Effect of Ni Content on the Glass Forming Ability (GFA) of Mg-Ni-Si Alloys by Mechanical Alloying (MA)

Haowen Xie, Jianguo Lin, Cui'e Wen and Peter D. Hodgson
Centre for Material and Fibre Innovation, Geelong Technology Precinct, Deakin University

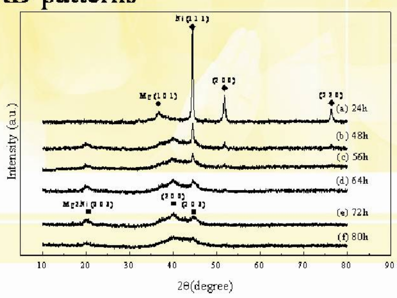
1. Introduction

Among amorphous alloys, Mg-based BMG are of special interest since they can provide the possibility to obtain new light alloys for structural applications. Mechanical alloying is considered as an effective method for producing Mg-based BMG. It has been found that the composition has a significant influence on the glass forming ability (GFA) and properties of these alloys. In the present study, the influence of the Ni content on GFA of Mg-Ni-Si system will be evaluated on the basis of theoretical calculation and X-ray diffraction analysis results.

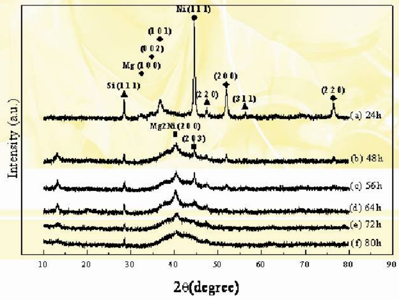
2. Experimental procedures

- Ball milling conditions:
  - ✓ Ball miller: Retsch, PM400
  - ✓ Rotation speed: 200rpm
  - ✓ Ratio of ball to powder: 20:1
- Target compositions:
  - ✓ Mg65Ni35-xSix
    x=2, 5, 10, 15, 25
- Starting materials:
  - ✓ Mg powder: purity 99.9% average diameter 180 μm
  - ✓ Ni powder: purity 99.9% average diameter 35 μm
  - ✓ Si powder: purity 99.9% average diameter 180 μm

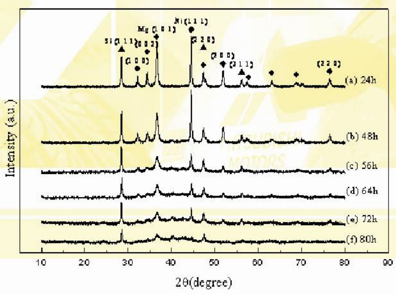
3. XRD patterns



XRD patterns of $Mg_{65}Ni_{33}Si_2$ at different milling time



XRD patterns of $Mg_{65}Ni_{25}Si_{10}$ at different milling time



XRD patterns of $Mg_{65}Ni_{10}Si_{25}$ at different MA time

Fig.1 XRD patterns of the mixtures with different compositions after ball milled for the selected time

- XRD patterns indicate:
  - ✓ **The GFA of Mg-Ni-Si alloys increases with the increase of the Ni content**
  - ✓ **The evolution of mixtures:**
    - Particle fining
    - Presence of intermetallic compound Mg_2Ni
    - Amorphization
  - ✓ **The powder consists of:**
    - Amorphous MgNiSi alloy
    - Intermetallic compound Mg_2Ni
    - Si (that having more Si content)

4. SEM observation

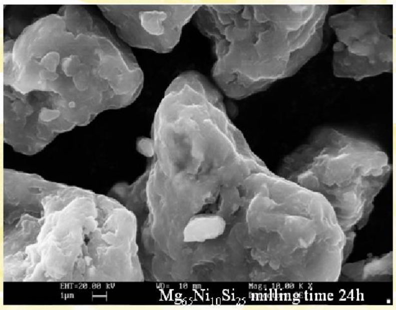


Fig.2(a) SEM image of the mixed powders after ball milled for 24h, showing a ductile fracture at early stage

Fig.2(b) SEM image of the mixed powders after ball milled for 80h, showing a brittle fracture at late stage

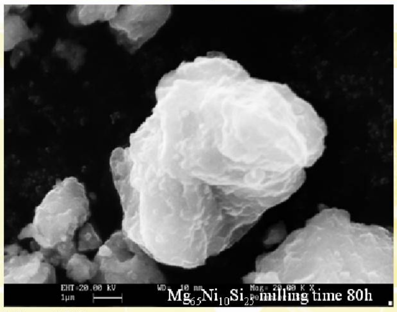


Fig.2 SEM images of Mg65Ni10Si25 mixtures after ball milled for 24h and 80h

5. Calculation of GFA of MgNiSi: Calculating & comparing the formation enthalpy of solid solution and amorphous phases

- The enthalpy of the mixing of a <u>solid solution</u>:

$$\Delta H_{ABC} = \Delta H^c_{ABC} + \Delta H^e_{ABC} + \Delta H^s_{ABC}$$

1. Chemical contribution: $\Delta H^c_{ABC} = \Delta H^c_{AB} + \Delta H^c_{BC} + \Delta H^c_{AC}$

$$\Delta H^c_{ij} = x_i x_j (x_i \Delta H^0_{jmi} + x_j \Delta H^0_{imj})$$

ΔH^0_{imj} **The enthalpy of solution at infinite dilution**

2. Elastic contribution: $\Delta H^e_{ABC} = \Delta H^e_{AB} + \Delta H^e_{BC} + \Delta H^e_{AC}$

$$\Delta H^e_{ij} = x_i x_j (x_i \Delta H^e_{jmi} + x_j \Delta H^e_{imj})$$

$$\Delta H^e_{imj} = 24\pi B_i \mu_j R_i R_j (R_i - R_j)^2 / (3B_i R_j + 4\mu_j R_i)$$

3. Structural contribution: neglected

- The enthalpy of formation of <u>amorphous</u>

$$\Delta H^a_{ABC} = \Delta H^c_{ABC} + x_A \Delta H^a_A + x_B \Delta H^a_B + x_C \Delta H^a_C$$

$$\Delta H^a_i = aT_{m,i}$$

$T_{m,i}$ **Melting point**

a **3.5J/mol K**

- GFA increases with the Ni content increase

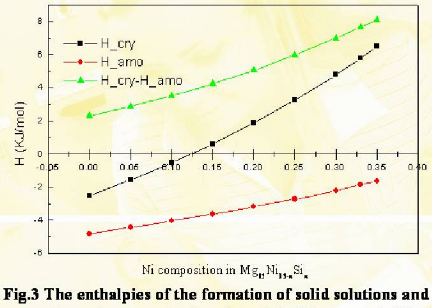


Fig.3 The enthalpies of the formation of solid solutions and amorphous phases as the function of the Ni content in Mg-Si-Ni

6. Conclusion

- **Complete amorphous phases were successfully obtained in $Mg_{65}Ni_{33}Si_2$ and $Mg_{65}Ni_{25}Si_{10}$ alloys after ball milled for 80h. The GFA of Mg-Ni-Si increase with the increase of Ni content;**
- **With the increase of the ball milling time, ductile fracture at the early stage was sustainedly replaced by brittle fracture, leading to the formation of the amorphous phase;**
- **The calculation results indicate that the difference of the formation enthalpy between the solid solution and amorphous phase increases with the increase of Ni content, implying the GFA in Mg-Ni-Si system increases with the increase of Ni content, which is in good agreement with the present experimental results.**

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