INSTANT BONDING EPOXY TECHNOLOGY

Chunfu Chen

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Instant Bonding Epoxy Technology

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FOREWORD

Instant Bonding Epoxy Technology describes in a comprehensive manner the fundamental theory and application knowledge of epoxy adhesive formulation technology with a focus on the latest developments—for the first time —in instant bonding epoxy technology and application: UV cure cationic epoxy, dual cure hybrid epoxy, snap thermal cure epoxy, induction cure epoxy, and snap ambient cure epoxy technologies. Written by an internationally leading expert with long-time working experience in epoxy adhesive technology, Instant Bonding Epoxy Technology is an invaluable resource for researchers, formulation chemists, and application engineers related to polymer science and technology in both academia and industry.

Dr. Chen deserves praise and thanks from the adhesion and adhesive community for distilling his vast experience in this book. All those involved or interested in adhesive bonding will find this book an indispensable reference.

K.L. Mittal
Former Editor-in-Chief, Journal of Adhesion Science and Technology
Former Editor-in-Chief, Reviews of Adhesion and Adhesives
Edison, NJ, USA

PREFACE

Epoxy adhesives form very strong and durable bonds with most materials and have been widely used as typical reactive adhesives in various bonding applications. A relatively long cure time, ranging from several days at room temperature to at least tens of minutes at elevated temperature, is usually required to cure epoxy adhesives. Recently, several new types of epoxy adhesives that can bond adherends instantly at the specified curing condition while still possessing satisfactory adhesion performance after full cure have been developed and successfully used in advanced applications, such as general bonding, semiconductor packaging, and electronics assembly.

This book describes comprehensive fundamental theory and application knowledge of epoxy adhesive formulation technology. The focus is on basic chemistry, cure methods, and equipment, as well as the latest application developments in instant bonding epoxy technology. The book is divided into six chapters. The Introduction chapter covers basic chemistry in formulating epoxy adhesives with a comprehensive description of various types of epoxy resins, curing agents, and epoxy formulations. Chapter 2 describes fundamental chemistry, UV cure equipment, UV cure epoxy adhesive, and application developments in UV cure cationic epoxy technology. Chapter 3 discusses acrylate chemistry, dual cure hybrid epoxy adhesive, and application developments in UV and thermal cure hybrid epoxy technology. Chapter 4 describes the fundamental chemistry of one-component thermal cure epoxy adhesive and application developments in snap thermal cure epoxy adhesive technology. Chapter 5 discusses fundamental chemistry, the induction heating principle, and induction cure equipment, as well as the introduction to the application of induction cure epoxy technology. Chapter 6 introduces snap ambient cure epoxy technology: fast room temperature cure epoxy adhesive, cyanoacrylate hybrid epoxy adhesive, and UV and room temperature cure epoxy adhesive technology.

As the first comprehensive overview of instant bonding epoxy technology, this book is an invaluable textbook for researchers, formulating chemists, and application engineers related to polymer science and technology in both academia and industrial societies.

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CHAPTER 1

Introduction

Abstract: Epoxy adhesives are composed of epoxy resin, curing agents, and catalysts with modifiers and additives. Bisphenol A-based epoxy resin, bisphenol F-based epoxy resin, novolac type epoxy resin, aliphatic glycidyl ether epoxy resin, glycidyl amine epoxy resin, glycidyl ester epoxy resin, and cycloaliphatic epoxy resin are typical epoxy resins. Polyamine, modified polyamine, mercaptan, phenol, anhydride, tertiary amine and imidazole compounds, and cationic initiators are typical curing agents and catalysts. Epoxy adhesives are supplied in both one-component and two-component packages depending on the curing agent used and the curing method applied. Typical room temperature cure epoxy adhesives, thermal cure epoxy adhesives, UV cure epoxy adhesives, and new trends in epoxy adhesive technology developments are described.

Keywords: Curing agent, Epoxy resin, Epoxy adhesive, One-component, Room temperature cure, Two-component, Thermal cure, UV cure.

INTRODUCTION

Epoxy resins are polymer materials containing at least one carbon-oxygen-carbon three-ring known as the epoxy group, epoxide, or oxirane, whose chemical structure is shown in Fig. (**1**). In the late 1890s, epoxy resin was first discovered. In 1909, N. Prileschajew prepared an epoxy resin *via* oxidation of olefin with benzoic acid peroxide. In 1934, P. Schlack filed a patent in Germany for using amine as a curing agent for epoxy resin [1-2]. In 1936, P. Castan prepared an epoxy resin from bisphenol A and epichlorohydrin and designed a thermoset composition by using phthalic anhydride as a curing agent targeted for dental application. In the late 1940s, epoxy adhesives were commercialized in Europe and USA. Various types of epoxy resins, curing agents, and epoxy adhesives have been developed and commercialized since then. Nowadays, epoxy adhesives have been widely used as typical reactive adhesives for various bonding applications in consumer uses, general industry, construction, electronics assembly, automobile production, and aerospace and defense markets [3-25], as summarized in Table **1**.

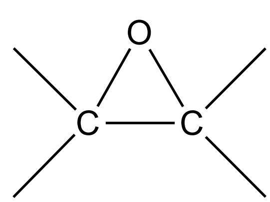

Fig. (1). Chemical structure of the epoxy group, epoxide or oxirane.

