ABSTRACT

Fe-based bulk metallic glasses (BMGs) have spurred a great scientific and technological interest owing to their exceptional mechanical properties, superior wear performance along with low alloying element cost. However, their commercial utilization is not yet realized owing to their poor section thickness and inherent brittleness. Processing of bulk Fe-based amorphous alloys via traditional rapid solidification techniques often poses difficulties associated with low section thickness. In this regard, quest for alternative techniques for processing of bulk amorphous alloys is ever increasing. To circumvent the issue of low toughness and brittle nature of the amorphous alloys, BMG composites were proposed wherein crystalline phases are incorporated in amorphous matrix to improve the toughness and plasticity. However, processing metallic glass composites via melt quenching techniques could result in uncontrolled crystallization in amorphous alloys, which could affect the final properties of the BMG composites. With regard to the aforementioned limitations, the current study is aimed in developing Fe-based amorphous alloys and *in situ* composites via powder metallurgy route by consolidation of metallic glass powders via spark plasma sintering. Two compositions were chosen for the current study: namely, Powder 1: $Fe_{57}Cr_9Mo_5B_{16}P_7C_6$ (at. %) and Powder 2: $Fe_{57}Cr_9Ni_7Mo_5B_9P_7C_6$ (at. %). With optimized sintering conditions, highly dense amorphous alloys and *in situ* composites were synthesized with varying amount of crystallinity. Sintering mechanism of the amorphous alloy powder during SPS was established. Role of sintering parameters on sintering kinetics and rate of densification was quantitatively assessed. Further, mechanical properties and wear behavior of the sintered amorphous alloys were evaluated with respect to the crystalline phase content and particle bonding characteristics.

High density amorphous alloy composites (> 98% relative density) with varying amount of crystalline phase fraction, i.e., 10 – 80 vol%, were synthesized via SPS using optimized sintering temperatures, high sintering pressure and low sintering time. Predominant sintering mechanism during SPS was found to be viscous flow aided plastic deformation. Role of

sintering parameters on shrinkage kinetics was studied and found that increase in sintering pressure and heating rate promote viscous flow driven plastic deformation at low sintering temperatures.

To assess the potential of the sintered Fe-based amorphous alloys and *in situ* composites, mechanical properties and wear behavior were investigated. Room temperature creep resistance of the BMG composites was found to be improved with increase in crystalline phase content up to 40 vol.%. Stress exponent (n) values for BMG composites were found to be significantly lower compared to the fully amorphous sample, indicating the shift in mode of plastic deformation from inhomogeneous to relatively homogeneous in *in situ* composites. Further, compressive behavior of the consolidated samples also showed a similar trend that with increase in crystalline phase fraction, compression strength was improved, which is attributed to the presence of crystalline phases in amorphous matrix and enhanced particle bonding. In terms of wear behavior, *in situ* amorphous alloy composites exhibited superior wear performance in comparison to the fully amorphous samples. Enhanced wear resistance of the *in situ* composites is ascribed to the combined effect of improved particle bonding, high hardness and the formation of oxide rich tribolayer.

At the outset, the current study presents the development of Fe-based amorphous alloys and their composites along with establishing the sintering mechanism of the amorphous alloy powders. The role of particle bonding and *in situ* induced crystalline phase content on the overall mechanical response and wear behavior was illustrated, which sheds the light on the potential of sintered Fe-based amorphous composites as structural materials.

Keywords: Fe-based amorphous alloys; Glass forming ability; Supercooled liquid region; *In situ* Fe-based BMG composites, Powder metallurgy; Spark plasma sintering; Frenkel model; Viscous flow; Indentation creep; Dry sliding wear