Feb. 16, 1971 R. G. WEST 3,563,897

FERROMAGNETC GARNET WITH STRESS INSENSITIVE B-H LOOP AND METHOD OF MAKING SAME

Filed April 3, 1968

2 Sheets-Sheet 1

Fig. 1.

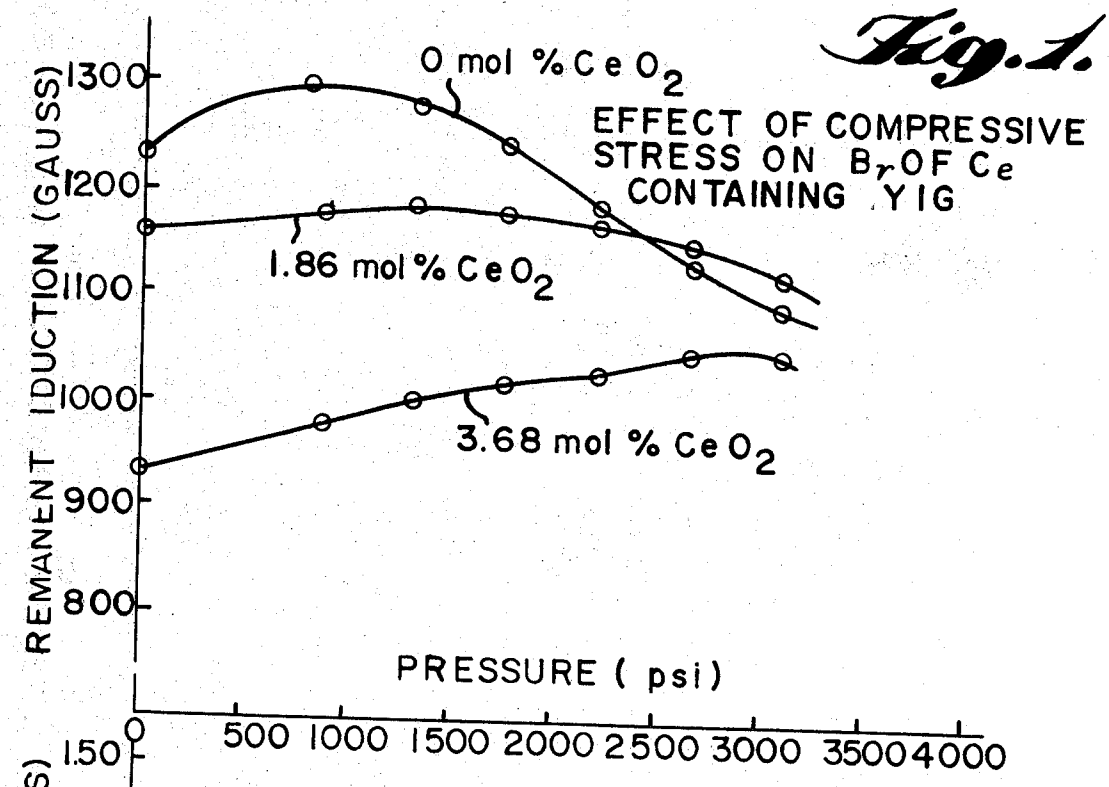
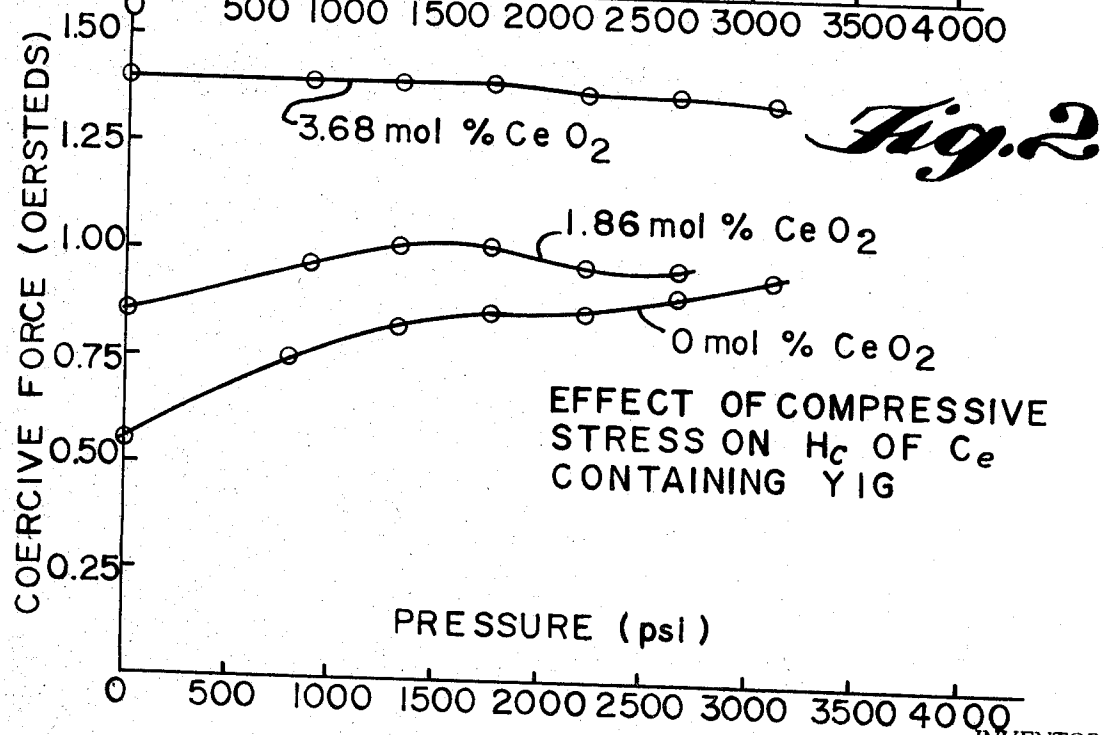


