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ELECTROMAGNETIC COILS

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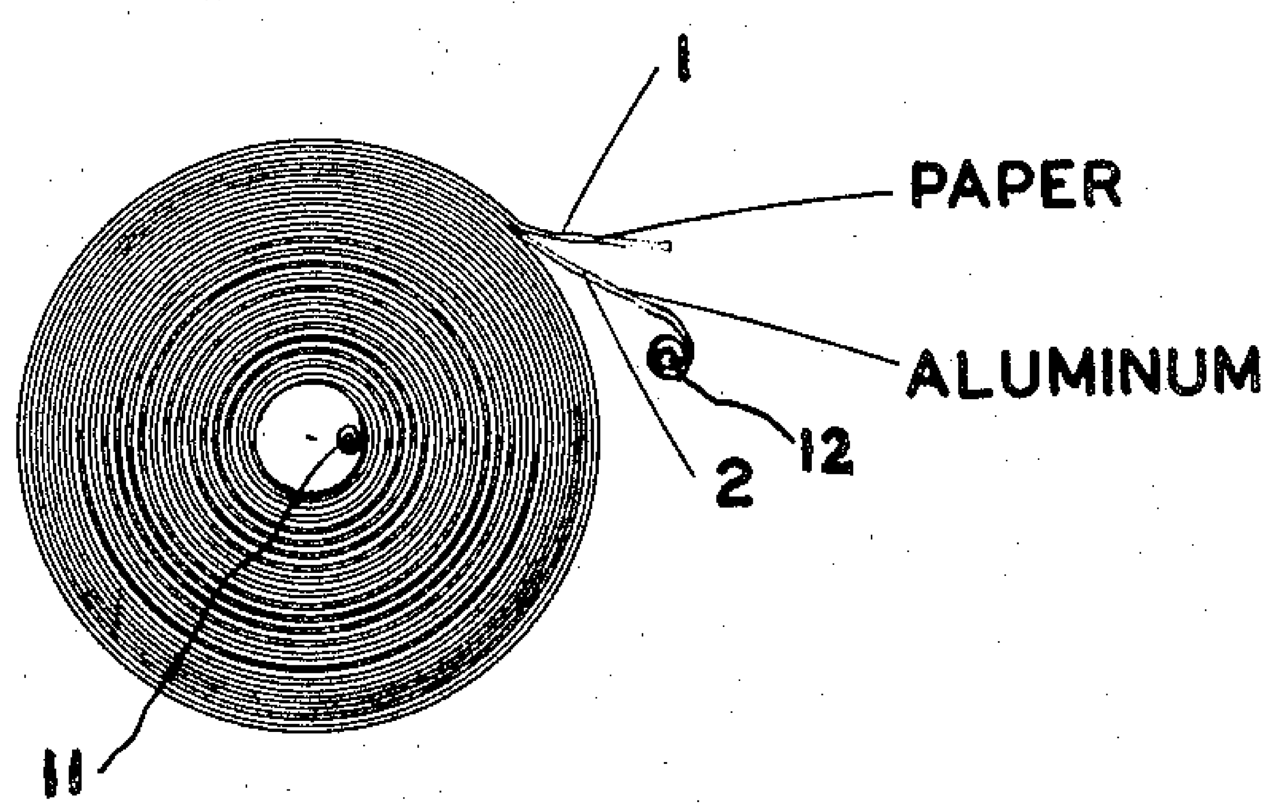

