Chapter 8

Future Work

I: In Chapters 5 and 6 the configurational enthalpy, Δh, and the isoconfigurational shear modulus, G, were experimentally measured for mechanically deformed samples. Additionally, the change in G with respect to Δh was found to be the same as that obtained due to thermal annealing. This was done assuming Δc_p and dG/dT were constant over the measured range of $G(\Delta h)$. It would be beneficial to directly measure the Δh associated with the different Gs for thermal annealing to verify that it is the absolute energy in the system that determines the material properties. This would easily be accomplished by thermally annealing samples from the same ingot at different temperatures followed by acoustic measurements and DSC scans to determine the G and enthalpy recovery of the specimens. The best correlation between the mechanically deformed specimens and the thermally annealed specimens would be achieved if all specimens were from the same original ingot and a common reference was used to calculate Δh for both sets of experiments. This would corroborate that the material properties are solely dependent on the energy of the system, and not the path by which it was reached.

II: All of the ultrasonic measurements done in the present study have been done at room temperature and ambient pressure. The effect of elastic energy on G has not been measured to date. Since metallic glasses deform by shear the best method to measure this change would be one in which the material is in pure shear. One possible way to measure this would be a modified Isopescu specimen[1], (the normal Isopescu specimen and test is detailed in ASTM Standard D5379). This would require that two polished parallel surfaces be machined on either side of the shear zone; see Fig. 8.1 for proposed geometry. The surfaces would allow the acoustic wave to be reflected through the shear zone. The problem with this setup is that the shear zone will be inhomogeneous. Another possible test would be a tube subjected to torsion [1]. The walls would need to be thick enough to accommodate the acoustic transducers. It would again be necessary to machine out surfaces to allow acoustic measurements to be made. It must be ensured that the shear zone between the surfaces is as uniform as possible and that the acoustic signal is of sufficient quality to measure the sound velocity. Both of these will be a function of the distance between the two parallel surfaces, the tube thickness, and the tube radius; see Fig. 8.2 for the geometry.

III: It is possible to probe the relaxation processes talked about in the present work by applying an Inverse Laplace Transform to the intensity decays seen in stress relaxation experiments. If I(t) is the intensity of the function versus time, this can then be described in terms of