Fig. 2.



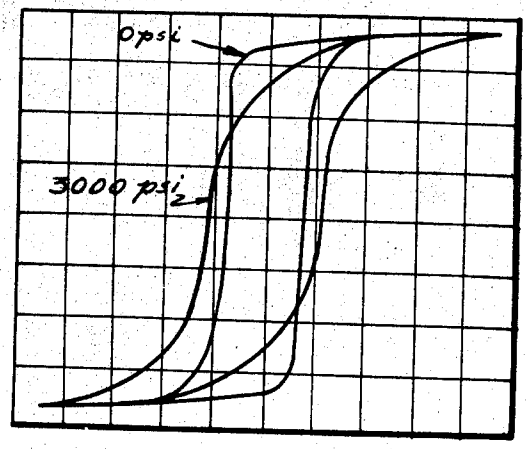
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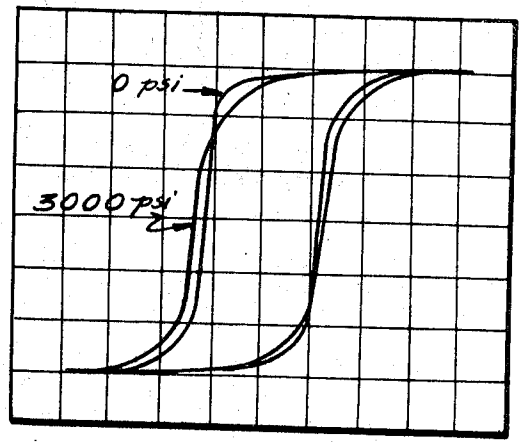


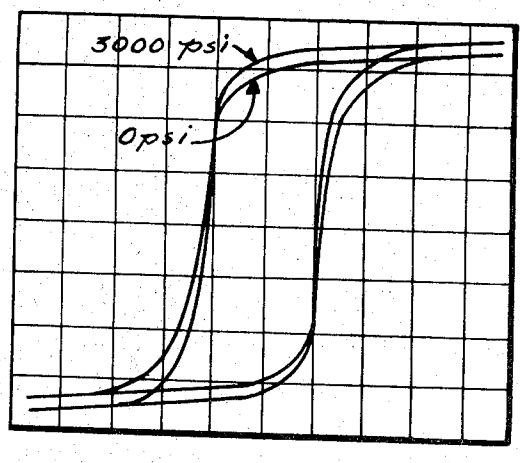
EFFECT OF MECHANICAL COMPRESSIVE STRESS ON THE HYSTERESIS LOOP OF $Y_3 Fe_5 O_{12}$

Fig. 3.

EFFECT OF MECHANICAL COMPRESSIVE STRESS ON THE HYSTERESIS LOOP OF $Y_{2.925} Ce_{0.075} Fe_5 O_{12}$

Fig. 4.





EFFECT OF MECHANICAL COMPRESSIVE STRESS ON THE HYSTERESIS LOOP OF $Y_{2.85} Ce_{0.15} Fe_5 O_{12}$

Fig. 5.

