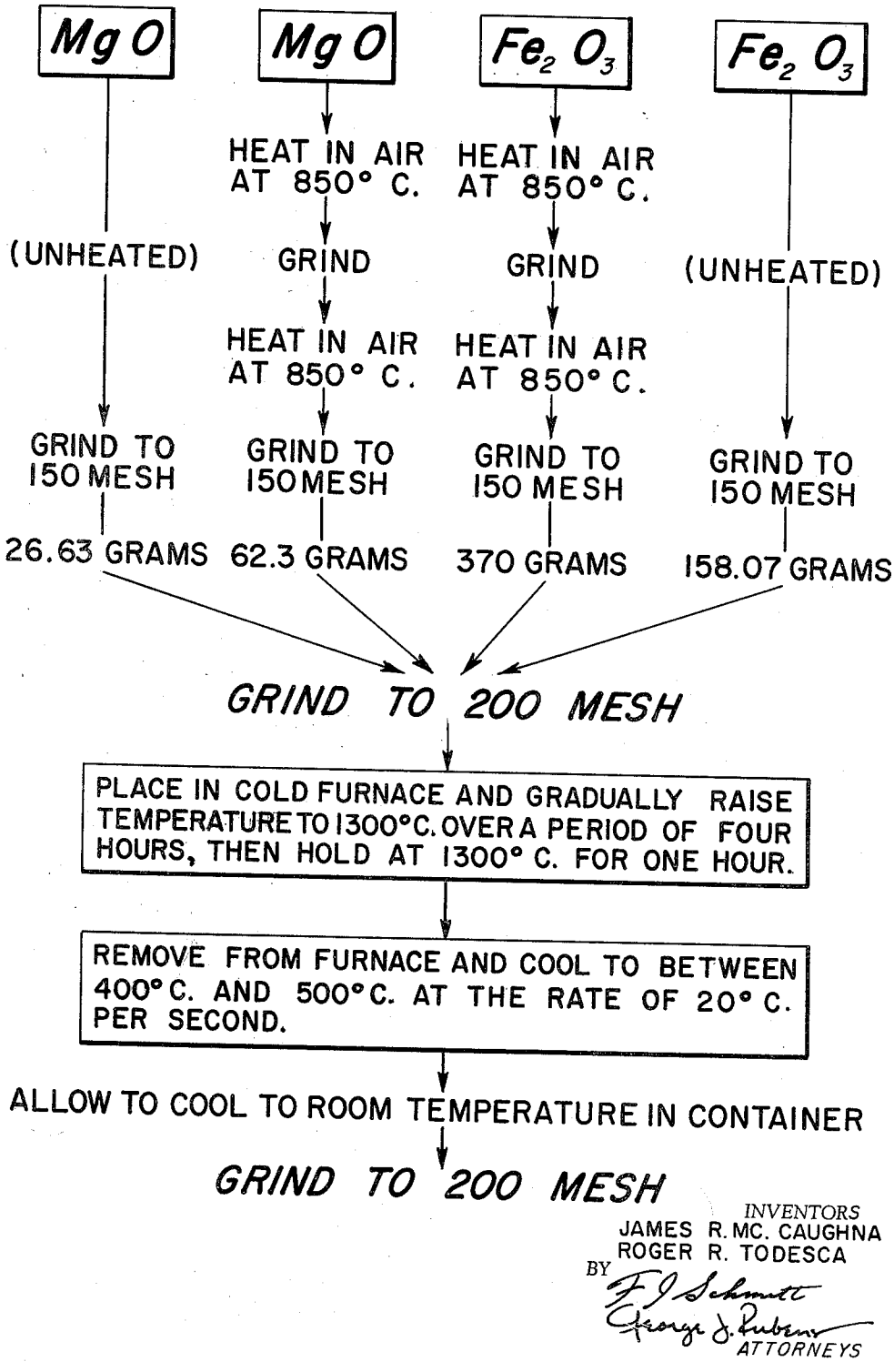
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MICROWAVE ABSORBER AND METHOD OF MANUFACTURE

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MICROWAVE ABSORBER AND METHOD OF MANUFACTURE

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The present invention relates in general to the absorption of electromagnetic energy, and more particularly to a substance having, in thin layers, the property of dissipating a substantial proportion of any high-frequency radiations received thereby.

