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METHOD FOR MAKING MICROMAGNETS

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FIG. 1

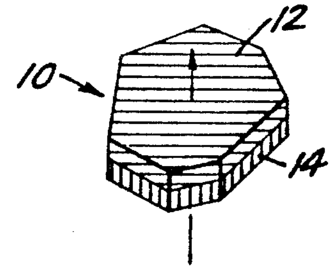
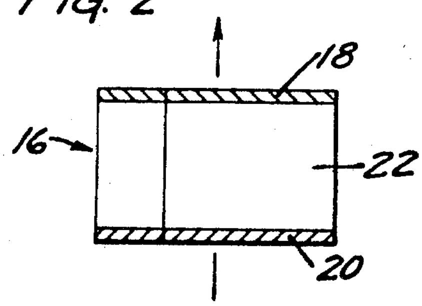


FIG. 2



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METHOD FOR MAKING MICROMAGNETS

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Original application May 26, 1966, Ser. No. 553,087, now Patent No. 3,406,363, dated Oct. 15, 1968. Divided and this application Feb. 26, 1968, Ser. No. 708,270
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ABSTRACT OF THE DISCLOSURE

Method for producing magnetically actuatable particles comprising providing at least two moldable compositions of contrasting colors, forming the compositions into a composite sheet, hardening the sheet, inducing a constant magnetization vector in the material and fracturing the sheet into tiny magnetized multi-colored particles.

This application is a division of application Serial No. 553,087, filed May 26, 1966, now Patent No. 3,406,363.

This invention relates to a method for forming improved micromagnets for magnetically actuatable visual display devices.

In U.S. Patent 3,036,388, since reissued as Reissue 25,363 and Re-Reissue 25,822, I have described magnetic writing materials employing magnetically orientable color coded particles. The particles in a liquid suspending medium beneath a transparent face plate, for example, may be oriented with their first-color poles toward the viewing surface by passing over the surface a flat erasing magnet. The particles are made to possess a low volumetric magnetization so that their magnetic strength is not sufficient to cause a magnetic interaction when in close association with each other, which would prevent selective orientation by an activating external magnetic force, and a magnetic field of opposite polarity applied to a portion of the surface reorients the affected particles with their second-color poles exposed to view thereby forming a visibly distinct pattern.

The present invention provides an improved method for the manufacture of magnetically orientable particles having two or more color zones. The method of this invention permits high production rates using relatively simple equipment.

Briefly summarized, the method of this invention involves the steps of providing at least two moldable compositions of contrasting colors, at least one of which contains finely divided magnetic material of high retentivity, then forming the compositions into thin superposed layers to form a composite sheet, hardening the sheet, subjecting the magnetic material in the sheet to a magnetic field of sufficient intensity and duration to produce a constant magnetization vector in the material, and then fracturing the sheet into irregularly shaped particles equal in thickness to the thickness of the original sheet and having a broad dimension at least as great as the thickness of the sheet. The fractured particles may be screened to select an optimum size range.

Further objects and advantages will be apparent from the accompanying detailed description and drawings wherein:

FIGURE 1 is a magnified perspective view of a typical two-colored magnetically orientable particle produced by the method of this invention; and

FIGURE 2 is a magnified view in elevation of a magnetically orientable shaped particle having three different color zones.

The magnetic orientation of the particles is illustrated by the arrow, the arrowhead, for convenience, indicating the north pole. Although other magnetic materials are also useful, I prefer to use small proportions of magnetic materials of high retentivity such as barium ferrite, together with a diluent or extender which usually serves as a binder for the powdered magnetic material.

The tiny particles are conveniently described as having a constant magnetization vector, the term including both direction and magnitude. The direction of magnetization, i.e., the permanent magnetic axis, may have any desired relationship to the surface color zones, as will be further described. The magnetic particles shall be referred to hereinafter as "micromagnets."

Micromagnets small enough to pass through a 325-mesh Tyler standard screen, i.e. about 45 microns, provide a smooth uniform appearance at the viewing surface since the individual micromagnets cannot be resolved by the eye. Micromagnets not larger than about 100 microns are preferred but micromagnets up to about 2000 microns are generally useful.

