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FERRITE MATERIAL CONTAINING LITHIUM AND ALUMINUM OXIDES

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Our invention is directed toward ferrite materials of the type useful in electronic apparatus operable at microwave frequencies.

When ferrites of this type are employed in various types of microwave devices, it has been found necessary to produce materials having controllable and variable values of saturation magnetization. More particularly, different values of saturation magnetization are required for different types of microwave devices.

In addition to the saturation magnetization, two other parameters of ferrite materials became important in microwave applications. The first of these, the Curie temperature, is a measure of the maximum temperature use to which ferrite materials can be subjected without losing their magnetic properties and hence become unusable. Since these materials necessarily absorb energy during operation and are thereby heated, the Curie temperature limits the power handling capacity of devices incorporating such materials. The second parameter, the dielectric loss, is a measure of energy absorbed by a ferrite during operation and, to minimize insertion losses and thus increase the efficiency of devices utilizing such material, must be as small as possible.

It is an object of our invention to provide new and improved ferrite materials characterized by a low dielectric loss, a relatively high Curie temperature, and a saturation magnetization variable over a wide range.

Another object is to improve ferrite materials operable at radio or microwave frequencies by increasing the Curie temperature and decreasing the dielectric loss of such materials at these frequencies.

Still another object is to provide new and improved ferrite materials operable over a wide frequency range and having a saturation magnetization which can be varied in accordance with any chosen frequency within said range.

These and other objects of our invention will either be explained or will become apparent hereinafter.

In accordance with the principles of our invention, the oxides of lithium, iron and aluminum are reacted together in the solid state to produce our ferrite material. The proportional concentration of each oxide in the total mixture, as expressed in molecular ratios, is defined by the approximate formula

$$(w)Li_2O+(x)Fe_2O_3+(y)Al_2O_3$$

wherein (w) is approximately 0.25 and the quantity $(x+y)$ ranges between 1.20–1.25. The ratio y/x can in principle have any value, but our best results have been obtained when the ratio y/x falls within the approximate range 0.0–.40.

We have found that depending upon the particular composition selected, the saturation magnetization can be varied at will within the approximate range 200–3500 gauss with a corresponding range of Curie temperature from 350° to 625° C. Further, the dielectric loss as expressed in terms of the dielectric loss tangent at a frequency of 10 megacycles per second (the dielectric loss tangent is a measure of the conductivity of a ferrite material when used as a dielectric in a capacitor) can be as low as 0.002 for compositions covering the entire range.

We have further found that the value of the dielectric loss obtained with the above described formulation is quite sensitive to small changes in stochiometric content as well as being sensitive to slight changes in processing conditions. However, when a small amount of manganese oxide is added to the above formulation, this undesired sensitivity can be sharply decreased. More particularly, the resultant material is defined by the approximate formula

$$(w)Li_2O+(x)Fe_2O_3+(y)Al_2O_3+(z)MnO$$

wherein (w), $(x+y)$ and y/x have the values indicated previously and (z) which is also a mole ratio, falls within the range 0.00–0.10.

In the copending patent application of D. H. Baird and J. J. Dymon, filed January 3, 1956, Serial No. 557,429, there is disclosed a process for producing ferrites in which suitable compounds of the metallic elements are first mixed together in the proper proportions. The mixture is then subjected to one or more calcining operations with intermediate pulverizing steps if required. The material is then pulverized once more with addition of suitable binding or plasticizing agents and is pressure molded into a compact. The end product is then produced by firing and then cooling this compact.

Our materials can be produced in accordance with the process taught in the above identified application or alternatively can be produced in accordance with more conventional ceramic processing techniques.

Our invention will now be described in detail with reference to the illustrative examples which follow:

EXAMPLE I

Various ferrite materials satisfying the formula

$$(w)Li_2O+(x)Fe_2O_3+(y)Al_2O_3$$

were prepared under such conditions that (w) was held constant at 0.25 and the quantity $(x+y)$ was held constant at 1.20. The saturation magnetization, Curie temperature, and dielectric loss tangent (measured at a frequency of 10 megacycles per second) were then determined for each formulation as indicated in Table I below.

