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(54) LOSSY RADIO FREQUENCY FILTER

(71) We, AMP INCORPORATED, a corporation organised and existing under the laws of the State of New Jersey, United States of America, of Eisenhower Boulevard, Harrisburg, Pennsylvania, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a lossy low-pass radio frequency filter comprising a substrate carrying a layer of dielectric material.

We have described in the complete specifications of our Patents Nos. 1,272,347 and 1,304,510 radio frequency filters comprising a substrate of ferrite or semi-conducting ceramic material having a layer of dielectric material deposited directly on to the substrate.

As described in these specifications the dielectric material can be barium titanate.

The dielectric strength of barium titanate makes it ill-suited for many high voltage feed-through applications, e.g., a microwave filter for use with the high voltage filament of a magnetron in a microwave oven. Tests on barium titanate indicate that it will undergo a breakdown with sustained use at a voltage of 600 to 700 volts which is the operating range of the magnetron filament of a microwave oven. Furthermore, many materials which could conceivably be substituted for the barium titanate exhibit unacceptably high leakage at the high ambient temperatures generated by the microwave oven.

The present invention is a lossy low-pass radio frequency filter comprising a substrate of a material having a high magnetic permeability, and a layer of glass which has been directly deposited on to a surface of the substrate, the glass having low electrical leakage at ambient temperatures in the range 200°C to 300°C.

An embodiment of the present invention

will now be described, by way of example, with reference to the drawing, in which:—

Figure 1 is an axial sectional view of a filter according to the invention;

Figure 2 is an axial sectional view of the filter of Figure 1 as incorporated in a connector assembly; and

Figure 3 is a schematic diagram of a magnetron circuit incorporating the filter of Figure 1.

The filter comprises a substrate in the form of an extruded ferrite tube 10 which carries a dielectric layer 12 comprising a glass characterised by low electrical leakage at ambient temperatures of 200° to 300°C and operating voltages of 600 to 700 volts. Metal plating 14 is applied to the glass layer 12 and the ferrite 10 along its axial bore 16. Spaced gaps 18 and 20 are left in the metal plating 14, for isolating centre and earthing electrodes as explained below.

Figure 2 shows the filter of Figure 1 in position on an electrical connector pin received in the bore 16 and in intimate engagement with the metal plating 14. The filter is received in a cavity 21 of an insulating body 23 and an earthing plane 24 on the insulating body has flange portions 25 which extend into the cavity 21 and engage intimately the plating 14 on the glass layer 12. Clearly the centre pin 21 is isolated electrically from the earthing plane 24 by the gaps 18 and 20 in the metal plating 14.

It has been found that a lead oxide glass may be used in the dielectric layer 12 to obtain the desired low leakage at high ambient temperatures. For example, a soft, G12 glass which is corrosive resistant at ambient temperatures of 200°C to 300°C and is also commercially available at a relatively reasonable cost may be used. A lead oxide glass such as G12 which is a low sodium glass displays the necessary low leakage characteristics at ambient temperatures of 200°C—300°C since there is little sodium ion migration through the glass.

It will of course be understood that the desired low leakage at these temperatures might also be achieved with other low sodium glasses wherein the sodium ions are replaced by other alkali metal ions such as barium or potassium. In general, it is preferable to use a glass which is characterised by a specific resistance greater than 1 megaohm centimetre.

The glass of the dielectric layer 12 has a co-efficient of thermal expansion which is only slightly less than the co-efficient of thermal expansion for the ferrite substrate 10, namely 90×10^{-7} per °C as compared with 100×10^{-7} to 110×10^{-7} per °C at room temperature. These relative co-efficients of thermal expansion establish a compressive force between the dielectric layer 12 and the ferrite substrate 10 to improve the mechanical strength of the glass.

The dielectric layer 12 includes aluminium oxide (Al_2O_3) which provides a rough outer surface to permit adhesion of the metal plating 14, e.g., silver, to the dielectric layer 12. Aluminium oxide is particularly desirable since it too has a co-efficient of thermal expansion which is less than the ferrite substrate so as not to adversely affect the compressive force between the dielectric layer 12 and the ferrite substrate 10.

The dielectric layer 12 is uniformly applied to the substrate 10 without any pin holes through the layer 12. This is accomplished by ball milling the glass for some 16 hours and then passing the glass through a 200 mesh screen. This is followed by the electrophoretic deposition of the glass and aluminium oxide using a slurry made with an organic solvent which will not adversely affect the glass components of the slurry to any appreciable degree. Ethyl acetate has been found to be particularly well suited for use as the organic solvent when utilised in accordance with the electrophoretic deposition process described in U.S. Patent 2,843,541. The filter is then fired in a suitable atmosphere such as nitrogen, argon or air and at a temperature sufficient to fire the glass particles into a smooth dense layer. However, the firing temperature must not be too high to avoid damaging the ferrite.

Although a ferrite substrate has been described, it will be understood that other high magnetic permeability, resistive substrates may be utilised. For example, a semiconductive ceramic material such as doped barium titanate might be used.

The filter of Figures 1 and 2 will now be described as part of a source of micro-

wave energy which is particularly well suited for use in a microwave oven. As shown in Figure 3, a magnetron 26 has a high voltage input circuit 28 and a filament 30 which is supplied by a filament transformer 32 through a low pass RF filter 34 according to the invention. The filter 34 which is a distributed impedance filter is indicated in the form of an equivalent circuit.

