Introductory Chapter: Properties and Processing of Metallic Glasses

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1. Introduction

With an amorphous atomic structure, metallic glasses (MGs) (also called amorphous alloys) own some unique features compared to the conventional metal alloys, which make them versatile materials [1–7]. For example, MGs commonly show very high strength [8, 9], and thus they are very promising materials for fabrication of aircraft frames. High hardness and excellent resistance to wear make them potential candidates for contact applications such as phone's shell. The high elasticity makes them suitable for applications as golf clubs or spring [10]. High-strength, low elastic modulus, and good corrosion resistance make MGs promising applications as biomedical materials [2]. Although great progress has been achieved for MGs in the past decades, their practical applications as structural and functional materials are greatly impeded due to three main problems [1, 11], that is, dimensional limit, poor tension plasticity, and hard-to-machining and shaping.

As the formation of amorphous structure requires a high cooling rate, the size of MGs is greatly limited. Although some MGs with relatively good glass forming ability (GFA) are developed recently, the size of MG sample is quite small compared to that of conventional metal alloys. Currently, some new methods such as laser additive manufacturing are employed to produce MGs [12–15], which are promising to solve the problem of dimensional limit. However, additional issues such as crystallization and crack appear, which require further investigation.

For applications as structural materials, tensile plasticity is necessary. However, most MGs exhibit brittle fracture under tensile stress due to the fast propagation of single or very few shear bands [16, 17]. Therefore, improving the tensile plasticity of MGs is a very significant topic for their practical applications. Recently, some methods such as introduction of secondary phase into the glass matrix (i.e., fabrication of metallic glass matrix composites (MGMC)) [18–20], mechanical pre-deformation [21], surface modification [22–25] are proposed to tune the tensile plasticity of MGs, achieving some progress. However, the foundational mechanism and physical nature for plastic deformation and improvement of the plasticity of MGs are still not very clear. Further investigation by advanced experiments and simulations is required.

For practical applications of MGs, shaping them into parts is the first step. Due to the superplasticity within the supercooled liquid region (SCLR), thermoplastic forming provides a unique method for processing MGs, which has been widely employed and investigated [4, 26, 27]. However, the flexibility of this method is quite low, and this method also requires expensive molds. Furthermore, it may be only suitable for MGs with large SCLR; otherwise, crystallization may occur. Apart from thermoplastic forming, conventional machining such as diamond cutting [28–32], and non-conventional machinings such as micro-electrical discharge machining (micro-EDM) and laser irradiation [33–36] are also attempted for processing MGs. Some progress is achieved by these methods but also challenges remain [29, 36, 37]. Further investigations on these processing methods as well as developing new methods are required.

2. The structure of this book

According to the description in Section 1, to solve the problems that hinder the practical applications of MGs, further investigation on preparation, properties, and processing of MGs is urgently required. This book aims to present some recent achievements and developments on properties and processing of MGs, mainly including thermoplastic forming of metallic glasses, atomic-level simulation on mechanical deformation of metallic glasses, metallic glass matrix composites, as well as tribo-electrochemical applications of metallic glasses.

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