US 20030082385A1

(19) **United States**

(12) **Patent Application Publication**

Li et al.

(10) **Pub. No.: US 2003/0082385 A1**

(43) **Pub. Date: May 1, 2003**

(54) QUICK CURE CARBON FIBER REINFORCED EPOXY RESIN

(75) Inventors: **Wei (Helen) Li**, Puyallup, WA (US); **Kishio Miwa**, Shiga (JP)

Correspondence Address:
LAW OFFICES OF RONALD M ANDERSON
600 108TH AVE, NE
SUITE 507
BELLEVUE, WA 98004 (US)

(73) Assignee: **Toray Composites (America), Inc.**

(21) Appl. No.: **09/905,264**

(22) Filed: **Jul. 13, 2001**

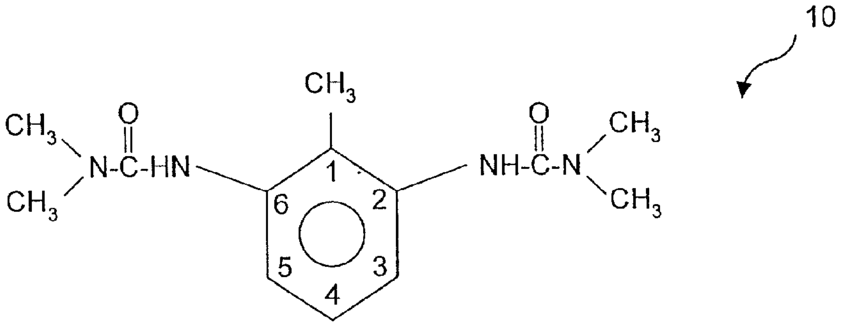
Publication Classification

(51) **Int. Cl.^{7}** **B32B 27/38**

(52) **U.S. Cl.** **428/417**

(57) ABSTRACT

An epoxy composition including an epoxy resin, a latent amine curing agent, and a specific catalyst. Preferably, the epoxy resin includes two epoxide groups per molecule, and the latent amine curing agent is a dicyanopolyamide, most preferably, dicyandiamide. The specific catalyst is preferably 2,4-toluene bis dimethyl urea. A prepreg employing the epoxy composition of the present invention can achieve a 95% cure in about one half of the time required by a prepreg that differs only in the catalyst employed. Furthermore, prepregs employing the epoxy composition of the present invention have glass transition temperatures higher than the curing temperatures when cured at a temperature range from about 80° C. to about 150° C., enabling cured prepregs to be removed from molds without being cooled. Use of the prepregs of the present invention thus enables composite component manufacturers to substantially increase production rates without requiring the use of additional molds.



100% 2,6-TOLUENE BIS DIMETHYL UREA

FIG. 1A PRIOR ART

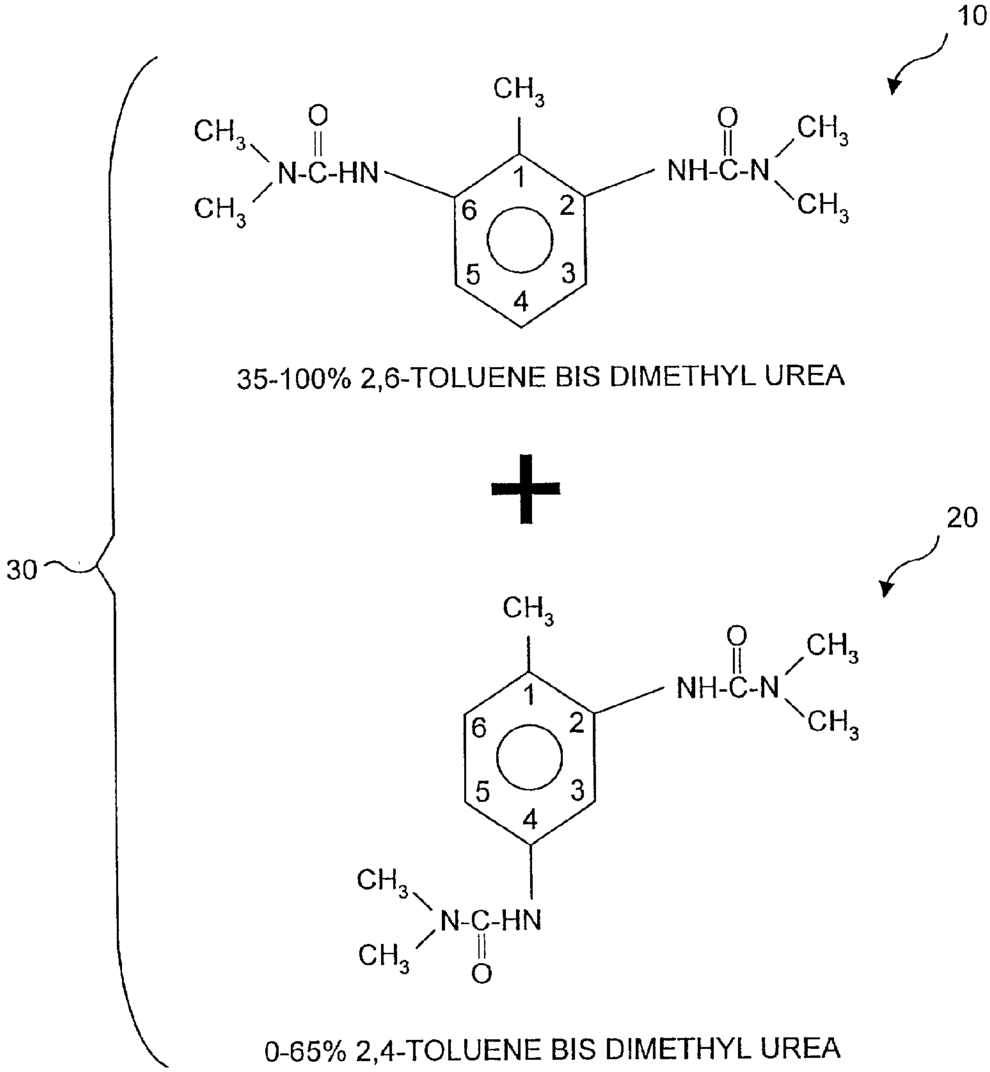
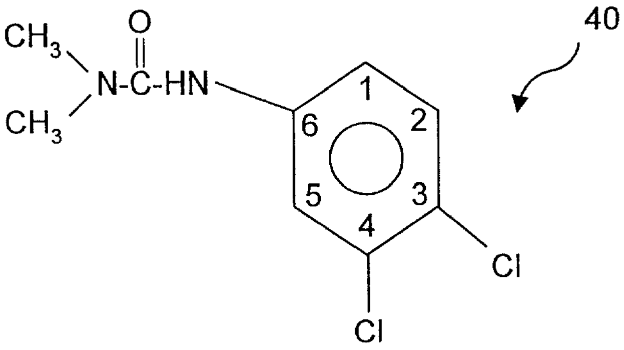
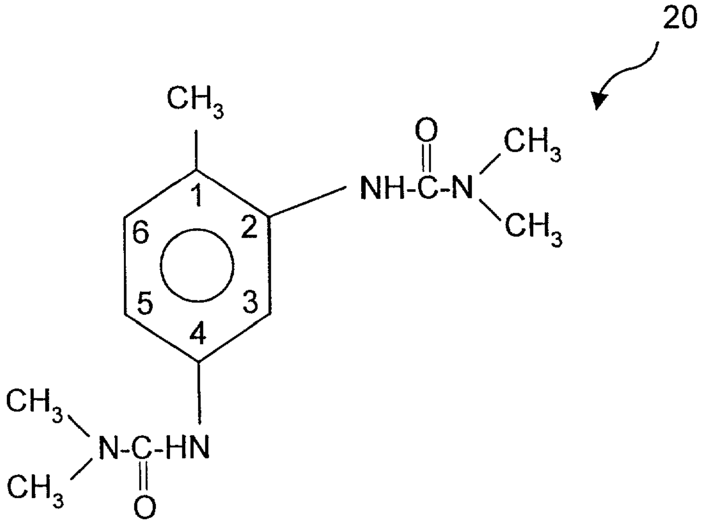


FIG. 1B PRIOR ART



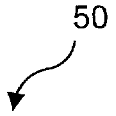
100% 3,4-DICHLOROPHENYL-N,N-DIMETHYL UREA (DCMU)

