LOW FIRING TEMPERATURE DIELECTRIC MATERIALS DESIGNED TO BE CO-FIRED WITH HIGH BISMUTH GARNET FERRITES FOR MINIATURIZED ISOLATORS AND CIRCULATORS

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Patent Application Serial No. 62/687,984, titled LOW FIRING TEMPERATURE DIELECTRIC MATERIALS DESIGNED TO BE CO-FIRED WITH HIGH BISMUTH GARNET FERRITES FOR MINIATURIZED ISOLATORS AND CIRCULATORS, filed June 21, 2018, which is incorporated by reference herein in its entirety.

BACKGROUND

FIELD

Embodiments of the disclosure relate to dielectric materials that can be co-fired with ferromagnetic ceramic elements to form circulators or isolators without the use of adhesives.

DESCRIPTION OF RELATED ART

Circulators and isolators are passive electronic devices that are used in high-frequency (e.g., microwave) radio frequency systems to permit a signal to pass in one direction while providing high isolation to reflected energy in the reverse direction. Circulators and isolators commonly include a disc-shaped assembly comprising a disc-shaped ferrite or other ferromagnetic ceramic element, disposed concentrically within an annular dielectric element.

SUMMARY

~~Disclosed herein are embodiments~~In a first aspect, the present disclosure provides ~~of~~ a composite material for use as a radiofrequency component comprising a low temperature fireable outer material, the low temperature fireable outer material having a garnet or scheelite structure, and the low temperature fireable outer material including a combination of $BiVO_4$, Al_2O_3 and one or more of yttrium vanadate gadolinium vanadate, or titanium oxide~~,~~; and a high dielectric constant inner material located within the outer material, the high dielectric constant inner material having a dielectric constant above 30, wherein the low temperature fireable outer material and the high dielectric constant inner material are configured to be co-fired together at temperature between 650- 900 ℃ without the use of adhesive or glue.

In some embodiments, the low temperature fireable outer material can be shaped like a ring. In some embodiments, the high dielectric inner material can be shaped like a disc.

~~Also disclosed herein are embodiments of~~ In a second aspect, the present disclosure provides a method of forming a composite material for use as an isolator or circulator in a radiofrequency device, the method comprising providing a low temperature fireable outer material, the low fireable outer material having a garnet or scheelite structure and the low temperature fireable outer material including a combination of $BiVO_4$, Al_2O_3 and one or more of yttrium vanadate, gadolinium vanadate, or titanium oxide, entering a high dielectric constant inner material within an aperture in the low temperature fireable outer material, the high dielectric constant inner material having a dielectric constant above 30, and co-firing the lower temperature fireable outer material and the high dielectric constant inner material together at temperature between 650-900ºC to shrink the low temperature fireable outer material around an outer surface of the high dielectric constant inner material without the use of adhesive or glue.

In some embodiments, the method can further include slicing the lower temperature fireable outer material and the high dielectric inner material after co-firing.

In a third aspect, the present disclosure provides a radio frequency isolator or circulator comprising the composite material according to the first aspect.

Further disclosed herein are embodiments of a radiofrequency isolator or circulator comprising a low temperature fireable outer material, the low temperature fireable outer material having a garnet or scheelite structure, and a high dielectric inner material located within the outer material, the high dielectric inner material having a dielectric constant above 30, wherein the low temperature fireable outer material and the high dielectric inner material are configured to be co-fired together at temperature between 650-900ºC without the use of adhesive or glue.

In accordance with an aspect disclosed herein, there is provided a composite material for use as a radiofrequency component. The composite material comprises a low temperature fireable outer material, the low temperature fireable outer material having a garnet or scheelite structure, and a high dielectric inner material located within the outer material, the high dielectric inner material having a dielectric constant above 30, the low temperature fireable outer material and the high dielectric inner material being configured to be co-fired together at temperature between 650-900 ºC to form an integrated magnetic/dielectric assembly without the use of adhesive or glue.

In some embodiments, the low temperature fireable outer material includes $BiVO_4$.

In some embodiments, the high dielectric inner material is shaped like a disc and the low temperature fireable outer material is shaped like a ring.

In some embodiments, the low temperature fireable outer material includes a combination of $BiVO_4$ and Al_2O_3.

In some embodiments, the low temperature fireable outer material has a dielectric constant between 20 and 80.

What is Claimed is:

CLAIMS

1. A composite material for use as a radiofrequency component comprising:

a low temperature fireable outer material, the low temperature fireable outer material having a garnet or scheelite structure, and the low temperature fireable outer material including a combination of $BiVO_4$, Al_2O_3 and one or more of yttrium vanadate gadolinium vanadate, or titanium oxide; and

a high dielectric constant inner material located within the outer material, the high dielectric constant inner material having a dielectric constant above 30, the low temperature fireable outer material and the high dielectric constant inner material being configured to be co-fired together at temperature between 650-900 ºC to form an integrated magnetic/dielectric assembly without the use of adhesive or glue.

2. The composite material of claim 1 wherein the low temperature fireable outer material substantially includes $BiVO_4$.

3. The composite material of claim 1 wherein the low temperature fireable outer material includes at least 90 wt./vol. % $BiVO_4$, or at least 95 wt./vol. % $BiVO_4$, or at least 99 wt./vol. % $BiVO_4$.

4. The composite material of claim 1 wherein the low temperature fireable outer material includes at least 94 wt./vol. % $BiVO_4$, or at least 96 wt./vol. % $BiVO_4$, or at least 98 wt./vol. % $BiVO_4$.

~~3~~5. The composite material of claim 1 wherein the high dielectric constant inner material is shaped like a disc and the low temperature fireable outer material is shaped like a ring.

