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Phase Transformation Mechanism of Mg-2Zn-0.7Ce Alloy During Cryogenic Treatment

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Abstract. This paper proposes the lattice density to determine whether the cryogenic treatment can promote the precipitation of the second phase in the magnesium alloy. The lattice density refers to the number of atoms per unit volume in the unit cell. Only when the lattice density of the second phase is smaller than the matrix, cryogenic treatment can play a role in promoting precipitation. The greater the difference in lattice density, the better the cryogenic treatment promotes precipitation.

Keywords: Magnesium alloy; Cryogenic Treatment; Phase change mechanism.

1. Introduction

Magnesium alloy is the lightest metal structural material used in aerospace and military industry and has a very broad prospect for development. However, magnesium alloys have poor plasticity, are resistant to wear, and are easily corroded [1-3]. These disadvantages greatly limit their applications. Therefore, there is a need for a suitable process to overcome these disadvantages of magnesium alloys. Cryogenic treatment means that the material is treated in an environment of -230°C-190°C. Cryogenic treatment can significantly improve the wear resistance, corrosion resistance and other properties of carbon steel, so it is widely used in the production of tool steel, high speed steel and hard alloy. The research on cryogenic treatment of magnesium alloys is of great significance, but there are few reports at home and abroad [4-6]. In this paper, the phase transformation mechanism of Mg-2Zn-0.7Ce alloy in cryogenic treatment is studied in the extruded Mg-2Zn-0.7Ce (at. %) alloy, and the precipitation of the second phase in the cryogenic treatment of the general alloy is summarized. law. The results of this study will provide a new research method for the phase transition of magnesium alloys. It will provide a new process for the improvement of the mechanical properties of magnesium alloys and has important theoretical value and application prospects.

2. Test results and analysis

After cryogenic treatment, a large amount of W phase particles precipitated in the Mg-2Zn-0.7Ce alloy. However, for different compositions of magnesium alloys, the precipitation behavior of the second phase after cryogenic treatment is different. Chen Ding studied the cryogenic treatment of AZ31 alloy and found no obvious second phase precipitation behavior. The different precipitation behaviors are mainly due to different types and compositions of the second phase due to different alloy compositions. This phenomenon can be explained by the cryogenic treatment mechanism of the carbon steel.

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For carbon steels, the retained austenite transforms into martensite in cryogenic treatment, which is mainly due to the great degree of undercooling in cryogenic environments. In general, when the carbon steel is quenched and cooled to room temperature, austenite to martensite transformation occurs, which is called martensitic transformation. Martensitic transformation is a non-diffusion-type phase transformation, and lattice reorganization is performed by shearing without involving a change in composition. Due to the non-diffusive nature of the martensitic transformation, phase transitions require a great deal of driving force and undercooling. Since the density of austenite is smaller than that of martensite, the crystal lattice expands during the phase change, and it appears as a volume expansion in the macroscopic view. In other words, when austenite transforms into martensite, extra space is needed to ensure the smooth transition. Usually, the first transformed martensite occupies space, and the subsequent austenite does not have enough space to undergo a phase change, that is, the first transformed austenite has an inhibitory effect on the transformation of untransformed austenite. Austenite is preserved as retained austenite. Only by further increasing the phase change driving force, that is, increasing the degree of subcooling can make the phase change continue. The cryogenic treatment not only provides enough subcooling as the phase change driving force, but also shrinks the Fe lattice under cryogenic conditions. It also provides additional space for phase transformation. Cryogenic treatment can eliminate most of the retained austenite.

Therefore, for the cryogenic treatment of common alloys, the phase transition in a cryogenic environment is closely related to the volume change of the lattice before and after the phase transformation. If the density of the second phase is less than the density of the matrix, the volume expansion occurs when the solute atoms are precipitated from the matrix as the second phase, that is, extra space is needed to ensure the smooth progress of the precipitation; conversely, if the density of the second phase Less than the density of the matrix, the volume shrinks when the second phase is precipitated, so there is no need to provide extra space to ensure the phase change, only to provide enough undercooling. In a cryogenic environment, the lattice of the matrix shrinks, providing additional space for phase transitions. Therefore, only when the density of the second phase is less than the density of the matrix, the cryogenic treatment can play a role in promoting precipitation when the phase change requires extra space. In addition, when the density of the second phase is less than the density of the matrix, the greater the difference in density before and after the phase transition, the greater the need for extra space for precipitation of the second phase, and the more efficient the extra space provided by the cryogenic treatment.

