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TRANSDUCER DIAPHRAGM IMBEDDED WITH CONDUCTIVELY-COATED FERROMAGNETIC PARTICLES

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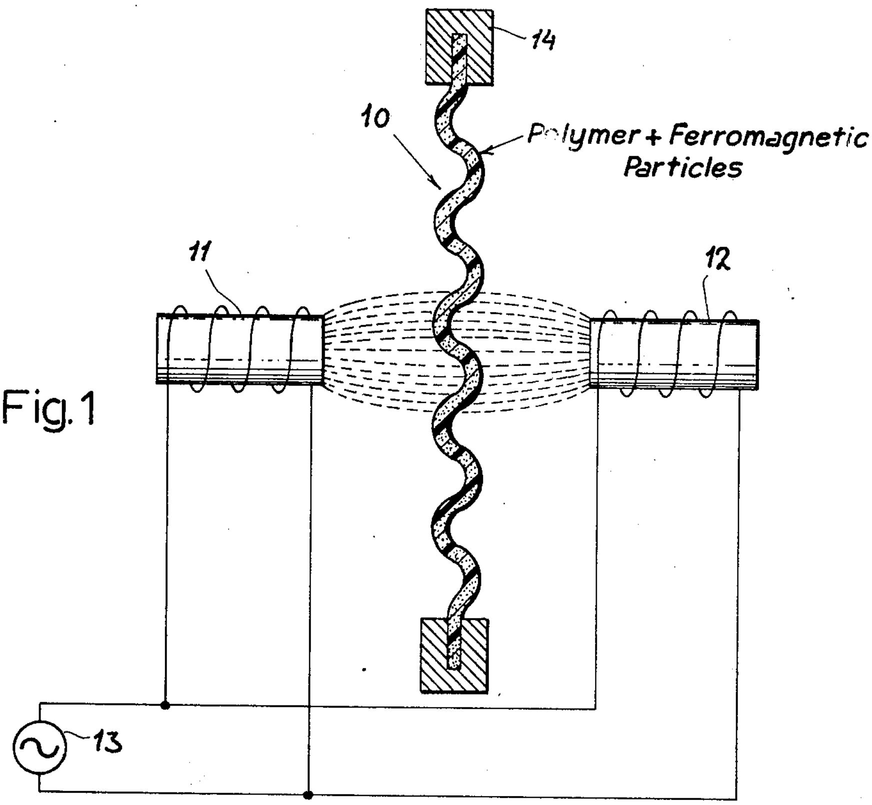

Fig. 1

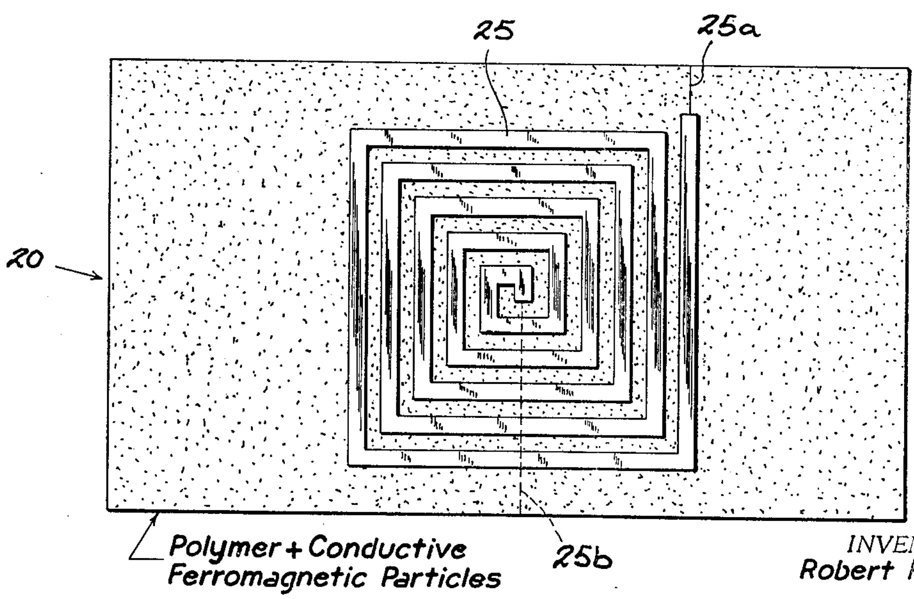

Fig. 2

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TRANSDUCER DIAPHRAGM IMBEDDED WITH CONDUCTIVELY-COATED FERROMAGNETIC PARTICLES

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ABSTRACT OF THE DISCLOSURE

A flexible diaphragm of polymeric material having ferromagnetic particles distributed therein which are conductively coated throughout a strip zone of generally spiral shape to form a coil; upon the passage of alternating or direct current through that coil, the diaphragm is set in vibration when permeated by a magnetic flux.