FIG. 1C PRIOR ART



100% 2,4-TOLUENE BIS DIMETHYL UREA

FIG. 1D PRIOR ART


50

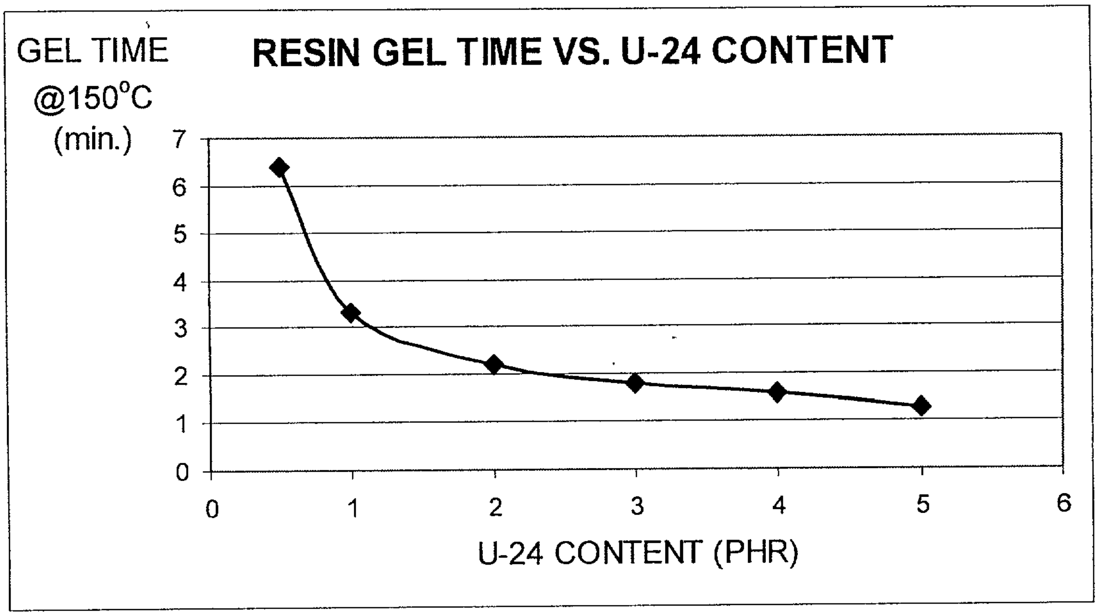

RESIN GEL TIME VS. U-24 CONTENT
GEL TIME @150°C (min.)
7
6
5
4
3
2
1
0
0
1
2
3
4
5
6
U-24 CONTENT (PHR)

FIG. 2

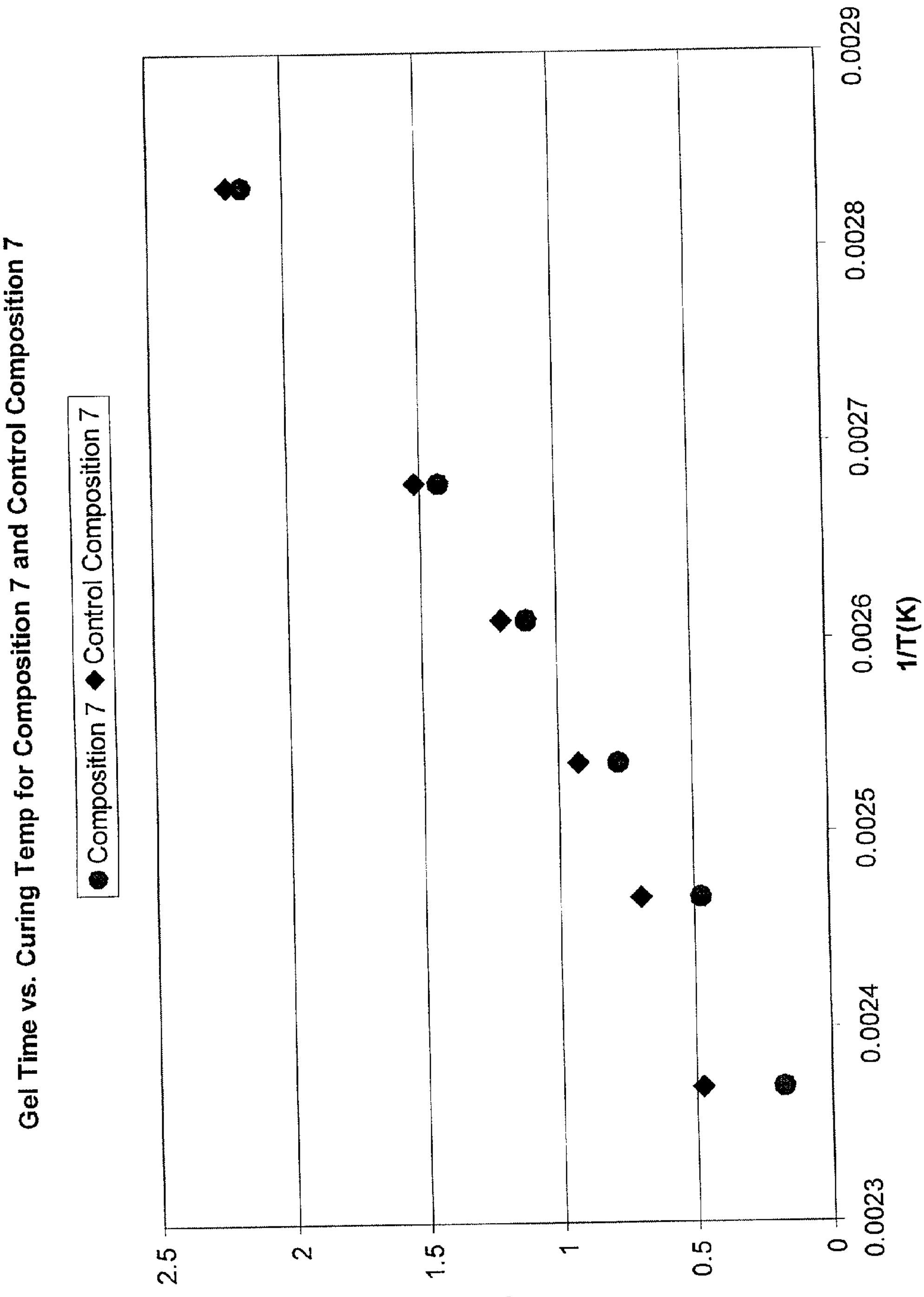

Gel Time vs. Curing Temp for Composition 7 and Control Composition 7
● Composition 7 ◆ Control Composition 7
LOG t_{gel} (min)
2.5
2
1.5
1
0.5
0
0.0023
0.0024
0.0025
0.0026
0.0027
0.0028
0.0029
1/T(K)

FIG. 3

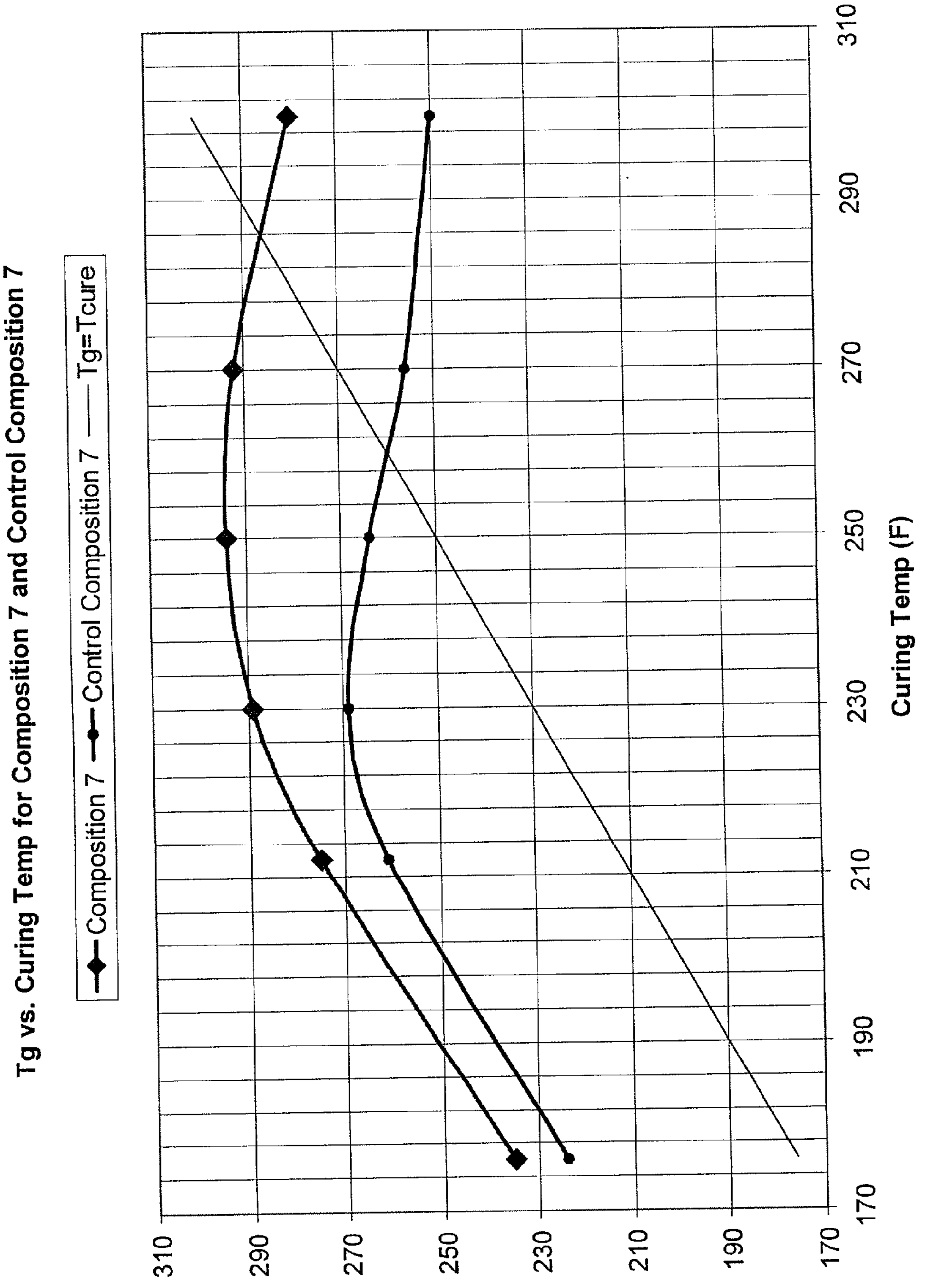

Tg vs. Curing Temp for Composition 7 and Control Composition 7
Composition 7
Control Composition 7
Tg=Tcure
Tg (F)
310
290
270
250
230
210
190
170
Curing Temp (F)
170
190
210
230
250
270
290
310

