

High Temperature Deformation of Vitrealloy Bulk Metallic Glasses and Their Composite

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Min Tao

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ABSTRACT

A complete understanding of the deformation mechanisms of BMGs and their composites requires investigation of the microstructural changes and their interplay with the mechanical behavior. In this dissertation, the deformation mechanisms of a series of Vitreloy glasses and their composites are experimentally investigated over a wide range of strain rates and temperatures, with focus on the supercooled liquid regime, by combining uniaxial mechanical testing with calorimetric and microscopic examinations. Various theories of deformation of metallic glasses and the composites are examined in light of the experimental data.

A comparative structural relaxation study was performed on two closely related Vitreloy alloys, $Zr_{41.2}Ti_{13.8}Cu_{12.5}Ni_{10}Be_{22.5}$ (Vit 1) and $Zr_{46.7}Ti_{8.3}Cu_{7.5}Ni_{10}Be_{27.5}$ (Vit 4). Differential scanning calorimetric studies on the specimens deformed in compression at constant-strain-rate in supercooled liquid regime showed that mechanical loading accelerated the spinodal phase separation and nanocrystallization process in Vit 1, while the relaxation in Vit 4 featured local chemical composition fluctuation accompanied by annealing out of free volume. The effect of the structural relaxation on their mechanical behavior was further studied via single and multiple jump-in-strain-rate tests.

The deformation and viscosity of a new Vitreloy alloy were characterized using uniaxial compression tests in its supercooled liquid regime. A new theoretical model named Cooperative Shear Model, which correlates the evolution of the macroscopic mechanical/thermal variables such as shear modulus and viscosity with the configurational energies of atom clusters in an amorphous alloy, was critically examined in this investigation. The model was successful in predicting the Newtonian and non-Newtonian viscosities of the material, as well as the shear moduli of the deformed specimens, in a self-consistent manner.

The plastic flow of an *in-situ* metallic glass composite, β -Vitreloy, was investigated under uniaxial compression in its supercooled liquid regime and at various strain rates

($10^{-4} \sim 10^{-1} s^{-1}$). The composite, with $\sim 25\%$ volume fraction of crystalline β -phase dendrites exhibited superplastic behavior similar to that of amorphous Vit 1. Significant strain hardening was observed when the material was deformed at high temperatures and low strain rates. A dual-phase composite model was employed in finite element simulations to understand the effect of the composite microstructure on its mechanical behavior.

TABLE OF CONTENTS

Acknowledgement	iii
Abstract	vi
Table of contents	iiiv
List of figures and tables	xi
Chapter 1 Introduction	1
1.1 Bulk metallic glasses and their composites	1
1.2 Mechanical and thermal properties of BMGs and their composites	4
1.3 Motivation outline	7
References	10
Chapter2 Deformation mechanism of two Zr-based metallic glasses in their super-cooled liquid regions	16
Abstract	16
2.1 Introduction	17
2.2 Experimental	22
2.2.1 Material and specimen preparation	22
2.2.2 High temperature compression test	23
2.2.3 DSC characterization	26
2.3 Results	27
2.3.1 Stress-strain	27
2.3.2 DSC	30
2.3.3 Multiple jump-in-strain-rate tests	40
2.4 Discussion	42

2.4.1	Deformation induced relaxation phenomena	42
2.4.2	Free volume change during jump in strain rate experiments	45
2.4.3	Effect of free volume on the flow stress	46
2.4.4	Activation volume in the non-Newtonian and Newtonian flow	47
2.5	Conclusions	50
	References	52
Chapter3 Deformation and viscosity of bulk metallic glass		
	Zr_{47.4}Ti_{8.0}Cu_{7.3}Ni_{9.8}Be_{27.5} in supercooled liquid state	59
	Abstract	59
3.1	Introduction	60
3.2	Experimental	63
3.2.1	Material and specimen preparation	63
3.2.2	High temperature deformation	65
3.2.3	Acoustic measurement of mechanical modulus	66
3.3	Result	68
3.3.1	Stress-strain	68
3.3.2	Deformation at $T = 583 K$ and wave speed measurements	71
3.4	Analysis and discussion	73
3.4.1	Cooperative Shear Model (CSM)	73
3.4.2	Shear-softening non-Newtonian viscosity of Vit 4'	78
3.4.3	Wave speed measurement vs. strain rate	80
3.5	Conclusions	82
	References	84