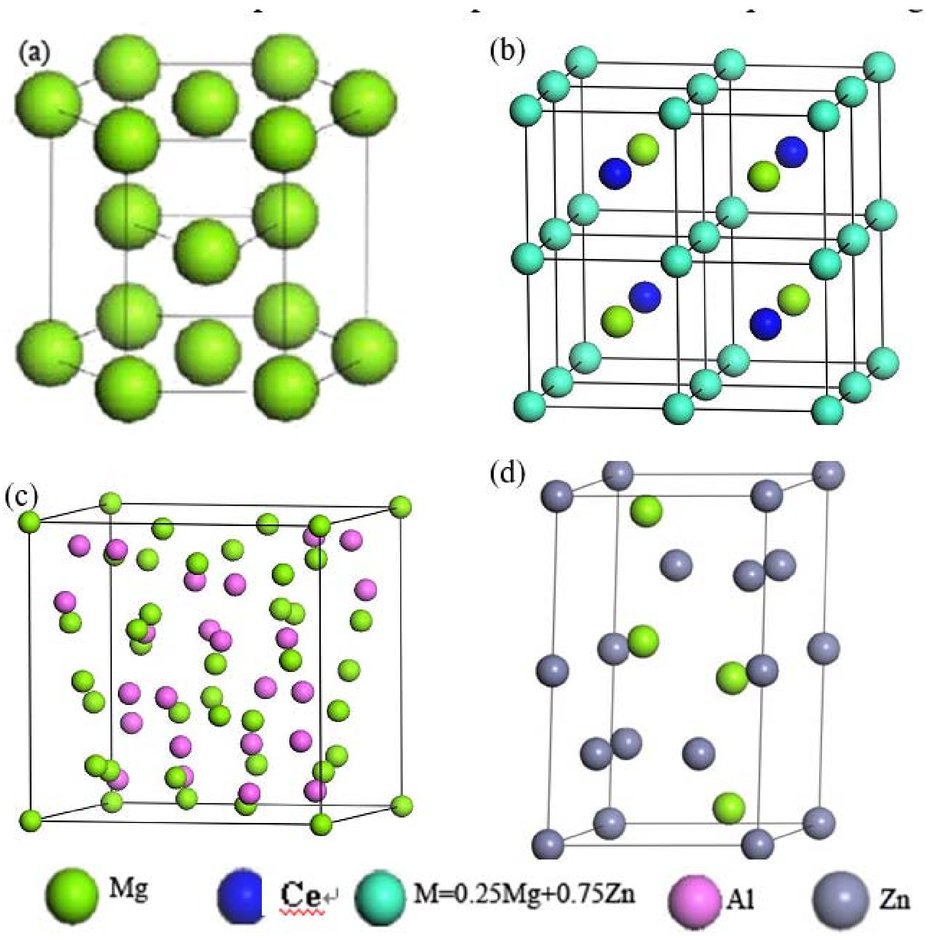

Fig. 1. The schematic lattice structure of α-Mg (a), W phase (b), $Mg_{17}Al_{12}$ (c)and $MgZn_2$ (d).

In order to analyze the difference in density before and after the phase transformation of the second phase, the concept of lattice density is introduced. The lattice density can quantitatively reflect the density of a certain phase, so as to judge whether the lattice has been expanded before and after the phase change. If the lattice density of the second phase is less than the lattice density of the matrix, the lattice expands when precipitated, so cryogenic processing is needed to provide extra space.

It can be seen that the lattice density of the Mg matrix is 57.1 nm^{-3}, which is larger than that of $Mg_{17}Al_{12}$ (52.3 nm^{-3}), Mg-Zn (13.1 nm^{-3}) and W phase (35.5 nm^{-3}), so theoretically the cryogenic treatment is the precipitation of these second phases can be promoted. However, the lattice density of the Mg17Al12 phase is 52.3 nm^{-3}, which is not much different from that of the Mg matrix, so its precipitation does not require much extra space. Therefore, the $Mg_{17}Al_{12}$ phase in the AZ31 magnesium alloy hardly precipitates in a cryogenic environment. After cryogenic treatment, only a small amount of $Mg_{17}Al_{12}$ phase precipitated in the AZ91 magnesium alloy, which may be due to the high content of Al in AZ91 and the lower solid solubility of Al in the Mg matrix under cryogenic conditions. The lattice density of the $MgZn_2$ phase is 13.1 nm^{-3}, which is far less than the lattice density of the Mg matrix. Therefore, the two phases need to provide extra space to ensure the smooth transition, so ZK60 and Mg-2Zn-0.7Ce There is a clear second phase precipitation in the cryogenic environment of the alloy. Therefore, it can be inferred that for the magnesium alloy, the cryogenic treatment has the effect of promoting the precipitation of the second phase only for the alloy system in which the lattice density of the second phase is much smaller than that of the matrix. Moreover, the greater the difference between the second-phase lattice density and the matrix, the better the effect. In addition, the lattice density of a certain phase can reflect its true density to some extent.

3. Conclusion

A criterion for the precipitation of the second phase in magnesium alloys under cryogenic conditions is proposed: lattice density. The lattice density can quantitatively reflect the density of the second phase to determine whether the lattice has expanded before and after the phase change. If the lattice density of the second phase is less than the lattice density of the matrix, precipitation of the second phase will cause the lattice to expand, so cryogenic processing is required to provide additional space. The cryogenic treatment has the effect of promoting the precipitation of the second phase only for the alloy system in which the lattice density of the second phase is much smaller than that of the matrix. Moreover, the greater the difference between the second-phase lattice density and the matrix, the better the effect.

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