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RADIATION CURE OF DETONATION TRANSFER EXPLOSIVE

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ABSTRACT

The radiation cured detonation transfer plastic bonded explosive (PBX) provides the potential for achieving improvements in processability, storability, cure reproducibility, physical strength, and reliability of performance over the Navy's present injectable detonation transfer communications explosive. The composition and properties of the radiation cured system will be presented.

Radiation cure of energetic materials is a relatively new process. It combines the advantages of an indefinitely long pot-life and storage life for the material mix with a very rapid cure. Neither of these features is available with conventional catalyzed thermal cure reactions.

INTRODUCTION

Many present-day energetic formulations contain finely ground explosives dispersed in polymeric binders. The binders are typically cured by catalyzed thermal reactions, i.e., chemical curing agents are incorporated into the mix and the energetic materials may be subsequently thermally cured in hot air ovens. Inherent in the processing procedure is the "pot-life" restriction brought about by a continually curing system. For example, a typical explosive or propellant pot-life is 4 to 6 hours at 60°C; all mixing, handling, and loading must be accomplished within that fixed time period.

For efficient large-scale production of energetic materials, it would be desirable to have a method which combines an indefinite pot-life for the material mix and an ambient temperature instant cure procedure. Neither of these options is available with current technology, but both could be provided by a radiation curing process. Since no chemical catalysts are used, the pot-life of a mix prior to irradiation is indefinite and the mixing viscosity remains constant. A radiation-induced cure requires much less time than the conventional catalyzed thermal cure. Suitable sources of ionizing radiation include x-rays and electron beams.

The net effect of ionizing radiation on most organic compounds is the production of free radicals. To be susceptible to cure by irradiation, the polymeric binder must possess chemical groups which respond efficiently to free-radical initiated reactions. A vinyl-terminated polymer, for example, introduces the necessary groups into the binder system to bring about chemical

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crosslinking when subjected to ionizing radiation. The vinyl end groups can also be incorporated into a rapidly homopolymerizing unsaturated monomer which is sensitive to ionizing radiation.

An example of a present-day application for which a radiation cured composition would offer many benefits is the Navy's injectable detonation transfer booster communications explosive. The existing explosive has the following problems:

- Processing is difficult in terms of mixing and extrusion because of the high viscosities encountered;
- Mix reproducibility is poor because the cure catalyst may be poisoned;
- The mixed uncured explosive has a shelf-life at ambient temperature of only 24 hours (8 mos. @ -29 to -51°C);
- The physical strength of the cured explosive is low, possibly leading to unreliable detonation propagation characteristics.

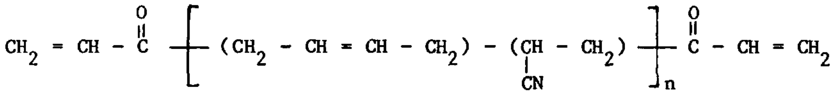
Use of the radiation cured explosive composition should offer these advantages over the present detonation transfer explosive:

- Processing would be easier because high mixing and extrusion viscosities would not be encountered;
- Cure catalysts would be eliminated;
- The energetic composition would have both an indefinite pot-life and shelf-life until the radiation flux is applied;
- The cured explosive should have more reliable detonation propagation characteristics because of the high tensile strength of the radiation cured binder.

This paper describes the preliminary development of a detonation transfer plastic bonded explosive curable by x-ray irradiation.

RADIATION CURABLE BINDER

Vinyl-terminated polybutadiene-acrylonitrile copolymer (VTBN, manufactured by the B. F. Goodrich Chemical Company) is the prepolymer component of the binder system under development. VTBN is a low molecular weight linear liquid polymer with reactive terminal vinyl groups. The structure for this polymer is:



$$CH_2 = CH - \overset{O}{\overset{\|}{C}} - \left[(CH_2 - CH = CH - CH_2) - (\underset{CN}{\underset{|}{CH}} - CH_2) \right]_n - \overset{O}{\overset{\|}{C}} - CH = CH_2$$

(ref. 1)

VTBN is cured to a solid elastomeric mass via a free-radical mechanism. Though the polymer can be homopolymerized, it is desirable to copolymerize VTBN with unsaturated monomers of low viscosity in order to improve processability and to improve mechanical properties by separating VTBN molecules with linear monomer units (ref. 1).