Chapter 4	High temperature behavior of β phase Vitreloy composite	89
	Abstract	89
4.1	Introduction	90
4.2	Experimental	95
	4.2.1 Material preparation	95
	4.2.2 High temperature compression	97
4.3	Results	99
	4.3.1 Stress-strain behavior of β -Vit composite	99
	4.3.2 Stress-strain behavior of the monolithic β -phase crystallite	103
	4.3.3 Morphological study	106
4.4	Analysis	114
	4.4.1 Strain rate sensitivity of β -Vit in its supercooled liquid regime	114
4.5	Computational Modeling	116
	4.5.1 Micromechanical model	117
	4.5.2 Material Modeling	119
	4.5.3 Results and discussion	120
4.6	Conclusions	123
4.7	Appendix A. Periodic boundary conditions for uniaxial compression on a unit cell	126
	References	131
Chapter 5	Summary and future work	138
	References	142

LIST OF FIGURES

- Fig. 2.1 True stress-strain curves from compression tests performed at 643 K and various strain rates: (a) Vitreloy 1, $\dot{\epsilon} = 0.04s^{-1}$, $\dot{\epsilon} = 0.003s^{-1}$ and $\dot{\epsilon} = 3 \times 10^{-4} s^{-1}$; (b) Vitreloy 4, $\dot{\epsilon} = 0.05s^{-1}$, $\dot{\epsilon} = 0.004s^{-1}$ and $\dot{\epsilon} = 5 \times 10^{-4} s^{-1}$. 28
- Fig 2.2 True stress-strain curves from compression tests performed at 643 K at two constant strain rates (one in the non-Newtonian regime and another in the Newtonian regime) and jump (drop) in strain rate with mode of deformation going from non-Newtonian to Newtonian regime: (a) Vitreloy 1, $\dot{\epsilon} = 0.04s^{-1}$, $\dot{\epsilon} = 3 \times 10^{-4} s^{-1}$ and $\dot{\epsilon} = 0.04 \rightarrow 3 \times 10^{-4} s^{-1}$; (b) Vitreloy 4, $\dot{\epsilon} = 0.05s^{-1}$, $\dot{\epsilon} = 5 \times 10^{-4} s^{-1}$ and $\dot{\epsilon} = 0.05 \rightarrow 5 \times 10^{-4} s^{-1}$. 30
- Fig. 2.3 DSC traces of Vitreloy 1 control test sample compared to that of the as-received sample. The annealing time for the control sample represented the longest testing time of Vitreloy 1 in this investigation. The DSC curves are shifted relative to one another along the ordinate for display purposes. 32
- Fig. 2.4 DSC traces of deformed Vitreloy 1 specimens compared to that of the as-received sample. The DSC curves are shifted relative to each other along the ordinate for display purposes. The amplitude of phase-separation spinode (circled in red) increases after mechanical deformation. 33
- Fig. 2.5 DSC traces of Vitreloy 4 control test sample compared to that of the as-received material. The annealing time of the control sample represented the longest testing time of Vitreloy 4 during compressive loading. 34
- Fig. 2.6 DSC traces of the deformed Vitreloy 4 specimens compared to that of the as-received material. The DSC curves are shifted relative to each other along the ordinate for display purposes. 35
- Fig. 2.7 DSC traces of specimens subjected to jump in strain rate compared to that of the as-received sample and specimens deformed at constant strain rates: (a) Vitreloy 1 and (b) Vitreloy 4. The DSC curves are shifted relative to each other along the ordinate for display purposes. 36
- Fig 2.8 Glass transition point on the DSC traces of (a) Vitreloy 1 and (b) Vitreloy 4. The Δc_p labeled in (b) is taken as an indication of the free volume stored in the material. Larger Δc_p means less free volume in the material before the DSC scan. 39