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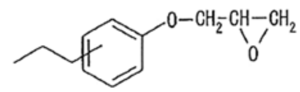
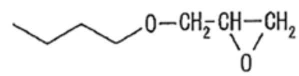
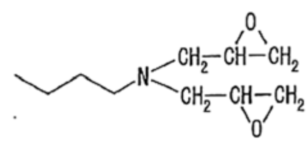
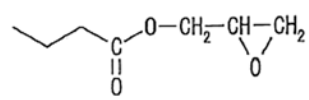
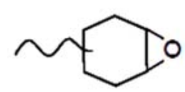
Table 1. Typical applications of epoxy adhesives.

Application	Typical Examples	Package Type	Cure Method
General industrial	Structural bonding	One-component Two-component	Room temperature cure Thermal cure UV cure
Construction	Concrete repairing Anchor bolt fixture	Two-component	Room temperature cure
Automotive industry	Structural bonding Hemming flange bonding	One-component Two-component	Thermal cure
Aerospace	Metal, Honeycomb and composite bonding, repairing	One-component Two-component	Thermal cure
Electronics	Electrically conductive Display assembly Image sensor assembly Semiconductor packaging Medical device bonding	One-component Two-component	Thermal cure UV cure Room temperature cure
Others	Sports equipment bonding Consumer applications	Two-component	Room temperature cure

Glycidyl ether epoxy resins such as Bisphenol A, Bisphenol F, novolac type, glycidyl amine epoxy resin, glycidyl ester epoxy resin, and cycloaliphatic epoxy resin are typical epoxy resins. Glycidyl-type epoxy resins are synthesized by the reaction of epichlorohydrin with phenols, alcohols, amines, or acids. Cycloaliphatic epoxy resins are prepared by the oxidation of olefins with peroxides. The preparation method and chemical structure of typical epoxy resins are summarized in Table **2**.

Table 2. Typical epoxy resins.

Type		Preparation from	Chemical Structure of the Epoxy Group
Glycidyl ether	Bisphenol A glycidyl ether	Bisphenol A + epichlorohydrin	
	Bisphenol F glycidyl ether	Bisphenol F + epichlorohydrin	
	Novalac epoxy resin	Novalac phenol + epichlorohydrin	
	Aliphatic glycidyl ether	Alcohol + epichlorohydrin	
Glycidyl amine epoxy resin		Amine + epichlorohydrin	
Glycidyl ester epoxy resin		Acid + epichlorohydrin	
Cycloaliphatic epoxy resin		Cycloolefin + peroxide	

Bisphenol A-Based Epoxy Resins

Bisphenol A-based epoxy resin, also called glycidyl ether of bisphenol A and often abbreviated as BADGE or DGEBA, was the first commercialized epoxy resin. It is still the most standard and widely used epoxy resin, constituting the majority, estimated over 75% in sales volume, of all epoxy resins used today. Bisphenol A epoxy resin is typically prepared by the reaction of bisphenol A and epichlorohydrin at 70 – 80°C under alkaline conditions, as illustrated in Fig. (**2**) [26]. Chemical

CHAPTER 2

UV Cure Cationic Epoxy Technology

Abstract: UV cure cationic epoxy adhesives are composed of epoxy resins and cationic photoinitiators with additives and modifiers. Cycloaliphatic epoxy resins are the main epoxy resins used for cationic epoxy formulations. Oxetanes are often combined with epoxy resins to improve curability and adjust viscosity. Cationic photoinitiators are all onium salts, composed of an organic cation with an inorganic anion. UV cure cationic epoxy adhesives can be cured quickly *via* UV light radiation and have been very successful in electronics assembly and general bonding applications. UV cure equipment, formulating, testing, and evaluation of UV cure cationic epoxy adhesives are described.

Keywords: Cationic photoinitiator, LED-UV lamp, Mercury lamp, Metal halide lamp, Oxetane, Sensitizer, UV cure equipment, UV cure, UV radiometer.

UV CURE CATIONIC EPOXY CHEMISTRY

Ultra-violet light (UV) cure cationic epoxy adhesives can be cured quickly and have been very successful in electronics assembly and general bonding applications, such as general glass bonding, optical parts assembly, image sensor module assembly, display panel bonding, and module assembly, that require fast production speed and high adhesion performance. UV cationic epoxy adhesives are primarily composed of epoxy resins, reactive additives, and cationic photoinitiators with additives and modifiers [1-10]. UV cure cationic epoxy adhesives provide significant advantages over UV cure acrylics.

- ✓ No oxygen inhibition.
- ✓ Low cure shrinkage.
- ✓ Good adhesion and chemical resistance.
- ✓ Dark curability.

Epoxy Resins and Oxetanes

Cycloaliphatic type epoxy resins are the main epoxy resins used for cationic epoxy adhesives because they can cure faster *via* cationic polymerization than normal glycidyl ether type epoxy resins such as bisphenol A epoxy resin. (3',4'-Epoxycyclohexane) methyl-3,4-epoxycyclohexylcarboxylate, often called ECC, is the principal cycloaliphatic epoxy resin used, providing a high cross-linked rigid chemical structure with high transition temperature after full cure. 3,4-Epoxycyclohexylmethyl-3',4'-epoxycyclohexanecarboxylate-modified epsilon -caprolactone, or bis(3,4-epoxycyclohexyl) adipate, is often combined to improve flexibility and toughness of ECC.