~~4. The composite material of claim 1 wherein the low temperature fireable outer material includes a combination of $BiVO_4$ and Al_2O_3.~~

~~5~~6. The composite material of claim ~~4~~1 wherein the low temperature fireable outer material has a dielectric constant between 20 and 80.

~~6~~7. The composite material of claim ~~4~~1 wherein the Al_2O_3 is present in the low temperature fireable outer material an amount up to about 6 wt%.

~~7~~8. The composite material of claim ~~4~~1 wherein $Bi_4V_2O_{11}$ is present in the low temperature fireable outer material as a phase separate from the $BiVO_4$.

~~8. The composite material of claim 4 wherein the low temperature fireable outer material further includes one or more of yttrium vanadate, gadolinium vanadate, or titanium oxide.~~

9. The composite material of claim ~~8~~1 wherein the titanium oxide is present in the low temperature fireable outer material in an amount up to 10 wt%.

10. The composite material of claim ~~8~~1 wherein one or both of yttrium vanadate~~,~~ or gadolinium vanadate form a solid solution with the $BiVO_4$ in the low temperature fireable outer material.

11. The composite material of claim ~~8~~1 wherein the titanium ~~di~~oxide is present in the low temperature fireable outer material as a phase separate from the $BiVO_4$.

12. The composite material of claim ~~8~~1 wherein the gadolinium vanadate is present in the low temperature fireable outer material in an amount up to 50 wt%.

13. The composite material of claim ~~8~~1 wherein $Bi_4V_2O_{11}$ and $BiVO_4$ are present in the low temperature fireable outer material as separate phases.

14. The composite material of claim 13 wherein $Bi_4V_2O_{11}$, $BiVO_4$, and $Bi_2Ti_4O_{11}$ are present in the low temperature fireable outer material as separate phases.

15. The composite material of claim 14 wherein $Bi_4V_2O_{11}$, $BiVO_4$, $Bi_2Ti_4O_{11}$, and TiO_2 are present in the low temperature fireable outer material as separate phases.

16. The composite material of claim ~~8~~1 wherein $Bi_4V_2O_{11}$ and $GdVO_4$ are present in the low temperature fireable outer material as separate phases.

17. A method of forming a composite material for use as an isolator or circulator in a radiofrequency device, the method comprising:

providing a low temperature fireable outer material, the low fireable outer material having a garnet or scheelite structure and the low temperature fireable outer material including a combination of $BiVO_4$, Al_2O_3 and one or more of yttrium vanadate, gadolinium vanadate, or titanium oxide;

entering a high dielectric constant inner material within an aperture in the low temperature fireable outer material, the high dielectric constant inner material having a dielectric constant above 30; and

co-firing the lower temperature fireable outer material and the high dielectric constant inner material together at temperature between 650-900ºC to shrink the low temperature fireable outer material around an outer surface of the high dielectric constant inner material to form an integrated magnetic/dielectric assembly without the use of adhesive or glue.

18. The method of claim 17 wherein one of the low temperature fireable outer material substantially includes $BiVO_4$, the low temperature fireable outer material includinges at least 90 wt./vol. % $BiVO_4$, or at least 95 wt./vol. % $BiVO_4$, or at least 99 wt./vol. % $BiVO_4$, or the low temperature fireable outer material including at least 94 wt./vol. % $BiVO_4$, or at least 96 wt./vol. % $BiVO_4$, or at least 98 wt./vol. % $BiVO_4$~~a combination of $BiVO_4$ and Al_2O_3~~, the Al_2O_3 is present in the low temperature fireable outer material an amount up to about 6 wt%, $Bi_4V_2O_{11}$ is present in the low temperature fireable outer material as a phase separate from the $BiVO_4$, ~~the low temperature fireable outer material further includes one or more of yttrium vanadate, gadolinium vanadate, or titanium oxide,~~ the titanium oxide is present in the low temperature fireable outer material in an amount up to 10 wt%, one or both of yttrium vanadate, gadolinium vanadate form a solid solution with the $BiVO_4$ in the low temperature fireable outer material, the titanium dioxide is present in the low temperature fireable outer material as a phase separate from the $BiVO_4$, the gadolinium vanadate is present in the low temperature fireable outer material in an amount up to 50 wt%, $Bi_4V_2O_{11}$ and $BiVO_4$ are present in the low temperature fireable outer material as separate phases, $Bi_4V_2O_{11}$, $BiVO_4$, and $Bi_2Ti_4O_{11}$ are present in the low temperature fireable outer material as separate phases,$Bi_4V_2O_{11}$, $BiVO_4$, $Bi_2Ti_4O_{11}$, and TiO_2 are present in the low temperature fireable outer material as separate phases, or $Bi_4V_2O_{11}$ and $GdVO_4$ are present in the low temperature fireable outer material as separate phases.

19. A radiofrequency isolator or circulator comprising the composite material of claim 1.~~:~~

~~a low temperature fireable outer material, the low temperature fireable outer material having a garnet or scheelite structure; and~~

~~a high dielectric inner material located within the outer material, the high dielectric inner material having a dielectric constant above 30, the low temperature fireable outer material and the high dielectric inner material being configured to be co-fired together at temperature between 650-900ºC without the use of adhesive or glue.~~

20. The radiofrequency isolator or circulator of claim 19 wherein the low temperature fireable outer material has a composition as recited in any of claims 2~~, 4,~~ or ~~6~~7-16.

21. The radiofrequency isolator or circulator of claim 19 included in an electronics device module.

22. The radiofrequency isolator or circulator of claim 19 included in a~~n RF~~ radiofrequency electronics device.