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United States Patent Office 3,563,897
Patented Feb. 16, 1971

3,563,897

FERROMAGNETIC GARNET WITH STRESS INSENSITIVE B–H LOOP AND METHOD OF MAKING SAME

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Filed Apr. 3, 1968, Ser. No. 718,536
Int. Cl. C04b 35/40
U.S. Cl. 252—62.57 11 Claims

ABSTRACT OF THE DISCLOSURE

Yttrium iron garnet ferrites, wherein the introduction of cerium oxide into the garnet reduces the mechanical pressure stress dependence of remanent magnetization and coercive force, are disclosed.

BACKGROUND OF THE INVENTION

Ferromagnetic garnet materials have been widely used, especially in microwave devices, since their discovery. It has, however, been noted that the yttrium iron garnet does not adequately satisfy certain design requirements for optimum microwave devices.

Yttrium iron garnet ferrites (hereinafter YIG ferrites), will produce a rotation of a plane of polarization of an incident plane polarized electromagnetic wave when properly disposed in a wave guide and biased by a magnetic field. The direction of the biasing magnetic field determines the manner in which the high frequency energy is affected. This property of ferrite materials has resulted in the development of nonreciprocal devices which utilize this rotation, commonly known as the Faraday rotation.

The prior art has substituted certain other ions in the YIG structure for certain magnetic effects. For instance, the Geller U.S. Pat. No. 3,006,855 discloses the use of garnet compounds such as calcium-tin garnets used in solution with YIG ferrites or other rare earth iron garnets, to produce ferrites with magnetic moments substantially higher than that of pure rare earth iron garnet. The Harrison et al. U.S. Pat. No. 3,132,105 discloses the incorporation of gadolinium in YIG ferrites to produce a relatively low saturation magnetization value, which remains substantially constant over an extended range of temperature values. A similar disclosure is found in the Zneimer et al. Pat. No. 3,125,534. The Geller Pat. No. 3,006,854 discloses incorporation of zirconium or hafnium ions into YIG ferrite structures.

One of the problems encountered by the user of YIG ferrites in microwave applications relates to stress-induced changes of magnetization. Mechanical stresses induce a variation of the remanent magnetization of YIG ferrites. That is, tensile or compressive stresses will alter the remanent magnetization of YIG ferrites, as well as altering the coercive force and the shape of the B–H hysteresis loop, of the ferrites. This effect is especially noticeable when a ferromagnetic toroid is utilized in microwave digital phase shifters. The toroid is rigidly located in a wave guide, and any change in tensile or compressive stresses, such as, for instance, those caused by temperature changes, will result in an alteration of the differential phase, since the phase shift is directly related to the remanence magnetization magnitude. This magnetization dependency upon stress is described by Stern and Temme, IEEE Trans. MTT, vol. 3, p. 873 (1965).

Comstock and Raymond, "Journal of Applied Physics," vol. 38, No. 9, p. 3,737 (August 1967) attempted to determine theoretical magnetostriction data for ytterbium and cerium iron garnets. The authors measured the temperature dependence of various constants of Yb^{3+} in YIG and of Ce^{3+} in YIG. The cerium iron garnet values

were determined by testing ferrites made by doping single crystals of YIG with cerium ions. These measurements allowed the authors to make theoretical predictions of the temperature dependence of certain magnetostriction constants of pure ytterbium iron garnet and pure cerium iron garnets (which cannot be grown per se).

Dillon and Neilsen "Physical Review," vol. 120, No. 1, pp. 105–113 (Oct. 1, 1960) performed resonance experiments on single crystals of YIG doped in a melt with rare earth ions, including Ce^{+++}. The authors found no significant effects in the cerium doping.

Blasse and Bril, "Applied Physics Letters," vol. II, No. 2, pp. 53–55 (July 15, 1967) added Ce_2O_3 to Y_2O_3 and hydrated alumina to produce $Y_3Al_5O_{12}$—Ce garnets. Chemical analysis excluded other oxidation states of cerium than Ce^{3+}. The garnet showed a bright yellow emission under excitation with cathode rays as well as with blue radiation, suggesting the use thereof for phosphors for flying-spot cathode-ray tubes for color television ($Y_3Al_5O_{12}$ is known to be non-magnetic).