Hydrogenated bisphenol A epoxy resin can be prepared by the hydrogenation of bisphenol A epoxy resin, as shown in Fig. (**1**) [11]. Hydrogenated bisphenol A epoxy resin can cure faster *via* cationic polymerization and shows better optical properties and light resistance than bisphenol A epoxy resin due to no existence of aromatic structure. Hydrogenated bisphenol A epoxy resin is a good alternative for cycloaliphatic epoxy resins where higher adhesion and humidity reliability performance are required.

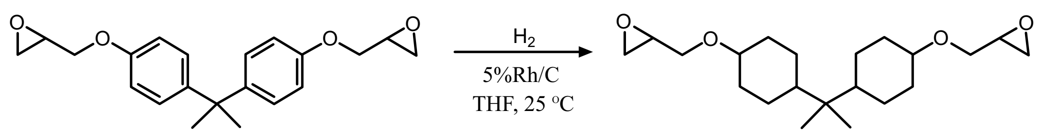
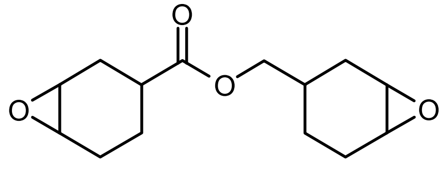


Fig. (1). Synthesis of hydrogenated bisphenol A epoxy resin.

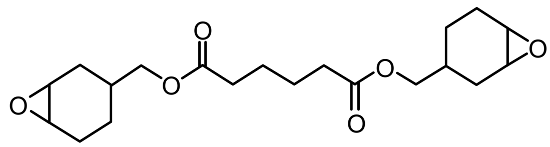
Oxetanes are heterocyclic organic compounds containing the oxetane group, having a four-membered ring with three carbon atoms and one oxygen atom. Oxetanes cure faster than epoxy resins *via* cationic polymerization. 3,3'-[Oxybis(methylene)] bis(3-ethyloxetane), or dioxetanyl ether (abbreviated as DOX), is a difunctional oxetane with very low viscosity. 3-Ethyl-3-hydroxylmethyl-oxetane, or oxetane alcohol (abbreviated as OXE), is an oxetane having a hydroxy group. Similar to polyol, the hydroxy group of OXE can enhance the cure speed of cationic polymerization through chain transfer. Oxetanes are often combined with epoxy resins to improve curability and adjust viscosity.

Chemical structure, viscosity, CAS No., and key features of cycloaliphatic epoxy resins, hydrogenated bisphenol A epoxy resin, and oxetanes are summarized in Fig. (**2**).



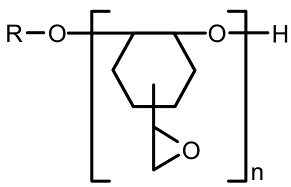
Viscosity: 300 mPa.s/25°C
CAS. No.: 2386-87-0
EEW: 135
High Tg

(3',4'-Epoxycyclohexane)methyl-3,4-epoxycyclohexylcarboxylate (ECC)



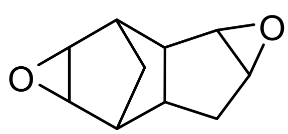
Viscosity: 600 mPa.s/25°C
CAS No.: 139198-19-9
EEW: 200
Flexibility

3,4-Epoxycyclohexylmethyl-3',4'-epoxycyclohexanecarboxylate-modified epsilon -caprolactone



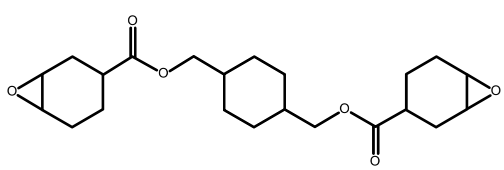
Softening point: 75°C
CAS No.: 244772-00-7
EEW: 177
High thermal resistance

Poly [(2-ethylene epoxide) - 1,2-cyclohexanediol] 2-ethyl-2 - (hydroxymethyl) - 1,3-propylene glycol ether



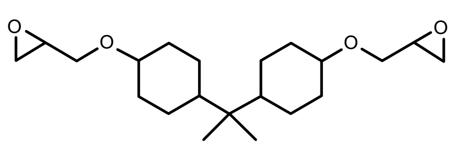
Softening point: 185 - 189°C
CAS No.: 81-21-0
EEW: 82 -85
High thermal resistance

Dicyclopentadienediepoxide



Softening point: 60°C
CAS No.: 20249-12-1
EEW: 190 - 210
Good weatherability

1,4-Cyclohexanedimethanol bis(3,4-epoxycyclohexanecarboxylate)



Viscosity: 2000 mPa.s/25°C
CAS No.: 30583-72-3
EEW: 220
Good adhesion

Hydrogenated bisphenol A epoxy resin

CHAPTER 3

Dual Cure Hybrid Epoxy Technology

Abstract: UV and thermal dual cure hybrid epoxy adhesives are composed of partially acrylated epoxy resin, acrylates, free radical photoinitiators, epoxy resins, and latent curing agents with modifiers and additives. The acrylate components are cured momently *via* light radiation and thus can instantly fix the bonding materials at room temperature. Their epoxy components can be cured at the post-thermal cure stage to achieve satisfactory adhesion performance. Dual cure hybrid epoxy technology has been very successfully used in electronics assembly and general bonding applications.

Keywords: Acrylate monomer, Acrylate oligomer, Cure shrinkage, Dual cure, Free radical photoinitiator, Oxygen inhibition, Partially acrylated epoxy resin.