FIG. 4

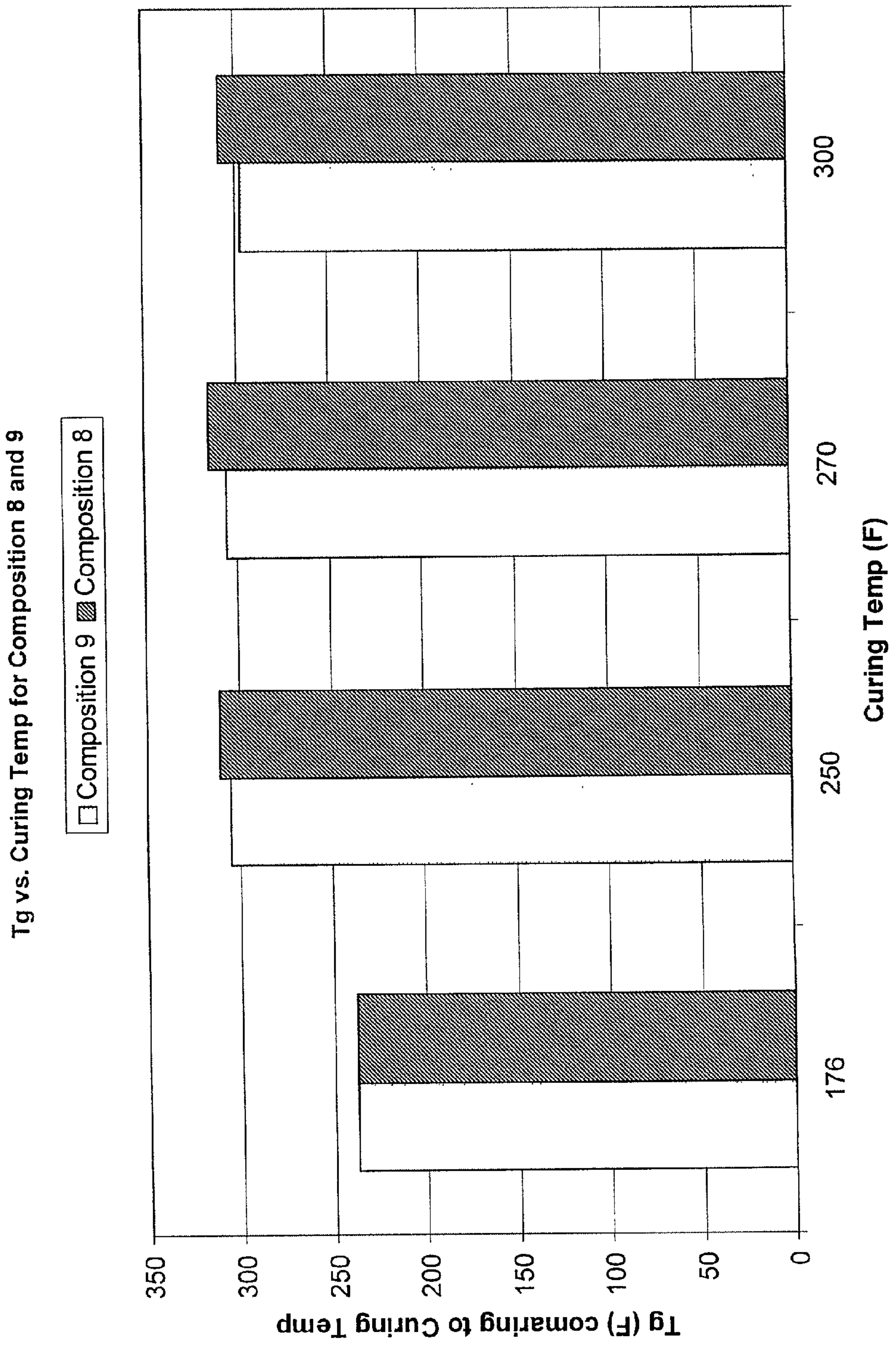

Tg vs. Curing Temp for Composition 8 and 9
☐ Composition 9 ▨ Composition 8
Tg (F) comaring to Curing Temp
350
300
250
200
150
100
50
0
176
250
270
300
Curing Temp (F)

FIG. 5

QUICK CURE CARBON FIBER REINFORCED EPOXY RESIN

FIELD OF THE INVENTION

[**0001**] The present invention generally relates to single part epoxy resin compositions, and more specifically, to quick cure and low temperature cure epoxy resin formulations suitable for use in prepregs, composites, and adhesive films.

BACKGROUND OF THE INVENTION

[**0002**] Advanced composites are increasingly used as reinforcing components in aircraft, automotive, and sporting goods applications. Typically, these composites comprise a strengthening component, such as carbon fibers, embedded in a thermosetting resin matrix. Components fabricated of such carbon fiber reinforced resin composites are produced by impregnating oriented carbon fibers (in the form of woven carbon cloth, or continuous carbon filaments) with thermosetting resins, and arranging the filaments of carbon fibers to form prepregs. Generally, prepregs include a paper backing onto which the fiber reinforcement is laid, and the selected resin is then forced into the fibers.

[**0003**] Thermosetting resins, which normally include a latent curing agent that is activated by increasing the temperature of the resin over a minimum cure temperature, are often preferred over two part resin systems that cure very quickly once the two parts are mixed. This preference arises from the ease of handling of thermosetting prepregs during the manufacture of components. Thermosetting prepregs can be produced in quantity with consistent properties, and stored at cold temperatures for a considerable length of time before use. Most of these thermosetting prepregs are provided as large rolls of material that include the paper backing and the epoxy impregnated fibers. To use this material, the desired portion is simply cut from the roll. In contrast, two part resin mixtures, which admittedly often have desirable properties, such as a rapid cure time, must be used immediately after being produced. Thus, component manufacturers can only produce small batches of composite material, and must then use each batch immediately after it is mixed. Furthermore, the chance that a bad batch of composite material will be produced on a manufacturer's production line is considerably higher than in a chemical plant where the focus is on the single task of producing a prepreg. The ease of use of prepregs is such that even though the curing performance of two part resin systems is generally better than that of thermosetting resins, prepregs are almost universally preferred for fabricating composite reinforcing components.

[**0004**] To fabricate a reinforcing component from prepregs, manufacturers generally apply multi-layer laminates of these prepregs over existing molds. To generate a rod or shaft, the prepreg is wound around a mandrel. Once a sufficient number of laminations have been achieved, the mold is heated to the cure temperature required to activate the latent curing agent in the thermosetting resin, using an oven or autoclave. Generally, a higher temperature results in a shorter cure time, while a lower temperature requires a longer cure time.

[**0005**] Suitable thermosetting epoxy resins generally have more that one epoxide group per molecule. In addition to the latent curing agent, which is often a functional amine, state-of-the-art epoxy matrix resin systems used in advanced composites often employ a catalyst, which helps to reduce cure times. It should be noted that cure times are important to end users of prepregs, especially when prepregs are used in conjunction with molds. Molds can range from the simple to the complex, depending on the component being produced. To ensure a high level of production quality, a manufacturer must spend considerable time and effort to ensure that each mold is identical. Furthermore, each mold must be able to be heated to activate the prepreg, thus increasing the equipment required for each mold. For example, in a golf shaft manufacturing process, commonly used prepregs need to be cured for more than 20 minutes at 150° C. in order to be removed from the mold or mandrel without changing shape. If a manufacturer can obtain a prepreg with a cure time that is one half that of a presently used product, then the manufacturer can double production without providing additional molds. It would therefore be desirable to provide an advanced epoxy resin system that substantially reduces cure time, to enable manufacturers to increase production without providing additional molds.

[**0006**] Because prepregs are often used to form reinforcing components, such as parts for airplanes, the resulting components must meet high quality standards. It is desirable that any reduction in cure time not negatively effect the physical properties, such as tensile strength, of such composite components.

[**0007**] In addition to preferring prepregs that have shorter cure times, composite component manufacturers also desire prepregs that cure at lower temperatures, particularly manufacturers who fabricate large scale composite components, such as those that might be employed in aviation or marine applications (boat hulls, for example). Low temperature curing prepregs are desirable for large parts manufacturing because such low temperatures require less sophisticated heating systems, and much reduced energy costs, which can be significant for large scale parts. Note that one major manufacturer of prepregs, Hexcel Corporation of Dublin, Calif., currently offers a low temperature curing prepreg (M34™), which cures at 65° C. (for 16 hours) or 75° C. for 8 hours. It would be desirable to provide an advanced epoxy resin system that substantially reduces cure time below that of currently available prepregs, particularly at low cure temperatures.

[**0008**] Many different types of epoxy resins systems are known in the art. Different combinations of epoxy resins, curing agents, and catalysts (also known as accelerators) have been formulated. A balance of desirable properties for prepregs include the following: (1) a tacky, dough-like consistency prior to curing; (2) low reactivity at room temperature; and, (3) a high degree of cure after heating for no more than 2 hours at nor more than 180° C. As noted above, the provision of a prepreg with a reduced cure time will offer component manufacturers significant efficiency advantages. Accordingly, there is an ongoing effort within the prepreg industry to produce a prepreg that has the desired consistency and low reactivity at room temperature, yet also exhibits reduced cure time at relatively low temperatures.