FIG. 1

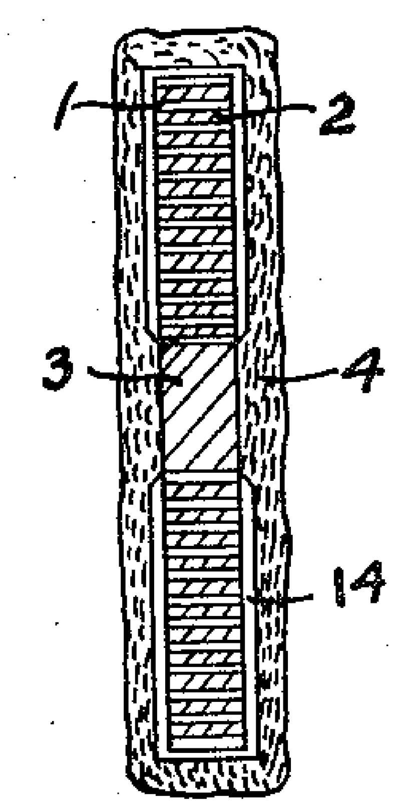

FIG. 5

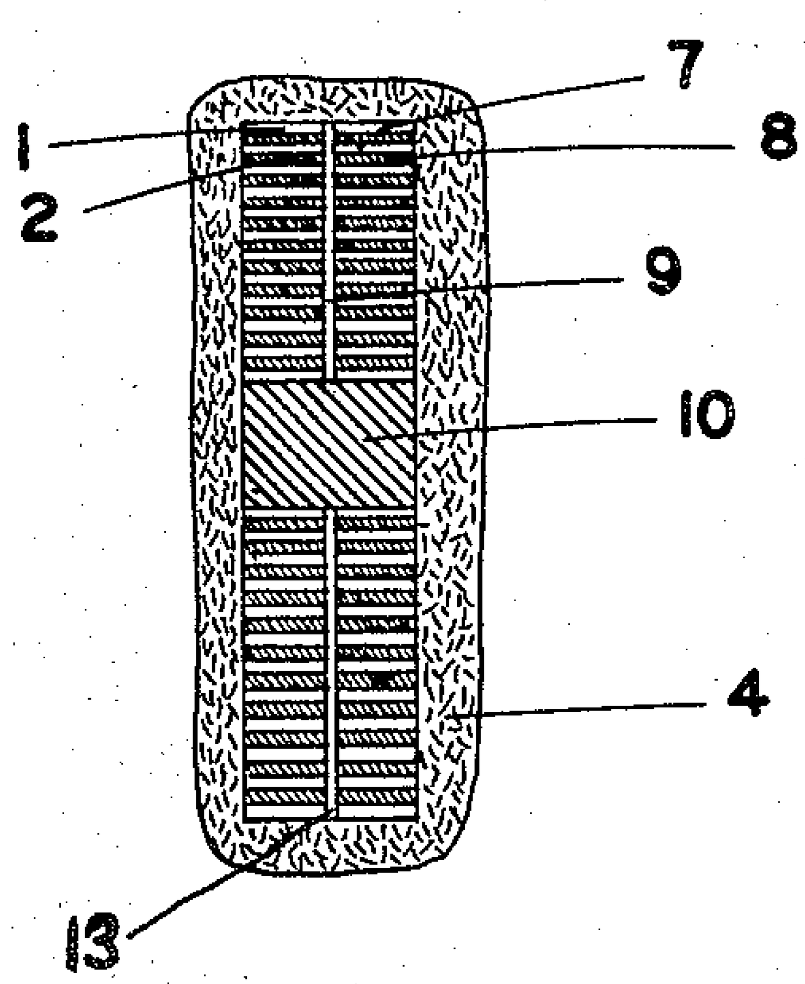

FIG. 4

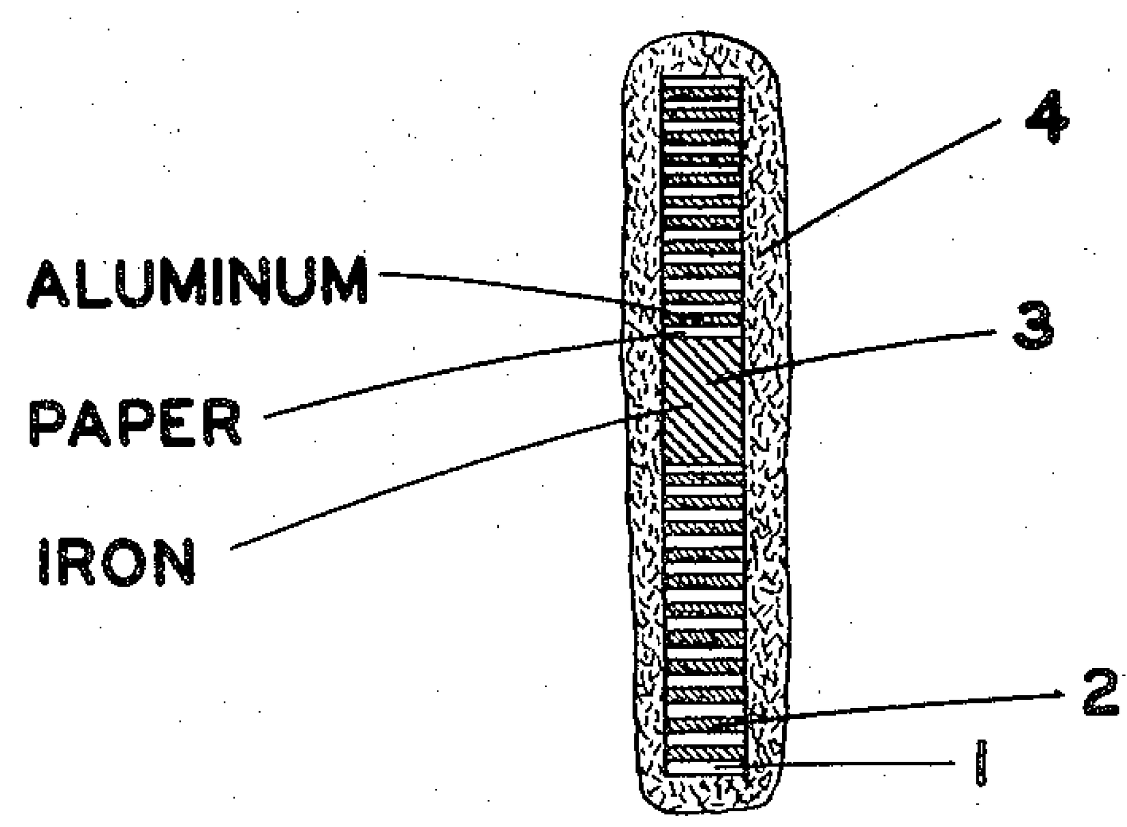

FIG. 2

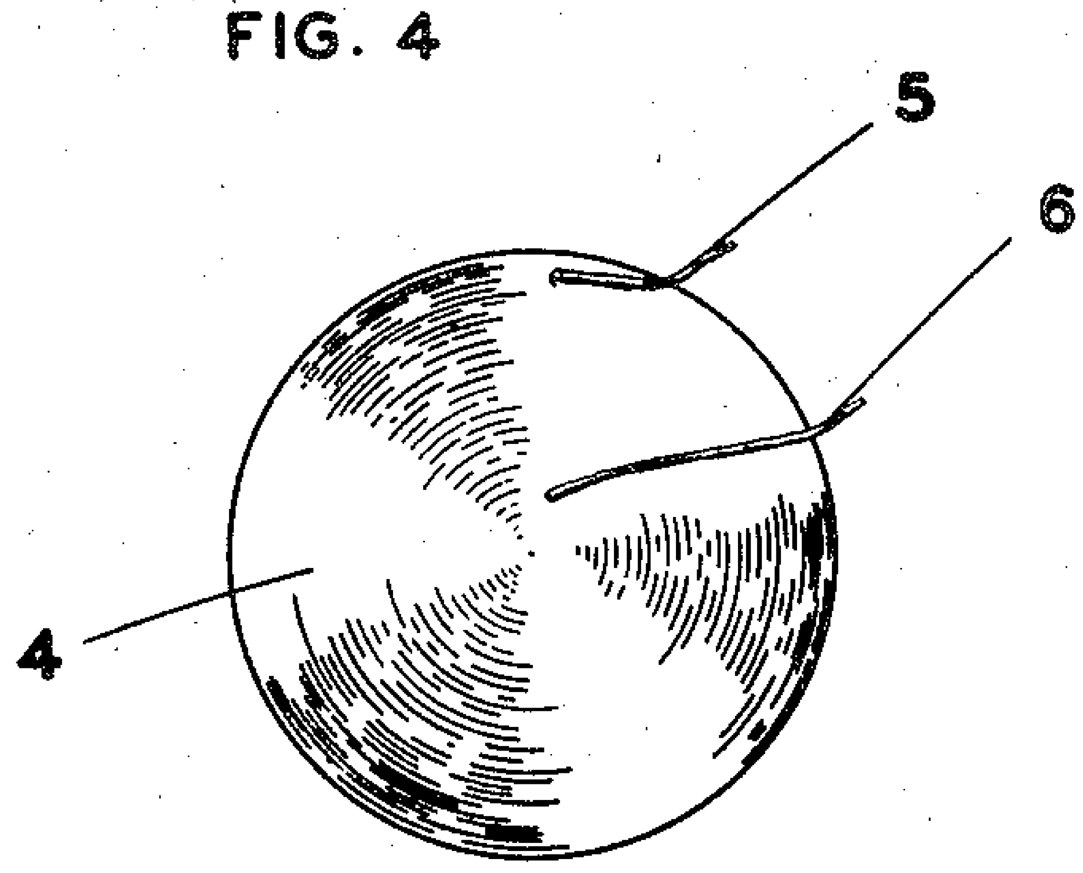

FIG. 3

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ELECTROMAGNETIC COILS

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11 Claims. (Cl. 336—83)

This invention relates to electromagnetic coils, and particularly to spiral coils.

An object of the invention is to improve the permeability and increase the inductance of such coils.

A further object is to insulate such coils, and yet another is to seal the coils against moisture penetration.

These and other objects are accomplished by covering the coil with a mixture of ferromagnetic powders in a binder such as a resin, lacquer, wax, glass or the like.

Other objects, features and advantages of the invention will be apparent from the following specification, taken in connection with the accompanying drawings, in which:

Figure 1 is a side view of a coil according to the invention, but before the application of the coating;

Figure 2 is a sectional view through the center, of a coated coil; and Fig. 3 is a side view of the coated coil.

Figure 4 is a view of one embodiment of a transformer according to the invention.

Fig. 5 is a view showing an embodiment of the invention in which an insulating coating covers the outside of the coil between the latter and a ferromagnetic coating.

In Fig. 1, the strip 1 of a conducting material, for

turn completely about their axis; this gives a uniform flow during drying. The rotation continues until the resin hardens, which generally takes from 4 to 12 hours.

The porous plastic can have a diameter or side of about 12 inches for convenience, and the coils can be set near the outer side of the material, the coils being supported about an inch or so from the porous plastic by their lead-in wires.

The dipping mixture in one example was the Minnesota Mining and Manufacturing Company's Scotchcast Resin #2, a room temperature thermosetting epoxy resin, with a Type C catalyst, various fillers being added to color the resin, to increase its viscosity and to modify the electrical characteristics of the wafer. One such mixture is:

