CHARACTERIZATION OF THE DIELECTRIC PROPERTIES OF UNIDIRECTIONAL ARAMID/EPOXY COMPOSITES AT VARYING TEMPERATURES BY RECTANGULAR WAVEGUIDE METHOD

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ABSTRACT

Aramid/epoxy composites process excellent dielectric properties and that can be greatly influenced by thermal fields. In this paper, the rectangular waveguide testing system was modified and equipped with heating, temperature control and heat dissipation units. The accuracy of the testing system was verified by the dielectric properties of reference materials. Then the properties of unidirectional aramid/epoxy composites were measured in X-band from room temperature to 200℃. It can be founded that both the dielectric constants linear increase as temperature increase while the loss tangents are non-linear changed.

1 INTRODUCTION

Aramid/epoxy composites have been widely used to fabricate radomes for communication base stations and modern aircrafts since it possess excellent dielectric properties [1-3]. Both the dielectric constants and dielectric losses are very sensitive to temperatures, as a result, the dielectric properties of structure components can be greatly influenced [4-6]. In this way, the dielectric properties of the fiber reinforced composites when exposed to varying temperature environments should be described accurately.

The dielectric testing approach can be classified into two categories: resonant methods and non-resonant methods [7,8]. Resonant methods are able to give more accurate test results over a relatively narrow frequency band or a single frequency, while the non-resonant methods are able to give knowledge of electromagnetic properties over a rather wide frequency range [9-10]. The frequency range of free space method is wider while its veracity is worse. From another aspect, the methods for the preparation of coaxial line method are more challenging. Hence the rectangle waveguide method is the best choice to measure the electromagnetic parameters of materials in the precondition of satisfying frequency requirement [11-14].

There are many commercial equipments for the dielectric measurement of liquids and semisolid while that of solid materials has not been well handled [15,16]. Compared with other methods, the rectangular waveguide testing system is more convenient to modify to achieve the heating and temperature control functions. More Specifically, the small size of rectangular waveguide make the heating process more efficient for time and energy. In addition, the specimen of waveguide fixtures is easy to be formed for fiber reinforced composites.

In this paper, the rectangular waveguide system was modified and quipped with heating and temperature control units. The accuracy of modified system was verified to less than ±2% by the dielectric properties of reference materials. The dielectric parameter of the unidirectional aramid/epoxy composites were measured in X-band. It was founded that the dielectric constants and dielectric losses of aramid/epoxy composites increase with temperatures and.

2 THE MODIFICATION OF RECTANGULAR WAVEGUIDE TESTING SYSTEM

A specialized rectangular waveguide fixture was designed to satisfy the varying temperature measurement of dielectric properties as shown in Fig. 1(a). As shown in the picture, there are two 6 mm diameters openings (*A* and *B*) on the side wall of the fixture which are used to place the heating roads. During the course of experiments, thermocouples is inserted to the opening *C* on the other wall of the fixture, 2 mm in diameter. The temperature control unit of the waveguide fixture is shown in Fig. 1(b), and the accuracy of temperature can reach ±2 ℃.

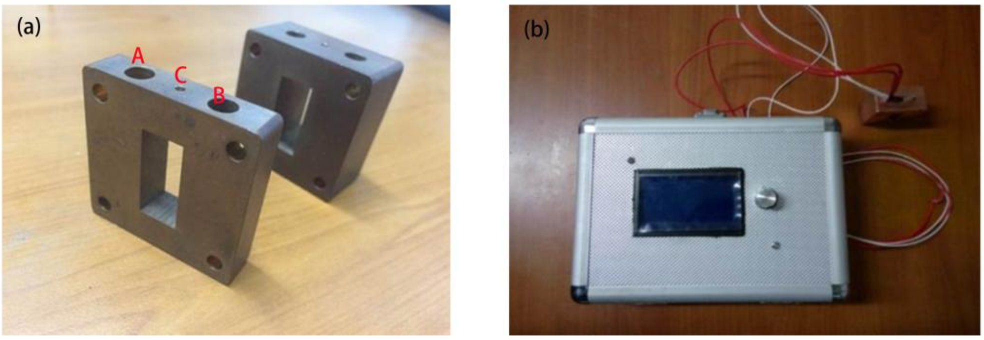

Figure 1 The heating components of the testing system: (a) the rectangular waveguide fixtures and (b) the temperature control unit

In order to protect the coaxial lines from the heat exchange with the waveguide fixture, a pair of waveguides was equipped with the system to dissipate the excess heat more sufficiently. The equipment of the modified rectangular waveguide testing system is shown in Fig. 2(a). For the heating units, it hard to maintain a steady temperature when the temperature difference with environments is too high. In this regard, an incubator can be applied to the testing system as shown in Fig. 2(b) and usually used when the temperature is higher than 150 ℃.