Fig 2.9	<p>True stress-strain curves for successive jump in strain rate tests of: (a) Vitreloy 1 deformed in the non-Newtonian flow region (solid line) with the strain rate history of $\dot{\epsilon} = 7.4 \times 10^{-2} \rightarrow 2.6 \times 10^{-2} \rightarrow 1.2 \times 10^{-2} \rightarrow 6.0 \times 10^{-3} s^{-1}$, deformed in the Newtonian flow region (dashed line) with the strain rate history of $\dot{\epsilon} = 2.6 \times 10^{-3} \rightarrow 1.2 \times 10^{-3} \rightarrow 6.2 \times 10^{-4} \rightarrow 2.4 \times 10^{-4} \rightarrow 1.3 \times 10^{-4} s^{-1}$; (b) Vitreloy 4, deformed in the non-Newtonian flow region (solid line) with the strain rate history of $\dot{\epsilon} = 6.8 \times 10^{-2} \rightarrow 3.4 \times 10^{-2} \rightarrow 1.2 \times 10^{-2} \rightarrow 8.9 \times 10^{-3} \rightarrow 6 \times 10^{-3} s^{-1}$, deformed in the Newtonian flow region (dashed line) with the strain rate history of $\dot{\epsilon} = 1.7 \times 10^{-2} \rightarrow 3.5 \times 10^{-3} \rightarrow 1.3 \times 10^{-3} \rightarrow 4.3 \times 10^{-4} \rightarrow 1.9 \times 10^{-4} s^{-1}$.</p>	41
Fig. 2.10	<p>Experimental and predicted strain rate dependence of flow stress from successive jump in strain rate tests at 643 K. For Vitreloy 1: (a) in the non-Newtonian flow region and (b) in the Newtonian flow region. For Vitreloy 4: (c) in the non-Newtonian flow region and (d) in the Newtonian flow region. The solid lines are model predictions using Eq. (1). See Table 2.3 for the model fitting parameters in each case.</p>	48
Fig. 2.11	<p>Strain rate and flow stress relation of all data points from successive jump in strain rate tests for Vit 1 and Vit 4. The Vit 1 data (red ones) from non-Newtonian and Newtonian regions fall on a master curve and could be fit using Eq. (1) (solid line), while the non-Newtonian and Newtonian data of Vit 4 (blue ones) do not form a master curve.</p>	49
Fig.3.1	<p>Differential scanning calorimetry (DSC) trace of the as-prepared Vit 4'</p>	64
Fig.3.2	<p>Time-Temperature-Transformation diagram of Vitreloy 1 (Reproduced from Waniuk et al. [32]).</p>	66
Fig.3.3	<p>True stress-strain curves of Vit 4' in uniaxial compression at various temperatures and strain rates: (a) T = 583 K; (b) T = 603 K; (c) T = 623 K; (d) T = 643 K. The strain rates are indicated in the legend.</p>	71
Fig.3.4	<p>True stress-strain curves of Vit 4' in uniaxial compression at T = 583K and various strain rates.</p>	72
Fig.3.5	<p>Model of the potential energy density of an atom cluster in amorphous alloys. Upon shearing, the cluster has a tendency to jump to a state with higher potential energy.</p>	74
Fig.3.6	<p>Various model fits of Newtonian viscosity data at different temperatures of Pd43Ni10Cu27P20 amorphous alloy.</p>	77
Fig.3.7	<p>Various model fits of Newtonian viscosity data of Zr47.4Ti8.0Cu7.3Ni9.8Be27.5 (this investigation) and Vit 1 at different temperatures.</p>	77

