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ELASTOMERIC SYNTACTIC FOAMS FOR
STRESS RELIEF OF ELECTRONIC COMPONENTS*

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Abstract

Elastomeric syntactic foams have been developed for use as stress relief coatings on electronic components in encapsulated electronic assemblies. Polysulfide, silicone, and polyurethane elastomers blended with microbubbles made from glass and phenolic resins have all been used to formulate syntactic foams for various applications. These foams are used to minimize the stresses caused by differential thermal expansion between the component and the encapsulant in electronic assemblies. Compressive stress strain curves have been used to determine the effects of temperature, formulation, and test configuration on these foams. The microbubble-resin blends are fluid enough to evacuate and pour before curing. These foams may be applied using a low-pressure injection molding technique or by simply brushing or dipping. Testing techniques, necessary to evaluate these sheets of elastomeric syntactic foams, were developed. These elastomeric syntactic foams have proven to be easily formulated, versatile materials that have been used in many applications to relieve the stresses caused by differential thermal expansion.

Introduction

The effect of formulation, temperature, and test techniques on the physical properties of elastomeric syntactic foams will be presented in this paper. In addition, a brief review of the processing and testing techniques will be given. These foams were developed for use as stress relief coatings on encapsulated electronic components. Encapsulation, as used here, does not refer to individual electronic components, but rather to electronic assemblies with many components. This unusual class of foams has been made with various castable thermosetting elastomers and microbubbles.

Foams have been made with urethane, silicone, and polysulfide elastomers blended with glass and phenolic microbubbles. The variety of compressive properties that are made available by varying the elastomer, microbubble, and the formulation has provided a useful engineering material that can be easily formulated for specific applications.

These foams are used in high quality electronic assemblies which have expected useful lifetimes of ~~up to twenty-four years~~ ^{over twenty years}. The assemblies must function over a broad temperature range often in very harsh mechanical environments. In addition, they must work after many years of temperature cycling from [↓]-54 to 74°C (-65 to 165°F). Encapsulation or potting with mineral or microbubble filled epoxy resins provides the necessary mechanical strength for otherwise delicate electronic assemblies; however, it can also cause failure because of thermally induced stress. add X - sign

This problem is illustrated in Figure 1. The low coefficient of expansion of glass and ceramic components and the relatively high expansion of the encapsulant cause very high stresses at the interface during thermal cycling. This stress not only causes failures in the electronic component but can also cause cracks in the encapsulant. A crack in the encapsulant can cause failure of the electronic assembly when it is subject to high accelerations. A thin coating of an elastomeric syntactic foam between the component and the encapsulant can be used to relieve this stress.

The foam system selected for a specific application is determined by the temperature range, the mechanical environment, and the electrical properties necessary. Syntactic foams provide good mechanical support because of their relatively high moduli. This and their ability to crush thereby relieving high stresses makes them ideal for this application.

Formulation and Properties

The formulations of three typical elastomeric syntactic foams, made with urethane, silicone, and polysulfide elastomers are given in Table I. The urethane elastomer/glass microbubble foam is a relatively high strength material which is difficult to process because of its high viscosity and short pot life. It is useful where high accelerations are expected. The silicone/glass microbubble foam is made with a low viscosity resin which has a long pot life. Because of its easy processing and constant properties over a wide temperature range it is the most widely used foam. The polysulfide/phenolic microbubble foam has good pot life and can be diluted with toluene to ease processing. It is useful for high voltage applications where a good bond is required.