It is preferred to suspend the micromagnets in a suspending fluid in which the micromagnets will rotate therein upon the application of a magnetic field. It is desirable to provide this fluid with a viscosity and thixotropy such that a certain minimum force must be applied in order to rotate the micromagnets. Such viscosity and thixotropy provide a degree of stability to the display device, minimizing unwanted disorientation of the micromagnets. Finely divided magnesium aluminum silicate (Bentone) may be dispersed in a light oil, for example, to provide the desired viscosity and thixotropy.

Micromagnets can be manufactured rapidly and economically by forming appropriately colored compositions containing magnetizable material into thin flat sheets made up of two or more distinctly colored layers. For example, different colored hardenable solutions or suspensions can be cast successively onto a smooth carrier web or other suitable casting surface to form a layered sheet. The sheet is subjected to a strong magnetic field to magnetize the magnetizable material, hardened, and broken up into a finely divided state by impacting in an agitator or in other suitable fragmentizer such as a mechanical blender. The order of these steps may be interchanged if desired. Hardening can be accomplished by curing and/or drying the compositions until relatively brittle. Although it might be expected that violently reducing the sheet to a virtual powder would result in particles either singly colored or unusable because of randomly different characteristics, it has been found that progressive fragmentation tends to break the sheet across the broad dimensions, which provide the lines of least resistance to fracture. Each micromagnet therefore tends to retain its individual magnetic and color zone integrity so long as fragmentation is stopped before the micromagnets are reduced in size and dimension to less than the thickness of the sheet.

The micromagnet shown in FIGURE 1 is typical of those produced by this method. As shown, the individual micromagnets have flat, generally parallel top and bottom surfaces and irregularly shaped edges. The particles illustrated are magnetized so that the magnetic axis of each micromagnet is substantialy normal to the flat parallel surfaces. Micromagnet **10** shown in FIGURE 1 has a first color **12** adjacent the north pole and a different color **14** adjacent the south pole.

In FIGURE 2 is shown an edge view of a three-colored micromagnet **16** which may be made by a similar procedure to that just described. Micromagnet **16** is provided with a first color **18**, for example blue, on the surface adjacent to the north pole and second color **20**, for example white, on the surface adjacent the south pole. Sandwiched between layers **18** and **20** is a third coroled layer **22**, for example red. When used in a display device micromagnet **16** will present its blue colored surface when the south pole of a magnet is passed over the display device and its white colored surface when a north pole of a magnet is passed in front of the display device. A magnet having closely adjacent north and south poles, passed over the surface, will orient the micromagnets between its poles to an edgewise position to display a mark of a third color, red. The colors may be selected to produce other colors in combination. For example, a yellow layer and a blue layer produces green when oriented to blend, and shades and blends may be also produced by orienting the micromagnets to intermediate degrees, the activating magnetic force in this case being of a strength and duration insufficient to cause a full 90° or 180° orientation.

The micromagnets of this invention may be carried in a liquid suspension medium or used in dry powder form and the external activating magnetic force may be that from a permanent magnet or from an electrical field. The micromagnets may be spread dry on a sheet of paper, for example, and an external activating magnetic force passed under the carrier to produce a visual display.

By subjecting a sheet containing magnetizable material to a magnetic field first in one direction and then in another, it is possible to produce particles having more than one magnetic axis. Such axes may be of equal or, more preferably, of differing strengths, thus making it possible to control the orientation of the particles in more than one direction. The same effect can be produced by forming two or more sheets of contrasting color, magnetizing the sheets in different directions, then laminating the sheets and fracturing the sheets to produce particles having multiple magnetic axes.

In some cases it is desirable to magnetize the particles in a direction other than parallel to the color axes, for example, in a direction normal thereto. For example, particles having three color zones could be formed in which the two outer zones are white and the middle zone is black having magnetic axes parallel to the layers. Such particles when lying at random would present a predominantly white viewing surface on which a black line could be produced by applying to the surface thereof either a north or south pole magnet.