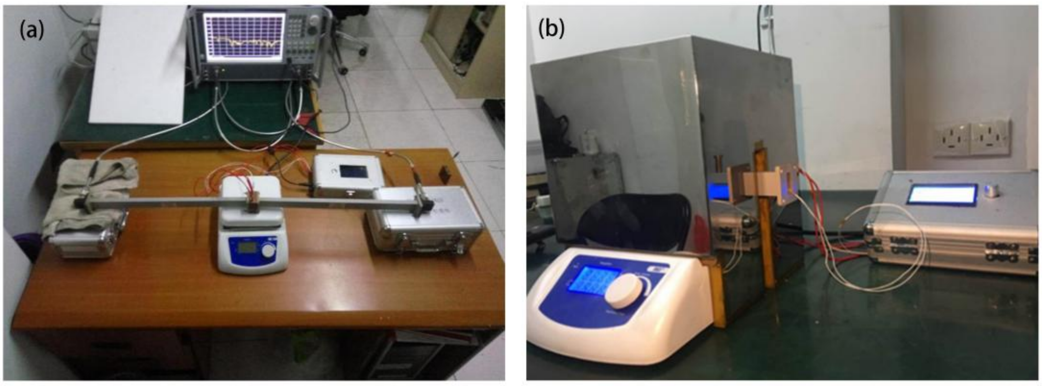

Figure 2 The modified rectangular waveguide system: (a) the main components of the testing system and (b) the incubator for heat preservation

Since the heat conductivity abilities of fiber reinforced resin composites are pretty poor, the specimens should be warmed sufficiently before experiments which usually take more than ten minutes. In addition, the thickness and phase compensation should be taken into consideration according to the change of physical properties of specimens caused by temperatures.

3 EXPERIMENTAL

3.1 Fabrication of specimens

The unidirectional aramid/epoxy prepregs used in this paper were provided by Aviation Industry of China, and the physical properties are listed in Table 1. The composites were fabricated by an autoclave vacuum bag molding process according to the curing cycle shown in Fig. 3. During the curing process, metal molds were placed on the tops of the specimens, a vacuum and a pressure of 0.7MPa were applied to obtain a smooth flat surface. The composite plates were trimmed into the standard size (22.86 mm*10.16 mm*4.72 mm) of the waveguide fixture. Unidirectional composites were used in this paper for further dielectric measurements.

Table 1 The physical properties of unidirectional aramid/epoxy prepregs.

Properties	Value
Density of aramid fiber (g/cm3)	1.44
Density of epoxy resin (g/cm3)	1.25
Resin content (%)	37~45
Surface density(g/m2)	133
Ply thickness(mm)	0.156

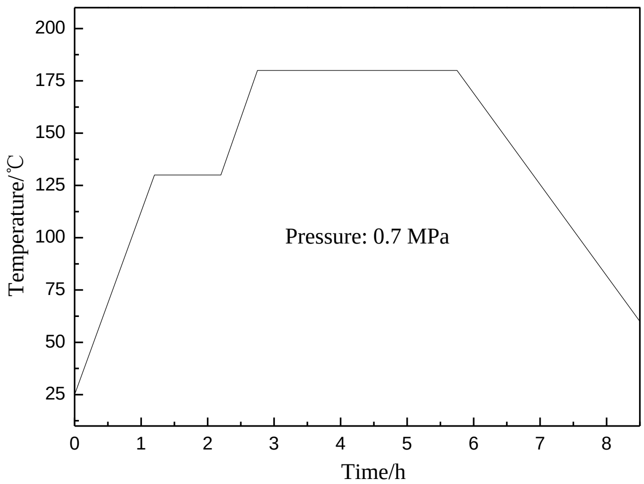

Figure 3 The curing cycle of unidirectional aramid/epoxy prepregs

3.2 Dielectric properties tests

The main components of the testing system is a rectangular waveguide, a pair of waveguide-to-coaxial transducer (HD Microwave, Xi'an, China), a Vector Network Analyzer (CETC AV3672B, Beijing, China) as shown in Figure 2. The dielectric properties of unidirectional aramid/epoxy composites were measure under the temperature range of 0-200℃ in X-band. The velocity of heating units is 1.5 ℃/min and the holding time before dielectric measurements is about 20 minutes.