75 grams resin
30 grams powdered zinc oxide

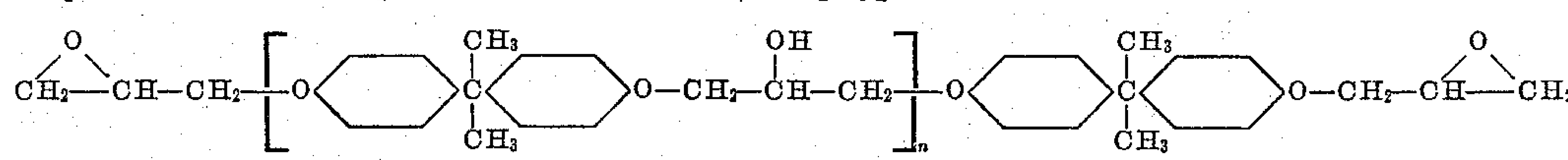
The zinc oxide serves to thicken the resin and to color it white. Other pigments can be used, especially where other colors are desired, for example, chromium oxide, cobalt oxide, carbon black, and iron oxide. Another mixture is:

100 grams resin
20 grams of finely powdered iron
20 grams of finely powdered mica

The iron serves to increase the inductance of the wafer and to reduce the resonant frequency. The mica gives the resin the necessary bulk.

The catalyst which can be ethylene diamine, or diethylene triamine, is preferably, about 10% by weight of the resin, the amount being preferably between 1 and 20%. The catalyst is added to the resin before the wafer coils are dipped into it.

The epoxy resin is a condensation polymer having the following typical structural formula:



example copper, aluminum or the like, is wound into a spiral, with successive turns being spaced apart and insulated from each other by the concentric spiral strip 2 of insulating material, for example, insulating paper, resin or the like. The coil may be formed as in copending application Serial No. 401,333, filed December 30, 1953, by Albert Zack.

The coil can have a core 3 of ferromagnetic material, or it can have an insulating core. The ferromagnetic material is preferably an iron powder embedded in a resin such as epoxy, although other ferromagnetic cores can be used.

Around the coil, and preferably extending all around it to form a closed magnetic circuit, is a coating 4 of ferromagnetic powder, for example powdered iron, in a binder such as epoxy resin, nylon, polystyrene, wax, shellac, varnish, polyethylene, lacquer, glass ceramic or the like. The coating can be applied by dipping, spraying, painting or in any other convenient manner. The binder can then be dried, or set. If a material such as epoxy resin is used, the coil can be set in a form of the desired size and shape, and the epoxy resin cast about the coil.

The wafers are preferably supported by their leads 5, 6 and immersed in a dipping resin. After immersion, they are dried. The drying is done by pushing the leads into a piece of porous plastic, for example Polarfoam, which can be mounted on a wooden piece fixed to a shaft which is rotated at a speed, for example, of three revolutions per minute. During the rotation, the wafers

The thickness of the coating 4 and the amount of ferromagnetic material in it can be varied to give the desired inductance or other results. The amount of ferromagnetic material can vary from a small amount, say a few percent by volume of the coating, to nearly 100%.

It may be desirable in some cases, say for the reduction of leakage flux, to space the conductor at its sides from the magnetic coating, as in Fig. 5. This can be done with an insulating washer or disk, or by first applying to the coil an insulating coating, of a material such as those mentioned above for use with the magnetic coating but without the magnetic material. A coating 4 of insulating material containing magnetic material can then be applied over the insulating coating 14.

Prior to the application of the coating, lead-in wires 5 and 6 are attached to the ends of the spiralled conductor strip 1. This can be done in any convenient manner, for example by soldering. The soldering will be facilitated if, before winding the strip 2, one end is wrapped around a metal wire 11, parallel to the axis of the coil, and the other end of strip 2 is wrapped around a similar wire 12.

If a transformer is desired instead of an inductance coil, two of the coils can be placed side by side as shown in Fig. 4, preferably on a common core 10 of ferromagnetic powder, and the ferromagnetic coating 4 applied over the resultant double coil, 1—2, 7—8. Coating should not be applied between the coils unless a considerable amount of leakage reactance is desired. The coils can have different numbers of turns to give a different voltage ratio.

Instead of placing two coils side by side, one coil can be wound over another, with lead-in wires such as **5**, **6** attached to each coil. The outer diameter of the inner coil will be less than the inside diameter of the outer coil, the two being concentric.

