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ORIGINAL PAPER

Tannic acid-based tough hyperbranched epoxy thermoset as an advanced environmentally sustainable high-performing material

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Abstract Bio-based resources are progressively replacing those of petroleum-based to address the detrimental impact on environment and health issues. In this regard, hyperbranched epoxy resins with three different compositions were synthesized by simple polycondensation reaction of bio-based branching reactant, diethanolamide of gallic acid with bisphenol-A, and epichlorohydrin. Diethanolamide of gallic acid was obtained from the reaction between tannic acid and diethanol amine in the presence of sodium methoxide catalyst. FTIR, ^{1}H NMR, and ^{13}C NMR spectroscopic analyses were employed to confirm the structure of branching unit and hyperbranched resins. Poly(amido amine)-cured hyperbranched epoxy thermosets exhibited superior properties, such as tensile strength (45–57.2 against 38.5 MPa), elongation-at-break (16.3–24.2 against 5 %), scratch hardness (>10 against 7 kg), toughness (577.8–859.1 against 150.2 MPa), tensile adhesive strength (1647–2086 against 581 MPa), and biodegradability (17.6–31 against 2.2 %), compared with the conventional bisphenol-A-based epoxy, prepared under the same conditions. These results simply indicate the advantageous of the bio-based moiety and hyperbranched architecture on the overall performance of the thermosets. Moreover, good antioxidative response of these thermosets expands their applications as protective coatings and adhesive materials. Thus, diethanolamide of gallic acid-based hyperbranched epoxy thermoset can be used as potent ecofriendly advanced material in multifaceted applications.

Keywords Hyperbranched epoxy · Tannic acid · Biodegradability · Antioxidant · Performance

Introduction

Since the time of their production, epoxy thermosets have occupied conspicuous position in industry as binders in coatings and paints, adhesives, electrical insulating materials, water proofing materials, etc, because of remarkable adhesive strength, tensile strength, thermostability, and resistance towards weather and different chemical environments [1–3]. However, certain shortcomings, such as high brittleness and low toughness, of the conventional bisphenol-A-based epoxy thermosets impeded their utility in numerous advanced applications. In this regard, hyperbranched epoxy (HBE) resins have gained tremendous attention, because of their distinctive structural architecture that offers several useful characteristics over the conventional epoxy resins [4–6]. Furthermore, simple one-pot preparative techniques allow mass scale production of HBE unlike analogous dendrimer [7–9].

Again, similar to many other synthetic materials, fossil fuel-based resources have been the major targeted raw materials for obtaining HBE in the past. However, mankind has tough times to confront continuous depletion of these non-renewable resources owing to the sole dependence on such resources over several decades for various related products [10]. Waste disposal is another severe environmental problem evoked by the fossil fuel-based materials, which are rendering our planet into a perilous state. Thus, most of the reported petroleum-based HBE resins are not environmentally benign. Moreover, multistep synthetic protocol has been employed to obtain the desired branch generating moiety for such HBE, as well as such resinification

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