4 RESULTS AND DISCUSSION

4.1 Correction of the testing system

In order to evaluate the accuracy of the testing system, PTFE and quartz whose dielectric properties are known quantities were used to correct the testing system. The dielectric properties of reference materials measured by the modified testing system are shown as follow:

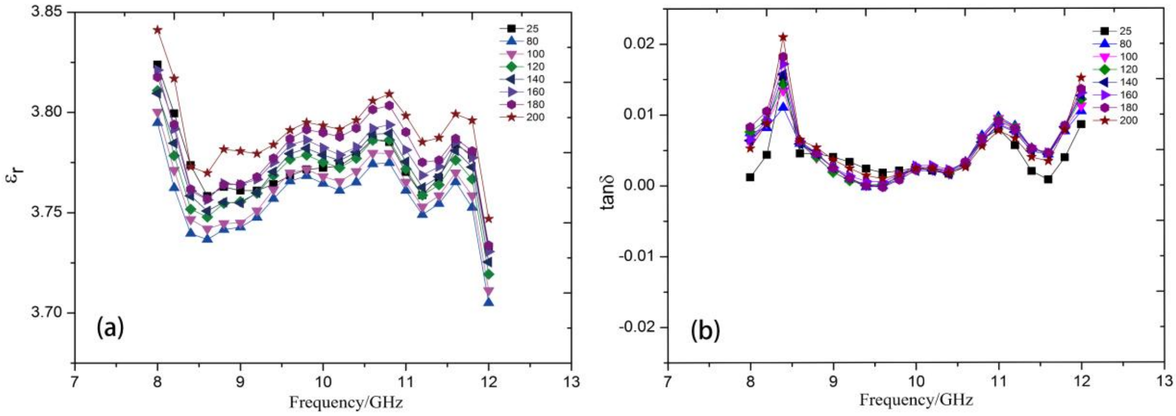

Figure 4 The dielectric properties of quartz under different temperatures: (a) the dielectric constants and (b) the dielectric loss tangents

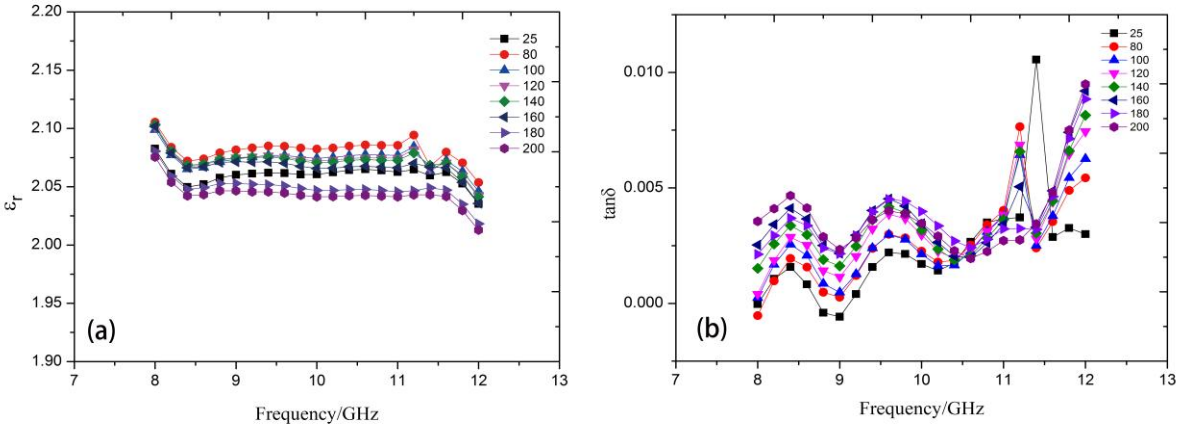

Figure 5 The dielectric properties of PTFE under different temperatures: (a) the dielectric constants and (b) the dielectric loss tangents

It can be seen that the dielectric constants of quartz changed about 0.05 when the temperature increased to 200℃ from room temperature. Since the thermal expansion coefficient of PTFE is larger than that of quartz and the change of thickness cannot be neglected during the inverse process of dielectric constants. The dielectric properties of PTFE after thickness compensation is shown in Fig. 5. The change of dielectric properties of standard matters are in accordance with the data in references [17-18]. This indicate that this modified rectangular waveguide testing system possesses good accuracy and can be well applied to the dielectric measurements of composites.

