ABSTRACT

- Anisotropic impurity diffusion coefficients of Al, Zn, Y, and Gd were investigated for the first time using diffusion couples with Mg single crystal.
- Anisotropic impurity diffusion coefficients of $D_x/D_y = 1.0\times1.3$, which is similar to Mg self-diffusion.
- Solute diffusion coefficients decreases with increasing temperature and can be neglected at normal materials processing temperature for Mg-based alloys.
- The Mg grain boundary diffusion coefficient was determined with misorientation by developing a new technique with CFE-SEM-EDS and found to be about two order of magnitude faster at 75° misorientation between adjacent Mg grains.
- Phase boundaries of stoichiometric compounds and solubility limits of solid solutions in the MgY and Mg-Gd systems were determined between 703 and 803 K and the phase diagrams of these two systems were re-optimized.

PROBLEM STATEMENTS

- Diffusion of alloying elements is key to control high temperature processes (annealing, rolling, extrusion, etc.).
- However, there is no systematic diffusion study or database for Mg.
- Mg has anisotropic hcp crystal structure (c/a ratio = 1.62).
- Self-diffusion in Mg is anisotropic $D_x/D_y = 1.13\times1.26$ [1-3].
- Diffusion of Mg, Zn, Y, and Gd also known to improve the properties of Mg alloys.
- There is no experimental study for anisotropic diffusion of Al, Zn, Y, and Gd in hcp Mg.

OBJECTIVES

- To determine the anisotropic impurity diffusion coefficients of Al, Zn, Y, and Gd in hcp Mg using single crystal Mg diffusion couples.
- To determine grain boundary diffusion coefficients of solutes with adjacent grain misorientation angles using Mg polycrystalline diffusion couples.
- To develop a diffusivity (mobility) database for Mg alloys.
- To develop ICME tools for the solidification and homogenization processes of Mg alloy production.

RESULTS

- Experimental conditions:
  - MgAl: Temperature = 638 - 693 K, Duration = 2 - 4 days.
  - MgZn: Temperature = 553 - 593 K, Duration = 4 - 20 days.
  - MgY: Temperature = 723 - 803 K, Duration = 2 - 5 days.
  - MgGd: Temperature = 703 - 743 K, Duration = 2 - 7 days.
- Diffusion equation (Fick's 2nd law):
  \[
  \frac{D_{eff}}{D_{c}^{2}} \frac{d^{2}C_{i}}{dx^{2}} = \frac{dC_{i}}{dx} = \frac{N}{A} \left( \frac{D_{eff}}{D_{c}} \right) \left( C_{j}^{eq} - C_{i}^{eq} \right)
  \]
- Solution of diffusion equation:
  \[
  C_{i}^{eq} = C_{i}' + \frac{N}{A} \left( \frac{D_{eff}}{D_{c}} \right) \left( C_{j}^{eq} - C_{i}^{eq} \right)
  \]
- Impurity diffusion coefficients of Al, Zn, Y, and Gd in comparison with Mg self-diffusion coefficients in hcp Mg.

SUMMARY

- Anisotropic impurity diffusion coefficients of Al, Zn, Y, and Gd in the HCP Mg matrix were experimentally determined for the first time.
- Diffusivities of Y and Gd are about one order of magnitude lower than those of Al, Zn, and Mg.
- Grain boundary diffusion coefficients of Al and Mg are two orders of magnitude higher at around 75° misorientation between adjacent Mg grains.
- Phase boundaries in the Mg-Y and Mg-Gd systems were determined accurately in the solid solutions and intermetallics, and phase diagrams were re-optimized.