UV CURE ACRYLATE CHEMISTRY

UV and thermal dual cure hybrid epoxy adhesives combine UV cure acrylate composition with thermal cure epoxy composition. Dual cure hybrid epoxy adhesives are primarily composed of partially acrylated epoxy resin, acrylates, free radical photoinitiators, epoxy resin, and latent curing agents. Their acrylate components can be cured instantly *via* light radiation, and thus, the bonding materials can be fixed momently at room temperature. Their epoxy components are cured at the post-thermal cure stage to achieve satisfactory adhesion reliability performance. Dual cure hybrid epoxy technology has been very successfully used in general structural bonding, camera module assembly, and LCD panel bonding applications. The dual cure hybrid epoxy adhesives combine the advantages of instant curability of UV acrylate composition with a high-reliability performance of thermal cure epoxy part very well.

Most widely used UV cure adhesives are acrylate-based [1-8]. Acrylate-based UV cure adhesives are primarily composed of acrylate monomer, acrylate oligomer, and photoinitiator. The photoinitiator will generate free radicals *via* UV radiation, initiating free radical polymerization of acrylate compositions rapidly. Acrylate-based UV cure adhesives can be cured instantly within a few seconds *via* UV light radiation. Surface cure issue, shadow cure problem, relatively high cure shrinkage, and poor humidity reliability are their main limitations.

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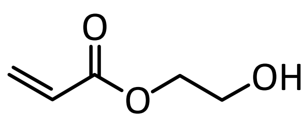
Acrylate Monomers

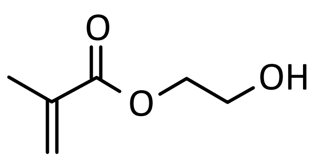
Acrylate monomer is the fundamental component of UV cure acrylate formulation technology. Acrylate monomer plays a key role in the determination of its cure behavior, handling property, and physical property and affects its adhesion performance. Acrylate monomers can be classified as mono-functional, di-functional, tri-functional, and multi-functional acrylates.

Chemical structure, viscosity, CAS No., molecular weight, and Tg of typical mono-functional acrylate and methacrylate monomers are shown in Fig. (**1**). Tg is their homopolymer's value.



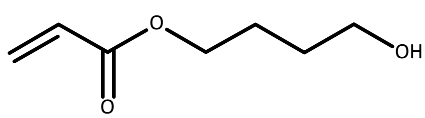
2-Hydroxyethyl acrylate

Viscosity: 6 mPa.s/20°C
CAS. No.: 818-61-1
Molar mass: 116
Tg: -15°C



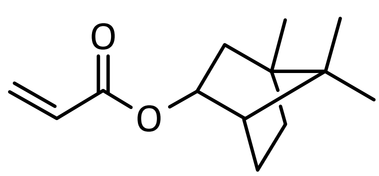
2-hydroxyethyl methacrylate

Viscosity: 6.8 mPa.s/20°C
CAS. No.: 868-77-9
Molar mass: 130
Tg: 25°C



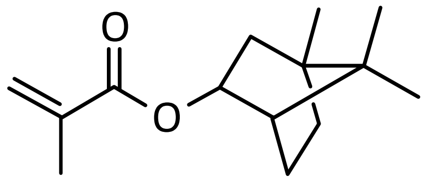
4-Hydroxybutyl acrylate

Viscosity: 5.5 mPa.s/25°C
CAS. No.: 2478-10-6
Molar mass: 144
Tg: -32°C



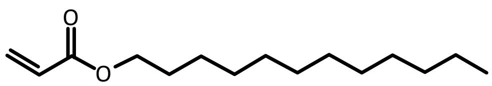
Isobornyl acrylate

Viscosity: 7.7 mPa.s/20°C
CAS. No.: 5888-33-5
Molar mass: 208
Tg: 97°C



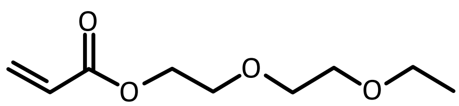
Viscosity: 6 mPa.s/25°C
CAS. No.: 7534-94-3
Molar mass: 222
Tg: 180°C

Isobornyl methacrylate



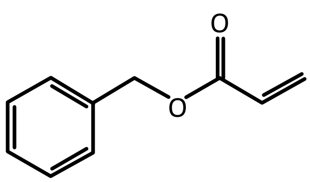
Viscosity: 4 mPa.s/25°C
CAS. No.: 2156-97-0
Molar mass: 240
Tg: 15°C

Lauryl acrylate



Viscosity: 2.9 mPa.s/25°C
CAS. No.: 7328-17-8
Molar mass: 188
Tg: -67°C

Ethoxyethoxyethyl acrylate

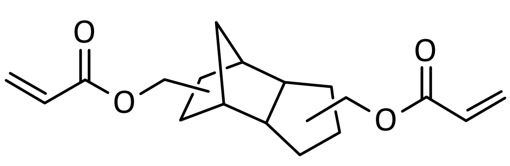


Viscosity: 2 mPa.s/25°C
CAS. No.: 2495-35-4
EEW: 162
Tg: 6°C

Benzyl acrylate

Fig. (1). Typical monofunctional acrylate monomers and methacrylate monomers.

Chemical structure, viscosity, CAS No., molecular weight, and Tg of typical di-, tri-, and multi-functional acrylate and methacrylate monomers are shown in Fig. (**2**). The combination use of these acrylates can increase the degree of cross-linking of the polymer matrix.