This application is a continuation-in-part of my application Ser. No. 117,169 filed June 14, 1961, now patent No. 3,247,476 issued Apr. 19, 1966.

In the above-entitled application and patent I have disclosed, but not claimed, a vibratile diaphragm which forms part of an electromagnetic device and which cooperates with a transverse magnetic field for the purpose of causing controlled vibrations in response to periodic changes in this external magnetic field and/or in a coacting magnetic field which may be generated by an electrical conductor wound spirally upon the diaphragm itself. A device of this type may be used, for example, as an electroacoustic transducer such as a loudspeaker.

As further disclosed in my aforementioned prior application and patent, the diaphragm may serve as a carrier for magnetically permeable particles designed to concentrate the magnetic lines of flux in the region of the axis of one or more electromagnetic coils that generate the alternating field.

The general object of my present invention is to provide an improved diaphragm of the last-mentioned type which can be produced in one continuous operation and which can be formed as a film of small thickness and minimum inertia.

This object is realized, in conformity with the present invention, by the provision of a diaphragm which comprises a flexible film of polymeric material having incorporated therein a ferromagnetic substance in finely comminuted form.

Depending on the degree of resiliency desired in the film, the polymeric material may be of more or less elastomeric character. Suitable elastomers include synthetic rubbers, such as acrylonitrile-butadiene copolymers, which may be admixed with the particulate ferromagnetic substance prior to vulcanization or cross-linking. Other polymers may have the ferromagnetic particles imbedded therein while in a plasticized state or in solution, this being followed by a hardening step preferably at elevated temperatures.

The resultant sheet may be calendered, e.g. while temporarily supported on a flexible substrate, or the solution may be cast onto a base from which it is subsequently stripped. This base need not be plane but may be embossed or corrugated to increase the effective surface of the resultant membrane.

Where it is desired to provide the magnetically permeable film with one or more conductive windings (e.g. in the form of Archimedean spirals) on one or both surfaces, as likewise disclosed in my prior application and patent, such conductor may be in the form of a strip of the same type of film whose ferromagnetic particles, however, have been specially treated to insure a high degree

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of electrical conductivity. Where these particles consist essentially of iron, which normally would carry an oxide film so as to be practically nonconductive, this film may be removed prior to admixture with the organic carrier material by immersion in a treatment solution, such as a dilute bath of nitric acid having a salt of a relatively noble metal (e.g. silver nitrate) dissolved therein, whereby the noble metal forms a thin conductive coating on the reduced ferrous particles. Other highly conductive metals, such as gold, may also be used, e.g. by treatment of the iron powder with an aqueous solution of gold cyanide. Naturally, a magnetically permeable strip conductor of this type could also be applied to a supporting film which does not have any ferromagnetic particles incorporated therein. Simple heat bonding may suffice to fasten the strip to its support.

Several examples of the manufacture of a magnetically permeable film according to my present improvement will now be given; all parts are understood to be by weight.

EXAMPLE I

	Parts
Barium ferrite ($BaFe_{12}O_{19}$ or $BaFe_{18}O_{27}$)	1125
Acrylonitrile-butadiene copolymer	1000
Benzothiazyl disulfide (accelerator)	16
Sulfur	17
Phenylbetanaphthylamine (antioxidant)	10
Dioctylphthalate (plasticizer)	375

The copolymer is masticated, e.g. in a conventional rubber mill of the differential-speed two-roll type, until banding occurs. The barium ferrite, wetted with the dioctylphthalate, is then slowly added until completely dispersed in the polymeric mass.

The remaining ingredients, previously mixed, are then rapidly added to the mass until they are also completely dispersed therein. The vulcanized mass is then cut from the mill in sheet form.

The sheet is calendered on a flexible substrate, such as a smooth-surfaced web of vegetable parchment, to a thickness of, say, 0.1 mm. and, after rewinding in a roll, is cured in an air oven for 12 minutes at 155° C. whereupon the magnetic film is stripped from the substrate.

EXAMPLE II

	Parts
Barium ferrite	875
Cis-1,4 polyisoprene	1000
Sulfur	24
Zinc oxide (filler)	28
Benzothiazyl disulfide	16
Powdered stearic acid (plasticizer and surface conditioner)	21
Phenylbetanaphthylamine	11

The treatment is similar to that of the preceding example, with the zinc oxide and the stearic acid added to the sulfur-containing mix which is dispersed within the mass after the introduction of the barium ferrite. The curing of the rolled-out sheet occurs at 145° C. for 20 minutes.

EXAMPLE III

	Parts
Barium ferrite	1000
Polyvinyl chloride (plastisol resin)	875
Dioctylphthalate (plasticizer)	750
Tribasic lead sulfate (surface conditioner)	22

The two last-mentioned ingredients are admixed with the barium ferrite in a ball mill and the resulting dispersion is blended with the plastisol resin to form a homogeneous mass. The latter is calendered, with either a web of vegetable parchment or one of laminated aluminum foil and paper, to a thickness which may be as little as 0.025 to 0.05 mm. The calendered composite sheet is exposed to a temperature of 290° C. until the polyvinyl chloride has become fused, the film being then stripped from its substrate.