SUMMARY OF THE INVENTION

Yttrium iron garnet ferrites with stress insensitive B–H hysteresis loops are produced by incorporating cerium oxide into the oxide mixture prior to the firing of oxides to produce the garnet ferromagnetic material. Generally, from about 0.5 to about 7.5 mole percent of the cerium oxide, based on the moles of total oxide, will be utilized. The remanent magnetization of the resultant ferrites is relatively insensitive to tensile and compressive stresses, and the ferrites are particularly suitable for use in microwave differential phase shift devices.

DESCRIPTION OF THE INVENTION

The introduction of oxides of cerium into yttrium iron garnet has an appreciable effect in controlling the stress dependence of the remanent magnetization of the ferrite. In addition, the coercive force of the YIG ferrite can be made stress-insensitive for quite large variations in mechanical stress. The microwave properties of the resultant ferrite are not appreciably deteriorated. To date, single crystals of YIG have been only of academic interest as toroids in microwave digital applications. It will therefore be appreciated that the present invention is concerned only with polycrystalline garnet structures, wherein the structure is of reduced stress dependency of B–H loops.

The microwave garnets of the present invention can be produced by conventional processes. In one process, the carefully weighed raw materials are first wet mixed with water, in a steel ball mill which preferably has a rubber or plastic lining. Other blending apparatus, such as high-speed blenders, colloid mills and attritors may be used. The resultant homogeneous mixture is then oven dried or spray dried. In this drying operation, water should be removed quite rapidly in order to minimize preferential settling of denser or larger particles. If desired, the mixture may be pressure filtered before drying to expedite water removal.

The dried material may then be presintered, or calcined, by heat treating at a temperature somewhat lower than the final firing temperature. This presintering step generally helps control shrinkage in the final stage and improves homogeneity. All or any portion of the material may be presintered as desired, as known to the art. After the presintering step, the material is comminuted to a particle size that is ceramically workable, preferably about two microns or less in size.

Several means of forming the comminuted particles into the desired shapes may be utilized, including die pressing, extruding and hydrostatic or isostatic pressing.

Organic additives may be introduced at this point to serve as a binder and particle lubricant, as desired.

The ferromagnetic ferrites are produced by a solid state reaction at temperatures of 1100 to 1500° C. If an organic additive is used, the formed shapes must be heated gradually during the low temperature range in the firing cycle in order to slowly volatize the organic additive. (Rapid evolution of vapors may crack the formed shapes.)

Hot pressing, which involves the simultaneous pressing and firing of the ferrite, may be used to advantage in many instances. The concurrent application of heat and pressure generally produces good control of density and crystal grain size.

It is known that ferrite materials are generally susceptible to changes in oxygen content during firing. It is therefore preferred to control the chemical valence of the compounds by precise firing schedules and controlled atmospheres during the heat treatment, as known to the art.

The YIG ferrites can be produced by the methods disclosed in U.S. Pats. Nos. 3,131,082, 3,062,746 or 3,051,656, the disclosures of which are hereby incorporated by reference.

Any one or several of the rare earths of atomic number 62–71 may be substituted for a portion of the yttrium in the ferrite of the present invention. Of these, gadolinium is the preferred material. Also, the iron may be replaced in part by aluminum, gallium, or indium, of which aluminum is the most preferred. Such replacements or substitutions will be by way of additions of the respective oxides (or precursors) in lieu of the replaced or substituted oxide. As used herein, unless otherwise specified, the term yttrium iron garnet is to be construed to mean yttrium with and without the presence of up to about 40 weight percent of the garnet of oxides of the rare earths of atomic number 62–71 and with and without the additional presence of oxides of aluminum, gallium or indium as partial substitution (up to 11 weight percent of the garnet) for the iron.

The garnet structure of the present invention will therefore be represented by the following composition:

$$Z_{3-x}Ce_xA_5O_{12} \qquad \text{Formula I}$$

wherein Z is yttrium alone or mixed with minor amounts (up to about 40 weight percent of the garnet) of oxides (or precursors) of rare earths of atomic numbers 62 to 71 inclusive, A is Fe or Fe mixed with up to about 11 weight percent of the garnet of oxides (or precursors) of Al, Ga or In, and x is a positive number of 0.02 to 0.30. Preferably, Z is pure yttrium or yttrium with up to about 38.5% by weight of the garnet of gadolinium oxide. A is preferably pure Fe or Fe mixed with up to about 10.5% by weight of the garnet of Al_2O_3. x is preferably 0.05 to 0.15 and most preferably about 0.08. It is to be emphasized that the above formula does not necessarily represent a given compound, but is only indicative of the elements in the garnet composition.

