

## SHORT GLASS AND MINERAL FILLED EPOXY MOLDING COMPOUNDS Processing Guide

### Chemistry and Features

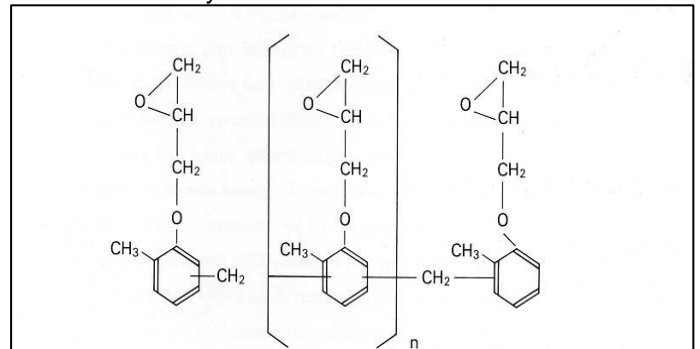
Epoxy molding compounds were commercialized in the early 1950's. They have become the most widely used material for encapsulation and have established the performance standards against which other materials often are evaluated. Epoxy molding compounds are desirable in electrical applications for the following reasons:

- Low Shrinkage
- Excellent adhesion to a wide variety of materials
- Good electrical properties
- Resistance to moisture and chemicals
- Compatible with most other materials used in electrical apparatus.

There are several classes of epoxy resins:

1. Novolac epoxies, particularly the epoxy cresol and epoxy phenol novolac resin with o-cresol or phenol and formaldehyde with epichlorohydrin. This material is used where good thermal properties, high resistance to solvents and chemicals are required. (Figure 1) This is the typical type of epoxy that SBNA manufactures.
2. The cycloaliphatics epoxy resins are important where arc track and weather resistance are required.
3. Another class of epoxy resins is based on aromatic diamines. These resins have good mechanical properties, high thermal capabilities and fatigue resistance. Epoxy resins must be cured with cross-linking agents (hardeners) or catalysts to develop the desirable properties. The epoxy and hydroxyl groups are the reaction sites through which cross-linking occur. Agents include amines, anhydrides, Alde Hyde condensation products, and novolacs and acid catalysts.

4. Aromatic amines are used where high heat deflection temperatures are required and elevated curing temperature is acceptable.
5. Anhydride resins are used where low exothermic, good adhesion, electrical and thermal properties are required. Long pot life is achieved with anhydride resins.



**Figure 1: Epoxidized Cresol Novolac Resin**

Most epoxy molding compounds exhibit low dielectric loss. High insulation value, low shrinkage and high mechanical strength that are maintained under severe moisture and high temperature. Epoxies range from slow burning to self extinguishing. These benefits have made epoxies one of the most popular plastics used in electrical/electronic field. Epoxies are highly chemically resistant, being affected only by strong acids and ketones. They are non-outgassing, flame resistant and have ease of flow with relatively low molding pressure.

### Flow Rheology

Compounds based on Epoxy resins are designed to process well in all types of molding equipment. Compounds are available in a variety of flow ranges, from very stiff for compression molding to very soft for injection molding. Their plasticities are normally measured by a special transfer molding procedure known as Mesa Spiral Flow (Figure 2) and Emmi Spiral Flow (Figure 3). This test provides an indication of the relative ability of the compound to flow and fill molds. Brabender torque rheometer measurements are sometimes utilized to characterize both flow and curing properties.



Figure 2: Mesa Spiral



Figure 3: Emmi Spiral

## Storage

Compounds based on Epoxy resin possess greater reactivity, and therefore cold storage of these materials is recommended. Normal storage life is about 6 months when kept at or below 40°F (4°C). The material should be brought to room temperature before containers are opened to prevent the introduction of condensed moisture from the atmosphere.

## Preforming or Screw Plasticating

Epoxy compounds can be charged directly into the mold cavity in granular form. This practice may be desirable in the case of single cavity compression molds for large components, as well as with presses utilizing automatic powder loading. The compound should be accurately weighed or volumetrically metered for each molding cycle.