4.2 The dielectric properties of the composites under varying temperatures

The dielectric properties of unidirectional aramid/epoxy composites are shown in Fig. 6. It can be seen that both the dielectric constants and loss tangent increase significantly as the temperature change. In order to get the relationship of dielectric properties and temperatures directly, the properties were fitted with different functions as shown in Fig. 7.

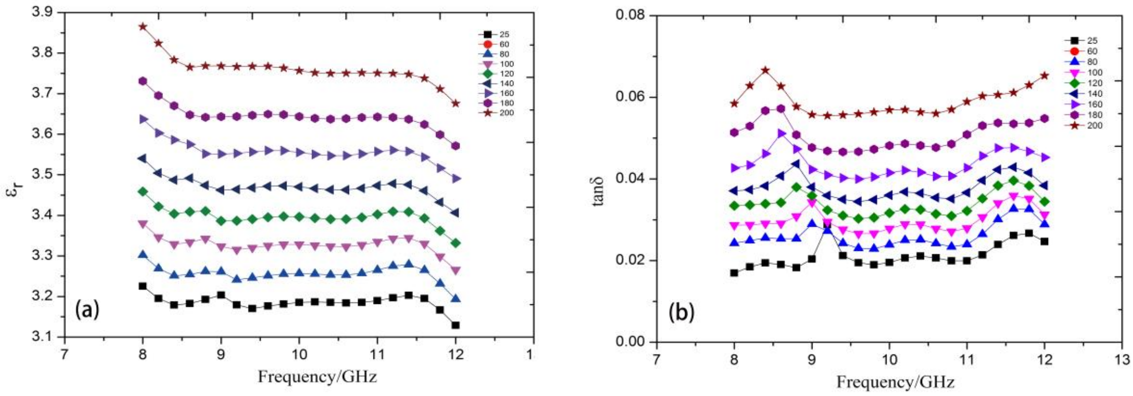

Figure 6 The dielectric properties of unidirectional aramid/epoxy composites under different temperatures: (a) the dielectric constants and (b) the dielectric loss tangents

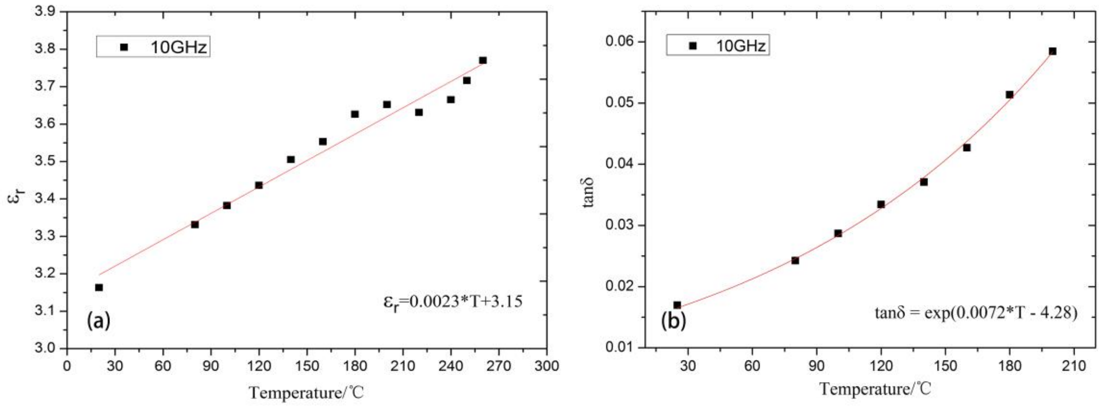

Figure 7 The relationship of dielectric properties of the composites and temperatures: (a) the dielectric constants and (b) the dielectric loss tangents

As shown in Fig.7, the dielectric constants of unidirectional aramid/epoxy composites increase linearly as the temperature increase. In the other hand, the relationship of dielectric loss tangents and temperatures are significant nonlinear. As the temperature increase, thermal motions of molecules were fastened then the orientation abilities of the composite changed which can increase dielectric losses greatly.

5 CONCLUSIONS

The rectangular waveguide testing system was modified for the measurements of the dielectric performance of fiber reinforced composites under varying temperatures. The units of heating temperature preservation and heat dissipation were equipped with the testing system. In addition, the system were verified by the dielectric properties of reference materials. The dielectric properties of unidirectional aramid/epoxy composites were measured from room temperature to 200℃. It can be concluded that both the dielectric constants and loss getting bigger as the temperature increase. The change of dielectric constants depend linearly on temperatures while that of the dielectric losses are non-linearly.

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