It is known that certain materials possess in varying degrees the ability to absorb incident energy. Particular use is made of these materials in anechoic chambers where the operating characteristics of antennae and other electrical circuit components are tested and evaluated. A number of energy-absorbent substances, such as layers of plastic or foam rubber, are satisfactory for this purpose, but these layers must be of considerable thickness in order to be effective.

When the principle of energy-absorption is considered from a military standpoint, as for example to render objects difficult or incapable of detection by radar, the physical characteristics of the above-mentioned substances make them impractical for extensive use. It would obviously not be feasible, for instance, to cover the exposed surface of a ship or plane with a thick layer of energy-absorbent rubber or plastic, since the added mass and weight would adversely affect the maneuverability of the craft. Any material intended for such use must be capable of employment in very thin layers which, in addition, must be highly resistant to the action of light and the corrosive effect of sea water. It is also highly desirable that the substance be easily applied and require a minimum of maintenance.

To meet the above requirements, a number of proposals have been submitted. These include (1) minute particles of conducting material (i.e., graphite powder) embedded in a dielectric base such as paraffin, and then applied as an even coating to a reflecting surface, (2) a sheet or plate covered with the graphite-paraffin mixture of (1) so that the outer surface of the mixture is in the form of minute pyramids acting to sequentially absorb, as well as to reflect inwardly, the incident electromagnetic energy at each point of impingement, and (3) energy-absorbing devices such as metal foil or loop antennae, arranged at right angles to the reflecting surface, and designed to resonate at the frequency of the incident energy.

The above proposals, however, only remotely approximate the ideal electrical properties of a perfect energy absorber. To permit use of extremely thin films in the order of a few thousandths of an inch, each particle of the absorbent material should possess approximately the characteristics of the whole.

According to a feature of the present invention, a mixture of inorganic ferromagnetic materials is treated by alternate heating and comminuting until essentially all the residual magnetism of the material disappears. Gradual heating, followed by rapid controlled cooling, results in a product which, when reduced to a particle size not exceeding 74 microns, possesses a specific electrical resistance of 7×10^3 ohms/cm. and a porosity of 10.8% of the volume. Highly reflective articles such as aluminum sheet coated with a layer of the invention material as thin as .003 inch exhibit an absorption as high as 68% of incident energy in the 10,000 megacycle band.

One object of the present invention, therefore, is to provide a comminuted mixture of ingredients which, in

extremely thin layers, has a high loss factor for microwave energy.

Another object of the invention is to provide a mixture of ferromagnetic materials which can be applied as a coating to a base member, and which, with respect to arriving electromagnetic waves, exhibits a high degree of absorption and consequently a low reflectivity factor.

A further object is to provide a material having the above characteristics and consisting of inexpensive and readily obtainable ingredients.

A still further object is to provide a method of combining and treating these ingredients to achieve the desired electrical and physical properties.

Other objects and many of the attendant advantages of this invention will be readily appreciated as the same becomes better understood by reference to the following detailed description when considered in connection with the accompanying drawing, the single figure of which illustrates a preferred series of steps by which the method of the present invention may be carried out.

The lossy composition of this invention consists of a mixture of ferromagnetic materials such as magnesium oxide (MgO) and ferric oxide (Fe_2O_3). Substitution of other oxides, such as those of aluminum, zinc, lead, strontium, and barium, yields acceptable but less satisfactory results. High purity of the ingredients is important—the presence of even a small amount of a sulphide or chloride in the starting material can markedly reduce the absorption factor. In like fashion, contamination during processing is equally undesirable—hence, ball milling by ceramic means is unacceptable, and comminution is preferably accomplished by using iron balls in an iron mill.

The following is a preferred method of producing the material of the present invention, a flow chart of the process being set forth in the drawing:

(1) Treat as follows a quantity of magnesium oxide (MgO) in excess of that required:

(*a*) Heat in air for one-half hour at 850° C.