For the production of small and medium-sized parts with multi-cavity compression molds or transfer molds, preforms are generally preferred. Preforms can be made in many shapes and sizes by compaction of the molding material in a die. Preforms are

easier to handle and can be more readily preheated than loosely packed bulk material.

Granular Epoxy compounds are easily preformed by any of the usual types of hydraulic or mechanical preforming presses or screw plasticating machines. Screw plastication combines both preforming and preheating in one process.

Automatic preformers require free-flowing granular compounds in order to maintain weight consistency and rapid cycles. Materials with the lowest bulk densities, such as those containing long glass fibers, cannot usually be preformed automatically in conventional equipment. These often require auxiliary feeding equipment or a manual weighing and pressing operation.

## Preheating

The molding compounds should be heated before being loaded into the mold. This reduces the time required to bring the material to a plastic state and allows shorter molding cycles than are possible with cold material. Preheating can increase productivity by 20 to 40% depending on the geometry of the part and the material being molded. The preheated material also flows more easily and uniformly and generally requires less pressure. Other benefits of preheating include smoother molded surfaces and enhanced physical properties.

The most commonly used preheating methods are dielectric (HF) heating of a densely packed perform or frictional heating using a screw plasticator.

Preheat temperature is one of the most critical molding parameters. The temperature should be optimized to provide the easiest flow. This usually means raising the temperature of the compound until obvious preure or short shots occur in molding, and then dropping back 10 to 15°F.

## Molding Methods

In general, Epoxy compounds can be processed by all conventional thermoset molding methods, such as compression, transfer or injection molding. Most thermoset molding machines are suitable for

these materials without the need for special equipment.

Transfer or plunger molding is a predominant method used with Epoxy compounds. This method is particularly useful for parts that contain molded-in inserts. Strength may be



Figure 3: Injection Molding Presses

somewhat lower and shrinkage somewhat higher than that of parts molded by compression. The magnitudes of these differences are dependent on runner and gate design plus the flow pattern in the mold cavity.

Formulations are available to take full advantage of the high productivity of injection molding. They offer excellent barrel and nozzle stability with fast cure in the mold.

In injection or transfer molding, a sound molding requires complete cavity filling and adequate packing before gelation. Mold filling time should neither be too short, to avoid trapping air or overheating material through friction, nor too long, to avoid gelation before the cavity is completely packed. If molding conditions do not allow sufficient packing pressure, part strength will be compromised. Other properties including dimensions are affected by cavity packing pressure as well. The curing time should be long enough for the part to be ejected from the mold without distortion.

Mold cavities should be well polished and plated with hard chrome to ensure easy release. A draft of  $\frac{1}{2}$  degree on cavity surfaces that are perpendicular to the mold parting line will facilitate easy part demolding. All transfer and injection molds must be properly vented at the parting line, and knock-out pins may need axial flat faces to provide more venting for deep recesses.

## Suggested Start-Up Conditions

Molding conditions may vary depending on the shape of the part, mold design, and composition of the material. Suggested start-up conditions and approximate curing times are provided in Figure 4 and 5.

## Postcuring and Degassing

Molded parts normally never attain complete cure under commercial conditions. In most cases, conditions are established which produce an acceptable degree of cure and attendant physical properties when the parts are removed from the mold. It is not necessary to postcure molded parts unless a specific application requires that resistance to high-temperature or chemical exposures be maximized or that the by-products of the curing initiators be driven off.

The retention of physical properties at elevated temperatures is governed by the  $T_g$ . For maximum thermal stability and retention of physical properties at high temperatures, molded parts can be postcured. This should be performed in a forced-draft oven having good temperature control and outside venting.

