1. Introduction

Bulk metallic glasses (BMGs), developed for numerous alloy systems, possess unique properties that can be rarely found in crystalline materials such as high strength, unusual corrosion resistance and good wear resistance, etc. [1,2]. Among these systems, Ti-Cu based BMG alloys have shown potential as structural materials due to their high strength (2.2 GPa compressive strength for Ti50Cu23Ni20Sn7 alloy [3]), good corrosion resistance and a relatively low density of the main alloying element Ti (4.5 g/cm³).

However, it has been difficult to prepare the Ti-Cu-based BMGs of large size. The maximum critical diameter of an as-cast bulk sample with a single amorphous phase obtained for the Ti-Cu-Ni-Sn system was only 5mm [3]. To overcome the size and shape limitations of BMGs, powder metallurgical methods of BMGs have been recently explored. Mechanical alloying (MA) has been employed for preparing homogenous amorphous alloy powders with good reproducibility [4]. In this work, Ti-Cu-Ni-Sn alloy powders of different compositions (Ti50Cu32Ni15Sn3, Ti50Cu25Ni20Sn5, and Ti50Cu23Ni20Sn7) were produced by ball-milling and their structure and thermal stability were investigated.

2. Experimental and Results

Elemental powders of Ti, Cu, Ni and Sn (purity ≥ 99.9%) were accurately mixed to compositions of Ti50Cu32Ni15Sn3, Ti50Cu25Ni20Sn5, and Ti50Cu23Ni20Sn7. MA was performed at a rotational velocity of 300rpm using an AGO-2 planetary high-energy ball-mill. The vials were evacuated and filled with protective Ar gas (5×10⁵ Pa). X-ray diffraction (XRD) was performed for structural characterization of the samples. Differential scanning calorimetry (DSC) analyses of amorphous samples were done at a heating rate of 20 K/min under Ar atmosphere. The chemical composition of alloy powders obtained after 20h of milling was determined using inductively coupled plasma (ICP) spectroscopy.

Figs. 1(a)-(f) show the XRD patterns of Ti50Cu32Ni15Sn3 milled for (a) 1h, (b) 2h, (c) 5h, (d) 10h, (e) 20h and (f) 30h.

Abstract

Ti-Cu-Ni-Sn quaternary amorphous alloys of Ti50Cu32Ni15Sn3, Ti50Cu25Ni20Sn5, and Ti50Cu23Ni20Sn7 composition were prepared by mechanical alloying in a planetary high-energy ball-mill (AGO-2). The amorphization of all three alloys was found to set in after milling at 300rpm speed for 2h. A complete amorphization was observed for Ti50Cu32Ni15Sn3 and Ti50Cu25Ni20Sn5 after 30h and 20h of milling, respectively. Differential scanning calorimetry analyses revealed that the thermal stability increased in the order of Ti50Cu32Ni15Sn3, Ti50Cu25Ni20Sn5, and Ti50Cu23Ni20Sn7.

Keywords : Ti-based alloys, amorphous, mechanical alloying
amorphous phase starts appearing. After 5h of milling, the Ni peaks vanish, and at the same time, the NiTi₂ intermetallic phases occur. An intermetallic phase, γCuTi, appears after 10h of milling. When the milling time was extended to 30h, only the halo peak remained. This means that milling has the effect of enhancing the chemical homogeneity until a steady state of the structural evolution is reached and a fully amorphous structure is formed.

Fig. 2. XRD pattern of Ti₅₀Cu₂₅Ni₂₀Sn₅ milled for (a) 1h, (b) 2h, (c) 5h, (d) 10h and (e) 20h.

Figs. 2 (a)-(e) show selected XRD patterns of the Ti₅₀Cu₂₅Ni₂₀Sn₅ alloy after different milling time. As observed for Ti₅₀Cu₃₂Ni₁₅Sn₃, a halo peak appears after 2h of milling. After milling 10h, only peaks of NiTi₂ intermetallic phase detected in amorphous matrix. A fully amorphous Ti₅₀Cu₂₅Ni₂₀Sn₅ alloy can be obtained after 20 h milling.

For Ti₅₀Cu₂₃Ni₂₀Sn₇ alloy we could not obtain a fully amorphous alloy even after 30h of milling. NiTi₂ and γCuTi intermetallic phases could be detected together with the amorphous phase.

Fig. 3 illustrates the DSC scans for the amorphous Ti₅₀Cu₃₂Ni₁₅Sn₃, Ti₅₀Cu₂₅Ni₂₀Sn₃ and Ti₅₀Cu₂₃Ni₂₀Sn₇ alloy samples after 20h of milling. The DSC curves exhibit an endothermic event characteristic of the glass transition, followed by a supercooled liquid region (SLR) ΔT_g=T_g−T_d and a peak resulting from primary crystallization. The glass transition temperature, T_g, the onset temperature of primary crystallization, T_d, and crystallization enthalpy values for all three alloys are given in Fig. 3.

The Ti₅₀Cu₂₃Ni₂₀Sn₇ alloy exhibited a relatively better thermal stability than other alloys.

3. Summary

Amorphous Ti₅₀Cu₃₂Ni₁₅Sn₃, Ti₅₀Cu₂₅Ni₂₀Sn₃ and Ti₅₀Cu₂₃Ni₂₀Sn₇ powders were produced by MA. Fully amorphous structure could be obtained within the resolution of XRD patterns for Ti₅₀Cu₃₂Ni₁₅Sn₃ and Ti₅₀Cu₂₅Ni₂₀Sn₃ after 30h and 20h milling respectively, while Ti₅₀Cu₂₃Ni₂₀Sn₇ showed nearly full amorphization after 30h of milling. The Ti₅₀Cu₂₃Ni₂₀Sn₇ alloy also somewhat exhibited better thermal stability than other alloys. The small changing in the actual composition of the amorphous phase may be the reason for the differences in thermal stability between mechanically alloyed powders and melt-spun ribbons.

4. References