Two VTBN prepolymers have been compared in binder studies. The 16.5% acrylonitrile content polymer is a commercial product and the 10.0% acrylonitrile content polymer is an experimental material custom-made for this program. Characterization data for the polymers are presented in Table 1.

TABLE 1

Properties of VTBN Polymers

Property	VTBN 1300X22	VTBN Experimental
Acrylonitrile content (VCN), %	16.5	10.0
Viscosity at 27°C, poise	2000	648
Vinyl equivalent weight	1316	1341
Specific gravity at 25°C/25°C	0.984	0.945

VTBN has been crosslinked and plasticized with acrylate or methacrylate monomers in binder studies (ref. 2, 3, 4). The combination of VTBN with hydroxypropyl methacrylate (HPMA) has yielded flexible, strong, rubbery binder materials with good mechanical (stress-strain) properties. A liquid plasticizer, dioctyl maleate (DOM), has been incorporated into the binder to modify viscosity and mechanical properties. Irganox 1035 (manufactured by the CIBA-GEIGY Corporation) serves as an antioxidant for the binder system.

The VTBN binders have been cured by x-ray irradiation at dose levels between 0.5 and 0.8 megarads. Formulation, mix viscosity, and mechanical property data for the binders are given in Table 2.

TABLE 2

Binder Formulation and Physical Property Data

	Binder #					
	1	2	3	4	5	6
Formulation, wt. %						
VTBN (10% VCN)	45.0	45.8	0	0	0	0
VTBN (16.5% VCN)	0	0	45.0	45.8	40.4	32.3
HPMA	30.0	39.2	30.0	39.2	34.6	27.7
DOM	24.5	14.5	24.5	14.5	24.5	39.5
Irganox 1035	0.5	0.5	0.5	0.5	0.5	0.5
Visc., Poise (27°C)	8.6	9.3	13.3	14.1	9.0	4.3
Dose, X 10^5 RAD	5.0	5.0	5.8	6.0	6.8	7.6
Physical Property (25°C)						
Stress, psi	380	490	390	950	630	480
Strain, %	110	60	130	120	110	200

IRRADIATION OF PETN

A pure sample of the energetic solid pentaerythritol tetranitrate (PETN) has been irradiated in order to determine the radiation stability of PETN and the safety characteristics of the irradiation process.

The preliminary evaluation of PETN detected no measurable degradation after irradiation. This conclusion is based upon measurements of (1) differential scanning calorimetry to monitor thermal stability and (2) high performance liquid chromatography and x-ray photoelectron spectroscopy to determine the presence of decomposition products and/or changes in the PETN molecular structure.

RADIATION CURABLE PBX COMPOSITIONS

Small-scale mixes (approximately 100 grams) are being made in the Baker-Perkins high-shear one-half pint mixer at the 80% solid loading level with superfine PETN in the VTBN binder system. A processing study is underway to optimize mixing parameters.

The energetic compositions will be cured by x-ray irradiation. It is anticipated that mechanical property, thermal stability, and detonation propagation data for these radiation curable compositions will be available in the near future.

CONCLUSIONS

The radiation curable detonation transfer PBX offers the potential for achieving improved processability, storability, cure reproducibility, physical strength, and reliability of performance over the present-day detonation transfer explosive.

FUTURE PLANS

Additional plans for the Radiation Curable Detonation Transfer PBX program include:

- Optimizing the formulation for reproducible extrusion characteristics
- Determining the influence of mixing and extrusion on detonation propagation characteristics
- Fully characterizing the final composition.

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