Optimum postcuring conditions are determined by the specific application requirements. When determining the oven temperature cycle, it is important to note that lower temperatures generally result in less thermal stress and less discoloration of the part. Most cycles begin at 275°F (135°C) and the temperature is gradually raised to avoid exceeding the  $T_g$ . The rate of temperature rise should be as fast as permissible without visual signs of degradation such as blistering or cracking. A final oven temperature of 175°C is usually sufficient to complete the crosslinking reactions without significant discoloration. For applications requiring minimum outgassing, the final oven temperature should be at least equal to the maximum service temperature and the parts should be baked from 4 to 6 hours at this final temperature or until the rate of weight loss is negligible.

**Technical Assistance:** Please contact your Sumitomo Bakelite representative if technical assistance is desired.

**Figure 4: Suggested Start-Up Conditions Hardware Grade**

<b>COMPRESSION/TRANSFER</b>	<b>PARAMETER SETTINGS</b>
Preforming Pressure Preheat Temperature Preheating Time (HF) Mold Temperature Molding Pressure – Compression -Transfer Cure Time	8,000-12,000 psi (544-816 bar) 180-225°F (82-107°C) ≤ 45 s 325-370°F (163-188°C) 1,000-5,000 psi (68-340 bar) 1,500-8,000 psi (102-544 bar) 60-90s (per 3.2 mm thickness)
<b>INJECTION</b>	<b>PARAMETER SETTINGS</b>
Barrel Temperatures R/M/N* Screw Speed Back Pressure Material Temperature Mold Temperature Injection Pressure Hold Pressure (Cavity) Cure Time	140/170/190°F (60/77/88°C) 50 rpm 700-2,200 psi (50-150 bar) 200-240°F (93-115°C) 300-350°F (149-180°C) 5,000-10,000 psi (340-680 bar) ½ of injection pressure 40 s (per 3.2 mm thickness)
*Rear Zone/ Middle Zone/ Nozzle	

**Figure 5: Suggested Start-Up Conditions Electrical Grade**

<b>COMPRESSION/TRANSFER</b>	<b>PARAMETER SETTINGS</b>
Preforming Pressure Preheat Temperature Preheating Time (HF) Mold Temperature Molding Pressure – Compression -Transfer Cure Time	8,000-12,000 psi (544-816 bar) 180-225°F (82-107°C) ≤ 45 s 250-350°F (121-177°C) 200-1,500 psi (14-102 bar) 100-2,000 psi (7-136 bar) 60-90s (per 3.2 mm thickness)
<b>INJECTION</b>	<b>PARAMETER SETTINGS</b>
Barrel Temperatures R/M/N* Screw Speed Back Pressure Material Temperature Mold Temperature Injection Pressure Hold Pressure (Cavity) Cure Time	140/170/190°F (60/77/88°C) 50 rpm 700-2,200 psi (50-150 bar) 220-240°F (104-115°C) 275-350°F (135-180°C) 5,000-10,000 psi (340-680 bar) ½ of injection pressure 40 s (per 3.2 mm thickness)
*Rear Zone/ Middle Zone/ Nozzle	

Figure 6: Injection Molding Trouble Shooting Guide

	Non Fills	Porosity	Staining	Gas Burns	Parts Stick	Blisters	Warpage	Excessive Flash	Excessive Shrinkage	Erratic Injection	Nozzle Cure	Sprue Sticking
Injection Pressure	↑	↑			↓	↑	↑	↓	↑	↑		↓
Back Pressure (Plasticizing)		↓	↓			↑			↑		↓	
Clamp Pressure								↑				
Material Feed Setting	↑	↑				↑		↓				
Nozzel Temperature		↓								↓	↓	↑
Barrel Temperature										↓	↓	
Mold Temperature	↓	↓	↓	↓	↓	↑			↓			↑
Injection Pressure Time							↑					
Injection Hold Pressure Time									↑			
Cure Time			↑		↑	↑	↑		↑			↑
Screw Plastication Delay											↑	
Material Flow	↑						↓	↓		↓	↓	
Poilish Sprue Bushing												↑
Gates Size	↑					↑	↑					
Venting		↑	↑	↑		↑						
Injection Speed		↓		↓								
Polish Mold			↑		↑							