Viscosity: 135 mPa.s/25°C
CAS. No.: 42594-17-2
EEW: 304
Tg: 186°C

Dimethylol triclodecane diacrylate

CHAPTER 4

Snap Thermal Cure Epoxy Technology

Abstract: Snap thermal cure epoxy adhesives are typically one-component epoxy composition, comprising epoxy resin, a new type latent curing agent, and an accelerator with modifiers and additives. Snap thermal cure adhesives can cure very fast at certain elevated temperature conditions and have been very successfully used in semiconductor packaging and electronics module assembly applications.

Keywords: Accelerator, Anisotropic conductive film (ACF), Dicyandiamide, Imidazole, Non-conductive paste (NCP), Thermal cationic initiator.

LATENT CURING AGENTS

Snap thermal cure epoxy technology is mainly based on one-component epoxy adhesive, typically formulated with epoxy resin, latent curing agent, and accelerator with various modifiers and additives. New type latent curing agents, such as modified imidazole type, modified polyamine type, and thermal cationic initiator, have been developed and commercialized in recent decades. One-component thermal cure epoxy adhesives incorporated with these new type curing agents can cure very fast at certain elevated temperature conditions and have been successfully used in semiconductor packaging and electronics assembly applications.

One-component epoxy adhesives are prepared by selecting latent curing agents. All ingredients, including epoxy resin and curing agent, are mixed thoroughly in advance. No additional pre-mixing process in actual use is required. One-component adhesives can be handled easily and are suitable for automatic dispensing systems because of their long enough pot life.

With the selection of suitable latent curing agents, various one-component thermal cure epoxy adhesives have been developed and supplied by major epoxy adhesive suppliers for different applications. Typical commercial latent curing agents are summarized in Table **1** [1].

Imidazoles

Imidazole compounds react with an epoxy group to form anionic species, which can initiate the polymerization of epoxy resin, as illustrated in Fig. (**1**) [2]. The additional amount of imidazole is quite small, ranging from 1 to 8 phr based on

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standard bisphenol A epoxy resin (EEW=190). Pot life is longer than normal amine-type curing agent, ranging from a few hours to several months at room temperature, depending on its structure. A thermal cure at elevated temperature is needed to achieve a full cure, but cure time becomes significantly shorter. Cured epoxy resin based on imidazole shows good adhesion and high glass transition temperature. Like tertiary amine, imidazoles are also used as an accelerator for other epoxy-curing agents such as anhydrates, phenols, and dicyandiamide.

Table 1. Typical commercial latent curing agents.

Latent curing agent	**Latency Mechanism**	**Curing Agent State**	**Typical Curing Temperature**
Imidazoles	Chemical blocking/physical separation	Liquid/solid	≧80℃
DICY		Solid	≧150℃
Dihydrazine			≧120℃
Modified imidazole	Physical separation	Fine powder	≧80℃
Modified polyamine			≧80℃
Onium salts	Chemical blocking	Solid	≧80℃
Amine-BF_3 complex		Liquid	≧130℃

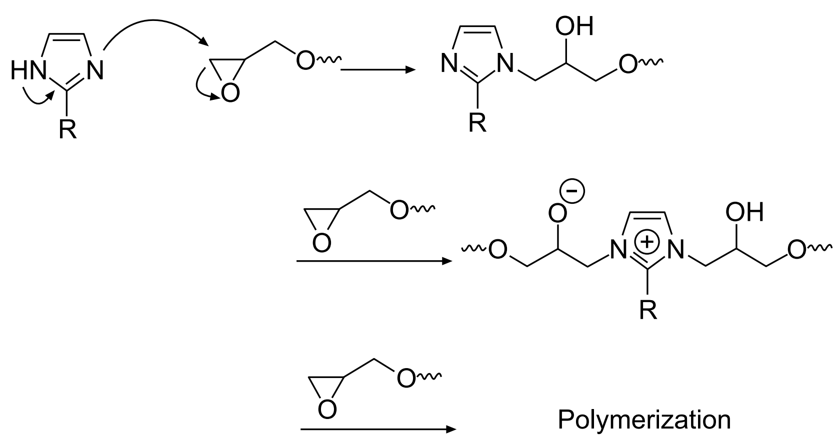
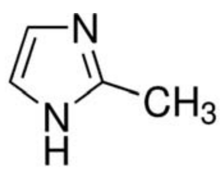


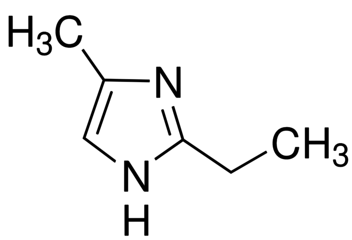
Fig. (1). Anionic polymerization of epoxy resin initiated by imidazole compound.

The chemical structure and physical properties of typical imidazole-type curing agents are shown in Fig. (**2**). 2-methyl imidazole and 2-ethyl-4-methyl imidazole are most widely used. 2-methyl imidazole is a white solid. The pot life of formulated epoxy resin is quite short, around 5 hours at room temperature. It has very good thermal curability. 2-methyl imidazole is often used as raw material for the synthesis of modified imidazole curing agents. 2-Ethyl-4-methyl imidazole is a pale-yellow liquid and has very good handling properties. The pot life of the formulated epoxy resin is around 8 hours at room temperature. It has very good thermal curability with a gel time of around 3 minutes at 120°C and around 1 minute at 150°C. Table **2** shows the cure behavior and physical properties of standard bisphenol A epoxy resin and 2-ethyl-4-methyl imidazole composition. 2-phenyl imidazole is a white solid [3]. The pot life of the formulated epoxy resin is around 20 hours at room temperature. It needs some higher temperature cure. Gel time is 17 minutes at 100°C. 1-Cyanoethyl-2-ethyl-4-methylimidazole has a longer pot life, around 4 days at room temperature, but the cure temperature needs to be slightly higher than 2-ethyl-4-methyl imidazole.