$$I(t) = p_1 e^{-k_1 t} + p_2 e^{-k_2 t} + \dots .$$

This leads to

$$I(t) = \sum_{k_o}^{\infty} p(k) e^{-kt} .$$

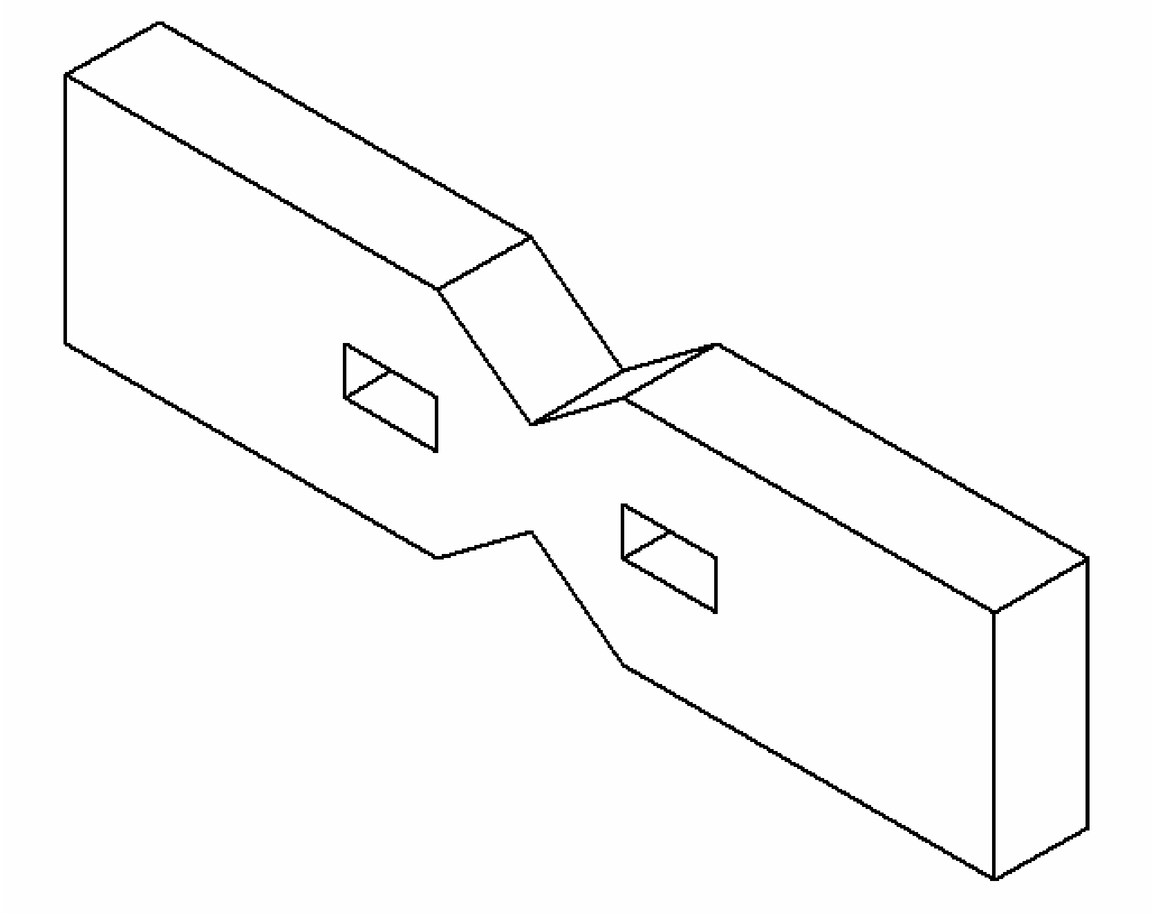

Figure 8.1. Modified Isopescu test specimen for measuring the isoconfigurational shear modulus under shear

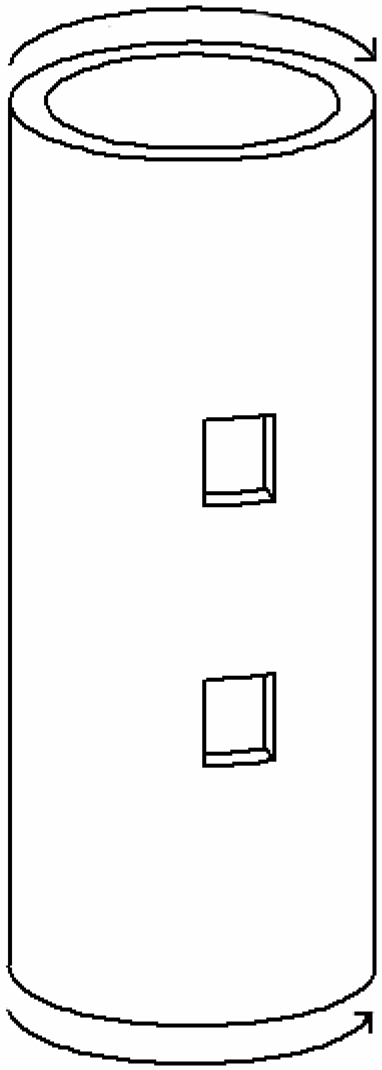

Figure 8.2. Torsional specimen for measuring the isoconfigurational shear modulus under shear

In this description k is the inverse of the relaxation time associated with individual decay functions and p(k) is the probability with which that decay occurs. The form of this function is a Laplace Transform of the probability associated with each decay rate. Furthermore, it is possible to construct the probability distribution p(k) by taking the Inverse Laplace Transform of the intensity. A distribution of activation energies can then be constructed from the probability distribution of k. Standard techniques have been developed within the photo spectroscopy community to handle Inverse Laplace Transforms such as these [2, 3]. For a continuous spectrum of activation energies the most appropriate fitting technique will involve Shannon Jean Entropy and Least Squares.

IV: *In situ* shear modulus measurements performed during mechanical deformation would be valuable in validating the results obtained at ambient conditions. This would require the modification of the setup described in Ref. [4]. The furnace elements would need to be modified to accommodate a quartz lead that is long enough to insure the acoustic transducer is protected from the heat. It would also be necessary to create a fixture capable of holding and applying pressure to the transducer to keep it in contact with the specimen. The specimens would also have to be rectangular to insure a flat surface for attachment of the quartz lead. The specimen must be sized properly to avoid excessive buckling or barreling. Also when determining the length used to calculate the sound velocity the total strain of the specimen at the time of the measurement must be used to estimate the actual thickness. A suitable transmission medium must be used to couple the quartz lead to the specimen. Possibilities include high-temperature adhesives and high-temperature greases. Both options have drawbacks. The adhesives will be stable at the deformation temperatures, but if the bond is brittle it will fail at larger strains. The grease will not fail due to deformation, but as the temperature increases the viscosity of the grease will decrease until it is too fluid to effectively transmit the shear wave. An appropriate joining medium must be identified before extensive testing is pursued. Additionally, barreling must be minimized to avoid distortion of the acoustic measurements.

V: As seen in Fig. 6.6, as the shear localization regime is approached Δh goes to a plateau. When the shear localization regime is reached, the rate at which energy can be dissipated is exceeded by the amount being stored and a catastrophic shear band forms to release that energy. The energy plateau that is seen in Fig. 6.6 is directly related to the barrier height. It would be an interesting exercise to map the plateau in Δh at different temperatures in an effort to probe the potential energy landscape of the material. To have any direct comparison between the different temperatures it would be necessary to have a common enthalpy reference for all specimens. See Chapter 5 for a complete description of how to access Δh and G for different strain rates and temperatures.

References

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[2] J. G. Lyubovitzsky, H. B. Gray, and J. R. Winkler, J. Am. Chem. Soc. 124, 5481 (2001).

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