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Review

Synthesis and application of epoxy resins: A review

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ABSTRACT

Epoxy resins have been widely used for coatings, electronic materials, adhesives, and matrices for fiber-reinforced composites because of their outstanding mechanical properties, high adhesion strength, good heat resistance, and high electrical resistance. The final properties of cured epoxy resins are affected by the type of epoxy resin, curing agent, and curing process. This paper aims to review the synthesis, curing process, and application of epoxy resins.

Contents

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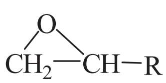
Introduction

Epoxy resins were discovered in 1909 by Prileschajew [1]. Epoxy resins are defined as low-molecular-weight pre-polymers containing more than one epoxide group of the form [2]:



Epoxy resins are thermosetting resins, which are cured using a wide variety of curing agents via curing reactions. Their properties depend on the specific combination of the type of epoxy resins and curing agents used [3–15]. Because of their excellent mechanical properties, high adhesiveness to many substrates, and good heat and chemical resistances, currently epoxy resins are intensively used across a wide range of fields, where they act as fiber-reinforced materials, general-purpose adhesives, high-performance coatings, and encapsulating materials [16–25].

In this paper, the synthesis and curing process of epoxy resins are reviewed in detail. In addition, the preparation and application of epoxy-based composites are discussed.

Synthesis of epoxy resins

Bisphenol-A epoxy resins

The diglycidyl ether of bisphenol-A (DGEBA) is produced by reacting epichlorohydrin with bisphenol-A in the presence of a basic catalyst. Fig. 1 shows the chemical structure of DGEBA. The properties of the DGEBA resin depend on the number of repeating units. Low-molecular-weight molecules tend to be liquids and higher-molecular-weight molecules tend to be more-viscous liquids or solids [26,27].

Yang et al. [28] synthesized a low viscosity epoxy resin by reaction of polyethylene glycol and DGEBA epoxy resin. The epoxy resin cured using a cationic photoinitiator under UV light, and the curing degree of the epoxy resin was beyond 90% within 40 s, as shown in Fig. 2. Czub [29] synthesized high-molecular-weight epoxy resins from modified natural oils and bisphenol A or bisphenol A-based epoxy resins. The resulting epoxy resins are highly viscous liquids. Wu et al. [30] synthesized liquefied bamboo–bisphenol A copolymer epoxy resins in a two-step process. The copolymer epoxy resin curing process can occur at room temperature after addition of triethylene tetramine, since curing is an exothermic reaction.

Cycloaliphatic epoxy resins

The cycloaliphatic epoxy resin (CAE), 3′,4′-epoxycyclohexylmethyl 3,4-epoxycyclohexanecarboxylate is synthesized by reacting 3′-cyclohexenylmethyl 3-cyclohexenecarboxylate with peracetic acid. Fig. 3 shows the chemical structure of CAE. This epoxy resin has an aliphatic backbone and a fully saturated molecular structure, which contribute to its excellent UV stability, good weatherability, good thermal stability, and excellent electrical properties. These properties are crucial for resins used to fabricate structural components requiring application in high-temperature environments [31,32].

Tao et al. [33] synthesized imide ring and siloxane-containing CAE, 1,3-bis[3-(4,5-epoxy-1,2,3,6-tetrahydrophthalimido) propyl] tetramethyldisiloxane (BISE), by a two-step procedure. Fig. 4 shows the chemical structure of BISE. The fully cured BISE epoxy resin has good thermal stability and a relatively low glass transition temperature (T_g) compared with commercially available CAE, as shown in Table 1.

Gao et al. [34] also synthesized transparent cycloaliphatic epoxy-silicone resins through a two-step reaction route for use in opto-electronic devices packaging. In comparison with CAE, the cured cycloaliphatic epoxy-silicone resins exhibited better thermal stability, lower water absorption, and higher UV/thermal resistance.

Trifunctional epoxy resins

A trifunctional epoxy resin, trimethylol propane-*N*-triglycidyl ether, can be prepared by the reaction of trimethylol propane and epichlorohydrin, as shown in Fig. 5. This epoxy resin is a low-viscosity, non-crystalline, plastic material that can be cured at low temperatures [35,36].

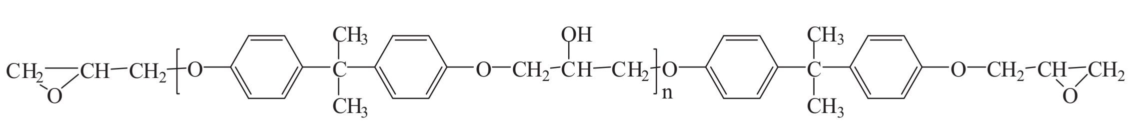


Fig. 1. Chemical structure of DGEBA.