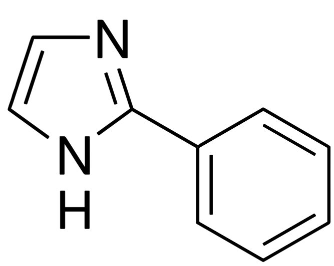
White solid
CAS. No.: 693-98-1
Molar mass: 82
Melting point: 142°C

2-Methyl imidazole



Ple yellow liquid
CAS. No.: 931-36-2
Molar mass: 110
Melting point: 47-54°C

2-Ethyl-4-methyl imidazole



White solid
CAS. No.: 970-90-2
Molar mass: 144
Melting point: 142-148°C

2-Phenyl imidazole

CHAPTER 5

Induction Cure Epoxy Technology

Abstract: Induction cure epoxy technology is based on the induction heating method. Induction heating is a very fast, highly efficient, and noncontact heating style. Induction heating works mainly on bonding applications on conductive metal materials or using specially designed induction curable epoxy adhesives. The induction cure principle and equipment, induction cure epoxy chemistry, and induction cure applications are described. In addition, laser cure epoxy adhesive technology and weld bonding epoxy adhesive technology have been briefly introduced.

Keywords: Conductive metal, Induction cure, Induction coil, Induction heating, Thermal conductivity.

INDUCTION CURE EPOXY CHEMISTRY

Induction cure epoxy technology is a technology based on the induction heating method to cure epoxy materials. Induction heating is a form of electromagnet heating. It is a very fast, highly efficient, and non-contact heating. Electric power is used to generate heat *via* conductive metal materials placed in an inductor coil of induction cure equipment. Induction heating works only on bonding applications where one substrate is a conductive metal material, such as steel, aluminum, or copper, or specially designed induction curable adhesives filled with conductive metal powders. The advantages of induction cure epoxy technology are listed below:

✓Instant curability because of very fast heating speed.

✓Thermal-sensitive material bonding because of localized heating.

✓High adhesion performance.

As shown in Fig. (**1**), there are two main cases in which epoxy adhesives are used to bond the substrates, depending on the adherend type [1]. If one of the adherends is metal that can generate induction heating, the heat generated will conduct thermally to the epoxy adhesive that will start to cure soon after a certain temperature is reached. The heating rates could be very fast, normally higher than 40°C/second, and thus can reach 190 – 230°C in a few seconds, where most epoxy adhesives can cure instantly. Metals that have been used in induction heating are iron, steel, copper, and aluminum. Typically, one-component epoxy adhesive is

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used for induction cure applications because of easy handling, while there are some applications using two-component epoxy adhesive.

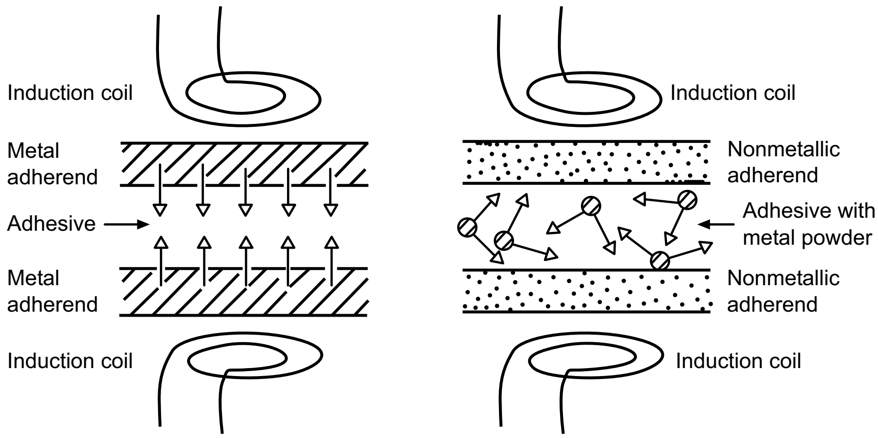

Fig. (1). Induction cure epoxy applications. Left: normal epoxy adhesive used in bonding metal adherend; Right: epoxy adhesive filled with metal powder in bonding non-metallic adherend.

In non-metallic adherend applications, specially designed induction curable epoxy adhesive, which is filled with enough amount of susceptor that can generate induction heating, needs to be used. Table **1** shows the typical composition of induction curable epoxy adhesive. Induction cure epoxy adhesive is fundamentally composed of epoxy resin, curing agent, and susceptor. Susceptors that can be used to generate induction heating are iron powder, steel powder, copper powder, and aluminum powder [2-10]. Aluminum powder is most commonly used due to its relatively low density. Fig. (**2**) shows a typical aluminum powder product and its micrograph. Overheating is always a big concern in induction cure applications. Precautions need to be made to avoid high cure exotherm in designing the adhesive formulation as the cure exotherm will significantly increase the heating temperature.

