

## Chapter 1 : Electron Beam Curing

*Electron beam curing is a viable and advantageous alternative to thermal curing for polymer matrix composites. Although it requires special materials it is faster, cheaper, can be used on thicker sections, requires no modifications to suit different materials and can produce better properties.*

C Vaishnavi, 32, Malony Road, T. Nagar, Chennai - 600 029, Tamil Nadu, India. This article has been cited by other articles in PMC. To compare the fracture toughness and wear resistance of indirect composites cured by conventional post curing methods and electron beam irradiation. Forty specimens were randomly assigned into four groups of ten each and were subjected to various post curing methods. Fracture toughness and wear resistance tests were performed and the results were tabulated and analyzed statistically using Kruskal Wallis and Mann-Whitney U test. It was found that Inlay system showed higher values followed by electron beam irradiation. Electron beam irradiation of dental composites gives comparable mechanical properties to other post curing systems. It can be concluded that further studies with increased radiation dose should be performed to improve the mechanical properties of indirect composites. However, direct restorations have their own inherent limitations like incomplete polymerization and poor mechanical properties. Studies show that indirectly fabricated composites overcome these limitations. The various advantages of indirect composites include better polymerization, better mechanical properties, better contacts and contours. The enhanced mechanical properties may largely be because of increased degree of conversion, which leads to increase in cross-linking. An increase in mechanical strength of the restoration, especially resistance to fracture and wear are the most important requisites for posterior restorations. Several post curing methods have been advocated to increase the polymerization, like curing in Nitrogen atmosphere, curing under heat and pressure or curing in inlay systems designed by the manufacturer. Therefore, this study was done to evaluate the fracture toughness and wear resistance of indirect composites that were subjected to electron beam irradiation as a post curing method and compare with conventional methods which included autoclave and the inlay system. The composite material was placed in the steel mould and light pressure was applied with the glass slide to remove the excess. Light curing was done for 20 sec using Lumamat light curing device. The specimens were then randomly assigned into four groups of ten each. Post curing protocol Group I - The specimens were subjected to electron beam irradiation using an electron beam accelerator Siemens at a dose of 1 KGy and 6 MeV. Group II - The specimens were cured under Lumamat inlay system specifically designed for Adoro material by the manufacturer for 25 min. Group IV - The specimens were not subjected to any post curing methods control group.

**Chapter 2 : Electron Beam Curing of Epoxide Modified MWNTs/Epoxy Composites**

*86 3 Electron Beam Curing Applied to Composite Molding Technologies Main advantage of this technique are the low costs involved with the preparation of the composites, which renders the technique to be effective for low-performance composite.*

It should be noted that the figures set forth herein are intended to exemplify the general characteristics of an apparatus, materials, and methods among those of this invention, for the purpose of the description of such embodiments herein. The figures may not precisely reflect the characteristics of any given embodiment, and are not necessarily intended to define or limit specific embodiments within the scope of this invention. The citation of references herein does not constitute an admission that those references are prior art or have any relevance to the patentability of the invention disclosed herein. All references cited in the Description section of this specification are hereby incorporated by reference in their entirety. The description and specific examples, while indicating embodiments of the invention, are intended for purposes of illustration only and are not intended to limit the scope of the invention. Moreover, recitation of multiple embodiments having stated features is not intended to exclude other embodiments having additional features, or other embodiments incorporating different combinations the stated of features. However, other embodiments may also be preferred, under the same or other circumstances. Furthermore, the recitation of one or more preferred embodiments does not imply that other embodiments are not useful, and is not intended to exclude other embodiments from the scope of the invention. Most items of manufacture represent an intersection of considerations in both mechanical design and in materials design. In this regard, improvements in materials frequently are intertwined with improvements in mechanical design. The embodiments describe compounds, compositions, assemblies, and manufactured items that enable improvements in irradiation-augmented polymer material synthesis to be fully exploited. The examples and other embodiments described herein are exemplary and not intended to be limiting in describing the full scope of compositions and methods of this invention. Equivalent changes, modifications and variations of specific embodiments, materials, compositions and methods may be made within the scope of the present invention, with substantially similar results. The embodiments relate to synthetic polymer chains especially materials having a halogenated polymer phase or portion from a process initiated with free radical formation derived from irradiation especially electron beam radiation of an element preferably a halogen element connected to a polymer chain. Carbon-chain-based polymeric materials polymers are usefully defined as falling into one of three traditionally separate generic primary categories: An important measurable consideration with respect to these three categories is the concept of a melting point—a point where a solid phase and a liquid phase of a material co-exist. Precursor components to the thermoset plastic material are usually shaped in molten or essentially liquid form, but, once the setting process has executed, a melting point essentially does not exist for the material. A thermoplastic plastic material, in contrast, hardens into solid form with attendant crystal generation, retains its melting point essentially indefinitely, and re-melts albeit in some cases with a certain amount of degradation in general polymeric quality after having been formed. An elastomeric or rubber-like material does not have a melting point; rather, the elastomer has a glass transition temperature where the polymeric material demonstrates an ability to usefully flow, but without co-existence of a solid phase and a liquid phase at a melting point. Elastomers are frequently transformed into very robust flexible materials through the process of vulcanization. Depending upon the degree of vulcanization, the glass transition temperature may increase to a value that is too high for any practical attempt at liquefaction of the vulcanizate. Vulcanization implements inter-bonding between elastomer chains to provide an elastomeric material more robust against deformation than a material made from the elastomers in their pre-vulcanized state. For the initial elastomer, when the material is in non-vulcanized elastomeric form, a non-vulcanized compression set value is measured according to ASTM D Method B and establishes thereby an initial compressive value for the particular elastomer. Under extended vulcanization, the elastomer vulcanizes to a point where its compression set value achieves an essentially constant maximum respective to further vulcanization, and, in so doing, thereby defines a material where a