[**0009**] While certainly not an exhaustive compilation, the following patents provide examples of thermosetting resin compositions known in the art. International Patent Publication No. WO 99/36484 describes a composite system that includes an epoxy resin having two or more epoxide groups per molecule, a latent hardener, and at least one solid organic acid that is substantially insoluble in the resin formulation. U.S. Pat. No. 3,759,914 (Simms) discloses an epoxy resin formulation including a polyepoxide having a plurality of epoxide groups, a latent amine curing agent, and an accelerator having a defined formula. U.S. Pat. No. 3,386,956 (Nawakowski) describes an epoxy resin formulation including a dicyandiamide (DICY) curing agent and an accelerator to increase the cure rate at low temperatures (less than 187° F.). The disclosed accelerator is a bis-urea having a specifically defined formula. A similar epoxy formulation is disclosed in U.S. Pat. No. 3,386,956 (Harrison), which employs a polyamine curing agent and a phenyl urea based accelerator (see also U.S. Pat. No. 3,988,257 for related methods). U.S. Pat. No. 3,956,237 (Doorakian) describes an epoxy resin formulation including a latent amine curing agent and a latent accelerator. A number of latent accelerators are disclosed, including a specific blend of different isomers of toluene bis dimethyl urea. U.S. Pat. No. 3,386,956 (Nawakowski) describes low temperature curable epoxy resin compositions comprising a polyepoxide, a curing agent selected from bis-ureas, polyureas, and a promoter. The bis-ureas described include 2,4-toluene bis dimethylurea. U.S. Pat. No. 4,569,956 discloses a rapid, low temperature curing epoxy resin adhesive composition comprising a polyepoxide, a catalytic amount of HBF_4, a finely divided filler (preferably an acidic filler), and, optionally, a polyalkylene ether glycol. Yet another epoxy formulation is disclosed in U.S. Pat. No. 4,783,518 (Goel), which teaches a rapid curing epoxy composition including a polyepoxide, a latent amine curing agent, a novel thiocyanate salt of the reaction product of an alkylene polyamine (such as ethylene diamine), and a bicyclic amide acetal. U.S. Pat. No. 5,407,978 (Bymark), which employs a dihydric bisphenol curing agent and a immidazole based accelerator to increase the cure rate. As a final example, U.S. Pat. No. 5,599,629 (Gardner) describes an epoxy resin formulation including a resin with at least three epoxide groups per molecule and a specific aromatic amine latent curing agent, the aforementioned formulation being specifically employed to produce prepregs.

[**0010**] While the above-cited references all assert that a functional formulation having desirable properties is achieved, composite component manufacturers still desire a prepreg material having faster cure times, and/or lower cure temperatures. It would be desirable to provide an epoxy formulation differing than those described in the prior art, that is adaptable to being employed as a prepreg, and which provides shorter cure times and lower cure temperatures than existing prepregs provide.

[**0011**] It should be noted that several different methods can be used to fabricate prepregs, including a solventless, hot melt impregnation method, and a solvent method. In a typical hot melt impregnation process, continuous sheets of resin matrix film supported by release paper are impregnated into fiber sheets under heat, pressure, and tension. The matrix has to have a certain viscosity at impregnation temperature so that the resin can wet-up the fiber. Furthermore, specific tack, drape, and shelf-life characteristics are required when utilizing the hot melt method. In contrast, a solvent-diluting impregnation method does not have such strict requirements. However, a superior prepreg is often achieved by the hot melt method, because micro-voids, caused by off gassing of volatile solvent, are often observed in prepregs prepared by the solvent-diluting impregnation method. It would be desirable to provide an advanced epoxy resin system adaptable to be employed to produce a prepreg, that substantially reduces cure time, that can be used with either the hot melt impregnation method, or the solvent based impregnation method.

[**0012**] In addition, it should be noted that the time required for a prepreg to cure is not always the limiting factor determining when the cured prepreg can be removed from a mold. For example, a commonly utilized prepreg material is produced from an epoxy formulation including epoxy resin A (a diglycidyl ether of bisphenol A having an epoxide equivalent weight of 176), epoxy resin B (a diglycidyl ether of bisphenol A having an epoxide equivalent weight of 1200-1400), a thermoplastic additive (PVF powder), a DICY curing agent, and a catalyst (3,4-dichlorophenyl-N,N-dimehtylurea, available as DYHARD UR200™, made by SKW Trostberg). Depending on the specific proportions of the above ingredients employed, it is possible to produce a prepreg whose glass transition temperature (T_g) is significantly lower (20° C.) than the optimal cure temperature. For instance, manufacturers of composite shafts frequently employ mold temperatures of 300° F.-310° F. (147° C.-153° C.) to obtain rapid cure times. However, such temperatures are generally above the T_g of the resin component, and while the resin component is fully cured, it will be too soft to be removed from the mold. In such cases, a manufacturer must cool the mold below the T_g before removing the cured component from the mold. This cooling step is an additional, undesirable step, which increases the time required to produce a component, lowers the number of components that can be produced by a mold during a work cycle, and undesirably increases costs. It would therefore be desirable to provide an epoxy resin formulation, suitable for making prepregs, that exhibits reduced cure times, and having a cure temperature that is either less than or about (within 10° C. of) the T_g of the cured prepreg material. While high temperature curing resin systems are known, which have a cure temperature that is less than the T_g of the cured resin, such resin systems require long (in excess of two hours) cure times. The prior art does not teach or suggest a rapid curing epoxy resin formulation whose cure temperature is sufficiently close to the T_g of the cured resin so that cooling of the mold is not required.

[**0013**] It would further be desirable to provide an epoxy resin formulation that is not only suitable for making prepregs, which can also be beneficially employed to fabricate thermosetting resin adhesive film products by coating a relatively thin layer of resin onto a backing material, such as paper or film. Such a thermosetting resin adhesive film product will desirably have good workability at room temperature, and be activated by exposure to an appropriate temperature condition.

SUMMARY OF THE INVENTION

[**0014**] In accord with the present invention, a resin matrix composition is defined that includes an epoxy resin having more than one epoxide group per molecule, and a catalyst consisting of 2,4-toluene bis dimethyl urea, wherein a viscosity of said composition is less than about 20,000 poise at about 40° C. Preferably, the composition also includes at least one latent curing agent. In at least one embodiment, the at least one latent curing agent is a dicyanopolyamide, most preferably DICY.

[0015] In at least one embodiment, the composition further includes a thermoplastic additive. Preferably the thermoplastic additive is at least one selected from of the group consisting of polyvinylfluorides (PVFs), polymethylmethacrylates (PMMA), polyarylethersulfones (PES), polysulfone (PSF), polyimides (PIs), polyetherimides (PEIs), and polyethylene oxide (PEO).

[0016] Preferably the epoxy resin utilized in the composition includes diglycidyl ethers of bisphenols, examples of which are bisphenol A, bisphenol F, epoxy phenol novolacs, trifunctional epoxy resins, tetrafunctional epoxy resins, and halogenated derivatives thereof. More preferably, the diglycidyl ethers have an average of not more than two vicinal epoxy groups per molecule. When the epoxy resin is bisphenol A, it preferably has an epoxide equivalent weight from about 170 to about 1400. Alternatively, the bisphenol A that is employed is a blend of a first, bisphenol A-type epoxy resin having an epoxy equivalent in the range of from about 180 to about 195, and a second, bisphenol A-type epoxy resin having an epoxy equivalent in the range of from about 1200 to about 1400, the amount and the molecular weight of the second epoxy resin being such that the blended bisphenol A-type epoxy resin has a number average molecular weight in the range of from about 200 to about 300.

[0017] Preferably, an amount of the catalyst included in the composition ranges from about 0.5 to about 10 phr (i.e., parts per hundred of epoxy resin). Most preferably, the amount ranges from about 2 to about 5 phr.

[0018] In at least one embodiment, the composition of the present invention is 95% cured after being heated to 150° C. for five minutes, and/or 95% cured after being heated to 120° C. for 20 minutes. Preferably, after being cured at 150° C., the composition has a T_g that is higher than 140° C., such that the composition does not need to be cooled before being removed from a mold.

[0019] Another aspect of the present invention is directed to an article resulting from curing a composition like that described above, which also includes a reinforcing agent. Preferably the reinforcing agent is at least one selected from the group consisting of glass fibers, aramid fibers, graphite fibers, woven fibers, matted fibers, and unidirectional fibers. Another aspect of the present invention is directed to a resin matrix composition that includes an epoxy resin made from a diglycidyl ether of bisphenol, which has an average molecular weight in the range of from about 200 to about 300. The matrix composition also includes a latent amine curing agent, and a catalyst consisting of 2,4-toluene bis dimethyl urea.

[0020] Yet another aspect of the present invention is directed to a resin matrix composition that includes an epoxy resin, a latent amine curing agent, and 2,4-toluene bis dimethyl urea, which is used as a catalyst. The epoxy resin of such a composition preferably is made from a mixture of a diglycidyl ether of bisphenol A having an epoxide equivalent weight (EEW) of 176, and diglycidyl ether of bisphenol A having an epoxide equivalent weight (EEW) of 1200-1400.