Table 1. Typical composition of induction cure epoxy adhesive.

Function	Component	Main Role	Typical Content (%)
Primary	Epoxy resin	Adhesive base	20 – 95
	Curing agents	Curability	0.5 – 60
	Accelerator	Cure speed enhancement	0 – 5

(Table 1) cont.....

Susceptor	Metal powder	Induction heating generation	10-80
Modifier	Filler Toughener	Property enhancement Toughness enhancement	0 – 80 0 – 20
Additive	Colorant Coupling agent Thixotropic agent	Coloring Adhesion promotion Rheology control	0 – 2 0 – 2 0 – 5

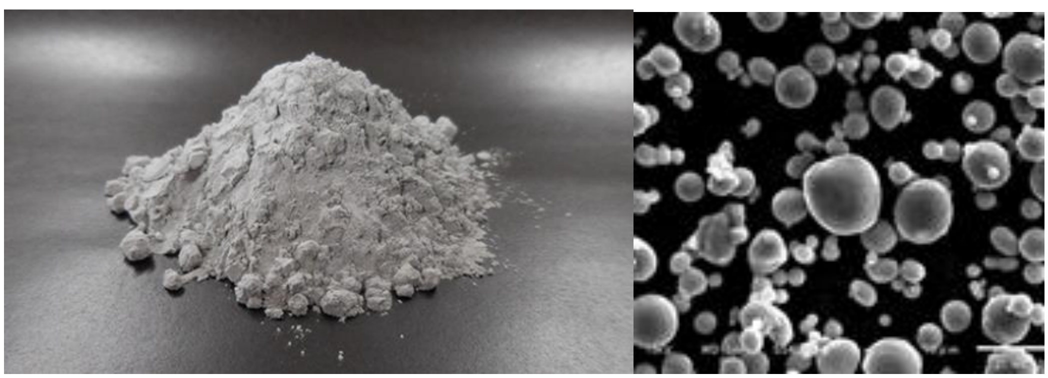

Fig. (2). Aluminum powder product.

INDUCTION CURE EQUIPMENT

Physical Principle of Induction Heating

The phenomenon of electromagnetic induction heating is based on three physical principles: 1) Transfer of energy from the inductor *via* electromagnetic fields, 2) Transformation of the electric energy to heat, and 3) Transmission of the heat inside the object *via* thermal conduction.

CHAPTER 6

Snap Ambient Cure Epoxy Technology

Abstract: Snap ambient cure epoxy technology is based on two-component room temperature fast cure epoxy adhesive systems, including fast room temperature cure epoxy adhesive, cyanoacrylate hybrid epoxy adhesive, and UV and room temperature cure epoxy adhesive. Their chemistry, cure behavior, key features, and applications are introduced.

Keywords: Cyanoacrylate, Free radical photoinitiator, Mercaptan, Room temperature cure.

FAST ROOM TEMPERATURE CURE EPOXY ADHESIVES

Snap ambient cure epoxy technology is based on two-component room temperature fast curable epoxy adhesive systems, including fast room temperature cure epoxy adhesive, cyanoacrylate hybrid epoxy adhesive, and UV and room temperature cure hybrid epoxy adhesive. Fast room temperature cure epoxy adhesive is primarily composed of epoxy resin as one part and mercaptan-type curing agent with a suitable basic catalyst as the other part. Cyanoacrylate hybrid epoxy adhesive is mainly composed of cyanoacrylate and cationic photoinitiator as one part and epoxy resin as the other part. UV and room temperature cure hybrid epoxy adhesive is mainly composed of epoxy resin, acrylates, and radical photoinitiator as one part and room temperature cure curing agent as the other part.

Mercaptans can cure epoxide very fast in the presence of a basic catalyst at room temperature and thus have been mainly used as curing agents for fast room-temperature epoxy formulations. The cure mechanism of epoxy resin and mercaptan in the existence of an imidazole catalyst is shown in Fig. (**1**) [1]. As a result, the epoxy group reacts with mercaptan almost equivalently to form alcohol and sulfide. Chemical structure, viscosity, CAS No., and SH equivalent of typical commercialized mercaptan-type curing agents are shown in Fig. (**2**).

As can be seen, there are mainly three types of mercaptan-type curing agents: primary thiol group linked to ether as in polymeric mercaptan, primary thiol group linked to ester as shown in TMMP, and secondary thiol group. Reactivity with epoxy resin decreases in the below sequence.

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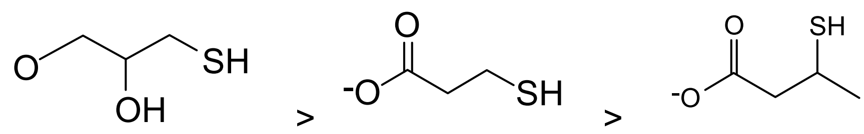