(*b*) Ball mill one hour, using iron mill and iron balls.

(*c*) Heat in air for one-half hour at 850° C.

(*d*) Ball mill 24 hours, using iron mill and iron balls.

(*e*) Sift through 150 mesh (100 micron) screen.

(2) Treat a quantity of ferric oxide (Fe_2O_3), in excess of that required, in the manner set forth under step 1.

(3) Ball mill for 24 hours, using iron mill and iron balls, a quantity of unheated magnesium oxide (MgO) in excess of that required and sift through a screen of 150 mesh.

(4) Ball mill for 24 hours, using iron mill and iron balls, a quantity of unheated ferric oxide (Fe_2O_3) in excess of that required and sift through a screen of 150 mesh.

(5) Add together, mixing thoroughly by hand:

(*a*) 62.3 grams of the material obtained by following step 1.

(*b*) 370 grams of the material obtained by following step 2.

(*c*) 26.63 grams of the material obtained by following step 3.

(*d*) 158.07 grams of the material obtained by following step 4.

(6) Ball mill the mixture resulting from step 5 for 24 hours in an iron mill using iron balls.

(7) Sift the material resulting from step 6 through a screen to produce a mixture of at least 74 microns (200 mesh).

(8) Place the milled and sifted material produced by step 7 in a cast iron container in a cold furnace. Then—

(*a*) Gradually raise the temperature of the furnace to 1300° C. over a period of 4 hours.

(*b*) Hold the temperature at 1300° C. for one hour.

(*c*) Remove from the furnace and cool to between 400° C. and 500° C. at the rate of 20° C. per second using a jet of cold air.

(*d*) Allow to cool to room temperature without removing from the container.

(9) Ball mill the material obtained by following step 8 for 24 hours, using an iron mill and iron balls.

(10) Sift the material produced by step 9 through a screen of 200 mesh.

A product obtained by following the above process possesses approximately the following characteristics:

Color—red-brown to black
Water absorption—2.74%
Specific gravity—4.49
Porosity—10.8% of the volume
Specific resistance—$7 \cdot 10^3$ ohms/cm.
Particle size—not exceeding approximately 74 microns.

While the 2:3 ratio of MgO to Fe_2O_3 (based upon the relationship of their gram-molecular weights) has been found to yield the highest energy absorption, other specific ratios, such as 1:1, may be only slightly less satisfactory in particular situations where a reduced absorption factor is acceptable. Once a specific ratio has been determined, however, departures therefrom which exceed approximately 11% in either direction cause a marked drop in absorption efficiency.

The temperatures stated are those which result in a production of the product desired. Other values may be substituted therefore as long as the end result is achieved. For example, forced cooling of the mixture to between 400 and 500° C. is performed rapidly in order to increase the magnetic properties of the material. If this forced cooling is terminated at a temperature which lies outside of the given range, or if the cooling is carried out at a rate which is too fast or too slow, the absorption factor is adversely affected.

In similar fashion, the stated particle size for the finished product is critical in the sense that this size should be small enough so that essentially all of the incident energy is intercepted by the particles and none passes through the interstices therebetween. Furthermore, excessive grain size is incompatible with high magnetic permeability. The latter is essential, along with an equally high dielectric constant. It is believed that the desired relationship is established by a rearrangement of the crystalline structure of the invention material, with a distinct lattice form being created which intertwines with the spinel lattice. This lattice intertwining apparently results in a crystal pattern exhibiting unexpectedly high permeability, matched to an equally high dielectric constant.

The mode of application of the invention material is determined by the environmental conditions to be encountered during use. For cases where these conditions are not unduly severe, the invention mixture may be added to a suitable liquid vehicle and then applied by ordinary painting or spraying. It is necessary that this vehicle have properties which cause the particles of the invention mixture to adhere to the surface on which they are applied. Resinous compounds in general are satisfactory for this purpose, such for example as that substance identified as #210 Epoxy Resin manufactured by the Applied Plastics Company of El Segundo, California. However, the material so employed should not contain any ingredient which would adversely affect the electrical characteristics of the resulting film, or, in other words, cause its energy absorption factor to be lowered.

