

TB6: KDT DI-200 Composites

Description:

KDT DI-200 is a low viscosity polysilazane that is designed to be used as a matrix for fiber reinforced composites. The resin finds specific utility as a matrix for composites that operate at the critical temperature regime between 300 °C and 600 °C where there is currently a void of matrix materials that are functional both thermally and mechanically. PMCs are typically not able to withstand temperatures greater than 300 °C and CMCs often lack the mechanical toughness and ease of processing required for most applications at those temperatures. DI-200 is able to meet the thermal requirements demanded for most applications while maintaining excellent mechanical properties and high toughness. Composites fabricated with DI-200 that are intended to function at 300 – 600 °C can be called polyceramic matrix composites (PCMCs) due to their ability to operate at the interface of traditional low temperature PMCs and high temperature CMCs.

Although KDT DI-200 is primarily used as a matrix for moderate temperature applications, it does possess exceptional high temperature capability due to its ability to convert to ceramic at high temperatures. Weight loss after 30 hours at 650 °C is only 4 % and in an air atmosphere weight loss at 1500 °C is 8 %. DI-200 also possesses excellent mechanical and electrical properties. Quartz reinforced DI-200 composites have a low, stable dielectric constant and low transmission loss over a broad temperature and frequency range. Such composites also have very low thermal conductivity and an extremely low water vapor transmission rate.

KDT DI-200 is compatible with a variety of reinforcement phases including quartz, carbon, glass, etc. Fabrication is relatively straightforward; DI-200 composites can be processed similar to organic thermoset resins such as epoxies.

Uses of DI-200 composites:

- Radomes
- Antenna windows
- Insulating foams
- Aircraft structural components

Fabrication of DI-200 Composites:

DI-200 composites using any of a number of fabrics may be fabricated using one of three fabrication methods. In the first method, the fabric is impregnated with a 50 % solids solution of DI-200 resin by simple brushing. The solvent is then flashed off at 120 °C and held at that temperature for 5 minutes to advance the resin cure. Alternatively, the layers can be laid up to the desired thickness, fixtured, and cured. Cure is achieved by heating to 260 °C under 200 psi pressure for at least 8 h. The part is then removed from the mold and post cured by heating at 260 °C for 12 h.

The second construction method, normally used for antenna window fabrication, involves several impregnations of a three-dimensional weave to achieve full cure. The third fabrication process involves the use of quartz microballoons to make a syntactic foam. Thermal cure cycles for the alternative fabrication process mimic those used in the 2-D laminate construction.

Thermal Properties:

KDT DI-200 resin has a polysilazane backbone with silicon and nitrogen bonded in an alternating sequence. As the resin is exposed to progressively higher temperature environments the polysilazane backbone gradually condenses to a polymer network (i.e. polyceramic) at moderate temperatures (300 – 600 °C) and to a silicon carbide/nitride ceramic at high temperatures (> 750 °C). DI-200 experiences very little loss in mass at high temperatures; in an air atmosphere DI-200 has a ceramic yield of 92 % at 1500 °C and a ceramic yield of 84 % at 1500 °C in a nitrogen environment (Figure 1). Weight loss after 30 hours at 650 °C is only 4 % (Figure 2).

