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The influence of stabilisers on resistance to gamma radiation for epoxy based polymeric composite material

Mamta Saiyad [a,*], N.M. Devashrayee [b], R.K. Mewada [c]

[a] Head Chemical and Plastic Engineering Department, Nirma University, 149, Sunrise Park, Opp. Drive in Cinema, Thaltej Road, Ahmedabad 380054, India
[b] VLSI Technology, EC Department, Nirma University, India
[c] Chemical Engineering Department, Nirma University, India

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ABSTRACT

In certain applications plastic materials are getting irradiated while in end use. High energy irradiation leads to the auto-oxidation and degradation. The primary approach for stabilization against post irradiation degradation is to use appropriate stabilisers. In this research work, an experimental analysis of the effect of dose rate of gamma irradiation on epoxy resin based samples prepared by using combinations of primary and secondary stabilisers is presented. The chemistry, reaction mechanisms and morphology changes are studied and its effect on mechanical properties is observed. The results show an improvement of mechanical strength as dose increases, indicating cross-linking over oxidative degradation.

1. Introduction

1.1. Objective

The objective of present study is to develop a plastic material for VLSI package, which could be a Radiation Hardened. Considering the ambient in the space, the frequency of radiation is very high. Hence, it is tried to develop a material which could be prevented from microcracks and could prevent material from early failure and increase life time. Selection of right stabilisers or a right blend of stabiliser will give the best results to get inhibition or slow down the structural deterioration of polymer.

1.2. Literature review

To overcome the back door lack of polymer composite aircrafts and spacecrafts over a metallic parts, design of a new light weight shield particularly for aeronautic application is needed, particularly in high frequencies of radiation [1]. For this, it's necessary to choose right stabilisers against degradation due to irradiation alongwith proper resin and matrix parts in the composites.

The primary approach for stabilization against post irradiation degradation is to use Anti Oxidants (AO) and radical scavengers. The blends of stabilisers may be used to get best results for irradiated samples, consisting of a hindered phenol, antioxidants, secondary stabilisers and hindered amine light stabilisers [2].

Organic materials, both natural and synthetic, readily undergo reactions with oxygen. Important properties of polymers often change and mainly molecular weight of polymers gets reduced by oxidative degradation as a result they may lose mechanical properties, surface appearance and discoloration of plastic parts. Oxidation may occur at every stage of life cycle of polymer. These phenomena can be inhibited or slow down by modifying polymers using suitable stabilisers [3].

1.3. Selection criteria for stabilisers

Following points were considered during the selection of stabilisers in accordance with Polymer Radiation Chemistry: [4].

- Charged particles above the electron binding energy eject an electron from the atom, that results in ionization. Particles below the binding energy may form excited states that generate free radicals (unpaired electrons), and/or a number of other chemical species.
- Irradiation may lead to either: (a) cross linking (b) chain scission.
- Cross linking results in: decreased elongation, increased tensile strength, increased modulus.
- Chain scission results in: brittleness, fracturing, gas generation, and sometimes depolymerization back to a liquid state.

Abbreviations: Comp., composition; ^{60}Co, Cobalt 60; AO, Anti Oxidants; SEM, scanning electron microscope; DMA, dynamic mechanical analysis.

* Corresponding author. Tel.: +91 9824076708.
E-mail address: ma2sa@yahoo.com (M. Saiyad).

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- All polymers are at risk; dose and damage assessment are required.

In general, hard glassy polymers that is crosslink are more resistant to radiation damage than soft or flexible polymers, it is to be noted that, in the presence of air, oxygen reacts strongly to generate oxygenated species, discoloration, molecular weight degradation, and much lower limiting doses.

Hindered amine light stabilisers do not absorb UV radiation, but act to inhibit degradation of the polymer. They slow down the photochemically initiated degradation reactions, to some extent in a similar way to antioxidants [5,6].