The magnetic strength of the particles can be varied by changing the proportion or the type of magnetizable material added, or by varying the strength of the magnetizing field. In the case of particles suspended within a liquid medium, the tendency to cluster can be reduced by using a more viscous liquid.

The following examples, in which proportions are given by weight unless otherwise indicated, will serve to illustrate but not limit the invention. Also the colors mentioned and the layer thickness given are illustrative and may be varied to produce displays having any desired combinations of colors and sharpness of images.

Example I

Color coded micromagnets were prepared with a binder of lacquer containing appropriate color pigments. The lacquer was a widely marketed type containing cellulose nitrate, ester gum, plasticizer, glycol esters, alcohols, aromatic and aliphatic hydrocarbons and was slightly thinned with lacquer thinner. A white portion contained 60 parts of lacquer, and 50 parts of titanium dioxide pigment. A red portion contained 75 parts of the lacquer and 25 parts of red pigment. A black portion contained 60 parts of lacquer, 20 parts of carbon black, and 10 parts of powered barium ferrite. Corn starch, added to the blends, will provide additional thickening, if desired.

The several blends were then coated in successive layers on a polyethylene carrier with intermediate drying. In spreading, the depth of each layer was controlled by drawing the sheet between spaced bars although other means such as the use of rollers are also suitable. Compositions

of lighter viscosity can be sprayed or otherwise coated. The dried sheet was made up of a first layer ½-mil thick of white, a central layer of ¾-mil of red, and a third layer of ¼-mil of the black, the layers being parallel to each other.

Several sheets of the coated carrier were stacked, each with the same color up, between the poles of a large electromagnet where they were subjected to a strong field to saturate the magnetizable barium ferrite component. The sheets were then peeled from the carrier and broken up by vigorous agitation by impacting in an agitator or in a mechanical blender into micromagnets capable of passing through a 325 mesh Tyler screen.

Micromagnets with more than three color zones can be obtained from a sheet having additional other colored layers and two color micromagnets can be made in this manner from a sheet having laminations with only two contrasting colors.

Example II

A curable epoxy resin composition is used as a binder, the composition consisting of 100 parts of liquid epoxy resin to which is added 35 parts of liquid curing agent just prior to coating and thoroughly mixed with this is 100 parts of titanium dioxide. The epoxy resin has a viscosity of 150–210 cps. at 77° F. and the curing agent has a viscosity of 150–400 cps. at 77° F. The mixture is then spread in an even layer to a thickness of about 1 mil on a temporary carrier, such as a sheet of glass, the surface of which has been previously prepared with a film of mold release agent, and is permitted to cure either by heat or the passage of time to a hardened state. A second layer, preferably thicker, from a composition of 100 parts of epoxy resin, 35 parts of curing agent, 15 parts of carbon black, and 15 parts of powdered barium ferrite, is then applied and similarly cured. Then another thin layer from a composition like that of the initial layer, except containing 40 parts of a red coloring pigment instead of white, is applied and permitted to cure. The cure material is directionally magnetized by placing the sheet between the pole pieces of an electromagnet where it is subjected to a magnetic field which magnetizes the barium ferrite component. The sheet is removed from the temporary carrier by peeling and is then fragmented to a virtual powder under vigorous agitation. Any oversized micromagnets are screened out.

Example III

A hardenable white composition was prepared by mixing the following ingredients:

	Parts
Styrene butadiene copolymer containing 65% by weight TiO_2 pigment (Goodyear Pliolite 1A-S5)	16.6
Toluol solvent	25

This composition was roll coated with a rotogravure 120 tri-helicoid roll at a rate of 15 yards per minute onto a plastic release web. This coating was oven dried at 250° F. The coating had a dry weight of .00073 gram/cm.^{2} of area. A black colored hardenable coating composition was prepared by mixing the following ingredients:

