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CHEMICAL AND PHYSICAL CHARACTERIZATION
OF A KEVLAR-FILLED EPOXY MOLDING COMPOUND

By J. W. McFarland
Department 814

Published April 1978

Topical Report
G. W. Edman, Project Leader

Prepared for the United States Department of Energy
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CHEMICAL AND PHYSICAL CHARACTERIZATION OF A KEVLAR-FILLED EPOXY
MOLDING COMPOUND

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Prepared by J. W. McFarland, D/814

An epoxy molding compound filled with 6 mm Kevlar fibers (E-20328), made by the Fiberite Corporation, has been characterized chemically and physically. The resin is an epoxy novolak and Kevlar is an aromatic polyamide. E-20328 has very good mechanical and electrical properties at 24°C, but these properties fall off sharply at 205°C. Transfer molded specimens had approximately half the flexural strength of compression molded specimens.

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SUMMARY

E-20328, a 6 mm (0.25 in.) fiber length Kevlar-filled epoxy molding compound made by the Fiberite Corporation, has been characterized chemically and physically. The physical characterization included a limited laboratory study to develop both transfer molding and compression molding techniques.

Infrared analytical methods were used to determine that the epoxy resin is a polyglycidal ether of a novolak. The curing agent was not identified. Kevlar is an aromatic polyamide (aramid) material made by Du Pont Corporation. The compound is 51.8 percent Kevlar and 48.2 percent resin.

Flexural bars were used to develop processing methods. When the transfer mold was used, it was necessary to open up the gate to 19 mm wide and 1.57 mm (0.75 by 0.06 in) deep. Two sets of transfer molded flexural specimens made in this mold tested 75.97 MPa (11.02 ksi) and 68.85 MPa (9.99 ksi) respectively. A set of compression molded specimens tested at this same time ran 149.34 MPa (21.66 ksi). The compression molded specimens were so much stronger than the transfer molded ones that all transfer molding work was stopped.

Test specimens were made for flexural, tensile, compressive, impact, heat distortion, dielectric strength, and insulation resistance tests. These tests were made at 24°C and results indicated that the material has excellent strength at that temperature. This was especially true of flexural strength and heat distortion tests.

All of the properties were determined at 205°C, except impact strength and heat distortion. It was found that both mechanical and electrical properties fell off considerably at 205°C. For instance, the flexural strength at 205°C was 19.1 percent of the flexural strength at 24°C, and the dielectric strength dropped from 15,412 volts/millimeter (391.5 volts/mil) to 6082 volts/millimeter (154.5 volts/mil).

DISCUSSION

SCOPE AND PURPOSE

The purpose of this project was to characterize E-20328 (a Kevlar-filled epoxy molding compound made by the Fiberite Corporation) both chemically and physically. Chemical testing included the identification of the resin and a determination of the volatile content. Physical characterization included testing for tensile, flexural, compressive, and impact properties as well as dielectric strength, and insulation resistance. Mechanical and electrical tests were run at temperatures of 24° and 205°C.

Another objective was to develop processing information and to investigate molding techniques. Process development included studies on both compression molding and transfer molding techniques.

PRIOR WORK

There is no record of prior work on Kevlar-filled molding material. The Fiberite Corporation has published a data sheet on E-20328, which is a Kevlar-filled epoxy molding compound with a fiber length of 6 mm (0.25 in.). Fiberite's data sheet indicates that the material has excellent physical properties.

ACTIVITY

Chemical Characterization

E-20328 is an epoxy resin system reinforced with 51.8 percent Kevlar-49, an organic fiber made by Du Pont Corporation. Kevlar-49 is classified as an aramid (aromatic polyamide) material. Infrared spectral data indicate that the epoxy resin is a polyglycidal ether of a phenol formaldehyde novolak. The curing agent was not identified.

By heating the resin for 30 minutes at 177°C, the volatile content was found to be 2.84 percent. The diameter of the Kevlar fiber was found to be 0.0127 mm (0.0005 in.) as measured with an optical microscope.

Physical Characterization

Transfer Molded Specimens

Processing techniques were developed by molding flexural bars. After the best molding methods for the flexural specimens were

established, other test specimens were fabricated. In the case of the transfer molded specimens, it was necessary to open up the gates considerably because of the strength of the Kevlar fibers. For this reason, it was decided to begin by testing transfer molded specimens for flexural strength only. If the flexural results warranted it, transfer molds would be built for impact, tensile, and compressive specimens; if the transfer molded flexural specimens did not show promise, no other molds would be built.