[0021] Still another aspect of the present invention is directed to a resin matrix composition that includes an epoxy resin made from a mixture of a diglycidyl ether of bisphenol A having an epoxide equivalent weight (EEW) of 176, a diglycidyl ether of bisphenol A having an epoxide equivalent weight (EEW) of 1200-1400, and an epoxy phenolic novalac resin with a functionality of above 3.6, having an epoxide equivalent weight (EEW) of 174-180. Such a matrix composition also includes a latent amine curing agent, and a catalyst consisting of 2,4-toluene bis dimethyl urea.

[0022] Yet another aspect of the present invention is directed to a resin matrix composition that includes an epoxy resin made from a mixture of a diglycidyl ether of bisphenol A having an epoxide equivalent weight (EEW) of 176, a diglycidyl ether of bisphenol A having an epoxide equivalent weight (EEW) of 1200-1400, and a tetra-functional epoxy having an epoxide equivalent weight (EEW) of 117-134. The matrix composition preferably also includes a latent amine curing agent, and a catalyst consisting of 2,4-toluene bis dimethyl urea.

[0023] Still another aspect of the present invention is a prepreg that includes an epoxy composition and a reinforcing fiber. The epoxy composition includes an epoxy resin having more than one epoxide group per molecule, a latent amine curing agent, and a catalyst consisting of 2,4-toluene bis dimethyl urea. In at least one embodiment, the epoxy composition further includes a thermoplastic additive selected from the group consisting of PVFs, PMMAs, PESs, PSF, PIs, PEIs, and PEO.

[0024] A different aspect of the present invention is a prepreg whose epoxy composition includes an epoxy resin having more than one epoxide group per molecule, a latent amine curing agent, a catalyst consisting of 2,4-toluene bis dimethyl urea, and a polyvinyl formal dissolved into the epoxy composition. The reinforcing fiber of such a prepreg can include at least one of glass fibers, aramid fibers, graphite fibers, woven fibers, matted fibers, and unidirectional fibers.

[0025] Yet another prepreg of the present invention includes an epoxy composition including an epoxy resin having more than one epoxide group per molecule, a latent amine curing agent, a catalyst agent for reducing a cure time provided by the latent amine curing agent; and a reinforcing fiber. Prepregs according to this aspect of the invention have a gel time of less than 1.5 minutes at 150° C., and a glass transition temperature of no less than 140° C. when heated to a temperature of 150° C. Such prepregs reach a 95% cure after less than five minutes when heated to a temperature of 150° C., reach a 95% cure after less than 20 minutes when heated to a temperature of 120° C. Preferably, these prepregs employ a catalyst consisting of 2,4-toluene bis dimethyl urea.

[0026] Still another aspect of the present invention is a prepreg whose epoxy composition includes an epoxy resin having more than one epoxide group per molecule, a latent amine curing agent, and a catalyst agent for reducing a cure time provided by the latent amine curing agent. Such prepregs also include a reinforcing fiber. These prepregs are characterized by requiring no more than three minutes to reach a 95% cure at 150° C. Further, such prepregs have a glass transition temperature of no less than 142° C. when heated to a temperature of 150° C. such prepregs also preferably employ a catalyst consisting of 2,4-toluene bis dimethyl urea.

[**0027**] A further aspect of the present invention is a prepreg whose glass transition temperature, when 95% cured, is such that the cured prepreg does not need to be cooled before being removed from a mold. Such a prepreg includes an epoxy resin having more than one epoxide group per molecule, a latent amine curing agent, a catalyst agent for reducing a cure time provided by the latent amine curing agent, and a reinforcing fiber. Preferably, the catalyst consists of 2,4-toluene bis dimethyl urea.

[**0028**] A different aspect of the present invention is a method for decreasing a time required to reach a 95% cure for a thermosetting epoxy resin formulation. The method steps include providing an epoxy composition having epoxy resin with more than one epoxide group per molecule, and a latent amine curing agent. The method requires adding at least 0.5 phr of a catalyst to the epoxy composition, the catalyst reducing the time required to reach a 95% cure. The catalyst consists of 2,4-toluene bis dimethyl urea. The resulting mixture is then heated to a curing temperature, and the presence of the catalyst reduces the time required to reach a 95% cure. Preferably, the step of heating includes selecting a curing temperature such that a glass transition temperature of the epoxy composition when 95% cured and at the curing temperature enables a 95% cured epoxy composition to be removed from a mold without requiring the 95% cured epoxy composition to be cooled before being removed from that mold. More preferably, the glass transition temperature is either greater than the curing temperature, or no more than 10° C. less than the curing temperature. Generally, the epoxy composition also includes a reinforcing fiber.

[**0029**] Yet another aspect of the present invention is directed at a carbon fiber reinforced epoxy resin article, superior in mechanical properties, resulting from curing of the prepregs described above.

[**0030**] Still another aspect of the present invention is directed to an adhesive film, superior in handling and curing properties, resulting from depositing a thin layer of the epoxy resin formulation described above onto a substrate.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[**0031**] The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

[**0032**] FIGS. **1A-1C** (Prior Art) illustrate the chemical structures of exemplary epoxy curing accelerators;

[**0033**] **FIG. 1D** (Prior Art) illustrates the chemical structure of a preferred catalyst used in the present invention;

[**0034**] **FIG. 2** is a graph showing the relationship between gel time and catalyst content when preferred resin compounds are mixed with the preferred catalyst of **FIG. 1D** in accord with the present invention;

[**0035**] **FIG. 3** is a graph showing the relationship between gel time and curing temperature, comparing a resin formulation embodiment of the present invention with a prior art resin formulation;

[**0036**] **FIG. 4** is a graph showing the relationship between glass translation temperature and curing temperature, comparing a resin formulation embodiment of the present invention with a prior art resin formulation; and

[**0037**] **FIG. 5** is a graph showing the relationship between glass translation temperature and curing temperature, comparing a first resin formulation embodiment of the present invention with a second resin formulation embodiment of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

[**0038**] Overview of the Present Invention

[**0039**] The present invention defines a thermosetting epoxy composition including an epoxy resin, a latent amine curing agent, and a specific catalyst. The epoxy composition of the present invention offers significantly reduced cure time compared to the cure time of epoxy resin compositions described in the prior art. This reduction in cure times is achieved across a wide range of temperatures, such that the present invention can be employed in a low temperature (i.e., less than 85° C.) cure environment, as well in high temperature cure environments (i.e., greater than 140° C.). The epoxy composition of the present invention is suitable for use as a prepreg composition. When used as a prepreg, reinforcing fibers as well as specialty fillers can be included to enhance the physical properties of the cured resin. Significantly, a glass transition temperature of a 95% cured resin composition produced in accord with the present invention is sufficient that even during high temperature, fast cure applications, the 95% cured resin does not need to be cooled prior to being removed from a mold. Thus, the use of the prepregs formed in accord with the present invention enables composite component manufacturers to increase production rates without requiring additional molds be provided, by offering reduced cure times as well as eliminating the need to cool a cured resin component prior to removing it from a mold.

[**0040**] Preferably the epoxy resin includes two epoxide groups per molecule, and the latent amine curing agent is a dicyanopolyamide, most preferably (DICY). It should be noted that diaminodiphenyl sulfone (DDS) can also be beneficially employed as a latent amine curing agent, as well as mixtures of DICY and DDS. The specific catalyst is 2,4-toluene bis dimethyl urea. While other resin compositions are known in which 2,4-toluene bis dimethyl urea is employed alone or in conjunction with additional catalysts, the use of 2,4-toluene bis dimethyl urea with the specific epoxy resins disclosed below provides a startling and unexpected reduction in the curing time for prepregs. For example, a prepreg employing the epoxy composition of the present invention can achieve a 95% cure in about one half of the time required by a prepreg that differs only in the catalyst employed.

[**0041**] The prepregs used in the present invention are most preferably prepared by the solventless, hot-melt impregnation method to avoid the formation of microvoids caused by residual volatile solvent, which are sometimes observed in prepregs prepared by the solvent-diluting impregnation method. However, the present invention can be implemented in accord with the solvent-diluting method, as well.

[**0042**] Suitable resin compositions for the prepreg material of the present invention can be selected from among those discussed below. However, the resin compositions that can be used for the prepreg material are not limited to those specifically noted. Generally suitable epoxy resins have more than one epoxide group per molecule. Such resins include, for example, diglycidyl ethers of bisphenols, such as bisphenol A, bisphenol F, epoxy phenol novolacs, trifunctional epoxy resins, tetrafunctional epoxy resins, as well as the halogenated derivatives thereof. Chlorine and bromine are the most common halogens used to form such derivatives. Brominated epoxy can add anti-flammability to the composition. Preferred epoxy resins include diglycidyl ethers having an average of not more than two vicinal epoxy groups per molecule.

[0043] As noted above, the preferred latent curing agent is DICY, which is employed in amounts from about 4 to about 8 phr, most preferably in amounts from about 5 to about 7 phr. A key element of the present invention is the use of a specific urea-based catalyst or accelerator. It should be noted that the term catalyst and accelerator are both employed in the art to describe an ingredient that reduces curing time. While the latent amine curing agent is still responsible for the curing process, the presence of small amounts of catalysts or accelerators can significantly reduce cure times. Thus, it should be understood that the terms "catalyst" and "accelerator," as used herein and in the claims that follow, refer to a chemical agent that reduces a cure time achievable with a curing agent alone. The specific urea catalyst employed in the present invention to achieve the previously unexpected reduction in curing time is 2,4-toluene bis dimethyl urea. This catalyst is employed in amounts of about 0.5 to about 10 phr, more preferably in amounts from about 2 to about 5 phr, and most preferably in amounts from about 3 to about 5 phr.

