 24 (a) and 34% (b). The phases had the following designations: A) $(Mg_{0.9-0.5}Zn_{0.1-0.5})_{10.1}Ce$; B) $Mg_7Zn_{12}Ce$; C) Mg_7Zn_3; and D) MgZn.

On the basis of the results produced, the authors plotted some polythermal sections (for constant Zn concentrations of 24 and 34%) of the Mg-Zn-Ce system (Fig. 1). Using the X-ray phase and microscope analyses of slowly-cooled alloys, it was confirmed that in the alloy, apart from the Mg-based α solid solution, there are the following phases: $Mg_{51}Zn_{20}$, $Mg_7Zn_{12}Ce$ $(Mg_{0.9-0.5}Zn_{0.1-0.5})_{10.1}Ce$. Typical microstructures are presented in Fig. 2. Phase $Mg_{51}Zn_{20}$ undergoes a eutectoid decomposition and, after etching, its color is grey. Due to incomplete transformation at 349°C, the $Mg_{51}Zn_{20}$ phase is present in the Mg + 7.3% Ce + 23.6% Zn alloy. The $Mg_7Zn_{12}Ce$ phase is of white color. The $(Mg_{0.9-0.5}Zn_{0.1-0.5})_{10.1}Ce$ phase, after etching, has an uneven, dark color. That unevenness of color is related to the existence of a wide homogeneity region.

According to X-ray microspectrometric analysis, the following phases were detected in the Mg + 73% Ce + 23.6% Zn alloy composition: Mg-based solid solution, [MgZn] phase, and two triple phases [MgZnCe] which are different in their Ce and Zn contents. X-ray phase analysis confirmed the presence in that alloy, apart from the α solid solution, of the binary phase $Mg_{51}Zn_{20}$, and the $(Mg_{0.9-0.5}Zn_{0.1-0.5})_{10.1}Ce$ and $Mg_7Zn_{12}Ce$ phases.

The alloy thermograms clearly detected the temperatures of two non-variant transformations: $L + (Mg_{0.9-0.5}Zn_{0.1-0.5})_{10.1}Ce \rightleftharpoons \alpha + Mg_7Zn_{12}Ce$ at 349 ± 1°C and $L \rightleftharpoons \alpha + Mg_7Zn_{12}Ce + Mg_{51}Zn_{20}$ and 341±1°C at 341 ± 1°C, as well as the temperatures of primary crystallization of the binary eutectic. The cooling curves did not show any transformations in the solid state. That is related to the small thermal effects of such transformations.

Fig. 2. Microstructures (340X) of the slowly-cooled Mg-Zn-Ce alloys: a) alloy Mg+33.7% Zn: $\alpha+(\alpha+Mg_{51}Zn_{20})$; b) alloy Mg+33.5% Zn+ 3.8% Ce; $\alpha+[\alpha+(Mg_{0.9-0.5}Zn_{0.1-0.5})_{10.1}Ce]+$ $+[\alpha+Mg_7Zn_{12}Ce] + (\alpha+Mg_7Zn_3\ Mg_7Zn_{12}Ce)$; and c) alloy Mg+33.7% Zn+ +15% Ce; $\alpha+[\alpha+(Mg_{0.9-0.5}Zn_{0.1-0.5})_{10.1}Ce]$.

CONCLUSIONS

In the Mg-Zn-Ce system, the existence of two non-variant transformations was established: the peritectic-type transformation $L+(Mg_{0.9-0.85}Zn_{0.1-0.15})_{10.1}Ce \rightleftharpoons \alpha+Mg_7Zn_{12}Ce$ at 349 ± 1°C, and the eutectic-type transformation $L \rightleftharpoons \alpha+Mg_{51}Zn_{20}+Mg_7Zn_{12}Ce$ at 341 ± 1°C.

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