Accordingly, a transfer mold was built with a gate that was 19 mm wide and 1.57 mm deep. After several trials, it was found that the E-20328 could be transferred through this gate, and work on the transfer molded flexural specimens was begun.

From the start, it was evident that the material would require some B staging (advancing the cure with heat prior to molding). Preforms that were B staged for 30 minutes, 45 minutes, and 60 minutes at 71°C all produced specimens with too much flash. Accordingly, the B staging temperature was increased to 93°C, and the time was set at 60 minutes. This schedule produced good specimens with the right amount of flash.

A set of test specimens was transfer molded using the parameters shown in Table 1. These specimens were tested at 24°C for flexural strength and flexural modulus according to ASTM D 790. The test results are shown in Table 2.

Table 2 shows that the flexural strengths of transfer molded specimens are not particularly high when compared to strengths of other epoxy compounds, which are often in the range of 130 to 140 MPa. Therefore, another set of transfer molded flexural test bars was made using the parameters shown in Table 1 except the molding temperature was raised to 180°C. The test results of these specimens are shown in Table 2. Flexural tests were conducted at 24°C according to ASTM D 790.

Increasing the cure temperature from 155° to 180°C resulted in slightly lower flexural strength and flexural modulus. These results were far below the intended values. In addition, the specimens were marginal in appearance. For these reasons, it was decided not to build the molds necessary to test for other properties.

Compression Molded Specimens

Again, flexural bars were used to develop the optimum processing conditions. In the B staging operation, loose material was placed in an oven at the designated temperature for a given length of time. It was then compressed into a pellet before being preheated in the dielectric heater. Table 3 shows the molding conditions

Table 1. Molding Parameters for
Transfer Molded Flexural
Test Bars

Parameter	Characteristic
B Stage Temperature	93°C
B Stage Time	60 minutes
Molding Temperature	155°C
Molding Time	50 minutes
Ram Pressure	10.3 MPa (1500 psi)

used for the compression molded flexural specimens. The specimens were tested at 24°C according to ASTM D 790, and the results are shown in Table 4.

Test specimens were made for flexural, tensile, compressive, impact, and heat distortion properties. These specimens were made approximately 4 months after the specimens described in Table 3 were made. It was found that the B staging had to be eliminated completely with the second set of specimens. Apparently, the cure of the material had advanced considerably during the intervening 4 months even though the material was stored at 4.4°C. Processing parameters are given in Table 5. The test results at 24°C and the test methods are shown in Table 6.

Tests were conducted at 205°C for flexural, tensile, and compressive properties. These specimens were made by the methods described in Table 5. The test bars were conditioned for 2 hours at 205°C and then tested at that temperature. Test results and test methods are shown in Table 7.

Table 7 indicates that the physical strength of the material drops off considerably at 205°C. At that temperature, it retained 19.1 percent of its room temperature flexural strength, 15.9 percent of its tensile strength, and 16.7 percent of its compressive strength. The flexural modulus and compressive modulus ran 23.0 percent and 32.3 percent respectively of their room temperature values.

It is seen that the flexural strength shown in Table 6 is somewhat higher than that shown in Table 4. The reason for this is not definitely known, but it is thought to be the result of operator experience with the material.

Table 2. Flexural Strength at 24°C of Transfer Molded Specimens

155°C Cure Temperature		180°C Cure Temperature	
Flexural Strength MPa (ksi)	Flexural Modulus GPa (ksi)	Flexural Strength MPa (ksi)	Flexural Modulus GPa (ksi)
93.08 (13.50)	7.65 (1110)	45.23 (6.56)	5.72 (830)
64.60 (9.37)	6.48 (940)	50.12 (7.27)	5.72 (830)
67.15 (9.74)	6.83 (990)	86.39 (12.53)	7.03 (1020)
75.15 (10.90)	7.17 (1040)	95.98 (13.92)	8.20 (1190)
74.46 (10.80)	7.58 (1100)	64.40 (9.34)	6.76 (980)
81.36 (11.80)	7.52 (1090)	70.95 (10.29)	7.10 (1030)
75.97 (11.02)*	7.21 (1045)*	68.86 (9.99)*	6.76 (980)*
*Average			

Table 3. Molding Parameters for
Compression Molded Flexural
Test Bars

Test Parameter	Characteristic
B Stage Temperature	93°C
B Stage Time	60 minutes
Milliamperes in Dielectric Heater	175 mA
Time in Dielectric Heater	30 seconds
Molding Temperature	149°C
Molding Time	40 minutes
Molding Pressure	55.16 MPa (8000 psi)

Electrical Testing

Electrical test specimens were made using the procedure given in Table 5. Tests for dielectric strength and insulation resistance were conducted at temperatures of 24° and 205°C. The results are shown in Table 8. At 205°C, the dielectric strength dropped to less than half the room temperature value, and the insulation resistance dropped from 2.18×10^{14} to 2.43×10^9 ohms.