Primary thiol linked to ether Primary thiol linked to ester Secondary thiol

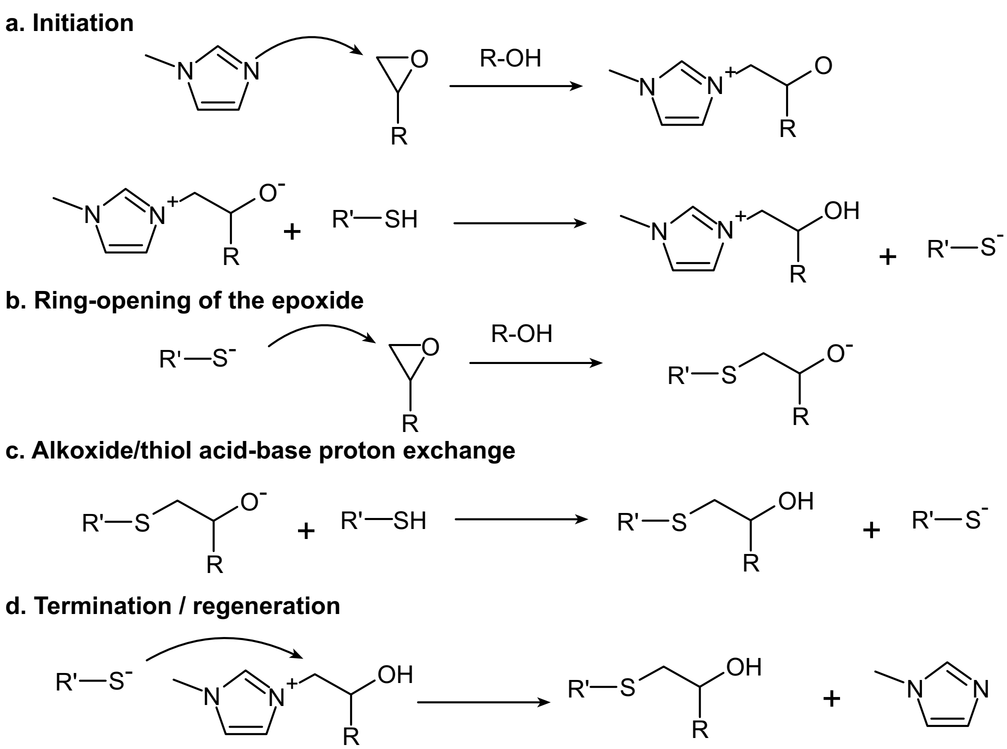
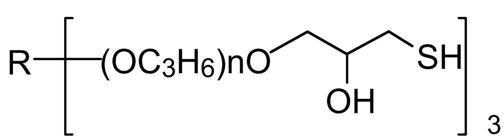
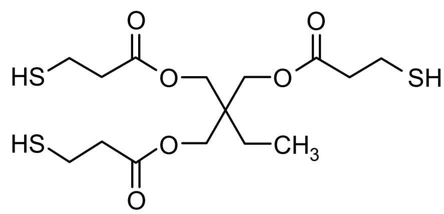


Fig. (1). Polyaddition mechanism of mercaptan with epoxy resin catalyzed by imidazole.



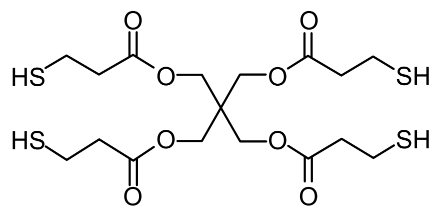
Viscosity: 128°C
Cas No.: 72244-98-5
SH equivalent: 286

Polymercaptan



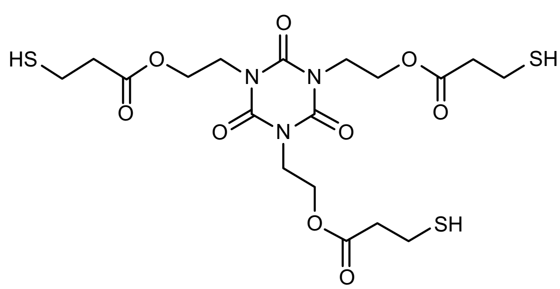
Viscosity: 150 mPa.s/25°C
Cas No.: 33007-83-9
SH equivalent: 141

Trimethylolpropane tris(3-mercaptopropionate) (TMMP)



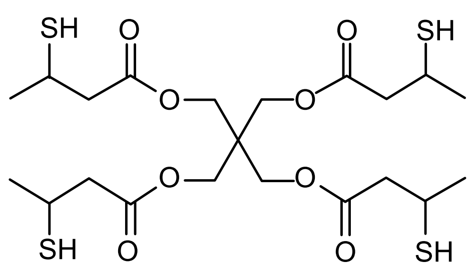
Viscosity: 510 mPa.s/25°C
Cas No.: 7275-23-7
SH equivalent: 127

Pentaerythritol tetrakis(3-mercaptopropionate) (PEMP)



Viscosity: 6000 mPa.s/25°C
Cas No.: 36196-44-8
SH equivalent: 180

Tris[2-(3-mercaptopropionyloxy)ethyl] Isocyanurate (TEMPIC)



Colorless to yellow liquid
Cas No.: 31775-89-0
SH equivalent: 136

Pentaerythritol tetrakis (3-mercaptobutylate)

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Chunfu Chen received Ph.D. in polymer chemistry in 1990 from Nankai University in Tianjin, China. Then he became assistant professor at Nankai University and served as a visiting researcher at Sophia University in Tokyo, Japan from 1991 to 1993. He is currently working as senior scientific principal -Epoxy- for Henkel Adhesive Technologies, based at Henkel Technology Center – Asia Pacific, Yokohama, Japan. He has abundant research experience, with over 35 years, in polymer science and material areas especially on epoxy adhesive technology. He has contributed to successful development in many new adhesive products for electronic assembly and general industry applications. In addition, he has invented 40 patents and published more than 45 international conference, research, and review articles.