EXAMPLE IV

	Parts
Carbonyl-iron powder (average particle size 3μ)	1550
Acrylonitrile-butadiene copolymer	1000
Benzothiazyl disulfide	17
Sulfur	21
Phenylbetanaphthylamine	11
Dioctylphthalate	425

The above ingredients are utilized in the same manner as those of Example I, with substitution of the iron powder for the barium ferrite. Curing may be performed at a slightly lower temperature (e.g. 122° C.) and over a somewhat longer period (e.g. 20 minutes).

EXAMPLE V

	Parts
Carbonyl-iron powder	1333
Cis-1,4 polyisoprene	925
Sulfur	21
Zinc oxide	31
Benzothiazyl disulfide	19
Powdered stearic acid	23
Phenylbetanaphthylamine	13

The procedure is analogous to that of Example II, although the curing temperature may be slightly higher (about 150° C.).

EXAMPLE VI

	Parts
Carbonyl-iron powder	1250
Polyphenylene oxide (molecular weight about 40,000 to 50,000)	1000
Methylene chloride (solvent)	6000
Stearic acid, triple pressed	5

The above ingredients are placed together in a ball mill where they are tumbled for about 24 to 30 hours, thus yielding a complete dispersion of the carbonyl iron in the mass.

The mixture is then spread, e.g. with the aid of a reverse-rotating roller, onto a base such as an embossed aluminum foil to form thereon a film having a thickness of about 0.025 to 0.05 mm. After heating to remove the solvent, the dried film strips easily from the foil.

It will be noted that Examples I, II and III describe the making of magnetically hard membranes and films whereas Examples IV, V and VI relate to magnetically soft diaphragms. The former may be utilized, of course, if the diaphragm is to be premagnetized for biasing purposes or if a selective magnetic pattern is to be impressed thereon.

The specific proportions, temperatures and treatment times given in the foregoing examples are, of course, not critical and may be modified in accordance with existing requirements. The polymeric materials, ferromagnetic substances, antioxidants, accelerators, plasticizers, solvents and fillers may also be replaced by other ingredients of known equivalent character.

Reference will be now made to the accompanying drawing in which:

FIG. 1 is a cross-sectional view of a membrane according to the invention, disposed in an alternating electromagnetic field; and

FIG. 2 is a face view of a similar membrane carrying a conductive spiral on one of its surfaces.

The membrane **10** shown in FIG. 1 is disposed between a pair of electromagnetic coils **11, 12** which are connected in parallel across a source **13** of alternating current. Held in a frame **14**, this membrane is free to vibrate in response to the changing magnetic field permeating its iron or ferrite particles which are dispersed throughout its polymeric body in the manner described with reference to the foregoing examples.

It will be noted that membrane **10** has a corrugated surface which may have been produced with the aid of a ribbed or embossed base on which it may have been cast or spread as described in Example VI.

In FIG. 2 I have shown a generally similar membrane **20** which may or may not incorporate ferromagnetic particles and which is overlain by a flat strip **25** of similar polymeric film material that may have been prepared in accordance with any of Examples IV–VI with a pretreatment of the carbonyl-iron powder designed to render its particles highly conductive by a reduction of their oxide coating and a plating with a relatively noble metal. Thus, the iron powder may have been immersed in a 1.6% aqueous solution of HNO_3 wherein 3% (by weight) of $AgNO_3$ was dissolved after being slowly stirred into the solution at a temperature of approximately 70° to 750° C.

The diaphragm **20** of FIG. 2 may be disposed in a constant external magnetic field, e.g. with replacement of the coils **11** and **12** by bar magnets, if the spiral conductor **25** is energized with alternating current via its leads indicated at **25***a* and **25***b*. The magnetic field will be concentrated either in the conductor **25** alone or, if the polymeric material of the membrane proper is also permeable, additionally in the body of that membrane. For good electrical conductivity, the weight ratio of the plated iron particles to the carrier resin advantageously is chosen somewhat greater than in Examples IV–VI, i.e. preferably on the order of 3:1.

I claim:

1. In an electromagnetic device having means for generating a magnetic field, the combination therewith of a vibratile diaphragm positioned transversely in said field and comprising a flexible film of polymeric material having incorporated therein a ferromagnetic substance in finely comminuted form, said film being substantially nonconductive except for a strip zone of generally spiral configuration in which the particles of said substance are provided with a conductive coating, said strip zone being provided with terminal leads on opposite ends thereof.

2. The combination defined in claim **1** wherein said particles consist of iron, said coating consisting of a noble metal.

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