ACCOMPLISHMENTS

A Kevlar-filled epoxy molding compound (E-20328 made by the Fiberite Corporation) has been characterized chemically and physically. Kevlar is an aromatic polyamide (aramid) made by the Du Pont Corporation. The resin is a novolak epoxy, but the curing agent was not identified. The finished compound contains 51.8 percent Kevlar fibers.

Mechanical and electrical specimens were tested at temperatures of 24°C and 205°C. At 205°C, the material retained about 15 to 19 percent of its room temperature strength.

In a limited processing study, it was found that the E-20328 was difficult to transfer mold. However, transfer molded flexural specimens were made after opening up the gate on the mold. The flexural strength of transfer molded specimens was less than half of the flexural strength of compression molded specimens.

Table 4. Flexural Strength at
24°C of Compression
Molded Specimens

Flexural Strength		Flexural Modulus	
MPa	(ksi)	GPa	(ksi)
131.00	19.00	15.17	2200
124.80	18.10	15.58	2260
170.30	24.70	16.75	2430
152.37	22.10	16.13	2340
168.23	24.40	17.37	2520
149.34*	21.66*	16.20*	2350*
*Average			

FUTURE WORK

A project will be initiated to study material having 12 mm (0.5 in.) fibers (as compared to 6 mm (0.25 in.) fibers). There is a possibility that the 12 mm molding compound may be significantly stronger than the 6 mm material.

The 6 mm compound that we are now using will be tested at temperatures of 80° and 122°C. In addition, a glass transition temperature and a thermal expansion curve will be obtained.

Process studies will be conducted on contoured configurations to evaluate the material's ability to be molded into thinner cross sections and complex shapes. Some additional work will also be done in the area of transfer molding in an attempt to obtain mechanical properties more closely resembling those of compression molded specimens.

Table 5. Molding Parameters for
Compression Molded Test
Specimens

Test Parameter	Characteristic
Milliamperes in Dielectric Heater	175 mA
Time in Dielectric Heater	20 seconds
Molding Temperature	155°C
Molding Time	40 minutes
Molding Pressure	41.37 MPa (6000 psi)

Table 6. Mechanical Properties at 24°C of Compression Molded
Test Specimens

Property	Value	ASTM Test Method
Flexural Strength	190.98 MPa (27.7 ksi)	D 790
Flexural Modulus	20.89 GPa (3030 ksi)	D 790
Tensile Strength	66.05 MPa (9.58 ksi)	D 651
Compressive Strength	166.16 MPa (24.1 ksi)	D 695
Compressive Modulus	8.69 GPa (1260 ksi)	D 695
Impact Strength	7.26 J/cm (13.6 ft-lb/in.)	D 256
Heat Distortion Temperature at 1 82 MPa (264 poi)	Greater than 316°C	D 648

Table 7. Mechanical Properties at 205°C of Compression Molded Test Specimens

Property	Value*	ASTM Test Method
Flexural Strength	36.53 MPa (5.30 ksi)	D 790
Flexural Modulus	4.81 GPa (697 ksi)	D 790
Tensile Strength	10.48 MPa (1.52 ksi)	D 651
Compressive Strength	27.72 MPa (4.02 ksi)	D 695
Compressive Modulus	2.81 GPa (407 ksi)	D 695

*Each value is an average of five determinations.

Table 8. Electrical Properties of Compression Molded Test Specimens

Property	24°C	205°C
Dielectric Strength	16240 V/mm (412.5 V/mil) 14583 V/mm (370.4 V/mil) 15412 V/mm (391.5 V/mil)*	5630 V/mm (143 V/mil) 6535 V/mm (166 V/mil) 6083 V/mm (154.5 V/mil)*
Insulation Resistance	2.24 x 10 ¹⁴ ohms 1.95 x 10 ¹⁴ ohms 2.35 x 10 ¹⁴ ohms 2.18 x 10 ¹⁴ ohms*	2.40 x 10 ⁹ ohms 2.40 x 10 ⁹ ohms 2.50 x 10 ⁹ ohms 3.43 x 10 ⁹ ohms*

*Average

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PLASTICS: Kevlar-Filled Epoxy

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