Figure 1: TGA of DI-200 in Nitrogen

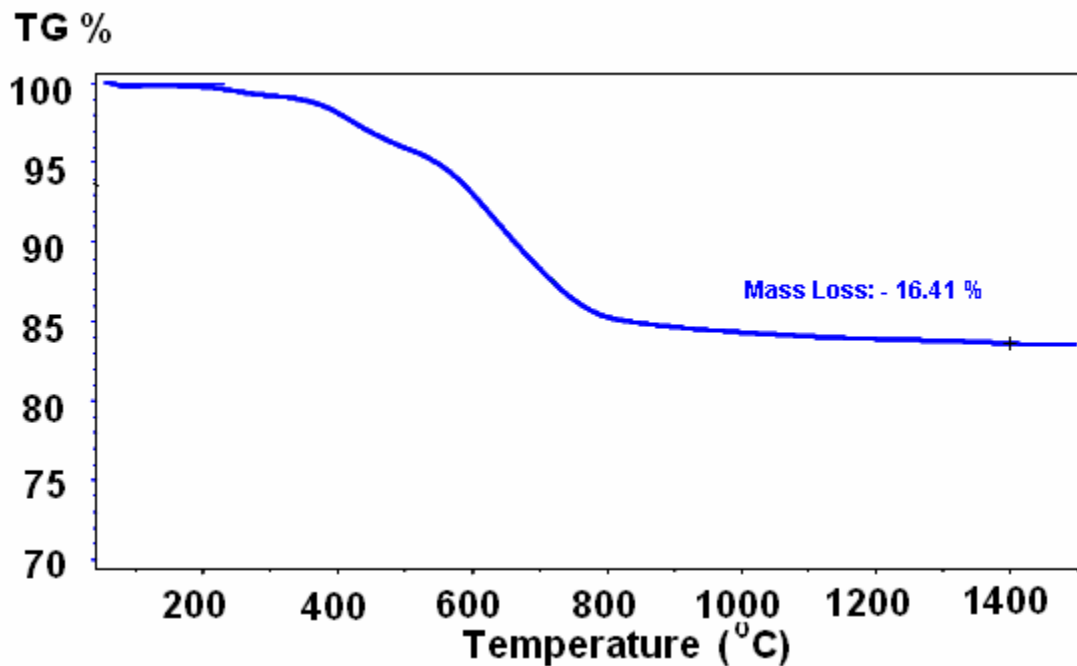
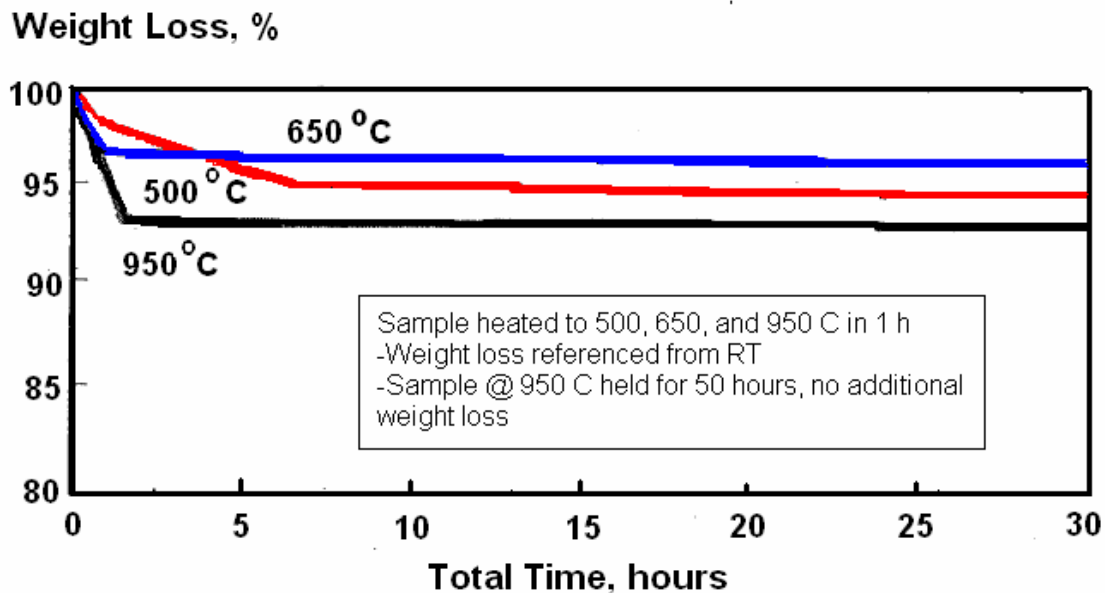


Figure 2: DI-200 Isothermal in Air



In addition to its thermal stability, KDT DI-200 also has a very low thermal conductivity. At room temperature the thermal conductivity is about 0.43 W/mK, specific heat is 1.05 kJ/kgK and thermal expansion is less than 0.0018 mm/mmK.

Electrical Properties:

Quartz reinforced DI-200 composites have a very low dielectric constant, approximately 3 at room temperature, with a loss factor of approximately 0.008. Figure 3 shows the dielectric constant and loss tangents of DI-200 composites as a function of temperature and frequency. The electrical properties of DI-200 composites are relatively constant over a wide temperature and frequency range. Figure 4 shows the electric properties over the frequency range of 30 megahertz to 30 gigahertz.