The cerium preferably is added as CeO_2 or a precursor thereof, such as a carbonate, acetate, oxalate, hydroxide and the like, or mixtures thereof. For instance, heating dry cerous carbonate at about 570° C. produces ceric oxide. Kirk-Othmer, "Encyclopedia of Chemical Technology" 2nd Edition, vol. 4 pp. 840–852, the disclosure of which is hereby incorporated by reference, sets forth properties of a number of cerium compounds.

CeO_2 is of quite high melting point (2600° C.) which is well above the garnet firing temperatures. The oxidation state of the cerium in the garnet structure is not known. It is possible that the Ce^{4+} converts, at least in part, to Ce^{3+} at the sintering temperatures. However, it is to be emphasized that the nature of such a conversion, if any, is not known at this time. The experimental results, as set forth in the working examples below, suggest that the mechanical pressure stress dependency of the remanent magnetization and the coercive force of

YIG garnet ferrites could be reduced by the addition of Ce_2O_3, or a precursor of Ce_2O_3, into the oxide starting material mixture. However, the "Handbook of Chemistry and Physics," Chemical Rubber Publishing Co., 36th Edition, indicates that cerous oxide (Ce_2O_3) ignites at about 200° C., suggesting that an inert atmosphere would be required. It will therefore be appreciated that the preferred embodiment of the present invention utilizes cerium oxide (CeO_2), or precursors thereof.

Regardless of the mechanism by which the cerium oxide is incorporated into the ferrite material, the presence of minor amounts of oxides of cerium render the B–H hysteresis loop stress insensitive, or relatively stress insensitive, which results in reducing the stress dependence of the remanent magnetization (remanent induction) and coercive forces, as well as illustrating a squarer B–H hysteresis loop under stress. The addition of cerium oxide also improves the high power handling characteristics of the garnet.

The preferred ferrites of the present invention can be represented by the following atomic composition:

$$Y_{3-x-v}Gd_vCe_xFe_{5-n}Al_nO_{12}$$

wherein v is 0 to about 2.0, x is 0.02. to 0.30, preferably 0.05 to 0.15, and most preferably 0.08, and n is 0 to about 1.5.

The microwave properties of cerium-containing YIG ferrites are not appreciably deteriorated. The 9.4 gHz. dielectric loss tangent generally remains below about 0.0001. The saturization magnetization appears to be relatively insensitive to cerium oxide in the YIG ferrite. The spin wave line width increases rapidly, and the ferromagnetic resonance line width increases moderately, with increasing levels of cerium oxide.

The present invention will be more clearly understood from the accompanying drawings, wherein

FIG. 1 is a diagram illustrating the effect of compressive stress upon the remanent induction (remanent magnetization) of YIG ferrites;

FIG. 2 is a diagram illustrating the effect of compressive stress upon the coercive force of YIG ferrites;

FIG. 3 is a B–H hysteresis loop for pure unmodified YIG;

FIG. 4 is a B–H hysteresis loop for modified YIG, wherein $x=0.075$; and

FIG. 5 is a B–H hysteresis loop for modified YIG wherein $x=0.15$.

The methods used to determine the values shown in FIGS. 1 and 2 are described in the Trans-Tech, Inc. advertisement entitled "Test for Hysteresis Loop Properties" appearing in Microwave, Hayden Microwave Corp., New York, N.Y., vol. 5, No. 9, p. 39 (Sept. 1966).

A controlled mechanical compressive force was applied into the major axis of the toroid under test. The cerium containing garnets were produced according to the examples of this application (the pure YIG garnet was produced in the same manner as Example 3, with the exception that no CeO_2 was utilized in the mixture, with compensating addition of Y_2O_3). All ferrites tested were of the same identical size and shape. 1.86 mole percent CeO_2 represents the situation wherein x in Formula 1 is 0.075 and 3.68 mole percent CeO_2 represents the situation wherein x in Formula 1 is 0.15. It will be readily seen that the composition containing 1.68 mole percent CeO_2 is relatively stress insensitive between 0 and 3000 p.s.i. compressive stress, especially when compared to the pure YIG ferrite material. As will be seen from FIG. 2, increasing amounts of cerium oxide, up to about 3.68 mole percent, render the resultant YIG ferrite more and more stress insensitive in coercive force. (It will be noted that at 3.68 mole percent CeO_2, the curve is essentially flat.)

