Shock Studies to Optimize ALOX Encapsulants

by **R. E. Setchell, S. T. Montgomery, M. U. Anderson, and D. E. Cox**

Motivation—Alumina-filled epoxy (ALOX) is used as an encapsulant in explosively driven pulsed power supplies. The shock loading experienced by the active elements in these devices, and consequently the overall device performance, is strongly influenced by the shock compression and release properties of the encapsulant. Previously we examined these properties in a specific, baseline composition. This material, which contains 43% by volume alumina particles, displays a complex behavior which includes unusually high release-wave velocities (Fig. 1). Our recent studies have examined ALOX materials with modified compositions with the goal of optimizing shock properties for encapsulation applications. To date we have examined changes in the alumina volume fraction, the alumina particle size and shape, and the host epoxy.

Accomplishment—To obtain useful insights using a minimum number of gas gun experiments, each composition was examined in a 1-D, symmetric-impact configuration at a fixed impact velocity. This provided a compressive wave profile, Hugoniot properties, and a release-wave velocity for each material at states of equal particle velocity, corresponding to nearly equal states of strain. Only minor differences were seen when the alumina volume fraction was held constant while varying the alumina particle characteristics and the host epoxy. Significant differences were seen when the alumina fraction was lowered in steps from the 43% baseline value down to 0%. Figure 2 shows measured shock and release velocities as functions of the alumina volume fraction. The release velocity decreases faster than the shock velocity with decreasing alumina, thus the ratio of these velocities decreases as well. This ratio is a measure of how rapidly downstream unloading events can overtake and attenuate a leading shock wave, which can be important in encapsulation applications. This trend was examined in more detail using the configuration shown in Fig. 3. In these 1-D "thin pulse" experiments, impactor and target dimensions were chosen to allow a release wave to overtake and attenuate the impact-generated shock wave before it can reach the window interface. The impactor material and dimensions, the impact velocity, and the target dimensions were held constant while the alumina fraction was varied in the target ALOX samples. Figure 4 shows the results of these experiments. In addition to the transmitted wave profiles, the figure lists the predicted impact stress and the measured average wave velocity for each case. Even though the impact stress decreased significantly as the alumina fraction was decreased, the peak particle velocity of the wave transmitted into the window progressively increased. The reduction in release velocity more than compensates for the reduced impact stress, with the transmitted wave experiencing less attenuation.

Significance—The initial symmetric-impact experiments examined how basic shock compression and release properties vary with ALOX compositional changes. The rapid reduction in the ratio of release and shock velocities as alumina fraction was decreased prompted additional "thin pulse" experiments. These experiments showed a surprising and important effect of alumina volume fraction in an encapsulant required to transmit a shock wave to a second material following a fixed, short-duration input stimulus. Reducing the alumina volume fraction appears to be a useful way to optimize ALOX shock properties.

Sponsors for various phases of this work include: Nuclear Weapons/Science & Technology

Contact: Robert E. Setchell, Radiation-Solid Interactions, Dept. 1111
Phone: (505) 844-3847, Fax: (505) 844-4045, E-mail: resetch@sandia.gov

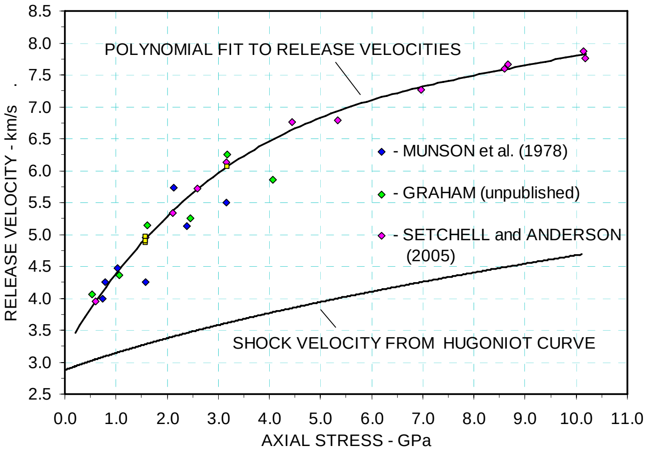


Figure 1. Baseline ALOX velocities for shock waves and release waves as functions of axial stress in the shocked state.

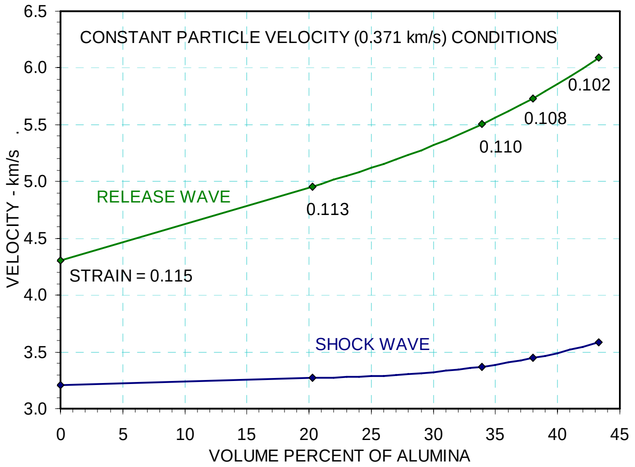


Figure 2. Velocities for shock waves and release waves as a function of the alumina volume fraction. All data are for a shocked state having a fixed particle velocity, corresponding to nearly equal states of uniaxial-strain.

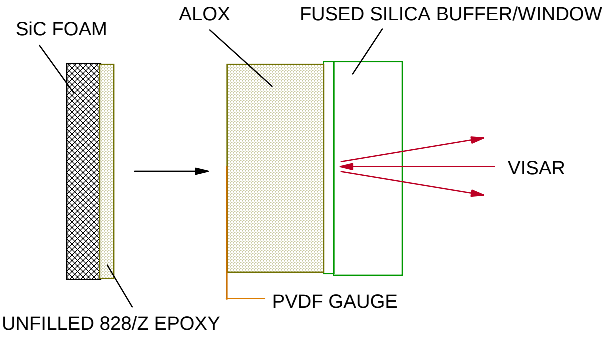
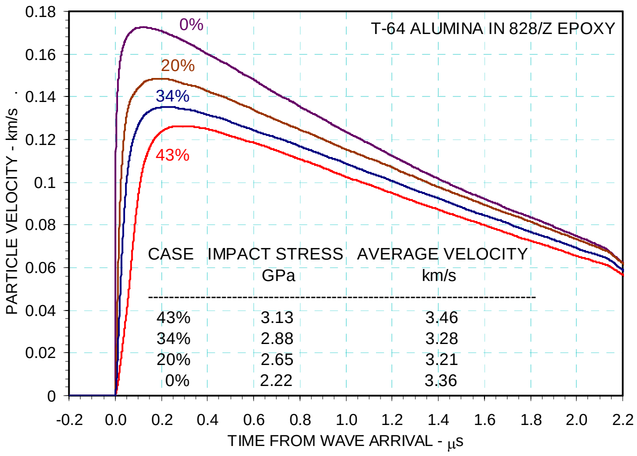


Figure 3. Configuration used for “thin pulse” uniaxial-strain experiments on ALOX.



CASE	IMPACT STRESS GPa	AVERAGE VELOCITY km/s
43%	3.13	3.46
34%	2.88	3.28
20%	2.65	3.21
0%	2.22	3.36

Figure 4. Wave profiles recorded in ALOX “thin pulse” experiments for materials with different alumina volume fractions. The impact velocity in every experiment was 1.05 km/s.