"SMART" PROCESSING OF TUNGSTEN-METALLIC GLASS ALLOY COMPOSITES

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ABSTRACT

Amorphous metal alloys have been developed with sufficiently slow crystallization kinetics to allow the casting of metallic glass alloy (MGA) components up to several centimeters in cross section. The challenge is to develop a process to produce large monolithic and composite structures from MGAs, e.g., tungsten heavy alloy composites. We used an instrumented Hot Isostatic Press (HIP) to monitor the densification of a powder compact and identify the maximum temperature required to reach full density while preserving the microstructure.

Instrumented-HIP experiments were performed on a hafnium-based amorphous powder and on a blend of tungsten and a hafnium-based amorphous powder. The measurements on the powder blend showed high densification rate near the crystallization temperature of the hafnium-based amorphous powder, followed by slow densification rate as the temperature is increased. Final densification occurred below the hafnium-based amorphous powder liquidus temperature. The microstructure of the composite was found to be very sensitive to maximum processing temperature, and an undesirable, brittle intermetallic layer can be formed along the tungsten-amorphous powder interface but its formation can be detected and prevented. These measurements illustrate the ability to monitor the densification, understand the different stages of densification of a powder or powder blend, and control the process to achieve the desired properties for the fully dense material.

INTRODUCTION

Metallic glass alloys (MGAs) are amorphous metals and have been reported as existing in thin ribbon form since as early as the 1950s. MGAs differ from conventional metals in that they lack crystalline structure. The atoms in the amorphous structure are randomly arranged, like in a liquid, rather than sitting on a repeatable, orderly lattice. This lack of crystalline structure means that metallic glasses also lack crystalline defects, such as grain boundaries and dislocations. Without these defects metallic glasses exhibit extraordinary mechanical properties, magnetic behavior, and corrosion resistance.

Because the equilibrium structure for a metal alloy is always crystalline, amorphous metals can only be produced by rapid cooling from the liquid state. Until recently, the cooling rates required were on the order of 10^5-10^6 K/s, which limits the thickness of a fully amorphous alloy to fractions of a millimeter. The resulting ribbons and wires are used extensively as transformer cores and magnetic sensors, but the small dimensions limit the structural applications of the material [1-3]. The development of zirconium (Zr)-based MGAs has opened the door for use of these fascinating materials in structural applications [4]. These alloys require cooling rates of only 1-100 K/s, so fully amorphous castings up to a centimeter thick can be manufactured using conventional casting methods. MGAs are already used in golf clubs, tennis rackets, baseball bats,