[0044] Also as noted above, suitable thermoplastic additives can be added to prepregs made from the resin composition of the present invention. Such thermoplastic additives can include any one or more of PVFs, PMMAs, PESs, PSF, PIs, PEIs, PEO. More preferred thermoplastic additives include PVFs and PESs. The most preferred thermoplastic additives include PVFs. The thermoplastic additives are employed in amounts ranging from about 0 to about 8% by weight (based upon the weight of total blended composition). More preferred amounts range from about 1 to about 4%, and most preferred amounts range from about 2.5 to about 3.5% by weight.

[0045] It should also be noted that elastomeric additives can be added to prepregs made from the resin composition of the present invention. Such elastomeric additives can include any one or more of natural latex rubbers, synthetic latex rubbers, silicones, and other elastomers. The elastomeric additives are generally employed in amounts of less than 10% by weight (based upon the weight of total blended composition).

[0046] It is anticipated that a particularly useful prepreg can be obtained by adding to the resin composition of the present invention a reinforcing material. Suitable reinforcing materials can be in the form of fabric, unidirectional fibers, and the like. These reinforcing materials can be prepared from glass fibers, aramid fibers, carbon fibers, and the like.

[0047] As noted above, it is known in the prior art to employ urea-based catalysts to reduce the curing time achievable with latent amine curing agents alone. **FIG. 1A** illustrates a chemical structure 10 representing one such urea based catalyst, 2,6-toluene bis dimethyl urea. The use of this catalyst is described in U.S. Pat. No. 3,956,237, entitled "EPOXY RESIN COMPOSITIONS COMPRISING LATENT AMINE CURING AGENTS AND NOVEL ACCELELATORS," filed Jul. 8, 1974. In addition to describing the use of 2,6-toluene his dimethyl urea as a catalyst that is used alone, this patent also discloses employing a combination of both 2,6-toluene bis dimethyl urea and 2,4-toluene bis dimethyl urea as a catalyst. The reference teaches using 35-100% 2,6-toluene bis dimethyl urea, and 0-65% of 2,4-toluene bis dimethyl urea as a catalyst. **FIG. 1B** shows such a catalyst mixture, including a chemical structure 20 of 2,4-toluene bis dimethyl urea, as well as a chemical structure 10 for 2,6-toluene bis dimethyl urea, and the disclosed percentages. Significantly, however, the '237 patent does not disclose the use of 100% 2,4-toluene bis dimethyl urea as a catalyst.

[0048] **FIG. 1C** illustrates a chemical structure 40 for another catalyst known in the prior art, 100% 3,4-dichlorophenyl-N,N-dimethyl urea (DCMU). This catalyst, which is sold under the name of DYHARD UR200® by SKW Trostberg, (Trostberg, Germany) was used to fabricate a control sample identical to a test batch of the preferred embodiment of the present invention except for the catalyst employed. As the following examples will show, the present invention provides both high temperature and low temperature cure times that are about one half of the cure times achieved when DCMU is employed as a catalyst.

[0049] **FIG. 1D** illustrates the chemical structure of the preferred catalyst in the present invention, 100% 2,4-toluene bis dimethyl urea. This catalyst is sold as OMICURE U-24™ by CVC Specialty Chemicals, Inc. U.S. Pat. No. 3,386,956, entitled "LOW TEMPERATURE CURABLE EPOXY RESIN ADHESIVE COMPOSITIONS WITH LONG STORAGE STABILITY," discloses the use of 2,4-toluene bis dimethyl urea as a catalyst, combined with DICY and polyepoxides to provide a resin formulation that reaches a 76% cure after 90 minutes at temperature of 187° F. (87° C.). Significantly, however, this patent does not teach or suggest that employing 2,4-toluene bis dimethyl urea as a catalyst will provide a fast curing epoxy resin formulation at elevated temperatures (in excess of 87° C.). Furthermore, while the patent discloses that many types of polyepoxide resins can be employed for the resin component portion of the formulation containing a polyepoxide resin, DICY and a 2,4-toluene bis dimethyl urea catalyst, no specific class of epoxies are identified that are known or expected to provide a more rapidly curing epoxy formulation.

[0050] The present invention arises from a discovery that epoxy resin formulations comprising polyepoxide resin, DICY and a 2,4-toluene bis dimethyl urea catalyst can be employed to provide a fast curing resin at higher temperatures than reported in the art, and that specific blends of polyepoxides enable a substantial improvement over the 90 minute, 74% cure rate reported in the prior art to be achieved. As will be detailed below, one embodiment of the present invention is an epoxy resin formulation comprising a specific blend of polyepoxides, DICY, and a 2,4-toluene bis dimethyl urea catalyst that obtains a 95% cure at 130° C. in 19 minutes, and a 95% cure at 150° C. in as little as 3 minutes.

[0051] The resin composition of the present invention can be cured at 150° C. for 3 to 120 minutes and reach a translation glass temperature of higher than 140° C., more preferably for 3 to 60 minutes, and most preferably for 3 to 20 minutes.

[0052] The resin composition of the present invention can be cured at 80° C. for 5 to 16 hours and reach a translation glass temperature of higher than 100° C., more preferably for 5 to 12 hour, and most preferably for 5 to 8 hours. Furthermore, one unique aspect of the present invention is the ability to produce prepreg formulations that can be cured at high temperatures, which are very close to the glass transition temperature (T_g) of the formulation. In some prior art formulations, the high temperatures required for a rapid cure time have been so much higher (greater than 13° C.) than the T_g of the prior art formulations that such resin compositions normally required cooling before being removed from a mold. As the examples provided below show, the present invention yields a faster curing resin (about 3 minutes instead of about 7 minutes required using a conventional resin that employs DCMU as a catalyst), with a smaller difference between T_g and the cure temperature. Thus, it is not necessary to first cool a component fabricated from the cured resin of the present invention before removing the component from a mold.

[0053] It is anticipated that the rapid curing/high temperature curing resin composition and prepregs of the present invention can be used to produce sporting goods, automobile components, aerospace components, and marine components. Such uses, and the following examples are illustrative of specific applications of the present invention, but are not to be construed as limiting its scope. It is further anticipated that the known epoxy resin formulation disclosed in the prior patent referenced above (which discloses the use of 2,4-toluene bis dimethyl urea as a catalyst, combined with DICY and polyepoxides) can be employed at higher temperatures with reduced cure times than the 76% cure after 90 minutes (at temperature of 187° F./87° C.) disclosed in this prior art patent.

[0054] The following epoxy resins are employed in the examples discussed below. It should be noted that these specific blends of epoxy resins are not suggested by the prior art, and empirical data indicates that these specific blends provide surprisingly faster cure times than suggested by the prior art in regard to epoxy compositions employing different epoxy resin components. Furthermore, the resin formulations identified below are expected to have viscosity's that are less than 20,000 poise. Epoxy formulations of less than 20,000 poise are preferred, having favorable properties such as tackiness, which is useful for compositions to be employed as prepregs or adhesive films. It is anticipated that other epoxy formulations than those specifically enumerated below can be beneficially employed in the present invention, if such formulations have a viscosity of less 20,000 poise. In addition to having a particular viscosity, it is also preferred for formulations in accord with the present invention to have an average molecular weight of around 200-300. To achieve this desired range, a quantity of a relatively high molecular weight resin (i.e., a molecular weight over 1,000) will be mixed with an appropriate quantity of a relatively low molecular weight resin (i.e., a molecular weight less than 200).

[0055] Epoxy resin A is a diglycidyl ether of bisphenol A having an epoxide equivalent weight (EEW) of 176. It is anticipated that diglycidyl ethers of bisphenol A having EEW of 170-195 can also be beneficially employed.

[0056] Epoxy resin B is a diglycidyl ether of bisphenol A having an epoxide equivalent weight (EEW) of 1200-1400.

[0057] Epoxy resin C is an epoxy phenolic novalac resin with a functionality of above 3.6, having an EEW of 174-180.

[0058] Epoxy resin D is a tetra-functional epoxy having an EEW of 117-134.

[0059] Thermoplastic additive is PVF powder.

[0060] Curing agent is DICY.

[0061] Catalyst is 2,4-toluene bis dimethyl urea (sold as OMICURE U-24™, made by CVC Specialty Chemicals, Inc.).

[0062] Catalyst in the control resin composition is 3,4-dichlorophenyl-N,N-dimehtylurea (sold as DYHARD UR200™, made by SKW Trostberg).

Exemplary Epoxy Compositions 1-6

[0063] Epoxy resin compositions described in Examples 1-6 were prepared by blending 100 parts of epoxy resin A and B (divided as shown in Table 1), 3.4 parts of PVF, and 5 parts of DICY with 0.5, 1, 2, 3, 4, and 5 parts of U-24, respectively. The gel time of each composition was determined by a gel machine at 150° C. Resin samples of each composition were cured at 150° C. for 15 minutes in an oven. The cured resin T_g was determined by dynamic mechanic analysis (DMA) on a TA Instruments machine, Model 2980.

TABLE 1

	Composition No./Amount (parts)					
	1	2	3	4	5	6
Epoxy Resin A	76.4	76.4	76.4	76.4	76.4	76.4
Epoxy Resin B	23.6	23.6	23.6	23.6	23.6	23.6
PVF	3.4	3.4	3.4	3.4	3.4	3.4
DICY	5.0	5.0	5.0	5.0	5.0	5.0
U24	0.5	1	2	3	4	5
Gel Time @ 150° C. (min.)	6.4	3.3	2.2	1.8	1.6	1.3
Tg by DMA G' (° C.)	119	130	140	145	141	140

[0064] **FIG. 2** illustrates a graph showing the relationship between U-24 content and gel time.