It will be understood that each line 36 of the filament 30 employs a filter assembly such as that shown in Figure 2. In other words, a pin 22 of the assembly shown in Figure 2 is connected between each line 36 and one terminal of the filament transformer 32. It will also be understood that earth as shown in Figure 3 is established by the earthing plane 24 as shown in Figure 2.

The filter exhibits an attenuation of 20dB at 915 MHZ which is more than adequate to prevent any microwave radiation hazard due to the propagation of microwave energy from the magnetron filament back to the power supply line.

WHAT WE CLAIM IS:—

1. A lossy low pass radio frequency filter comprising a substrate of a material having a high magnetic permeability and a layer of glass which has been directly deposited on to a surface of the substrate, the glass having low electrical leakage at ambient temperatures in the range 200°C to 300°C.

2. A filter as claimed in Claim 1, in which the substrate is of a ferrite material.

3. A filter as claimed in Claim 1, in which the substrate is of a semi-conducting ceramic material.

4. A filter as claimed in Claim 3, in which the substrate is doped barium titanate.

5. A filter as claimed in any preceding claim, in which the glass layer has a rough outer surface carrying a metal plating layer.

6. A filter as claimed in Claim 5, in which the glass layer contains aluminium oxide.

7. A filter as claimed in any preceding claim, in which the glass layer is of a low sodium glass having low sodium ion migration at high temperatures.

8. A filter as claimed in claim 7, in which the glass layer is of a lead oxide glass.

9. A filter as claimed in any preceding claim, in which the substrate is in the form of a tube carrying the glass layer on its outer surface, the outer surface of the glass layer and the inner surface of the substrate tube carrying individual isolated metal plating electrodes.

It will of course be understood that the desired low leakage at these temperatures might also be achieved with other low sodium glasses wherein the sodium ions are replaced by other alkali metal ions such as barium or potassium. In general, it is preferable to use a glass which is characterised by a specific resistance greater than 1 megaohm centimetre.

The glass of the dielectric layer 12 has a co-efficient of thermal expansion which is only slightly less than the co-efficient of thermal expansion for the ferrite substrate 10, namely 90×10^{-7} per °C as compared with 100×10^{-7} to 110×10^{-7} per °C at room temperature. These relative co-efficients of thermal expansion establish a compressive force between the dielectric layer 12 and the ferrite substrate 10 to improve the mechanical strength of the glass.

The dielectric layer 12 includes aluminium oxide (Al_2O_3) which provides a rough outer surface to permit adhesion of the metal plating 14, e.g., silver, to the dielectric layer 12. Aluminium oxide is particularly desirable since it too has a co-efficient of thermal expansion which is less than the ferrite substrate so as not to adversely affect the compressive force between the dielectric layer 12 and the ferrite substrate 10.

The dielectric layer 12 is uniformly applied to the substrate 10 without any pin holes through the layer 12. This is accomplished by ball milling the glass for some 16 hours and then passing the glass through a 200 mesh screen. This is followed by the electrophoretic deposition of the glass and aluminium oxide using a slurry made with an organic solvent which will not adversely affect the glass components of the slurry to any appreciable degree. Ethyl acetate has been found to be particularly well suited for use as the organic solvent when utilised in accordance with the electrophoretic deposition process described in U.S. Patent 2,843,541. The filter is then fired in a suitable atmosphere such as nitrogen, argon or air and at a temperature sufficient to fire the glass particles into a smooth dense layer. However, the firing temperature must not be too high to avoid damaging the ferrite.

Although a ferrite substrate has been described, it will be understood that other high magnetic permeability, resistive substrates may be utilised. For example, a semiconductive ceramic material such as doped barium titanate might be used.

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wave energy which is particularly well suited for use in a microwave oven. As shown in Figure 3, a magnetron 26 has a high voltage input circuit 28 and a filament 30 which is supplied by a filament transformer 32 through a low pass RF filter 34 according to the invention. The filter 34 which is a distributed impedance filter is indicated in the form of an equivalent circuit.

It will be understood that each line 36 of the filament 30 employs a filter assembly such as that shown in Figure 2. In other words, a pin 22 of the assembly shown in Figure 2 is connected between each line 36 and one terminal of the filament transformer 32. It will also be understood that earth as shown in Figure 3 is established by the earthing plane 24 as shown in Figure 2.

The filter exhibits an attenuation of 20dB at 915 MHZ which is more than adequate to prevent any microwave radiation hazard due to the propagation of microwave energy from the magnetron filament back to the power supply line.

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2. A filter as claimed in Claim 1, in which the substrate is of a ferrite material.

3. A filter as claimed in Claim 1, in which the substrate is of a semi-conducting ceramic material.

4. A filter as claimed in Claim 3, in which the substrate is doped barium titanate.

5. A filter as claimed in any preceding claim, in which the glass layer has a rough outer surface carrying a metal plating layer.

6. A filter as claimed in Claim 5, in which the glass layer contains aluminium oxide.

7. A filter as claimed in any preceding claim, in which the glass layer is of a low sodium glass having low sodium ion migration at high temperatures.

8. A filter as claimed in claim 7, in which the glass layer is of a lead oxide glass.

9. A filter as claimed in any preceding claim, in which the substrate is in the form of a tube carrying the glass layer on its outer surface, the outer surface of the glass layer and the inner surface of the substrate tube carrying individual isolated metal plating electrodes,



(12)

10. A filter as claimed in Claim 9, in which reference to Figures 1 and 2 of the drawing.
the glass layer has a co-efficient of thermal expansion slightly less than that of the substrate tube.

5 11. A lossy low-pass radio frequency filter substantially as hereinbefore described with

For the Applicants,
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