However, it should be noted in FIG. 1 that the composition containing 3.68 mole was not as stress insensitive in remanent magnetization as the garnet containing 1.68 mole percent CeO_2.

A comparison of FIGS. 3, 4 and 5 will show the remarkable improvement in the reduction of stress sensitivity of yttrium iron garnets accomplished by the present invention. The B–H loops of FIGS. 4 and 5 are much squarer under stress and less stress sensitive than the B–H loop of FIG. 3. The compressive stress value of 3000 p.s.i. was arbitrarily chosen for the above tests. The reduction in stress sensitivity obtained by the cerium-containing garnets of the present invention will be noted for much lower and much higher pressures. For instance, the slopes of the curves of FIGS. 1 and 2 indicate that pure YIG ferrite, unlike the compositions of the present invention, is quite stress sensitive at low pressures.

Generally, amounts of cerium oxide in the YIG ferrite corresponding to values of x in Formula 1 of less than 0.02 will not have an appreciable effect upon the ferromagnetic properties of the resultant garnet. Amounts of cerium oxide greater than that represented by the value of 0.30 for x in Formula 1 will result in a garnet which is of increasing stress dependency in remanent induction and coercive force, as compared to cerium oxide levels within the ranges herein.

The invention will be understood more readily by reference to the following examples; however, these examples are intended to illustrate the invention and are not to be construed to limit the scope of the invention.

EXAMPLES OF THE INVENTION

Example 1

(Preparation of modified YIG garnet of the composition $Y_{2.925}Ce_{0.075}Fe_5O_{12}$.)

The following materials were mixed together:

	Grams
Y_2O_3 (1.50 micron average particle size)	44.487
CeO_2 (1.65 micron average particle size)	1.739
Fe_2O_3 (0.5 micron average particle size)	53.774

(All particle sizes were measured on a Fisher Sub-Sieve Sizer.)

The oxides were blended together in a "Waring Blender" with 150 ml. of distilled water for 15 minutes. The resultant slurry was placed in a covered steel pan and heated at 200° C. for about 20 minutes to evaporate the water. The dried cake was then calcined in air at 1250° C. for 8 hours. The calcined powder was placed in a 500 ml. polyethylene jar containing a ⅓ volume charge of ⅜ in. stainless steel balls in 120 ml. of distilled water and milled for 10 hours, at which time the average particle size was less than 2 microns. The resultant milled slurry was dried in a covered steel pan at 200° C. for about 20 minutes. The dried powder was granulated by forcing it through a No. 20 sieve, and then was isostatically pressed into compacts at a pressure of 6000 p.s.i.g. The compacts used in all of the examples were toroids with rectangular outer dimensions of 1½" x 1" x ¾". A centrally located rectangular hole 1" x ⅛" passed through the compact, opening on the 1½" x 1" sides. The compacts were sintered in oxygen (air) at a temperature of 1480° C. for 10 hours. The sintered ferrites were machined to outer dimensions of 1 1/16" x ⅜" x ⅜". The centrally located hole was not machined, but a volume shrinkage of about 17% was noted. The compressive stresses were applied to the ⅜" x ⅜" sides of the toroid in all B–H load determinations.

The garnet had the atomic composition:

$$Y_{2.925}Ce_{0.075}Fe_5O_{12}$$

and had the following properties:

$4\pi M_s$ (gauss)	1750
ϵ^1	14.4
tan δ, dielectric loss tangent	0.0001
ΔH (oersteds)	130
g-Effective	2.00
ΔH_K (oersteds)	5.2

The B–H hysteresis loop for the garnet is shown in FIG. 4 of the accompanying drawings.

Example 2

(Preparation of modified YIG garnet of the composition $Y_{2.92}Ce_{0.08}Fe_5O_{12}$.)

The following materials were mixed together:

	Grams
Y_2O_3 (1.50 micron average particle size)	44.393
CeO_2 (1.65 micron average particle size)	1.854
Fe_2O_3 (0.5 micron average particle size)	53.753

The garnet of this example was prepared using the same procedure as described in Example 1.

The resultant garnet structure corresponded to the following atomic composition: $Y_{2.92}Ce_{0.08}Fe_5O_{12}$.

The garnet had the following intrinsic electrical and magnetic properties:

tan δ, dielectric loss tangent	0.0001
ϵ'	14.7
ΔH (oersteds)	99
ΔH_K (oersteds)	5.8
g-Effective	1.99
$4\pi M_s$ (gauss)	1600

The B–H hysteresis loop of the garnet produced by this example was very similar to that shown in FIG. 4.

