Extending the Shelf Life of Solid Rocket Motors Through Mechanical Activation of \textit{gem}-Dichlorocyclopropanes in HTPB

Emilio Cantu, Capt. Hope Klukovich, Dr. Timothy Haddad
California State University, Bakersfield; Air Force Research Laboratory; Air Force Research Laboratory

Abstract
A great deal of interest has been given to extending the life of our fleet of solid rocket motors. Once poured, these motors are essentially stored, unused, and are therefore subject to various environmental conditions. Cycling between high and low temperatures causes thermal expansion and contraction of motor materials. This will eventually lead to cracks forming and propagating in the rocket motor, rendering it unreliable and thus must be re-poured at great expense. A common binder material used in these motors is hydroxy-terminated polybutadiene (HTPB), which when cured with a diisocyanate, creates the solid matrix to house the energetic materials of the motor. HTPB can be post-synthetically modified to incorporate mechanically reactive moieties (mechanophores) along the polymer chain that will react via the stress felt through environmentally induced cycling. These mechanophores will act to relieve the tension in the binder matrix vs. binder material failure. gem-Dichlorocyclopropanes were installed along the backbone of HTPB, and the functionalized HTPB was cured with the typical diisocyanate curative. The material was then subjected to quantitative tensile testing typically utilized to determine the mechanical properties of solid rocket motor materials. Once the material was tested to failure, the material was analyzed to determine if the \textit{gem}-DCC moieties were mechanically activated.

Poured SRM
Unfunctionalized, Chain Scission, Natural Failure

Dog Bone Mechanical Activation

Differential Scanning Calorimetry Spectra of HTPB (red) and \textit{gem}-DCC-HTPB (green)

Stress Strain Curve of HTPB

NMR Analysis

Conclusion

- HTPB was easily functionalized with \textit{gem}-DCC mechanophores, and over 70% functionalization was achieved.
- Curing the \textit{gem}-DCC HTPB with the diisocyanate was unsuccessful as evidenced by its solubility and dog bone test.
- Curing was hindered due to loss of OH functionality on the HTPB as determined by titration.
- Due to improper curing, the material was uncharacteristically amorphous and thus sufficient restoring force was not felt along the \textit{gem}-DCC HTPB backbone to elicit ring opening.

This material is based upon work supported by the S.D. Bechtel, Jr. Foundation, National Marine Sanctuary Foundation, Carnegie Corporation of New York, and/or National Science Foundation under Grant Nos. 0952013 and 0833353. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the funders.

The STAR program is administered by the Cal Poly Center for Excellence in Science and Mathematics Education (CESAME) on behalf of the California State University.

DISTRIBUTION A: Approved for public release; distribution unlimited. RM: 134427