The compressive stress strain curves on these elastomeric syntactic foams illustrate the wide variety of properties obtainable. (Figure 2). These curves provide the engineering data necessary for design. The initial modulus and the compression properties to thirty percent strain are normally determined. The problems of testing thin elastomeric sheets and interpreting the data will be covered later. The void volume, listed after density in Figure 2, simply means the gas volume in the foam. It is a useful measure of the foam's compressibility. The urethane elastomer/glass microbubble system has a relatively high void volume which causes the plateau region in the curve. Because of its high compressive modulus of 647MPa (97,000 PSI) and a plateau over 8.3MPa (1200 PSI) the urethane elastomer foam is used where high strength is required. The silicone elastomer/glass microbubble foam also has a high void volume, thus providing nearly constant crush strength over a wide strain range. The glass microbubbles, because of their brittle failure mode, also contribute to this wide plateau region. The polysulfide/phenolic microbubble foam with its low void volume has

practically no plateau, thus giving a compressive stress strain curve more typical of a high density elastomeric foam.

The effects of temperature on these foams is presented in Figures 3 through 5. These compressive stress strain curves obtained at -40 , 20 , and 60°C (-40 , 68 , 140°F) show a wide variation in the effects of temperature. The compressive stress of the urethane elastomer/glass microbubble foam (Figure 3) shows a large increase at -40°C and a large decrease at 60°C . As might be expected, the silicone foam has the most constant properties over the temperature range (Figure 4). The compressive stress of the polysulfide foam shows very little decrease at 60°C , however has a tremendous increase at -40°C . (Figure 5).

The ease of obtaining wide variations in the physical properties to meet a specific design requirement is illustrated in Figure 6 and Table II. These silicone elastomer/glass microbubble foams were formulated with various density glass microbubbles. Although these foams have similar densities, initial moduli, and void volumes, the compressive stress at higher strains varies considerably with the microbubble density. These data show that at small strains the properties are determined by the microbubble content as evidenced by the similar moduli. As the strain increases and the microbubbles are crushed the effect of the higher density higher strength microbubbles is evident.

Processing and Testing

The elastomeric syntactic foams discussed in this paper were all formulated to provide pourable systems that could be evacuated to remove mixed-in air before curing. The difficulty of processing varied with the individual elastomer. The exothermic urethane system increases in viscosity quite rapidly after mixing. This severely limits the processing time. Contributing

to this problem are the microbubbles in the blend which tend to shorten pot life in an exothermic system because of their insulating effect. The polysulfide foams were diluted with toluene to reduce the viscosity. This allowed easy processing but made a vacuum bakeout necessary to remove the solvent. The silicone resin has relatively low viscosity and a long pot life which makes it by far the easiest system to work with.

These foams have been applied to components by dipping, brushing, and a low-pressure injection molding technique. Dipping gives the poorest quality coating because of the tendency to get the thinnest coat on the corners of the component where the stresses are the highest. The viscosity of the blend can be adjusted using fumed silica fillers to minimize this problem. The polysulfide foams have been brushed on some components using two coats to assure complete coverage. Because of tolerances in many electronic assemblies it is often necessary to use a low-pressure injection molding technique. Although more expensive than dipping or brushing, it provides a uniform coating with good dimensional tolerances. As with foam selection, the application technique is dictated by the specific application.

Special test techniques were required to obtain meaningful physical property data on these foams. The compressive stress strain data were obtained using molded specimens which were tested in a subpress to assure parallelism. The deflection was measured using a deflectometer across the platens. The effect of specimen thickness or height on the compression properties is shown in Figure 7. These data were obtained on 29 mm diameter specimen with heights ranging from 0.6 to 25 mm. It is readily observed that there is a large change in the measured initial modulus and the stress strain properties. These data pose two questions: 1. What are the true material properties?, and 2. How can we test to obtain them?

These foams are used as thin coating on electronic components which are surrounded by a high modulus encapsulant. As the temperature is decreased on the electronic assembly the foam is compressed from all sides. This is called bulk compression. Because of their high coefficient of friction and Poisson's ratio, the bulk properties of an elastomeric syntactic foam can be determined by testing very thin sheets. Specimens 1.3 mm thick were used to obtain the data in this paper. Specimen parallelism and accurate strain measurement are imperative to obtain useful data on these thin specimen. Contained compression testing is another useful technique for obtaining bulk properties. The problems with this technique are obtaining good ram alignment and minimizing friction between the ram and cavity.