	Parts
Styrene butadiene copolymer containing 40% carbon black (Goodyear Pliolite 2C–S5)	4.5
Barium ferrite containing polymer (.224 parts barium ferrite, 0.071 parts clear styrene butadiene copolymer Pliolite S5–E, 0.295 parts toluol	0.59
Toluol	14.5

This composition was coated using the 80 tri-helicoid rotogravure roll over the white layer and oven dried at 250° F. The black layer had a dry weight of 0.00065 gram/cm.^{2}. The combined layers had a weight of 0.00138 gram/cm.^{2} and a calculated density of 1.77 grams per cc. The combined layers had a barium ferrite content of 2.2%. The hardened material was passed on the carrier web between the poles of an electromagnet, magnetized at 9000 gauss at a speed of 1 foot per second. Material was removed from the carrier web by flexing and air blasted and conveyed at high velocity through a tortuous path and impinged against itself and other obstructions until the average particle diameter was about 1½ times its thickness. Oversized particles were removed by screening. A suspension in oil of the black and white micromagnets thus obtained was formed by mixing the particles into the following oily mixture:

	Parts
Low molecular weight chlorotrifluoroethylene polymer having a density of 1.9 and a Brookfield viscosity at 72° F., #1 spindle, 30 r.p.m., of 124 centipoise (Kel F Oil #3, 3M Co.)	300.00
Oil having a density of 0.85 and a Brookfield viscosity at 72° F. of 24 centipoise #1 spindle, 60 r.p.m., (Retrax, Std. Oil Co.)	269.00
Purified bentonite with an organic base, gelling agent (Bentone 38, Nat. Lead Co.)	1.00
Stearic acid	4.75

The oil mixture had an approximate density of 1.21 and approximate viscosity of 70 centipoise when measured on the Brookfield Viscosimeter using a #1 spindle at 30 r.p.m.

A resin mixture was formulated by mixing the following ingredients:

	Parts
Copolymer of vinyl acetate and a carboxylated monomer (Gelva C5–V10, Shawinigan Corp.)	86.0
Saturated polyester resin, plasticizer (Harflex 340, Harchem Div., Wallace & Tiernan, Inc.)	8.6
Methanol	180.0

The resin mixture had a calculated density of approximately 0.91 and a Brookfield viscosity of 140 centipoise. An oil resin emulsion was formed by mixing 1 part by volume of the magnet contained oil mixture with 3.5 parts by volume of the resin. After mixing, an emulsion was formed in which the resin was a continuous phase having dispersed therein oil droplets averaging about 10 mils in diameter as a discontinuous phase. One or more colored micromagnets were contained within the preponderant number of oil droplets. The emulsion was knife coated using a 0.025 setting on 2 mil hard aluminum foil precoated with a 2 mil thick black-pigmented vinyl acetate based coating. The coating was dried by passing high velocity room temperature air thereover until a surface skin was formed followed by air drying overnight.

What is claimed is:

1. A method for producing multi-colored micromagnets comprising:

(a) providing at least two moldable compositions of contrasting colors, at least one of said compositions comprising finely divided magnetic material of high retentivity;

(b) forming said compositions into thin superposed layers to form a composite sheet;

(c) hardening said sheet;

(d) subjecting said magnetic material to a magnetic field of sufficient intensity and duration sufficient to produce a constant magnetization vector in said material;

(e) fracturing said sheet into a plurality of tiny particles, equal in thickness to said sheet and having a broad dimension at least as great as the thickness of said sheet.

2. Method according to claim **1** wherein said hardenable compositions comprise liquid synthetic organic polymers.

3. A method according to claim **1** wherein said magnetic material is barium ferrite.

4. A method according to claim **2** wherein said compositions comprise a volatile organic solvent, and said hardening is effected by drying said solvent.

5. A method according to claim **1** wherein said layers are formed by casting said compositions onto a releaseable carrier sheet which is stripped from said composite sheet after said sheet is hardened.

6. A method according to claim **1** wherein said magnetization vector is in a direction normal to the surface of said sheet.

7. A method according to claim **1** wherein said sheet is fractured into irregularly shaped particles.

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