VARIATION OF THE STRUCTURE OF MAGNESIUM-CADMIUM ALLOYS DURING ORDERING

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The ordering of magnesium-cadmium alloys (Mg$_2$Cd, MgCd, and MgCd$_3$) has been investigated many times [1, 2]. It has been shown that the ordering of alloys whose composition is close to the stoichiometric Mg$_2$Cd and MgCd$_3$ compositions results in a hexagonal close-packed lattice. In the MgCd alloy an orthorhombic lattice is formed and is transformed into a disordered hexagonal structure above 280°C.

However, at present there have been no investigations of the effect of ordering on the ductility and strength of these alloys.

Previously we investigated the variation of the ductility of ordered magnesium-cadmium alloys in different states at high temperatures [3]. We showed that there is an anomalous change in the ductility of alloys in the state close to the ordered state. In magnesium-cadmium alloys of stoichiometric composition we found a sharp increase of ductility (superductility) in a narrow temperature range directly adjacent to the ordering range.

We made additional experiments to clarify the nature of the anomalous increase in ductility. We used an experimental cast magnesium-cadmium alloy in the ordered state and investigated its microhardness and the change in the crystal structure after quenching from different temperatures. The quenching temperature was chosen so as to enable us to investigate the transition from order to disorder in the greatest detail. The conditions of treatment were as follows. Two samples were placed in a furnace and covered with carnallite flux, heated to the desired temperature, kept at this temperature 1 h, and then quenched in ice water. One sample was used to measure the microhardness, the other was used for x-ray analysis. Then the samples were heated to the next temperature and the treatment was repeated. The method of preparation and the conditions of homogenization of magnesium-cadmium alloys are described in [3].

We also made a thermographic investigation (with a Kurnakov pyrometer) of cast and homogenized samples, the heating rate from room temperature to the melting point being 1.3°C/min.

The microhardness of the samples was determined with the PMT-3 apparatus under a load of 10 g; the crystal lattice was studied with a URS-50I diffractometer, using copper radiation. The results are shown in Figs. 1 and 2. The thermographic investigation of cast samples and case samples quenched from 300°C showed two transformations. The temperature of the first transformation in the cast sample was 254-257°C (and 248-252°C for the quenched sample), which agrees with the data in the literature on the Kurnakov point for the composition (250°C).

The second transformation occurs close to the solidus temperature is 397-410°C for the cast sample and 392-396°C for the homogenized sample. The melting point for this alloy is 418°C (determined from the thermograms). Some investigators [4,5] assume that at 250°C it is not a decomposition of the ordered MgCd alloy but its polymorphic transformation which occurs, and that above 250°C there is not a solid
Fig. 2. Variation of the lattice constants of magnesium-cadmium alloys with the quenching temperature. a) Cast; b) homogenized.

The most interesting results are from the investigation of the crystalline structure of samples during quenching from different temperatures (Fig. 2). X-ray photographs showed that in cast as well as homogenized samples there is a mixture of two phases in the whole range of quenching temperatures investigated (up to 350°C).

We identified the lines of two lattices:

1) Disordered, hexagonal close-packed, belonging to the intermediate metastable phase, with lattice constants 
   \( a = 6.072 \text{ kX}, \ c = 10.018 \text{ kX}, \) and \( c/a = 1.65 \) (\( a \) and \( c \) being approximately double those of the disordered stable phase at room temperature);

2) Rhombohedral ordered, with \( a = 4.993 \text{ kX}, \ b = 3.216 \text{ kX}, \) and \( c = 5.256 \text{ kX}. \)

The investigation showed that the lattice constants change relatively little with the quenching temperature between room temperature and 220°C, and above 280°C. The greatest changes of the lattice constants and the intensities of lines occur for samples quenched from 220-280°C. In cast and ordered (homogenized) samples the constants change by a jump, and the jump is much greater in ordered than in disordered samples. In ordered samples there are two jumps of the constants on both sides of the Kurnakov point and a minimum at 280°C. In the cast samples there is a jump-like increase of the constants above the ordering temperatures (at 260-280°C).

Below and above the Kurnakov point there is a mixture of ordered and disordered phases, but below 250°C the intensity of the reflection of the rhombohedral lattice increases and at higher temperatures it decreases. We did not succeed in obtaining a completely disordered phase after prolonged annealing and quenching of samples from temperatures above the Kurnakov point. This is explained by a rather high kinetic energy of ordering which develops during quenching or aging at room temperature before examination with the diffractometer.

The analysis of the experimental results shows that the maximum change of all the properties investigated and also of the crystal structure of cast and ordered alloys occurs at 250°C, i.e., coincides with the ordering-disordering transformation temperature.

The x-ray investigation showed that tensile stress samples subjected before testing to heat treatment identical to the heat treatment of samples used for the investigation of the crystal structure consist of a mixture of two phases. One is the ordered rhombohedral phase, with lattice constants \( a = 4.993 \text{ kX}, \ b = 3.216 \text{ kX}, \) and \( c = 5.256 \text{ kX}. \) and the other is a metastable intermediate phase, with lattice constants \( a = 6.072 \text{ kX}, \ c = 10.018 \text{ kX}, \) and \( c/a = 1.65. \)

When the samples are deformed at temperatures close to 250°C the diffusional process of ordering-disordering is quite intense. This process ensures high ductility when the relationship between the kinetics of transformation and solution but a partially dissociated intermetallic compound. Possibly the point of secondary transformation on the thermogram corresponds to complete decomposition of the compound.

Figure 1 shows that the microhardness changes considerably in cast samples at about 100°C and close to the Kurnakov point, and at 150-250°C in the homogenized samples. In the cast and quenched sample the change in the microhardness indicates the development of the aging process resulting from the metastability following rapid crystallization and an effect due to the development of ordering-disordering during quenching of the cast sample.

According to the data on microhardness, the degree of disordering of the samples is rather high during quenching, since the microhardness due to disordering is almost twice that of the initial microhardness (121 as compared to 174 kg/mm²). The maximum hardness, which is apparently related to phase cold hardening occurring during disordering, corresponds to 200°C. A lower maximum microhardness also occurs for this sample at 250°C.