fully vulcanized compression set value for the particular elastomer is measurable. In applications, the elastomer is vulcanized to a compression set value useful for the application. Augmenting the above-mentioned three general primary categories of thermoset plastic materials, thermoplastic plastic materials, and elastomeric materials are two blended combinations of thermoplastic and elastomers vulcanizates generally known as TPEs and TPVs. Thermoplastic elastomer TPE and thermoplastic vulcanizate TPV materials have been developed to partially combine the desired properties of thermoplastics with the desired properties of elastomers. Traditionally, the elastomer vulcanizate phase and thermoplastic plastic phase co-exist in phase admixture after solidification of the thermoplastic phase; and the admixture is liquefied by heating the admixture above the melting point of the thermoplastic phase of the TPE or TPV. Another form of modification to the traditional three general primary categories of thermoset plastic materials, thermoplastic plastic materials, and elastomeric materials is cross-linked thermoplastic material, where a thermoplastic undergoes a certain degree of cross-linking via a treatment such as irradiation after having been solidified to contain crystals of the thermoplastic polymer. In this regard, while the melting point of crystals in a cross-linked thermoplastic is sustained in all crystalline portions of the thermoplastic, the dynamic modulus of the cross-linked thermoplastic will be higher than that of the non-crosslinked thermoplastic due to crosslinkage between thermoplastic molecules in the amorphous phase of the thermoplastic. Some embodiments of this specification derive from the inter-linking of molecules of an elastomer or vulcanizate with molecules of a thermoplastic. In this regard, a new type of compound is formed: In some embodiments, the plastic moiety is derived from thermoplastic plastic; in other embodiments, the plastic is derived from thermoset plastic. Some further embodiments of this specification derive from the inter-linking of molecules of an elastomer or vulcanizate with molecules of a ceramic compound. Other embodiments of this specification derive from the inter-linking of molecules of an elastomer or vulcanizate with a metal element. In this regard, a molecule usually a macromolecule having a metal element bonded to an elastomer or vulcanizate provides a new form of elastomer. In this regard, it is to be noted that a traditional practice of bonding an elastomer or vulcanizate to a metal employs a silane-derived group to conjoin a metallic silane to the elastomer with hydrogen bonds or van der Waals forces. In one embodiment, the elastomeric moiety is generated from bombarding an elastomeric molecule with a beam of energy that is sufficiently significant to dislodge an element preferably a halogen element such as fluorine from the carbon chain of the elastomer but sufficiently mitigated to avoid breaking or severing of the chain. After the element halogen or other element is dislodged, a free radical derivative of the original elastomeric molecule exists with a free radical site on the element usually carbon in the polymer chain to which the dislodged element the halogen, usually was previously bonded. While free-radicals usually react very rapidly with other materials indeed, they are frequently referenced as very short-term intermediary entities in kinetic models describing rapidly-executed multistage chemical reactions, a free radical polymer chain appears to be surprisingly stable in the free radical state, especially if the polymeric free radical is constrained from movement and also constrained from contact with other materials that would bond to the free radical site of the polymer chain. Indeed, the stability of such free radical sites on polymer chains is surprising when a halogenated polymer is irradiated with electron beam radiation to energize a halogen element on the polymer with energy sufficient to remove that halogen from the polymer and thereby generate a free radical site on the polymer chain. A preferred method of generating the free radical site is with an electron beam. It is known that modifications in polymeric structures are effected by radiation. The radiation is alternatively radioactively sourced, laser sourced, or sourced by an electron accelerator. After irradiation of the polymer molecules, the polymer chains are modified to include dangling bonds between the atoms of the polymer chains or to have broken, bent, or strained chains. Irradiative treatment can also generate either free radicals or high-energy chemical bonds in molecules of admixed polymers. And it has been shown that another polymeric item may be bonded to the irradiated polymeric structure without further use of adhesives. The second material may be a metal, a ceramic compound, or a thermoplastic polymer. As should also be appreciated, the amount of energy is also controlled to minimize destruction of the polymeric chains upon which free radical sites are being generated. In this regard, it is efficacious in the new molecules of the embodiments for the free radical sites to be at interim locations on the