Table I

Molar Composition		Saturation Magnetization (Gauss)	Curie Temp. (° C.)	Dielectric Loss Tangent
Fe_2O_3	Al_2O_3			
1.20	0.00	3,500	625	in excess of 1.
1.15	0.05	2,900	585	Do.
1.10	0.10	2,250	560	Do.
1.05	0.15	1,500	520	0.0027.
1.00	0.20	1,050	485	0.0040.
0.95	0.25	900	450	0.0056.
0.90	0.30	450	405	0.0022.
0.85	0.35	200	360	0.0020.

As the ratio y/x is increased, the saturation magnetization decreases rapidly, and the Curie temperature decreases at a relatively slow rate. Since Al_2O_3 and Fe_2O_3 will always form a solid solution, irrespective of the relative proportions of each component, the ratio y/x can take any value between zero and infinity. However, our best results have been obtained when the ratio y/x falls within the range 0.0–0.40.

When the quantity $(x+y)$ is increased from 1.20 toward a maximum of about 1.25, the values of the saturation magnetization and Curie temperature of the material increase somewhat. When this quantity is further increased, the dielectric loss increases to less usable values. Further, when this quantity is decreased much below the indicated minimum value, the Curie temperature decreases to less usable values.

EXAMPLE II

Various ferrite materials satisfying the formula

$$(w)Li_2O+(x)Fe_2O_3+(y)Al_2O_3+(z)MnO$$

were prepared with (w) and $(x+y)$ having the values indicated in Example I and (z) being held constant at 0.06. The saturation magnetization, Curie temperature, and dielectric loss tangent were then determined (in the same manner as in Example I) as indicated in Table II below.

Table II

Molar Composition		Saturation Magnetization (Gauss)	Curie Temp. (° C.)	Dielectric Loss Tangent
Fe_2O_3	Al_2O_3			
1.20	0.00	3,450	610	0.095.
1.15	0.05	2,800	570	0.025.
1.10	0.10	2,200	550	0.0427.
1.05	0.15	1,700	515	0.0026.
1.00	0.20	1,400	470	0.003.
0.95	0.25	970	425	0.008.
0.90	0.30	450	385	0.0026.
0.85	0.35	225	350	0.0023.

As indicated by the data of Table II, the addition of manganese oxide does not materially change the results of Example I. However, as stated previously, the dielectric loss parameter is rendered less sensitive to small stoichiometric and processing variations. The sensitivity of the loss parameter tends to decrease as quantity (z) is increased. However, an excess of manganese oxide will adversely influence the magnetic properties of the ferrite, such as the Curie temperature, so that (z) should have a maximum value of about 0.10. Since the valences of the manganese in this product cannot be accurately evaluated at present, it will be understood that the manganese in the product is not necessarily in the divalent state.

While we have shown and pointed out our invention as applied above, it will be apparent to those skilled in the art that many modifications can be made within the scope and sphere of our invention.

What is claimed is:

1. A ferrite material composed of Li_2O, MnO, Fe_2O_3 and Al_2O_3 and defined by the approximate formula $(w)Li_2O+(x)Fe_2O_3+(y)Al_2O_3+(z)MnO$, wherein the quantities w, x, y and z are mole ratios, the quantity w being approximately equal to 0.25, the quantity $(x+y)$ falling within the approximate range 1.20 and 1.25 and the quantity z falling within the approximate range 0.00–0.10, the ratio y/x falling within the approximate range 0.044–0.40, said material having a saturation magnetization falling within the range 200–3500 gauss and a Curie temperature falling within the range 350°–625° C.

2. A ferrite material composed of Li_2O, MnO, Fe_2O_3 and Al_2O_3 and defined by the approximate formula $(w)Li_2O+(x)Fe_2O_3+(y)Al_2O_3+(z)MnO$, wherein the quantities w, x, y, and x are mole ratios, the quantity w being approximately equal to 0.25, the quantity $(x+y)$ being approximately equal to 1.2 and the quantity z being approximately equal to 0.06, the ratio y/x falling within the approximate range 0.044–0.40, said material having a saturation magnetization falling within the range 200–3500 gauss and a Curie temperature falling within the range 350°–625° C.

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