Figure 3: DI-200 Composites Electrical Properties vs Temperature

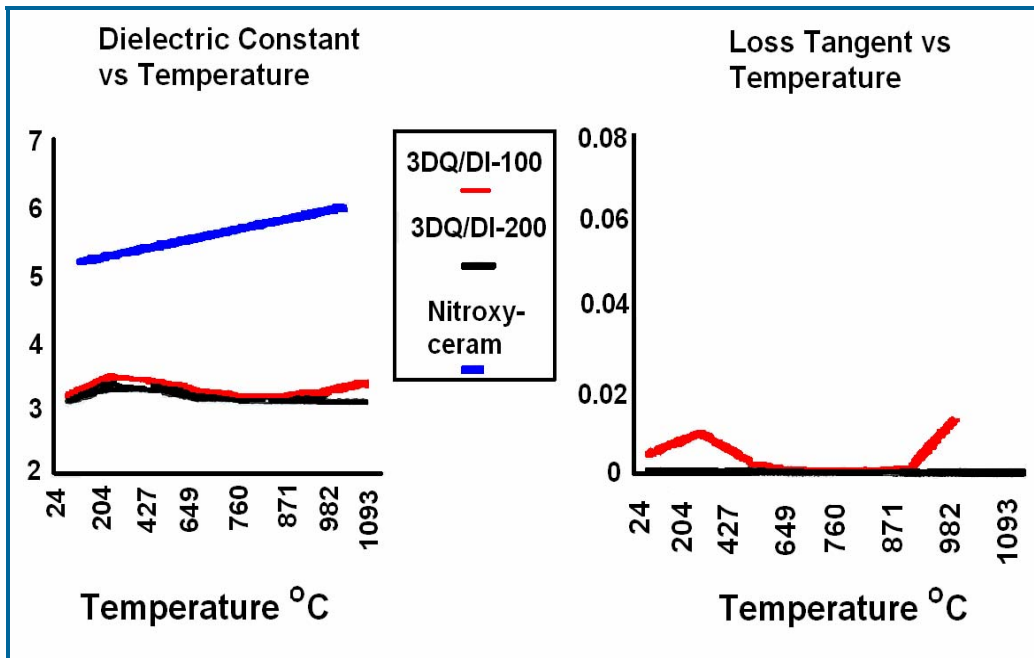
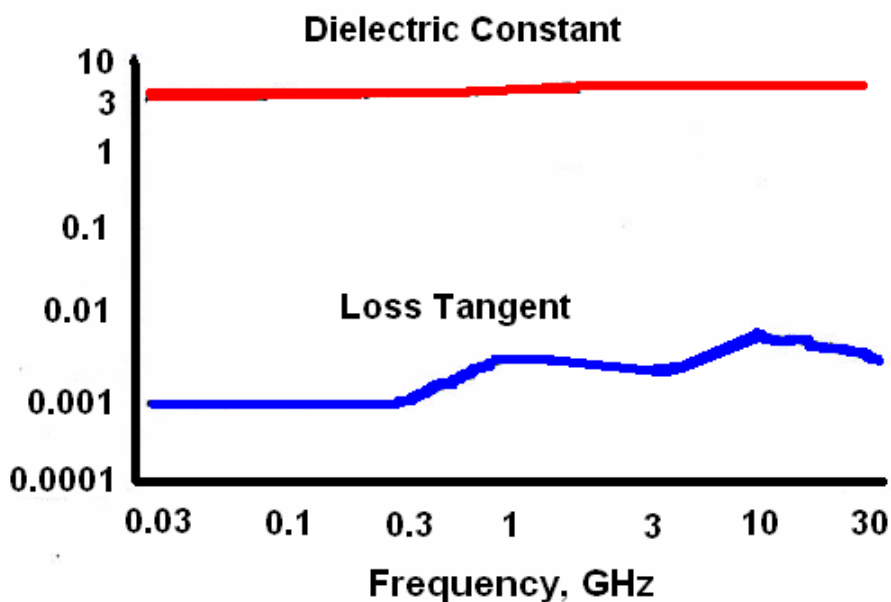


Figure 4: Electrical Properties vs Frequency



Mechanical Properties:

A variety of continuous fiber reinforcement phases have been used to prepare DI-200 composites. Mechanical properties for different DI-200 composites are displayed in Table 1. To date, quartz fiber has been the most widely used reinforcement because of its good thermal stability and dielectric properties.

TABLE 1. MATERIAL PROPERTIES FOR 2D, DI200 COMPOSITES

Property	Composite Fiber Composition				
	Quartz	Alumina	Aluminosilicate	Aluminoborosilicate	Carbon
Composite Density, g/cc		2.73	2.35	1.93	1.48
Tensile Strength, MPa	267	-	-	-	400
Flexural Strength, MPa	70	145	125	100	-
Flexural Modulus, GPa	20	110	75	32	-
Interlaminar Shear Strength, MPa	17	4	4	7	12

Radome Fabrication Steps:

Overview

Radomes can be fabricated using quartz socks that are woven to fit the radome contours. The DI-200 resin is delivered as a 50% ligroin solution.

Fabrication

1. Molding
 - a. A cone/ogive radome design of the shape shown in the attached drawing is to be fabricated.

- b. The molds should consist of one male mold and two female split molds. One female mold should be used to mold an inner shell consisting of 8 layers of scoured style 581 quartz fabric (socks). The socks can be impregnated on the mandrel. A copper screen should be used as the second layer on the male mold.
- c. The composite should be molded using the smaller of the two split female molds.
- d. The mold can then be placed in a heated press and the composite press cured for 15 hours at 550°F at which point the mold can be removed from the press.
- e. The female mold is then removed but the composite will remain on the male mold.
- f. A second copper screen is applied to the molded shape using a pressure sensitive adhesive (supplied) to hold it in place.
- g. Two additional quartz fabric socks are then placed over the copper, impregnated with the resin and the assembly placed in the second female mold.
- h. The assembly can then be cured as before.
- i. Upon completion of the cure the part can be removed from the mold and cut to length.
- j. The radome should then be given a 2 hour post cure in air.

2. Base Attachment Point

It may be necessary to build up the base thickness of the radome to accept an internal cylindrical attachment. If this could not be molded in, a separate ring would have to be made that could be bonded to the radome shell. The ring would have an internal diameter that would fit over the cylindrical attachment point.

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