polymer chains rather than at endpoints where the initial polymer chains were severed or broken by the radiation. With respect to the bonding, the size of the free-radical molecules molecular weight of from about to about 10,, for the free radical elastomer molecule, and from about to about 10,, for a free radical thermoplastic molecule when the non-elastomer is a thermoplastic molecule is also desired for providing optimal mobility of the free-radicals the polymeric chains with a free radical site to ultimately bond at their respective high energy electron sites and thereby create the new molecules of the embodiments. The radiation is absorbed by an element a first element on the elastomer, and that first element is boosted to an energy level whereby it detaches from the general elastomer molecule. As noted before, this leaves another second element in the polymer chain where the second element was previously attached to the first element with a free radical site. Electron beam processing is usually effected with an electron accelerator. Individual accelerators are usefully characterized by their energy, power, and type. Low-energy accelerators provide beam energies from about keV to about 2. Medium-energy accelerators provide beam energies from about 2. High-energy accelerators provide beam energies greater than about 9. Accelerator power is a product of electron energy and beam current. Such powers range from about 5 to about kW. The main types of accelerators are: In one embodiment, the particular combination of an elastomer alternatively, a vulcanizate with any of a metallic element, a ceramic, and a polymeric carbon chain thermoplastic by use of radiation-facilitated bonding appears to create a new compound when the elastomer molecule is treated with radiation such as an electron beam. This compound corresponds to the Formula I: AD where A is a polymeric carbon chain elastomeric moiety containing elastomeric functionality and having a collective atomic weight of from about to about 10,, and D is any of a metallic element, a ceramic moiety, and a polymeric carbon chain thermoplastic moiety. In the case of D being a polymeric carbon chain thermoplastic moiety, D is a free radical polymeric derivative of a thermoplastic molecule having a molecular weight of from about to about 10,, In the case of D being a ceramic moiety, D is a free radical ceramic compound derivative of a ceramic compound. In either of the cases, where D is a polymeric carbon chain thermoplastic moiety or a ceramic moiety, electron-beam treatment of the precursor respective thermoplastic molecule or ceramic compound is the preferred manner for making the respective free radical derivatives. The A moiety is derived from a free radical polymeric derivative of an elastomer molecule. In the case of D being a polymeric carbon chain thermoplastic moiety, D is derived from a free radical polymeric derivative of a thermoplastic molecule. Turning now to FIG. Region defines blends of respective tetrafluoroethyl, hexfluoropropyl, and vinylidyl fluoride overall block amounts that combine to form fluoroelastomer FKM polymers. Region defines blends of respective tetrafluoroethyl, hexfluoropropyl, and vinylidyl fluoride overall block amounts that combine to form ethylene tetrafluoroethylene polymers. Region defines blends of respective tetrafluoroethyl, hexfluoropropyl, and vinylidyl fluoride overall block amounts that traditionally have not generated useful co-polymers. Region defines blends of respective tetrafluoroethyl, hexfluoropropyl, and vinylidyl fluoride overall block amounts that combine to form polytetrafluoroethylene PTFE polymers. Region defines blends of respective tetrafluoroethyl, hexfluoropropyl, and vinylidyl fluoride overall block amounts that combine to form polyvinylidene fluoride PVdF polymers. Region defines blends of respective tetrafluoroethyl, hexfluoropropyl, and vinylidyl fluoride overall block amounts that combine to form polyhexfluoropropylene PHFP polymers. Returning to a consideration of the compound of Formula I, the embodiment of Formula I provides, in one perspective, a molecular chimera bi-modal molecule where one portion is elastomeric in its fundamental nature and a second portion is a non-elastomeric in its fundamental nature. A molecule of this structure therefore provides a chemical structure having one portion that is structurally conformant with an elastomer and a second portion that is structurally conformant with a non-elastomer. Accordingly, the general bonding between an elastomeric region and a non-elastomeric region is potentially very high when such molecules exist as inter-bonding molecules at the interface between the two regions. In preferred embodiments of the compound of Formula I, D is halogenated plastic and A is from a molecule corresponding to the Formula II: One embodiment of the molecule compound according to Formula I is partially depicted by molecular schematic in FIG. Moiety is derived from a fluoroelastomer. Moiety is derived from a halogenated thermoplastic. Accordingly, Z is independently within any of the sub-blocks replicated in any of the respective m instances, n instances, and o

