Structural/Radiation-Shielding Epoxies

Pendant aliphatic groups are incorporated as integral parts of molecular structures.

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A development effort was directed toward formulating epoxy resins that are useful both as structural materials and as shielding against heavy-ion radiation. Hydrogen is recognized as the best element for absorbing heavy-ion radiation, and high-hydrogen-content polymers are now in use as shielding materials. However, high-hydrogen-content polymers (e.g. polyethylene) are typically not good structural materials. In contrast, aromatic polymers, which contain smaller amounts of hydrogen, often have the strength necessary for structural materials. Accordingly, the present development effort is based on the concept that an ideal structural/heavy-ion-radiation-shielding material would be a polymer that contains sufficient hydrogen (e.g., in the form of aliphatic molecular groups) for radiation shielding and has sufficient aromatic content for structural integrity.

As part of this development, an aromatic/ aliphatic diamine (see Figure 1) was prepared for incorporation into structural-epoxy formulations. The diamine reacts with the epoxy in the same manner as the ones in conventional structural epoxy systems giving a crosslinked network. The aliphatic portions of the diamine molecules are covalently attached to the aromatic portions in a pendant fashion and are not involved in the crosslinking molecular network. Thus, aliphatic content is introduced without negatively affecting mechanical properties. In addition, the aliphatic chains cannot leach out, as sometimes happens in formulations that include hydrogen-bearing molecules as additives.

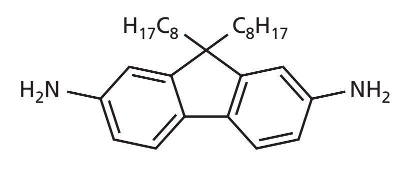

Figure 1. This **Aromatic/Aliphatic Diamine** was included in epoxy formulations as a means of incorporating high permanent hydrogen content without excessively compromising strength and stiffness.

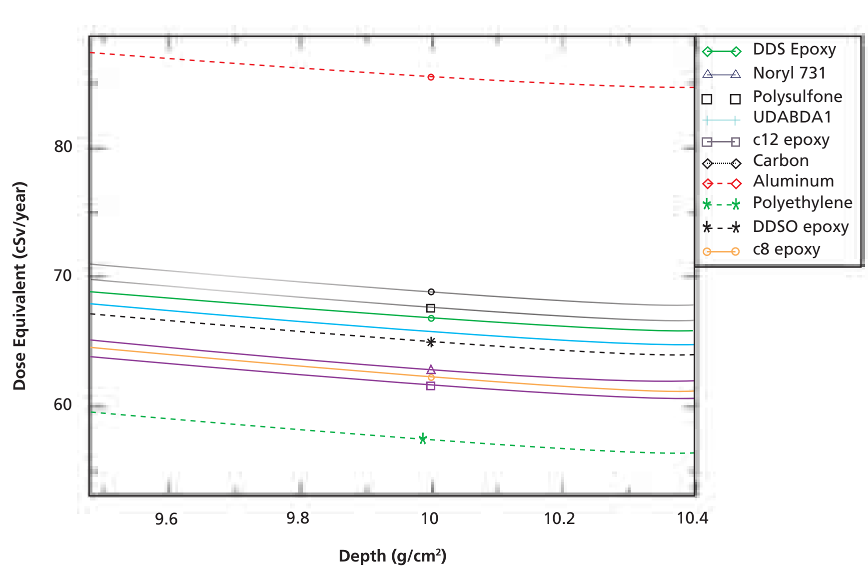

Figure 2. **HZETRN Modeling** is shown for various materials.

In a typical reaction, the aromatic/aliphatic diamine was slowly added to tetraglycidyl methylene dianiline (an epoxy) while heating to a temperature of 60 °C in a stainless steel mold. The mixture was subsequently heated to 80 °C under vacuum, then placed in a conventional oven and heated to 100 °C for 14 h, 120 °C for 1 h, 140 °C for 1 h, and 177 °C for 1 h to complete the cure.

The predicted radiation-shielding properties of two variants of this epoxy, were compared to those of polyethylene, aluminum, carbon, and other structural materials including a conventional structural epoxy system (DDSO epoxy) using a well-tested NASA radiation-transport computer code known as HZETRN (Figure 2). The radiation-shielding properties of the two variants of this epoxy, c8 and c12 in Figure 2, were the closest to those of polyethylene.

Mechanical tests were performed on samples of this epoxy to determine its potential as a structural material. The average compressive modulus and the apparent compressive strength from four specimens were 2.86 ± 0.19 GPa and 52.5 ± 3.7 MPa, respectively. The compressive modulus is nearly equal to that of a typical untoughened tetrafunctional aerospace epoxy resin. The compressive strength should be regarded as a lower bound because specimens in these tests were too thin and did not fail in pure compression, and chips on their edges initiated brittle failures.

This work was done by John W. Connell, Joseph G. Smith, Jeffrey Hinkley, and Steve Blattnig of Langley Research Center; Donavon M. Delozier and Kent A. Watson of the National Institute of Aerospace; and Sayata Ghose of the Oak Ridge Associated Universities. Further information is contained in a TSP (see page 1).

This invention is owned by NASA, and a patent application has been filed. Inquiries concerning nonexclusive or exclusive license for its commercial development should be addressed to the Patent Counsel, Langley Research Center, at (757) 864-3521. Refer to LAR-16874-1.