TABLE OF CONTENTS

Session 3

Session 3

STUDIES OF SHEAR BAND PROCESSES IN BULK METALLIC GLASSES USING HIGH-SPEED DATA ACQUISITION AND NANOINDENTATION TECHNIQUES

W.D. Nix, Wedelin J. Wright, Gang Feng, and R.H. Dauskardt
Stanford University, USA
E-mail: nix@stanford.edu

Plastic deformation of metallic glasses well below the glass transition temperature occurs by shear band processes in which deformation is highly localized in narrow bands about 10 nm in thickness. This localization of deformation involves a dramatic reduction of the viscosity in the shear band, brought about either by the creation of free volume in the band or local adiabatic heating, or both. In previous work we have argued that localized heating in the shear bands is minimal and that free volume creation is the primary cause of the localization. These arguments rested primarily on the direct measurement of the work dissipated during a single serration and thermal modeling of the maximum heating effects of such localized deformation. The critical quantity in these measurements has been the time duration of the serration. Here we report on recent work utilizing strain gages and high-speed data acquisition, which shows that the time duration of the serrations is about 2-3 ms and that the heating effects are minimal.

We also report on a study of shear band processes using nanoindentation techniques. We have observed discrete discontinuities in the loading curves during nanoindentation of metallic glasses. These discontinuities appear to be associated with shear band processes. We show that the magnitude of the largest of these displacement discontinuities increases linearly with indentation depth, suggesting a scaling relationship between the size of the shear band displacements and the size of the indentation. Direct observations of the shear band offsets in the field of the indentation are compared with the size of the displacement discontinuities. These studies show that shear band plasticity can be studied using indentation methods.

STRESS STATE AND TEMPERATURE EFFECTS ON FLOW AND FRACTURE OF BMG AND RELEVANCE TO DEFORMATION PROCESSING

John J. Lewandowski
Case Western Reserve Univeristy, USA
E-mail: JJL3@po.cwru.edu

The effects of systematic changes in stress state on the flow and fracture of a bulk metallic glass have been determined over a range of test temperatures. In addition to tension, compression, and microhardness testing at temperatures ranging from 77K up through 650K, tests with various levels of confining pressure have been conducted in order to more completely characterize the flow and fracture mechanisms operating in these materials in the different temperature regimes. Deformation processing experiments have been conducted with the use of this knowledge. The presentation will summarize the observations in the light of the various flow/fracture mechanisms proposed for such materials, and will highlight processing opportunities. The presentation builds upon work presented at Bulk Metallic Glasses I and extends this work to other stress states. The effects of incorporating large devitrified regions on the flow and fracture behavior will also be discussed.

PREPARATION OF BULK $Zr_{55}Al_{10}Ni_5Cu_{30}$ METALLIC GLASS RING BY CENTRIFUGAL CASTING

Yoshihito Kawamura
Materials Science, Kumamoto University, Japan
E-mail: rivervil@gpo.kumamoto-u.ac.jp

There have been three major subjects of limitation of product size, lack of workability and impossibility of welding in metallic glasses. The size limitation and poor workability have, however, been solved by developments of bulk metallic glasses with a thermally stable supercooled liquid. Bulk metallic glasses can be fabricated directly from the melt in a bulk form with a thickness of ~10 mm at slow cooling rates of the order of 1-100 K/s. The bulk metallic glasses also exhibit high-strain-rate superplasticity and excellent workability in the supercooled liquid state. Powder metallurgy processing using the superplasticity, moreover, enables the production of large-scaled bulk metallic glasses with the same tensile strength as the cast bulk. The problem of welding has, however, been still unsolved. Recently, we have succeeded in welding bulk metallic glasses together with keeping the amorphous state by friction, pulse-current, explosion and electron-beam methods. No crystallization was observed in the interface and heat-affected zones. Invisible defect or clack was detected in the interface, showing an achievement of metallurgical bonding of bulk metallic glasses. The tensile strength of the welded bulk metallic glasses was the same as that of the parent bulk metallic glasses. Moreover, the friction, explosion and electron-beam welding methods have provided a great success in welding the bulk metallic glasses to crystalline metallic materials. The friction welding is a supercooled-liquid state process where we used the superplasticity of the supercooled liquid. The pulse-current, explosion and electron-beam welding methods are liquid state processes where we used the high glass forming ability. The successful results obtained in this study are expected to push forward the application of bulk metallic glasses. We will discuss the welding mechanism of bulk metallic glasses in these welding methods.

MECHANICAL RESPONSE OF PD-BASED BULK GLASSY ALLOY UNDER DYNAMIC LOADING

Toshiji Mukai
Osaka Municipal Technical Research Institute, Japan
E-mail: toshiji@pp.iij4u.or.jp
T.G. Nieh, Lawrence Livermore National Laboratory
Yoshihito Kawamura, Kumamoto University
Akihisa Inoue, Institute for Materials Research, Tohoku University
Kenji Higashi, Osaka Prefecture University

Recently, bulk glassy alloys attracted increasing attention because of the basic science and potential engineering application of the materials. Understanding of the dynamic failure mechanism in bulk metallic glass is important for the application of this class of materials to a variety of engineering problems. This is true not only for design environments in which components are subject to high loading rates, but also when components are subject to quasi-static loading conditions where observations have been made of damage propagation occurring in an unstable, highly dynamic manner. Limited data are currently available for the dynamic mechanical properties. In the previous study of Zr-based bulk metallic glass, it has been demonstrated the compressive strength was independent of strain rate, while it has been reported the tensile strength of a rapidly solidified Zr-based ribbon specimen decreased with increasing strain rate. The strain rate effect is possibly varied with the specimen dimensions and loading condition. The purpose of this study is to clarify the influence of strain rate on the mechanical response in tension and compression. Tensile and compression behavior of a bulk metallic glass $Pd_{40}Ni_{40}P_{20}$ was characterized under both quasi-static and dynamic strain rate conditions. No major difference was observed for tension test. Multiple shear bands formed in samples tested at the dynamic strain rate. Shear band interaction appears to have an insignificant effect on the plasticity of the alloy. However, compressive ductility was drastically reduced at the dynamic strain rate. The difference of the fracture behavior between tension and compression was discussed.