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Crystallization of amorphous $Cu_{50}Ti_{50}$ alloy prepared by high-energy ball milling

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Abstract

Amorphous $Cu_{50}Ti_{50}$ alloy was prepared by short-term (20 min) high-energy ball milling (HEBM). According to TEM, electron diffraction, and HAADF STEM results, the material was 93% amorphous with an admixture of nanocrystalline particles 2–8 nm in their size. Thermal stability and crystallization of amorphous $Cu_{50}Ti_{50}$ was studied by differential scanning calorimetry (DSC) and time-resolved XRD (TRXRD). Depending on heating rate, the crystallization of $Cu_{50}Ti_{50}$ took place within the temperature range 298–397°C. The activation energy (199 ± 4 kJ/mol) was found by using the Kissinger equation. Time-resolved diffraction patterns have revealed that the phase transition proceeds without melting within a time period of 20–30 seconds and the onset of crystallization gets started around 300°C which is markedly lower than the melting temperature in the Cu–Ti system (982°C). Based on our TRXRD results, a mechanism of the phase transition under study was suggested.

Keywords: amorphous phase, high-energy ball milling, Cu–Ti glass, time-resolved X-ray diffraction, thermal stability

1. Introduction

Amorphous alloys, or metallic glasses, are a relatively new class of materials with a specific combination of technologically interesting properties. These materials are characterized by the absence of regular crystal structure (short-range ordering). Such a structural configuration ensures a unique combination of properties that cannot be attained in crystalline materials, such as high mechanical strength, corrosion/radiation resistance, and specific electric/magnetic properties [1–5]. It explains ever growing interest in studies on the formation of amorphous structures and their crystallization, and on industrial-scale implementation of amorphous materials. However, the amorphous state is essentially metastable; it inherently possesses the possibility of transforming into more stable crystalline state. To study the kinetics of crystallization and thermal stability of amorphous alloys is very important for finding possible applications.

Metallic glasses can be produced in several routes such as solid-state reaction, mechanical alloying (MA), fast quenching, etc. [6–10]. Compared to other conventional techniques, MA has an advantage that (a) amorphous alloys can be obtained at temperatures much below the crystallization temperature of its constituents and (b) structural changes may happen during the amorphization reaction. HEBM is a solid-state non-equilibrium process suitable for production of nanocrystaline or amorphous metallic alloys, intermetallic phases, stable and metastable metallic compounds, bulk metallic glasses, nanocrystalline reinforced amorphous alloys, etc. [4, 11–13]. More than 50 years after their discovery, many systems have demonstrated extraordinary abilities unattainable by other manufacturing methods [4, 11, 14]. A good example is glass forming in binary systems. Many studies have been reported on the Cu-based metallic glasses regarding their structure, crystallization behavior, and thermal stability [15–20]. Over a few last

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