Example 3

(Preparation of modified YIG garnet of the composition $Y_{2.85}Ce_{0.15}Fe_5O_{12}$.)

The following oxides were mixed together:

	Grams
Y_2O_3 (1.5 micron average particle size)	43.088
CeO_2 (1.65 micron average particle size)	3.457
Fe_2O_3 (0.5 micron average particle size)	53.455

The garnet of this example was prepared using the procedure of Example 1, and the garnet had the atomic composition $Y_{2.85}Ce_{0.15}Fe_5O_{12}$.

The garnet had the following properties:

$4\pi M_s$ (gauss)	1760
ϵ'	14.2
tan δ, dielectric loss tangent	0.0001
ΔH (oersteds)	190
g-Effective	2.03
ΔH_K (oersteds)	8.6

The B–H hysteresis loop for this garnet is shown in FIG. 5 of the accompanying drawings.

Example 4

(Preparation of modified YIG garnet of the composition $Y_{2.7}Ce_{0.3}Fe_5O_{12}$.)

The following oxides were used as starting materials:

	Grams
Y_2O_3 (1.5 micron average particle size)	40.341
CeO_2 (1.65 micron average particle size)	6.833
Fe_2O_3 (0.5 micron average particle size)	52.827

This example used the procedure of Example I. The garnet had the following electric and magnetic properties:

$4\pi M_s$	1780
ϵ'	14.9
tan δ, dielectric loss tangent	0.0001
ΔH (oersteds)	150
g-Effective	2.02
ΔH_K (oersteds)	16.6
T_c (° C.)	268

While the coercive force of this garnet was of reduced compressive stress sensitivity, the remanent magnetization was much more sensitive to compressive stress than the garnet of Example 3. This suggests that this composition is about the upper limit of CeO_2 addition for the most stress-insensitive B–H loop garnets.

The resultant garnet corresponded to the following atomic composition:

$$Y_{2.7}Ce_{0.3}Fe_5O_{12}$$

Example 5

(Preparation of modified YIG garnet of the composition $Y_{2.98}Ce_{0.02}Fe_5O_{12}$.)

A modified YIG garnet was produced utilizing the following raw materials:

	Grams
Y_2O_3 (1.50 micron average particle size)	45.523
CeO_2 (1.65 micron average particle size)	0.466
Fe_2O_3 (0.5 micron average particle size)	54.011

The garnet of this example was prepared using the same procedure as described in Example 1. The resultant garnet had the following atomic composition:

$$Y_{2.98}Ce_{0.02}Fe_5O_{12}$$

The garnet produced by this example had a B–H loop which was squarer under stress and less sensitive to compressive stresses than the same garnet (of FIG. 3) without the cerium oxide present. The improvement in stress insensitivity was marginal, suggesting that this example may be taken as the general lower working limit of cerium oxide content.

Example 6

(This example relates to a cerium and gadolinium modified YIG garnet of the composition

$$Y_{1.12}Ce_{0.08}Gd_{1.8}Fe_5O_{12})$$

The oxides used were:

	Grams
Y_2O_3 (1.5 micron average particle size)	14.608
CeO_2 (1.65 micron average particle size)	1.591
Gd_2O_3 (0.6 micron average particle size)	37.684
Fe_2O_3 (0.5 micron average particle size)	46.117

The garnet was produced using the procedure of Example 1.

The resultant garnet structure corresponded to the following atomic composition: $Y_{1.12}Ce_{0.08}Gd_{1.8}Fe_5O_{12}$.

The garnet produced by this example had a B–H loop which was squarer under stress and less sensitive to compressive stresses than the same garnet without the cerium oxide present (compensated by the stoichiometric addition of Y_2O_3, of course).

Example 7

(This example relates to a cerium and aluminum modified YIG garnet of the composition

$$Y_{2.92}Ce_{0.08}Fe_{3.6}Al_{1.4}O_{12})$$

The oxides used were:

	Grams
Y_2O_3 (1.5 micron average particle size)	49.949
CeO_2 (1.65 micron average particle size)	1.961
Fe_2O_3 (0.5 micron average particle size)	40.930
Al_2O_3 (1.35 micron average particle size)	10.160

The same process was used as was used in Example 1, except that the compact was sintered in oxygen (air) at a temperature of 1530° C. for 10 hours.