Exemplary Epoxy Composition 7

[0065] An epoxy resin composition having the following formulation was prepared by blending 100 parts of epoxy A and B (in the relative amounts shown in Table 2), 3.4 parts of PVF, 5 parts of DICY, with 4.2 parts of U-24. The viscosity of the resin or resin mixture was determined by a Rheometric Model ARES plate rheometer running from about 40° C. to about 160° C. at 2° C./minute temperature ramp, and at a 10 rpm frequency. The heat stability was determined by the viscosity increase versus the time at 70° C. The gel time was determined by a gel machine. Digital Scanning Calorimetry was utilized to monitor the time to reach 95% cure. The total heat detected during the DSC measurement is identified to the heat evolved by the curing reaction when resin was heat from 10° C. to 225° C. at 10° C./min rate. The degree of curing was given by

$$\text{cure }\% = \frac{(\Delta Hi - \Delta He)}{\Delta Hi} \times 100$$

[**0066**] where ΔHi is the heat generated by the uncured resin heated from 10° C. up to fully cured at 225° C. and ΔHe the heat generated by the certain degree cured resin heated up to fully cured at 225° C.

[**0067**] The value of T_g was determined by dynamic mechanic analysis (DMA) on an Alpha Technologies Model APA 2000.

[**0068**] A resin sample was degassed and poured into a mold consisting of two 13 in.x13 in.x0.125 in. (330 mmx330 mmx3.175 mm) polished steel plates, separated by 0.125 in (3.175 mm) silicone rubber spacers. The case mixtures were allowed to cure at about 120° C. for about 120 min. After cooling, the cast sheet was demolded and prepared for testing by the following methods: ASTM D-638 (tensile); ASTM D-790 (flexural); and ASTM D-5045 (fracture toughness).

Control Epoxy Composition 7

[**0069**] An epoxy resin composition having the following composition was prepared by blending 100 parts of epoxy A and B (in the relative amounts shown), 3.4 parts of PVF, 5 parts of DICY, with 4.2 parts of UR200. The resins and resin mixtures and results of the experiments are given in Table 2.

TABLE 2

	Composition 7	Control Composition 7
Epoxy resin A parts	76.4	76.4
Epoxy resin B parts	23.6	23.6
PVF parts	3.4	3.4
DICY parts	5.0	5.0
U24 parts	4.2	
UR200 parts		4.2
Total parts	112.6	112.6
Gel time (min.)		
@ 130° C.	3.9	6.0
@ 150° C.	1.5	3.0
Time to reach 95% cure (min)		
@ 130° C.	19	50
@ 150° C.	3	10
Tg (° C.) (Max G")		
Cured at 130° C. for 60 min	142	125
Tensile		
Ult. Strength, ksi	12.2	10.8
Modulus, msi	0.46	0.43
Elongation, %	5.0	3.9
Flexure		
Yield Strength, ksi	19.2	18.1
Modulus, msi	0.46	0.45
Compression		
Yield Strength, ksi	16.3	15.2
Modulus, msi	0.45	0.45
K_{1c} (ksi-in$^{1/2}$)	1.16	0.83

Properties of Exemplary Epoxy Composition 7 and Control Epoxy Composition 7

[**0070**] The resin compositions of Exemplary Epoxy Composition 7 and Control Epoxy Composition 7 were tested for isothermal cure properties at 176° F. (80° C.), 212° F. (100° C.), 230° F. (110° C.), 250° F. (121° C.), 270° F. (132° C.), and 300° F. (149° C.). All tests were done on the ALPHA Technologies APA 200 equipped with parallel plate pies. **FIGS. 3 and 4** show the gel time and T_g of these resins (Exemplary Epoxy Composition 7 and Control Epoxy Composition 7) cured at the afore mentioned temperatures.

[**0071**] Next, a frozen resin block of Exemplary Epoxy Composition 7 was heated at 70° C. for a short time and coated onto a releasing paper to obtain a resin film. This resin film was set in a prepreg machine and impregnated into a sheet of unidirectional arranged carbon fiber (Type T600S, commercially available from Toray Industries, Inc.) to obtain a prepreg having a resin content Wr of 42%.

[**0072**] Exemplary Prepreg 1 (prepared from Exemplary Epoxy Composition 7) was cured at 135° C. for 2 hours and tested for mechanical properties. Exemplary Prepreg 2 (also prepared from Exemplary Epoxy Composition 7) was cured at 80° C. for 5 hours and tested for mechanical properties. Table 3 reveals the cure characteristics of these two prepreg examples.

TABLE 3

	Cured at 135° C./2 hr	Cured at 80° C./5 hr
0° Tensile		
Strength (ksi)	377	367
Modulus (msi)	19.9	20.1
Strain (%)	1.8	1.8
90° Tensile Strength (ksi)	8.2	6.7
0° Compression Strength (ksi)	201	220
ILSS (ksi)	11.7	12.2
0° Flexure		
Strength (ksi)	254	282
Modulus (ksi)	20.8	20.2
+/− 45° IPS Strength (ksi)	18.5	16.1
T_g by DMA G' (° C.)	144	118

[**0073**] The resin composition and prepregs of the present invention can cure about twice as fast as the control materials, and have a T_g that is higher than the cure temperature when used as a 250° F. cure system. Their shelf life and work life (heat stability) are as good as the slow cured control materials. Furthermore, the resin composition and prepregs of the present invention can also be used in low temperature curing application such as at curing at 80° C.

Exemplary Epoxy Compositions 8 and 9

[0074] Epoxy resin compositions 8 and 9 were prepared by blending 100 parts of epoxy A, B and C or A, B and D (in the relative amounts shown in Table 3), 3.4 parts of PVF, 5 parts of DICY, with 4.2 parts of U-24. The resin compositions 8 and 9 were tested for isothermal cure properties at 176F (80° C.), 250F (121° C.), 270F (132° C.), and 300F (149° C.). All tests were done on the ALPHA Technologies APA 200 equipped with parallel plate pies. The value of T_g was determined by dynamic mechanic analysis (DMA) on an Alpha Technologies Model APA 2000.

TABLE 4

	Composition 8	Composition 9
Epoxy resin A parts	37.5	63.5
Epoxy resin B parts	23.6	23.6
Epoxy resin C parts	38.9	
Epoxy resin D parts		12.9
PVF parts	3.4	3.4
DICY parts	5.0	5.0
U24 parts	4.2	4.2
Total parts	112.6	112.6

[0075] **FIG. 5** shows the T_g of these resins cured at the previously mentioned temperatures.

[0076] It should be noted that there exist several different methods of measuring and reporting T_g. For example, when storage modulus (G'), loss modulus (G"), and Tan Delta versus temperature curves are plotted for a polymer, the T_g can be generally identified by the portion of the curve that has a pronounced change in slope. How that slope is interpreted results in differences in reported T_g values. For example, T_g values can be expressed as onset G' values, mid-point on G' slope values, Max G" values, and Max Tan Delta values, each representing a different portion of the heat versus temperature curve. The selected value is generally based on some preference of the user, or a default employed by a specific analytical unit. It should be noted that the T_g values listed in Table 1 are the mid-point on G' slope values, while the T_g values listed in Table 2 and **FIGS. 4 and 5** are Max G" values.

[0077] Although the present invention has been described in connection with the preferred form of practicing it, those of ordinary skill in the art will understand that many modifications can be made thereto within the scope of the claims that follow. Accordingly, it is not intended that the scope of the invention in any way be limited by the above description, but instead be determined entirely by reference to the claims that follow.

The invention in which an exclusive right is claimed is defined by the following:

1. A resin matrix composition comprising:

(a) an epoxy resin having more than one epoxide group per molecule; and

(b) a catalyst consisting of 2,4-toluene bis dimethyl urea, wherein a transition glass temperature of said resin matrix composition is higher than about 140° C. after being heated to 150° C. for as little as 3 minutes.

2. The resin matrix composition of claim 1, further comprising at least one latent curing agent.

3. The resin matrix composition of claim 2, wherein said at least one latent amine curing agent comprises a dicyanopolyamide.

4. The resin matrix composition of claim 2, wherein at least one latent amine curing agent comprises dicyandiamide.

5. The resin matrix composition defined by claim 1, further comprising a thermoplastic additive.

6. The resin matrix composition of claim 5, wherein said thermoplastic additive is at least one selected from the group consisting of polyvinylfluorides (PVFs), polymethylmethacrylates (PMMAs), polyarylethersulfones (PESs), polysulfone (PSF), polyimides (PIs), polyetherimides (PEIs), and polyethylene oxide (PEO).

7. The resin matrix composition of claim 1, wherein said epoxy resin comprises least one epoxy resin selected from the group consisting of: bisphenol A based epoxy resins, bisphenol F based epoxy resins, epoxy phenol novolacs, trifunctional epoxy resins, tetrafunctional epoxy resins, and halogenated derivatives thereof.

8. The resin matrix composition of claim 7, wherein said bisphenol A based epoxy resin has an epoxide equivalent weight of from about 170 to about 1400.

9. The resin matrix composition of claim 7, wherein said bisphenol A based epoxy resin is a blend of a first, bisphenol A based epoxy resin having an epoxy equivalent in the range of from about 180 to about 195 and a second, bisphenol A based epoxy resin having an epoxy equivalent in the range of from about 1200 to about 1400, the amount and the molecular weight of said second epoxy resin being such that the blended bisphenol A based epoxy resin has a number average molecular weight in the range of from about 200 to about 300.

