Dynamic Mechanical Properties of Alumina-Filled Encapsulants

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

Motivation—The shock loading history experienced by a ferroelectric element in an explosively driven power supply is strongly influenced by the shock compression and release properties of the surrounding alumina-filled epoxy (ALOX) encapsulant. In past years we examined these properties in a baseline ALOX containing 43% by volume alumina particles distributed within an epoxy matrix (Fig. 1). Gas gun experiments showed a complex behavior characterized by extended shock profiles and unusually high release-wave velocities. Recent changes in the availability of encapsulant materials have prompted additional studies to examine the effects of modifying the baseline composition. Under current consideration are changes in the total alumina volume fraction, the alumina particle size and morphology, and the epoxy constituents.

Accomplishment—To obtain useful insights into compositional effects on dynamic behavior using a minimum number of gas gun experiments, two types of experimental configurations were chosen (Fig. 2). The first is a conventional uniaxial-strain configuration, which provides a Hugoniot state, a compressive wave profile, and a release-wave velocity. The second type generates a multidimensional diverging, attenuating, wave structure similar to that generated in an explosively driven power supply. This configuration provides a transmitted wave profile, a wave transit time, and a measure of wave curvature. An experiment of each type was conducted with each composition of interest while keeping sample dimensions and impact velocities constant. Figure 3 shows shock and release profiles recorded in uniaxial-strain experiments using samples having different volume fractions of the baseline alumina. These experiments determined the extent to which the average wave velocity, the final Hugoniot state, and the release-wave velocity decreased with decreasing alumina content. Figure 4 shows the wave profiles recorded in corresponding multi-dimensional experiments. Each profile reflects the velocity history that results from axial and lateral release waves overtaking and attenuating an initially stronger compressive wave. A consistent trend with alumina content is no longer apparent, with the strongest wave corresponding to the lowest alumina content. This indicates that lower release velocities can have a stronger effect than reduced Hugoniot properties as alumina content is reduced. In addition to the results shown in Figs. 3 and 4, we have examined compositions having a constant alumina volume fraction but either a different particle morphology or a different epoxy matrix.

Significance—The uniaxial-strain experiments show how basic shock properties change with compositional variations, but the multi-dimensional experiments show effects that reflect a combination of changing properties. A similar combination of compression and release behavior occurs during explosively generated wave propagation, and will govern the stress history experienced by a ferroelectric element. The results shown in Fig. 4, which indicate that a material with lower alumina content could be preferable to the baseline material, suggest that early studies of ALOX properties were insufficient to determine an optimum baseline composition. Our studies of dynamic mechanical properties, together with concurrent studies of other properties, are providing new insights into optimization.

Sponsors for various phases of this work include: Nuclear Weapons/Science & Technology, Advanced Design & Production Technologies/IPPD, and Neutron Generator Development

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

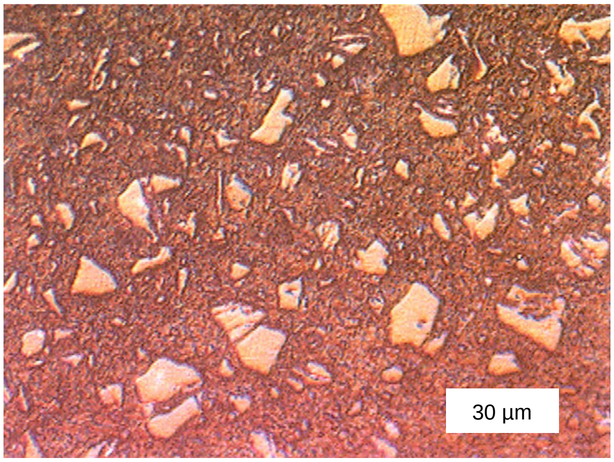

Figure 1. Microscope image of a polished sample surface (baseline ALOX).

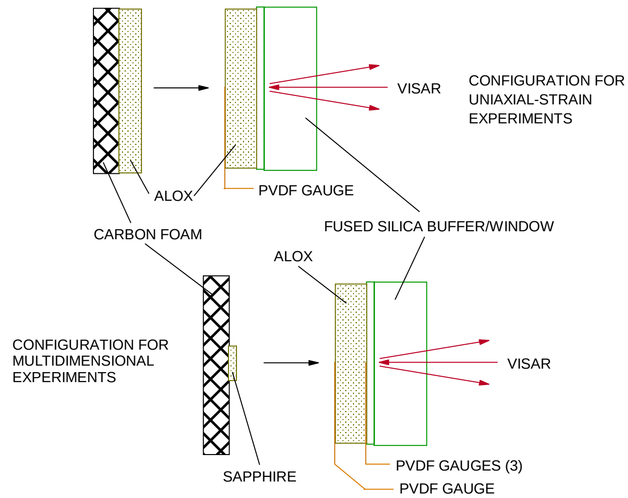

Figure 2. Configurations used for uniaxial-strain shock and release experiments (top) and multidimensional loading experiments (bottom).

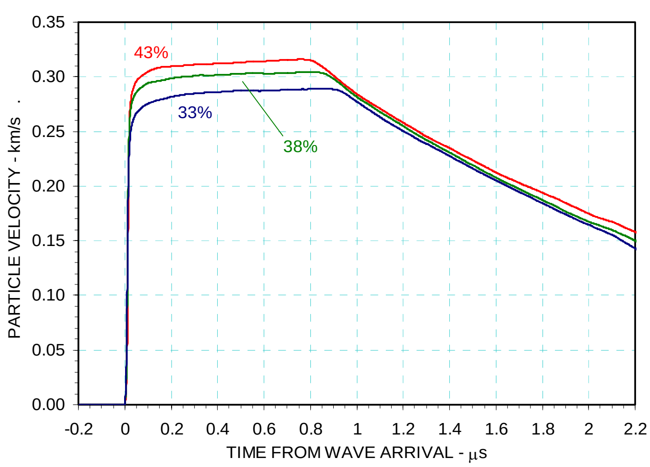

Figure 3. Shock and release wave profiles recorded in uniaxial-strain experiments using ALOX samples with different amounts of alumina. A fixed impact velocity of 0.74 km/s was used in all cases.

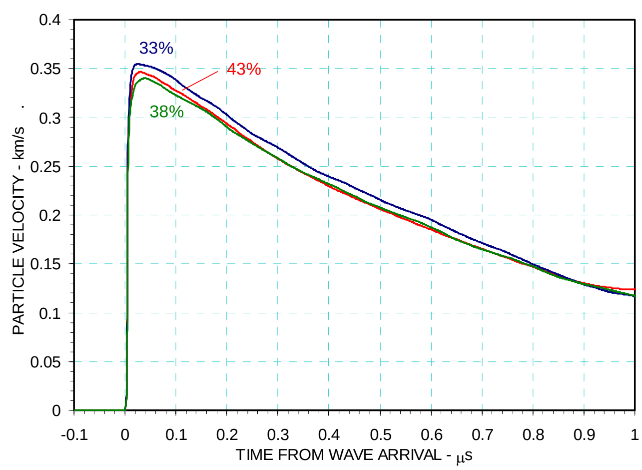

Figure 4. Wave profiles recorded in multi-dimensional loading experiments. A fixed impact velocity of 1.14 km/s was used in all cases.