The resultant garnet structure corresponded to the following atomic composition: $Y_{2.92}Ce_{0.08}Fe_{3.6}Al_{1.4}O_{12}$.

The garnet produced by this example had a B–H loop which was squarer under stress and less sensitive to compressive stresses than the same garnet without the cerium oxide present (compensated by the stoichiometric addition of Y_2O_3, of course).

Example 8

(This example relates to the preparation of a cerium, gadolinium and aluminum modified YIG garnet of the composition $Y_{2.52}Ce_{0.08}Gd_{0.4}Fe_{4.6}Al_{0.4}O_{12}$.)

The oxides used were:

	Grams
Y_2O_3 (1.5 micron average particle size)	37.515
CeO_2 (1.65 micron average particle size)	1.815
Gd_2O_3 (0.6 micron average particle size)	9.558
Fe_2O_3 (0.5 micron average particle size)	48.424
Al_2O_3 (1.35 micron average particle size)	2.688

The garnet was produced by the procedure of Example 1, except that the compact was sintered in oxygen (air) at a temperature of 1495° C. for 10 hours.

The resultant garnet structure corresponded to the following atomic composition:

$$Y_{2.52}Ce_{0.08}Gd_{0.4}Fe_{4.6}Al_{0.4}O_{12}$$

The garnet produced by this example had a B–H loop which was squarer under stress and less sensitive to compressive stresses than the same garnet without the cerium oxide present (compensated by the stoichiometric addition of Y_2O_3, of course).

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. Polycrystalline yttrium iron garnet structure of reduced mechanical stress dependency of remanent magnetization and coercive forces consisting essentially of a modified yttrium iron garnet represented by the atomic composition:

$$Z_{3-x}Ce_xA_5O_{12}$$

wherein Z is selected from the group consisting of yttrium and mixtures thereof with at least one rare earth of atomic numbers 62–71 inclusive the amount of rare earth, calculated as oxide being up to about 40% by weight of the garnet A is selected from the group consisting of iron and mixtures thereof with at least one member selected from the group consisting of aluminum, gallium and indium, the amount of aluminum, gallium and indium, calculated as oxide being up to about 11% by weight of the garnet, and x is about 0.02 to about 0.30.

2. A composition as claimed in claim **1** wherein x is 0.05 to 0.15.

3. A composition as claimed in claim **1** wherein x is about 0.08.

4. The composition of claim **1** wherein said modified yttrium iron garnet is represented by the atomic composition:

$$Y_{3-x-v}Gd_vCe_xFe_{5-n}Al_nO_{12}$$

wherein v is 0 to about 2.0, x is about 0.02 to about 0.30, and n is 0 to about 1.5.

5. A composition as claimed in claim **4** wherein v and n are both 0.

6. A composition as claimed in claim **5** wherein x is 0.05 to 0.15.

7. A composition as claimed in claim **5** wherein x is about 0.08.

8. A composition as claimed in claim **1** wherein said rare earth is gadolinium present in an amount, calculated as oxide of up to about 38.5% by weight of the garnet.

9. A composition as claimed in claim **1** wherein A is iron with up to 10.5% by weight of the garnet of aluminum, calculated as oxide.

10. In a process for producing polycrystalline yttrium iron garnet ferrites of the $Z_3A_5O_{12}$ type wherein Z is selected from the group consisting of yttrium and mixtures thereof with at least one rare earth of atomic numbers 62–71 inclusive, the amount of rare earth, calculated as oxide being up to about 40% by weight of the garnet, and A is selected from the group consisting of iron and mixtures thereof with at least one member selected from the group consisting of aluminum, gallium and indium,

the amount of aluminum, gallium and indium, calculated as oxide being up to about 11% by weight of the garnet, said process comprising the steps of mixing and blending of raw materials of said yttrium iron garnet ferrites together in the form of oxides or oxide precursors, forming the blended material into formed shapes, and thereafter sintering said formed shapes at temperatures of up to about 1500° C. to obtain ferromagnetic garnets, the improvement comprising adding cerium as an oxide or precursor thereof, as a substitute for a portion of the yttrium, in an amount of from 0.5 to 7.5 mole percent, calculated as oxide, to said raw materials, based on the total moles of raw materials.

11. The process as claimed in claim **10** wherein about 1.86 mole percent of cerium oxide, based on the total number of moles of said raw materials, are added.

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U.S. Cl. X.R.

252—62.58