10. The resin matrix composition of claim 1, wherein an amount of said catalyst ranges from about 0.5 to about 10 phr.

11. The resin matrix composition of claim 10, wherein said amount ranges from about 2 to about 5 phr.

12. The resin matrix composition of claim 1, wherein said composition is more than 95% cured after being heated to about 150° C. for about five minutes.

13. The resin matrix composition of claim 1, wherein said composition is more than 95% cured after being heated to about 120° C. for about 20 minutes.

14. A resin matrix composition comprising:

(a) an epoxy resin having more than one epoxide group per molecule; and

(b) a catalyst consisting of 2,4-toluene bis dimethyl urea, wherein a transition glass temperature of said resin matrix is higher than about 100° C. after being heated to 80° C. for as little as 5 hours.

15. The resin matrix composition of claim 14, further comprising at least one latent curing agent.

16. The resin matrix composition of claim 15, wherein said at least one latent amine curing agent comprises a dicyanopolyamide.

17. The resin matrix composition of claim 15, wherein at least one latent amine curing agent comprises dicyandiamide.

18. The resin matrix composition defined by claim 14, further comprising a thermoplastic additive.

19. The resin matrix composition of claim 18, wherein said thermoplastic additive is at least one selected from the group consisting of polyvinylfluorides (PVFs), polymethylmethacrylates (PMMAs), polyarylethersulfones (PESs), polysulfone (PSF), polyimides (PIs), polyetherimides (PEIs), and polyethylene oxide (PEO).

20. The resin matrix composition of claim 15, wherein said epoxy resin comprises at least one epoxy resin selected from the group consisting of: bisphenol A based epoxy resins, bisphenol F based epoxy resins, epoxy phenol novolacs, trifunctional epoxy resins, tetrafunctional epoxy resins, and halogenated derivatives thereof.

21. The resin matrix composition of claim 20, wherein the bisphenol A based epoxy resin has an epoxide equivalent weight of from about 170 to about 1400.

22. The resin matrix composition of claim 20, wherein the bisphenol A based epoxy resin is a blend of a first, bisphenol A based epoxy resin having an epoxy equivalent in the range of from about 180 to about 195 and a second, bisphenol A based epoxy resin having an epoxy equivalent in the range of from about 1200 to about 1400, the amount and the molecular weight of said second epoxy resin being such that the blended bisphenol A based epoxy resin has a number average molecular weight in the range of from about 200 to about 300.

23. The resin matrix composition of claim 14, wherein an amount of said catalyst ranges from about 0.5 to about 10 phr.

24. The resin matrix composition of claim 23, wherein said amount ranges from about 2 to about 5 phr.

25. The resin matrix composition of claim 14, wherein a transition glass temperature thereof is higher than about 118° C. after being heated to 80° C. for 5 hours.

26. An article resulting from curing the resin matrix composition of claim 1, said resin matrix composition further comprising a reinforcing agent.

27. The article of claim 26, wherein said reinforcing agent comprises at least one selected from the group consisting of glass fibers, aramid fibers, and graphite fibers, and wherein said fibers comprise at least one of woven fibers, matted fibers, and unidirectional fibers.

28. An adhesive film resulting from curing the resin matrix composition of claim 1, said resin matrix composition further comprising a supporting material.

29. The adhesive film of claim 28, wherein said supporting material comprises at least one selected from the group consisting of polyester and nylon.

30. A prepreg comprising:

(a) an epoxy composition including:

(i) an epoxy resin having more than one epoxide group per molecule; and

(ii) a catalyst consisting of 2,4-toluene bis dimethyl urea, wherein a transition glass temperature of said epoxy composition is higher than about 140° C. after being heated to 150° C. for as little as 3 minutes;

(b) a plurality of reinforcing fibers.

31. The prepreg of claim 30, wherein said plurality of reinforcing fibers comprise at least one type of reinforcing fiber selected from the group consisting of glass fibers, aramid fibers, graphite fibers, woven fibers, matted fibers, and unidirectional fibers.

32. The prepreg of claim 30, further comprising at least one latent curing agent.

33. The prepreg of claim 32, wherein said at least one latent amine curing agent comprises a dicyanopolyamide.

34. The prepreg of claim 32, wherein said at least one latent amine curing agent comprises dicyandiamide.

35. The prepreg of claim 30, further comprising a thermoplastic additive.

36. The prepreg of claim 35, wherein said thermoplastic additive comprises at least one thermoplastic additive selected from the group consisting of polyvinylfluorides (PVFs), polymethylmethacrylates (PMMAs), polyarylethersulfones (PESs), polysulfone (PSF), polyimides (PIs), polyetherimides (PEIs), and polyethylene oxide (PEO).

37. The prepreg of claim 30, wherein said epoxy resin comprises at least one epoxy resin selected from the group consisting of: bisphenol A based epoxy resins, bisphenol F based epoxy resins, epoxy phenol novolacs, trifunctional epoxy resins, tetrafunctional epoxy resins, and halogenated derivatives thereof.

38. The prepreg of claim 37, wherein the bisphenol A based epoxy resin has an epoxide equivalent weight of from about 170 to about 1400.

39. The prepreg of claim 37, wherein the bisphenol A based epoxy resin is a blend of a first, bisphenol A based epoxy resin having an epoxy equivalent in the range of from about 180 to about 195 and a second, bisphenol A based epoxy resin having an epoxy equivalent in the range of from about 1200 to about 1400, the amount and the molecular weight of said second epoxy resin being such that the blended bisphenol A based epoxy resin has a number average molecular weight in the range of from about 200 to about 300.

40. The prepreg of claim 30, wherein an amount of said catalyst ranges from about 0.5 to about 10 phr.

41. The prepreg of claim 40, wherein said amount ranges from about 2 to about 5 phr.

42. The prepreg of claim 30, wherein said prepreg is more than 95% cured after being heated to about 150° C. for less than five minutes.

43. The prepreg of claim 30, wherein said prepreg is more than 95% cured after being heated to about 120° C. for less than 20 minutes.

44. A prepreg comprising:

(a) an epoxy composition including:

(i) an epoxy resin having more than one epoxide group per molecule; and

(ii) a catalyst consisting of 2,4-toluene bis dimethyl urea, wherein a transition glass temperature of said epoxy composition is higher than about 100° C. after being heated to 80° C. for as short as 5 hours; and

(b) a plurality of reinforcing fibers.

45. The prepreg of claim 44, wherein said plurality of reinforcing fibers comprise at least one type of reinforcing fiber selected from the group consisting of glass fibers, aramid fibers, graphite fibers, woven fibers, matted fibers, and unidirectional fibers

46. The prepreg of claim 44, further comprising at least one latent curing agent.

47. The prepreg of claim 46, wherein said at least one latent amine curing agent comprises a dicyanopolyamide.

48. The prepreg of claim 46, wherein at least one latent amine curing agent comprises dicyandiamide.

49. The prepreg defined by claim 44, further comprising a thermoplastic additive.

50. The prepreg of claim 49, wherein said thermoplastic additive comprises at least one thermoplastic additive selected from the group consisting of polyvinylfluorides (PVFs), polymethylmethacrylates (PMMAs), polyarylethersulfones (PESs), polysulfone (PSF), polyimides (PIs), polyetherimides (PEIs), and polyethylene oxide (PEO).

51. The prepreg of claim 44, wherein said epoxy resin comprises at least one epoxy resin selected from the group consisting of: bisphenol A based epoxy resins, bisphenol F based epoxy resins, epoxy phenol novolacs, trifunctional epoxy resins, tetrafunctional epoxy resins, and halogenated derivatives thereof.

52. The prepreg of claim 51, wherein the at bisphenol A based epoxy resin has an epoxide equivalent weight of from about 170 to about 1400.

53. The prepreg of claim 51, wherein the bisphenol A based epoxy resin is a blend of a first bisphenol A based epoxy resin having an epoxy equivalent in the range of from about 180 to about 195 and a second, bisphenol A based epoxy resin having an epoxy equivalent in the range of from about 1200 to about 1400, the amount and the molecular weight of said second epoxy resin being such that the blended bisphenol A based epoxy resin has a number average molecular weight in the range of from about 200 to about 300.

54. The prepreg of claim 44, wherein an amount of said catalyst ranges from about 0.5 to about 10 phr.

55. The prepreg of claim 54, wherein said amount ranges from about 2 to about 5 phr.

56. The prepreg of claim 44, wherein a transition glass temperature thereof is higher than about 118° C. after being heated to 80° C. for 5 hours.

57. A method to enable a thermosetting epoxy resin formulation to rapidly reach a 95% cure, said method comprising the steps of:

(a) providing an epoxy composition including an epoxy resin having more than one epoxide group per molecule, and a latent amine curing agent;

(b) mixing at least 0.5 phr of a catalyst in said epoxy composition, said catalyst reducing the time required to reach a 95% cure and consisting of 2,4-toluene bis dimethyl urea; and

(c) heating said epoxy composition with said catalyst to at 150° C. for at least 3 minutes, said catalyst substantially decreasing the time required to reach a 95% cure.

58. The method of claim 57, wherein a glass transition temperature of the epoxy composition is from about 140° C. to greater than 150° C.

59. The method of claim 57, wherein said epoxy composition further comprises a plurality of reinforcing fibers.

* * * * *