Summarizing, therefore, the invention material is effective in thin, homogeneous layers, and it is substantially unaffected by light, moisture, and ambient temperature variations. It may be utilized to shield objects from detection by radar, or in anechoic chambers for the testing of such electrical components as antennas. The material is formed of ingredients which are readily obtainable and low in cost. Lastly, when used as a radar shield, it is completely free from undesirable directional effects.

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.

We claim:

1. The process of preparing a product which, with respect to impinging electromagnetic energy, exhibits a high degree of absorption and a correspondingly low reflectivity factor in thicknesses not exceeding approximately 1/100 of an inch, said process including the steps of: adding to a selected quantity of unheated magnesium oxide a larger quantity of magnesium oxide that has been heated to approximately 850° C., and then comminuting this mixture using an iron mill and iron balls to approximately 150 mesh; adding to a selected quantity of unheated ferric oxide a larger quantity of ferric oxide that has been heated to approximately 850° C., and then comminuting this mixture using an iron mill and iron balls to approximately 150 mesh; combining the magnesium oxide mixture and the ferric oxide mixture in a molar ratio of approximately two parts by gram-molecular weight of the former to three parts by gram-molecular weight of the latter, heating the resulting mixture to approximately 1300° C. and maintaining such temperature for approximately one hour; cooling approximately to between 400° C. and 500° C. at the rate of approximately 20° C. per second; further cooling at a slower rate to room temperature; and then comminuting using an iron mill and iron balls the cooled product so that the size of any single particle thereof is not in excess of approximately 74 microns.

2. The process of preparing a product which can be applied as a coating to a reflective base member so that the resulting article has the property of absorbing incident electromagnetic energy, said process consisting of the steps of combining, in a ratio of approximately 3:2 parts by gram-molecular weight, respectively, ferric oxide with a metallic oxide selected from the group consisting of the oxides of magnesium, aluminum, zinc, lead, strontium, and barium, heating the mixture at least as high as its Curie temperature, rapidly reducing the temperature of the mixture to between 400° C. and 500° C., further cooling the mixture to room temperature at a slower rate, and then comminuting the mixture using an iron mill and iron balls.

3. A process comprising the steps of:

(1) Treating as follows a quantity of magnesium oxide (MgO) in excess of that required:
  (*a*) Heating in air for one-half hour at 850° C.
  (*b*) Ball milling one hour, using iron mill and iron balls
  (*c*) Heating in air for one-half hour at 850° C.
  (*d*) Ball milling 24 hours, using iron mill and iron balls
  (*e*) Sifting through 150 mesh (100 micron) screen
(2) Treating a quantity of ferric oxide (Fe_2O_3), in excess of that required, in the manner set forth under step (1)
(3) Ball milling for 24 hours, using iron mill and iron balls, a quantity of unheated magnesium oxide (MgO) in excess of that required
(4) Ball milling for 24 hours, using iron mill and iron balls, a quantity of unheated ferric oxide (Fe_2O_3) in excess of that required
(5) Adding together, mixing thoroughly by hand:
  (*a*) 62.3 grams of the material obtained by following step (1)
  (*b*) 370 grams of the material obtained by following step (2)
  (*c*) 26.63 grams of the material obtained by following step (3)
  (*d*) 158.07 grams of the material obtained by following step (4)
(6) Ball milling the mixture resulting from step (5) for 24 hours in an iron mill using iron balls

(7) Sifting the material resulting from step (6) through a screen to produce a mixture of at least 74 microns (200 mesh)

(8) Placing the milled and sifted material produced by step (7) in a cast iron container in a cold furnace, then

(*a*) Gradually raising the temperature of the furnace to 1300° C. over a period of 4 hours

(*b*) Holding the temperature at 1300° C. for one hour

(*c*) Removing from the furnace and cooling to between 400° C. and 500° C. at the rate of 20° C. per second using a jet of cold air

(*d*) Allowing to cool to room temperature without removing from the container

(9) Ball milling the material obtained by following step (8) for 24 hours, using an iron mill and iron balls

(10) Sifting the material produced by step (9) through a screen of 200 mesh.

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