

e.g., a 500 Watt mercury arc source with an output of 1 milliwatt per square centimeter or a high intensity light source, e.g., a 2000 Watt mercury arc source with an output of 11 milliwatt per square centimeter. The imaged films were developed with 1,1,1-trichloroethane as a development solvent. The radiation times used compare with those radiation times necessary to obtain 6 mil vias in the photodefinable dielectric. These times were 5 seconds on the high intensity imaging and 13 seconds with the low intensity imaging source.

The degree of cure as measured by polarization measurements was compared with Sol fraction data obtained from the extraction of the films in methylene chloride and reported as 1-% Sol. The glass transition temperature of the films was measured on a Dupont-1090 with a 943 Thermal Mechanical Analyzer module using an expansion probe.

Referring to FIG. 2 there is shown a graph indicating the measure of cure of films prepared from Mixture No. 1 as determined by polarization measurements as a function of photopolymer cure time for a photopolymer cured with both high and low intensity radiation. FIG. 3 is a similar graph which shows the measure of cure for the same system, but determined as a function of % Sol. As can be seen from comparing FIGS. 2 and 3, the measure of the degree of cure achieved as a function of cure time by raw polarization data and from % Sol data are comparable. In fact, the data compares even more closely when the polarization measurements are corrected for film thickness as shown in FIG. 4.

The method was also evaluated by determining the degree of cure of mixture No. 1 with increasing amounts of TMPTA (mixtures 2-4) added to the mixture (see Table 1). All films were cured using the same curing times and power densities of U-V cure radiation. As can be seen with reference to FIG. 5, as expected, the amount of polarization and hence, the degree of cure increases with added TMPTA, a crosslinking agent. Also, at 15% TMPTA, the limiting value of polarization of the dye which relates to the total absence of rotational motion, and hence, a high degree of polymer crosslinking, is nearly reached. Also, the measure of the degree of crosslinking obtained from the polarization data follows that obtained from measurement of the T_g .

In addition to evaluating the method in systems which exhibit complex interactions between components, systems referred to in Table 1 as mixtures A, B & C were also examined. These systems eliminate the rubber-modified epoxy constituents which should negate any interaction which may occur between the fluorophore and the acrylonitrile or unsaturated groups. Mixture A differs from mixture B essentially in the fluorophore employed. PRODAN is a single, small size (MW-227) fluorophore having a relatively large dipole moment and is subject to changes in emission maximum based upon the polarity of its environment. The polarization results of films made from these mixtures are shown in FIG. 6. It can be seen that both the initial and final polarization values are lower and the curvature less steep than with mixture No. 1.

It should be noted that the method is not limited to the use of any particular fluorophore nor to measuring the extent of cure or control of cure of any particular type of polymer. Further, the method is operable whether or not the polymer is a free film or on a substrate and is independent of the nature of the substrate.

In addition, it should be understood that the fluorophore may be part of the polymer as a pendant group bonded to the polymer as well as a separate compound.

What is claimed is:

1. A non-destructive method of measuring the degree of cure of a polymer system having a fluorophore therein comprises:

- (a) exciting the fluorophore in the polymer with linearly or plane polarized radiation;
- (b) collecting the fluorescent emission from the fluorophore at two predetermined angles with respect to the exciting radiation;
- (c) comparing the relative fluorescent emission from each of the two collecting angles so as to determine the degree of polarization or anisotropy of the fluorophore in the polymer; and
- (d) determining the degree of cure of the polymer from changes in the degree of polarization or anisotropy of the fluorophore.

2. The method set forth in claim 1, wherein the cured polymer is in the form of a film.

3. The method set forth in claim 1, wherein the fluorophore is added as a separate component to the polymer system.

4. The method set forth in claim 1, wherein the fluorophore is pendant to the polymer chain.

5. The method recited in claim 1, wherein the fluorophore is excited with a laser.

6. The method recited in claim 1, wherein the fluorescent emission is collected by a fiber optic detector and including the steps of passing the detected radiation through a polarizer and photomultiplier to a dual port clock-counter for comparing the collected emissions.

7. The method recited in claim 1, wherein the polymer is a film on a substrate and wherein the exciting radiation impinges the polymer at an angle of about 45° from the axis perpendicular to the plane of the substrate.

8. A non-destructive method for measuring and controlling the degree of cure of a polymer having a fluorophore therein comprises:

- (a) exciting the fluorophore with linearly or plane polarized radiation;
- (b) collecting the fluorescent emission from the fluorophore at two predetermined angles with respect to the exciting radiation;
- (c) determining the degree of polarization or anisotropy of the fluorophore from its fluorescent emission;
- (d) comparing the degree of polarization or anisotropy determined with a predetermined value or standard; and
- (e) controlling means for inducing curing of the polymer in response with the measured comparison.

9. The method recited in claim 8, wherein said means for inducing curing of the polymer is controlled by an output from a comparator and wherein said means is selected from UV radiation or heat means.

10. The method recited in claim 8, wherein said polymer is in the form of a film or continuous web.

11. The method recited in claim 8, wherein the fluorophore is present as a separate component mixed with the polymer.

12. The method recited in claim 8, wherein the fluorophore is part of the polymeric molecule being pendant to the polymer chain.

13. The method recited in claim 8, wherein the fluorophore is excited by means of a laser.

14. The method recited in claim 8, wherein the polymer is on an opaque substrate and the exciting radiation is on a 45° angle incident to the substrate.

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