Chapter 14
Tribological Studies of Bulk Metallic Glasses:
Structure, Preparation, Surface Treatment, and Coating

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ABSTRACT

The materials research community has been very interested in bulk metallic glasses (BMGs) over the past two decades because of their demonstrated friction and wear properties, as well as their potential for use in a variety of important tribological applications. Because of their superior chemical, physical, and mechanical properties, BMGs are a promising candidate material for advanced engineering applications. Compared to conventional crystalline metals and alloys, BMGs have higher strength, higher elastic strain, and higher hardness, making them a promising material class for tribological applications. A unique deformation process is realized in these materials due to the lack of a crystalline structure and faults such as misalignments, which display high strength, hardness, strong wear resistance, massive plastic deformation, corrosion-resistant, and hardness. In this chapter, the authors describe the research achievements in the field of BMGs, the tribological properties, structure, and applications.

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INTRODUCTION

Tribology is the study of friction, wear, and lubrication. Over the past few decades, there has been a steady increase in interest in alloys with tribological properties. The advent of bulk metallic glasses (BMGs) has increased demand for a better understanding of their composition, preparation, surface treatments, and coatings (Khan et al., 2018). BMGs are amorphous alloys with distinctive structure and physical characteristics that come from amorphous phases that crystallize during cooling the melt at low temperatures (<600°C). BMGs possess the advantages of high strength and good corrosion resistance. However, as a class of material, they exhibit many unique properties, which has led to tremendous interest in the area of BMGs for commercial applications such as automotive, aerospace, and biomedical (Hutchings & Shipway, 2017; Ludema & Ajayi, 2018). For example, it is used to design better bearings and lubricants. There are different types of tribological studies that can be performed to address specific needs or problems (Czichos, 2009). One type is BMGs (Khan et al., 2018) has a structure made up of many small grains with high-density amorphous regions between them (Khan et al., 2018; Wang et al., 2004). This gives BMGs their unique mechanical properties, such as hardness and low coefficient of friction (Khan et al., 2018; Suryanarayana & Inoue, 2013). BMGs have been studied to determine how they behave when exposed to different environments and conditions. Compared to equivalent alloys, they have a much greater resistance to wear and corrosion, improved ability to withstand high pressure, and the potential for electrically stimulating reversible shape memory (Chen, 2011; Löffler, 2003; Suryanarayana & Inoue, 2013; Trexler & Thadhani, 2010). In addition, BMGs can be manufactured at low temperatures in a single step from inexpensive starting materials, which makes them environmentally friendly (Johnson, 1996; Kruzic, 2016; Wang, 2009).

Furthermore, BMGs are typically composed of 60% to 90% metals, and the rest is either glass or metal oxides (Zhang & Huang, 2019). These materials have been described as "glassy metals" because they don't have the distinct crystalline structure that other metals do. This makes them super strong and durable. One of the most common causes of damage to engineering materials these days is the failure of the materials in industrial applications. In this regard, tribological features of BMGs have received substantial attention because of their mechanical performance and properties (Liao et al., 2018; Medina et al., 2020; Zhou et al., 2021).

Additionally, BMGs exhibit several features, such as amorphicity and high strength, which can be transferred to a range of other materials, such as the most common glasses, metallic glasses, metals, alloys, and different nanocomposite materials (Cornuault et al., 2020; Jiang et al., 2015; Lu & Liu, 2004; Zhou et al., 2020). However, the most distinguishing feature of BMGs, along with other properties, is the glass transition, which converts super-cooled liquids to a glassy state when cooled from a high to a low temperature and vice versa (Li et al., 2007; Löffler, 2003; Park & Kim, 2005). BMGs are extremely strong at low temperatures and plasticity at high temperatures, as amorphous alloys with a glass transition and their thermodynamic and physical characteristics change dramatically at the glass transition temperature (Tg). However, for practical reasons and to improve the reliability and performance of the material, it is desirable to lower Tg. The Klement research group was the first to successfully manufacture a glassy alloy with an $Au_{75}Si_{25}$ composition (Klement et al., 1960). On the order of 10^5-10^6 KS^{-1}, metal alloys' essential cooling rate is estimated to freeze the liquid structure. It was demonstrated experimentally in 1959 by utilizing a cool metal plate instead of water, oil, or air to demonstrate the validity of this concept. During solidification, they discovered that good contact between liquid droplets and cold metal prevented the creation of gaseous layers, which resulted in a limited amount of heat being released.

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