Although the metal strip **2** is marked "Aluminum" in some of the figures, it can be of copper or other metal or conducting material. However, due to the space factor of the spiral coils of the invention, the use of aluminum will generally give as compact a coil as copper would, and often as low a resistance, together with a saving in weight. Similarly, although the insulating layer is marked "Paper" in the figure, it can be of other insulating material, and can even be a coating of insulating enamel, lacquer, oxide, resin or the like on the metal conductor. If the conductor is aluminum, anodization of the aluminum can provide the insulation, the anodization producing an oxide coating on the aluminum.

Two conducting strips separated by insulating strips can be wound in a bifilar manner, if desired, to form a transformer.

If desired, the core of the spiral may be left open, that is, so that the coil is annular in form, and if desired, a screw-threaded plug of ferromagnetic powder embedded in a binder can be screwed into said coil until the desired inductance or mutual inductance is attained.

In cases where it is desired merely to insulate the coils, a coating of insulating material alone, for example, of the insulating material specified above, may be applied to the coils. Whether or not a ferromagnetic powder is incorporated in the insulated material, a colored pigment may also be incorporated, to give the finished coil, a white, blue, red or other color. Different colors can be used for different types of coil, for example, a coil of one inductance could be white, of another inductance blue, and the like.

Zinc oxide or similar fillers in the coating will change the distributed capacity of the coil.

Where two coils are used, the capacity of the coil can be varied by changing the spacing between the coils or the dielectric constant of the spacing material **13**. The inductance will also vary with the spacing.

What we claim is:

1. An electromagnetic device comprising a substantially flat, one-turn wide spiral of metal ribbon, a one-turn wide spiral of solid non-magnetic insulating ribbon filling the space between the turns of said spiral, and a coating of ferromagnetic powder in insulating material over the outside of said spiral.

2. The combination of claim 1, in which the insulating material is epoxy resin.

3. An electromagnetic device comprising a substantially flat, one-turn wide spiral of metal ribbon, a one-turn wide spiral of solid non-magnetic insulating ribbon filling the space between the turns of said spiral, a coating of ferromagnetic powder in insulating material over the outside only of said spiral, and a ferromagnetic core within said spiral, the whole forming a wafer-like inductive unit.

4. An electromagnetic device comprising a substantially flat, one-turn wide spiral of metal ribbon, a one-turn wide spiral of solid non-magnetic insulating ribbon filling the space between the turns of said spiral, another one-turn wide spiral of metal ribbon coaxial with but spaced from said first spiral of metal ribbon, a second one-turn wide spiral of solid non-magnetic insulating ribbon filling the space between the turns of said second-mentioned spiral of metal ribbon, a filling of solid non-magnetic insulating material in the space between said two spirals of metal ribbon, and a coating of ferromagnetic material over the outside surface of said combination of spirals of metal ribbon.

5. The combination of claim 4 and a ferromagnetic core within said coils.

6. The combination of claim 4, in which the insulating material is epoxy resin.

7. An electromagnetic device comprising a substantially flat, one-turn wide spiral of electrically-conductive material, solid non-magnetic insulating material between the turns of said spiral to space the same apart, a coating of insulating material over said spiral, and a coating of ferromagnetic material in an insulating binder over said first-mentioned coating of insulating material.

8. An electromagnetic device comprising a substantially flat, one-turn wide spiral of metal ribbon, a one-turn wide spiral of solid non-magnetic insulating ribbon filling the space between the turns of said spiral, and a coating of ferromagnetic powder and a powdered coloring pigment in a binder over the outside of said spiral.

9. The combination of claim 8, in which the insulating material is epoxy resin.

10. An electromagnetic device comprising a substantially flat, one-turn wide spiral of metal ribbon, a one-turn wide spiral of solid non-magnetic insulating ribbon filling the space between the turns of said spiral, and a coating of a powdered coloring material in an insulating binder over the outside of said spiral.

11. The combination of claim 10, in which the insulating material is epoxy resin.

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