The UV absorber 2-(2′-hydroxy-3′,5′-dipentyl-phenyl) benzotriazole shows excellent stabilizing effectiveness in the γ-ray-induced degradation. UV Absorber could effectively inhibit the formation of alkyl free radicals under γ-irradiation, and it is possibly the fundamental reason for its high stabilizing efficiency [7].

Organic phosphites combined with hindered amine light stabilizers (HALS) were used as stabilizers. A strong synergistic effect may observe for the molecule with HALS and phosphite. The efficiency of the mixture depends upon the chemical structure of generally, the mixture of HALS and phosphite exhibit synergistic, antagonistic or additive effects. the phosphite and HALS structural units as well as on the ratio of the components [8].

2. Experimental

2.1. Method

On the basis of literature review the specimen thickness was determined i.e. 3 mm. Performed research had a number of character because eight different fillers are applied. The study is discussed, only up to different blends of stabilisers applied.

A commercial-grade epoxy resin with a density of 1.12 g/cm^3 with 15 poise viscosity at 25 °C was used. And specimens were cast into our own designed steel frame. The sheets of 300 mm × 300 mm × 3 mm size were prepared and the samples cut for the irradiation experiments. Samples were prepared according to ASTM standard D 638 for the tensile tests. Also Mechanical strength tests were carried out on a universal testing machine, applying all the requirements of ASTM standard D 638 for the tensile tests. All tests were carried out at the room temperature [9].

The gamma irradiation process was carried out at the Bhabha Atomic Research center, Mumbai. This equipment operates with ^{60}Co sources.

According to the ASTM standards, D 638, five samples were required for each determination of mechanical strength. Therefore, six sets of samples, mainly, for three compositions, for five radiation doses and one without radiation, were exposed inside the irradiation chamber using five dose rates .

2.2. Materials

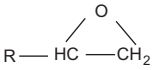
The thermosetting matrix used in this study was Bisphenol which a based unmodified epoxy resin cured at room temperature with 50% by weight of hardener. The density of the epoxy resin was 1.12 g/cm^3. Basic characteristics of stabilisers used are shown in Table 1.

2.3. Procedure

At the first stage, 400 ml of Epoxy resin is taken in a beaker and stirred with a very low rpm (Approximately 20–30 rpm). After this, stabilisers are diluted in suitable solvent and added into the resin drop wise. Stabilisers were taken in the ratio as shown in Table 1. The mixture is stirred slowly so that there is no formation of bubbles, however, continuous stirring is advisable. After adding hardener into the mixture, it is stirred for 10 min. to create homogeneous mixture. The curing time depends upon the amount of hardener added. Now the mixture is poured very slowly into the frame fabricated to get sheet of 300 mm × 300 mm × 3 mm. It was covered with toughened glass by applying releasing agent on it. It must be allowed to be cured for 6 h. The cured sheet is kept at room temperature for 8 h and then kept into the hot air oven for 24 h for post curing. The samples from different regions are cut using milling machine with suitable clamp of specified standard ASTM D638.

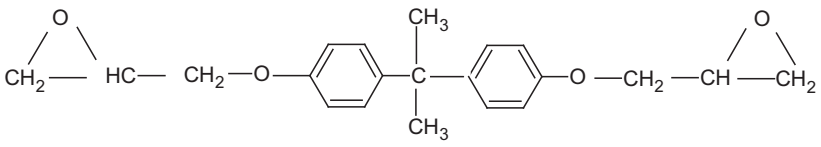
3. Chemistry

3.1. Chemistry of epoxy resin

The term epoxy resin is applied to both the prepolymers and to cured resins, the former contain reactive groups,  (Epichlorohydrin), hence they are called as "epoxy" functionality [10].

Liquid epoxy resins are converted through these reactive epoxy sites into tough, insoluble and infusible solids.

The simplest epoxy resin derived from the reaction of bisphenol A and epichlorohydrin is (2,2 – bis[4-(2′3′epoxy propoxy)phenyl]propane) commonly called diglycidyl ether of bisphenol A.



The higher homologs are represented by the following theoretical structure.