These data illustrate a common problem in physical property testing. Test techniques and specimens are often chosen for convenience without any appreciation that the data obtained may be useless for design. To avoid this problem tests should be performed on samples which are characteristic of the intended application thus avoiding the geometry dependence of compression testing.

Conclusions

Elastomeric syntactic foams made with various elastomers and micro-bubbles have been developed for use as stress relief coatings on encapsulated electronic components. Physical property tests were developed to obtain compressive stress strain data that can be used for engineering design. Because of the wide variety of castable elastomers and micro-bubbles available, foams can be formulated to meet the requirements of many specific applications.

TABLE I

TYPICAL ELASTOMERIC SYNTACTIC FOAM FORMULATIONS

← ELASTOMER →			← MICROBUBBLES →			← FOAM →			
POLYMER	DESIGNATION	PARTS	MATERIAL	DESIGNATION	PARTICLE DENSITY Kg/m ³	PARTS PER 100 RESIN	DENSITY Kg/m ³	VOID VOLUME %	INITIAL MODULUS MPA
URETHANE	EN-7 ¹	100	GLASS	B22A ²	200	11.1	640	32.1	647
SILICONE	SYLGARD ³ 184	100	GLASS	B18A ²	160	15.0	610	40.7	256
POLYSULFIDE	PRC-1201Q ⁴	100	PHENOLIC	BJO ⁵ 0930	230	2.7	1500	13.3	27.4

Notes: Supplied by: 1. Conap Inc., 2. 3M Co., 3. Dow Corning Corp., 4. Products Research and Chemical Corp.,
5. Union Carbide Corp.

TABLE II

FORMULATIONS AND PROPERTIES OF ELASTOMERIC SYNTACTIC
FOAMS MADE WITH VARIOUS DENSITY MICROBUBBLES

← SILICONE ELASTOMER →		← GLASS MICROBUBBLES →			← FOAM →			
DESIGNATION	PARTS	DESIGNATION	PARTICLE DENSITY Kg/m ³	PARTS PER 100 RESIN	DENSITY Kg/m ³	INITIAL MODULUS MPa	VOID VOLUME %	MICROBUBBLE VOLUME %
SYLGARD ¹ 184	100	B22A ²	200	15.0	630	59.2	40.7	44.1
SYLGARD ¹ 184	100	B35A ²	325	25.0	740	66.7	38.1	44.7
SYLGARD ¹ 184	100	B40A ²	375	33.3	730	78.6	40.1	48.3

Notes: Supplied by: 1. Dow Corning Corp., 2. 3M Co.

PROBLEM: THERMALLY INDUCED STRESS

SOLUTION: FOAM COATING ON COMPONENT

FIGURE 1: ELASTOMERIC SYNTACTIC FOAMS FOR STRESS RELIEF OF ENCAPSULATED ELECTRONIC COMPONENTS.

FIGURE 2 : COMPRESSION PROPERTIES OF VARIOUS ELASTOMERIC SYNTACTIC FOAMS.

FIGURE 3 : EFFECT OF TEMPERATURE ON THE COMPRESSION PROPERTIES - URETHANE ELASTOMER/ GLASS MICROBURBLE.

FIGURE 4 : EFFECT OF TEMPERATURE ON THE COMPRESSION PROPERTIES - SILICONE ELASTOMER/ GLASS MICROBUBBLE.

FIGURE 5: EFFECT OF TEMPERATURE ON THE COMPRESSION PROPERTIES — POLYSULFIDE ELASTOMER/PHENOLIC MICROBUBBLES.

FIGURE 6: EFFECT OF MICROBUBBLE DENSITY ON THE COMPRESSIVE PROPERTIES OF A SILICONE ELASTOMERIC SYNTACTIC FOAM,

FIGURE 7: EFFECT OF SPECIMEN HEIGHT ON THE COMPRESSION PROPERTIES - SILICONE ELASTOMER/ GLASS MICROBUBBLES