Fig.3.8	Non-Newtonian viscosity of Vit 4' deduced from the compression tests at various temperatures and strain rates. The solid lines are the numerical solutions of CSM predictions obtained using Newton-Raphson method. Symbols represent experimental data at various temperatures.	80
Fig.3.9	Shearing viscosity of Vit 4' deduced from the results of compression tests conducted at T= 583 K and different strain rates.	81
Fig. 3.10	Comparison of shear modulus from wave speed measurements (circles) and viscosity from compression tests (squares). The cooperative shearing model prediction is shown as a solid line.	82
Fig 4.1	DSC trace of as-prepared β -Vit composite material.	96
Fig. 4.2	Time-temperature-transformation diagram for a series of Vitreloy family of alloys (Reproduced from Waniuk <i>et al.</i>)	99
Fig. 4.3	True stress-strain curves of β -Vit1 in uniaxial compression at various temperatures and strain rates: (a) T=613 K; (b) T=623 K; (c) T=633 K; (d) T=643 K.	102
Fig. 4.4	Compressive stress-strain response of the monolithic β -phase crystallite, all tests are performed at the strain rate of $\dot{\epsilon} = 2.5 \times 10^{-4} s^{-1}$ and at different temperatures.	103
Fig. 4.5	Compressive stress-strain response of the monolithic β -phase crystallite at a strain rate of $\dot{\epsilon} = 1.0 \times 10^{-3} s^{-1}$ and at different temperatures, 613 K and 643 K.	106
Fig. 4.6	SEM micrograph of the as-received β -Vit composite. The white regions are the Zr-Ni-Ti rich crystalline (bcc) dendritic phase and the black regions is the glassy matrix.	108
Fig. 4.7	SEM micrographs of a specimen deformed at T=613 K, $\dot{\epsilon} = 2.2 \times 10^{-4} s^{-1}$ in the Newtonian flow mode. The images (a), (b), (c) were taken at the center, left, and right hand side of the center in the cross section perpendicular to the loading axis, respectively. The dendrites show the radial flow from the center to the periphery of the specimen.	109
Fig. 4.8	SEM images of a section cut at 45° to the loading axis in a specimen tested at $T = 643K$, $\dot{\epsilon} = 0.07 s^{-1}$, which underwent non-Newtonian flow: (a) upper corner; (b) lower corner. The directions of the dendrite alignment are labeled with white arrows in the figures.	111
Fig. 4.9	SEM images of the specimen tested at $T = 643K$, $\dot{\epsilon} = 2.5 \times 10^{-4} s^{-1}$, which underwent hardening deformation. (a) and (b) were taken at	

	two random locations on the cross section and they showed high inhomogeneity in the dendrites size and distribution.	113
Fig. 4.10	SEM image of the undeformed specimen heated at $T = 643K$ for 2400 seconds which had the same thermal history as the specimen whose stress-strain response is shown in Fig. 4.9. Dendrite coalescence (circled in red) was observed and could account for the inhomogeneity in the dendrite size in Fig. 4.9.	114
Fig. 4.11	Flow stress dependence of β -Vit composite on strain rate at temperatures $T=613K, 623K, 633K,$ and $643K$.	115
Fig. 4.12	Viscosity dependence of β -Vit on strain rate at temperatures of $T=613 K, 623 K, 633 K$ and $643 K$. The insert shows that of Vit 1 glass [5] which features flattening at high temperature and low strain rate corresponding to the Newtonian flow, which is not present in the composite in the temperature and strain rate regime explored here.	116
Fig. 4.13	A typical composite unit cell for FEM simulation (24.5% VF of rectangular parallelepiped dendrites), scales are given to show the relative sizes of the cell and the particle.	117
Fig. 4.14	True stress-strain relations of Vit 1, monolithic dendrite and β -Vit1 composite in uniaxial compression at temperature, $T=643K$ and strain rate, $\dot{\epsilon} = 2.5 \times 10^{-4} s^{-1}$.	120
Fig. 4.15	True stress-strain relations of models with volume fractions of 16%, 24.5% and 39.2%, compared to the result from uniaxial compression of β -Vit composite at temperature, $T=643K$ and strain rate, $\dot{\epsilon} = 2.5 \times 10^{-4} s^{-1}$.	121
Fig. 4.16	Model of computational unit cells with different dendrite sizes and shapes. (a) a single rectangular inclusion at the center of the unit cell; (b) 8 smaller distributed rectangular inclusions and (c) a tree shape inclusion. The VF of inclusions in each unit cell is 24.5%.	122
Fig. 4.17	True stress-strain relations of models containing the same volume fraction (24.5%) but different sizes and shapes of dendrites. The red dotted line corresponds to the unit cell in Fig. 4.16 (a), the black solid line corresponds to the unit cell in Fig. 4.16 (b), and the pink dash line corresponds to the unit cell in Fig. 4.16 (c).	122
Fig. 4A-1	Model of a unit cell with inclusion.	126
Fig. 4A-2	Unit cell under uniaxial compression of δ , with scale exaggerated.	127

LIST OF TABLES

Table 2.1	Summary of the DSC results of Vitreloy 1	33
Table 2.2	Summary of the DSC results of Vitreloy 4	36
Table 2.3	Fitting parameters for the free volume model (Eq. (2.1)) from the successive strain rate jump tests	49
Table 4.1	Physical and mechanical properties of Vit 1 and β -Vit composite	93