instances any of F, Cl, I, Br, H, or a functional group; and X is independently within any of the sub-blocks replicated in any of the respective m instances, n instances, and o instances any of F, Cl, I, or Br. In this regard, halogenated polymers demonstrate especially good free radical generation through removal of a halogen from their carbon chains when subjected to electron beam radiation preferably with electron beam radiation of from about 0. As previously noted, the general bonding between an elastomeric region and a non-elastomeric region is potentially very high when molecules according to Formula I exist as inter-bonding molecules at the interface between the two regions. Several alternative embodiments of materials, compositions, and articles having such diverse regions benefit from these inter-bonding molecules. One embodiment of a diverse region material having a continuous phase and a dispersed phase is admixture as shown in FIG. Admixture is a polymeric blend admixture of an elastomer alternatively, vulcanizate phase and a plastic phase, where the plastic phase is initially admixed as a thermoplastic. After admixing, admixture, is irradiated preferably with electron beam radiation to cross-link the thermoplastic and further vulcanize or otherwise modify the elastomer or vulcanizate. An admixture, such as admixture, established by admixing phases of polymer usually differentiates the continuous phase and dispersed phase on the basis of relative viscosity between two initial polymeric fluids where the first polymeric fluid has a first viscosity and the second polymeric fluid has a second viscosity. The phases are differentiated during admixing of the admixture from the two initial polymeric fluids. In this regard, the phase having the lower viscosity of the two phases will generally encapsulate the phase having the higher viscosity. The lower viscosity phase will therefore usually become the continuous phase in the admixture, and the higher viscosity phase will become the dispersed phase. When the viscosities are essentially equal, the two phases will form an interpenetrated structure of polymer chains. Accordingly, in general dependence upon the relative viscosities of the admixed elastomer and thermoplastic, several embodiments of admixed compositions derive from the general admixing approach and irradiation. In a first admixture embodiment, admixture has a continuous phase of cross-linked plastic cross-linked from prior thermoplastic polymer. Admixture also has a dispersed phase of vulcanized elastomer in a plurality of vulcanized elastomeric portions such as portion dispersed in continuous phase. Admixture in this embodiment is therefore derived from intermixing relatively high viscosity elastomer or partially vulcanized elastomer with relatively low viscosity thermoplastic and then irradiating preferably with electron beam radiation the admixture.

### Chapter 3 : Electron Beam Curing of Composites - Hanser Publications

*"Electron beam curing technology for advanced composites has emerged as a credible and attractive alternative to thermal curing for most composite products.*

### Chapter 4 : Study on Electron Beam Curing of APTES Functionalized MWNTs/ Epoxy Composites

*The electron beam curing of composites includes the irradiation of composites fabricated from carbon fiber and epoxy. The process of curing consists of three-dimensional polymerization of the epoxy. One method of curing is based on electron or gamma irradiation.*