United States Patent

Trimble

[15] **3,685,144**

[45] **Aug. 22, 1972**

[54] **METHOD OF MAKING A MAGNETIC TRANSDUCER**

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[73] Assignee: **The National Cash Register Company,** Dayton, Ohio

[22] Filed: **Aug. 14, 1970**

[21] Appl. No.: **63,902**

Related U.S. Application Data

[62] Division of Ser. No. 668,528, Sept. 18, 1967, Pat. No. 3,549,825.

[52] **U.S. Cl.** ....**29/603,** 179/100.2 C

[51] **Int. Cl.** **G11b 5/42,** H01f 7/06

[58] **Field of Search** ....29/603, 625; 179/100.2 C; 346/74 MC; 340/174.1 F; 336/200

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Primary Examiner—John F. Campbell
Assistant Examiner—Carl E. Hall
Attorney—Louis A. Kline, Albert L. Sessler, Jr. and Elmer Wargo

[57] **ABSTRACT**

A planar magnetic transducer comprising a planar coil means, in the general shape of a spiral, with at least a portion of the coil means being sandwiched between the pole ends of two magnetic circuit plates. The method utilizes printed circuit techniques to batch-fabricate single end bifilar coil transducers which may be miniature in size.

9 Claims, 20 Drawing Figures

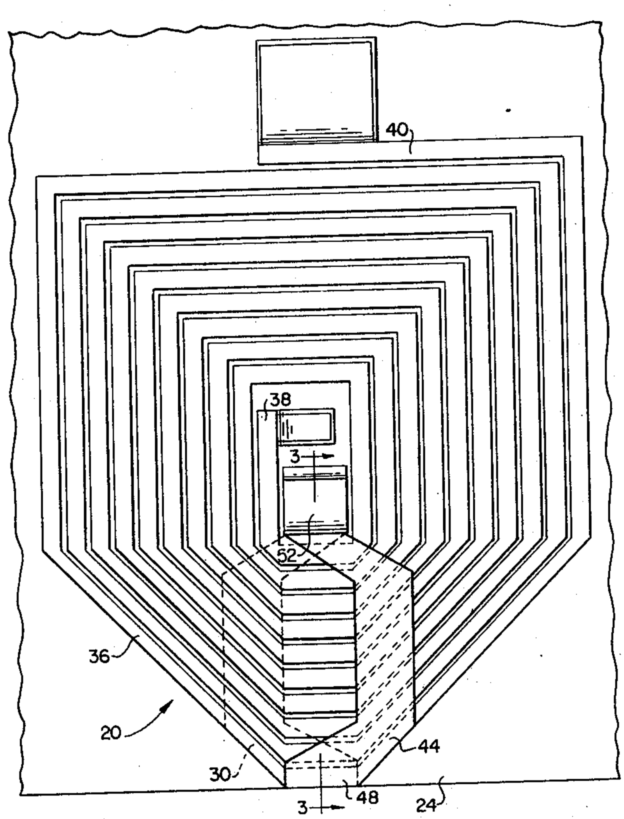


FIG. 2

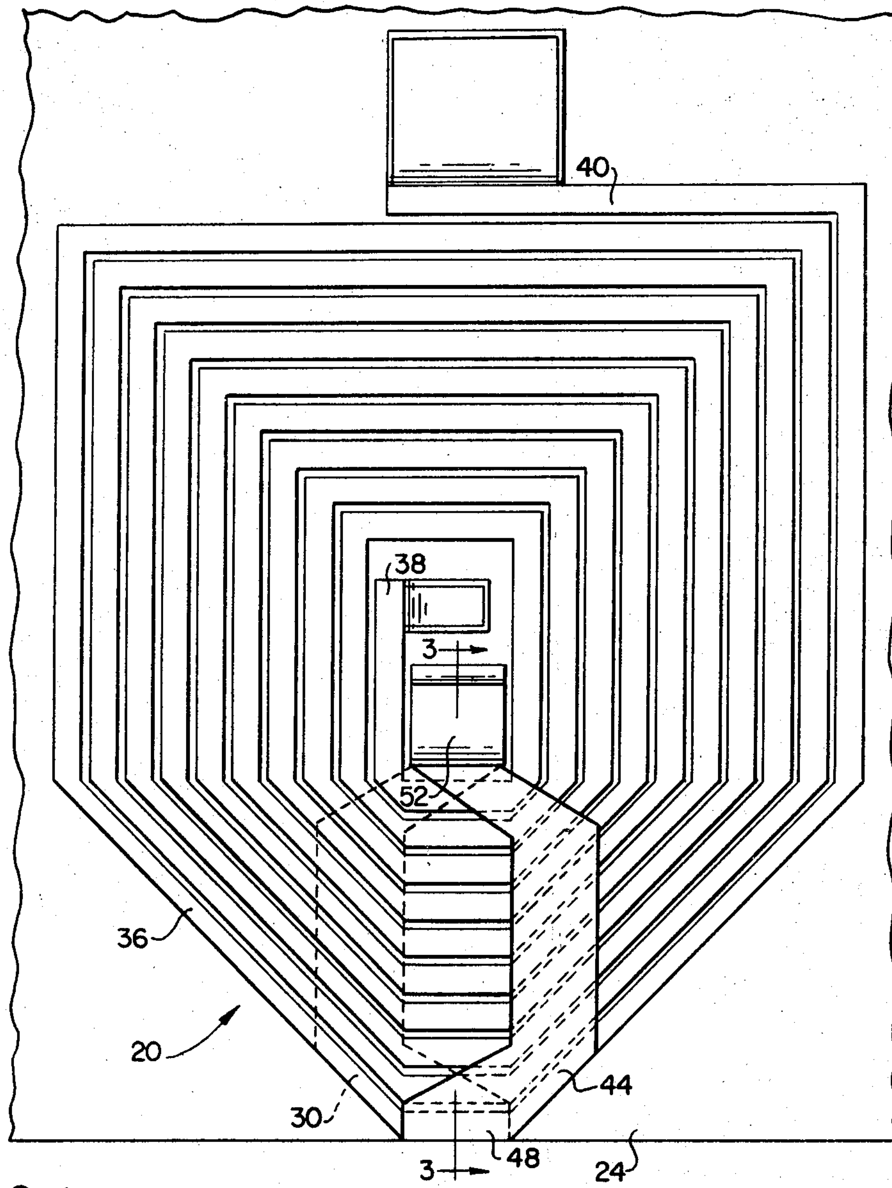
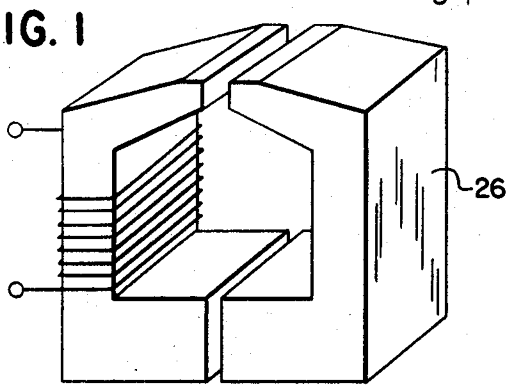


FIG. 1



(PRIOR ART)

FIG. 3

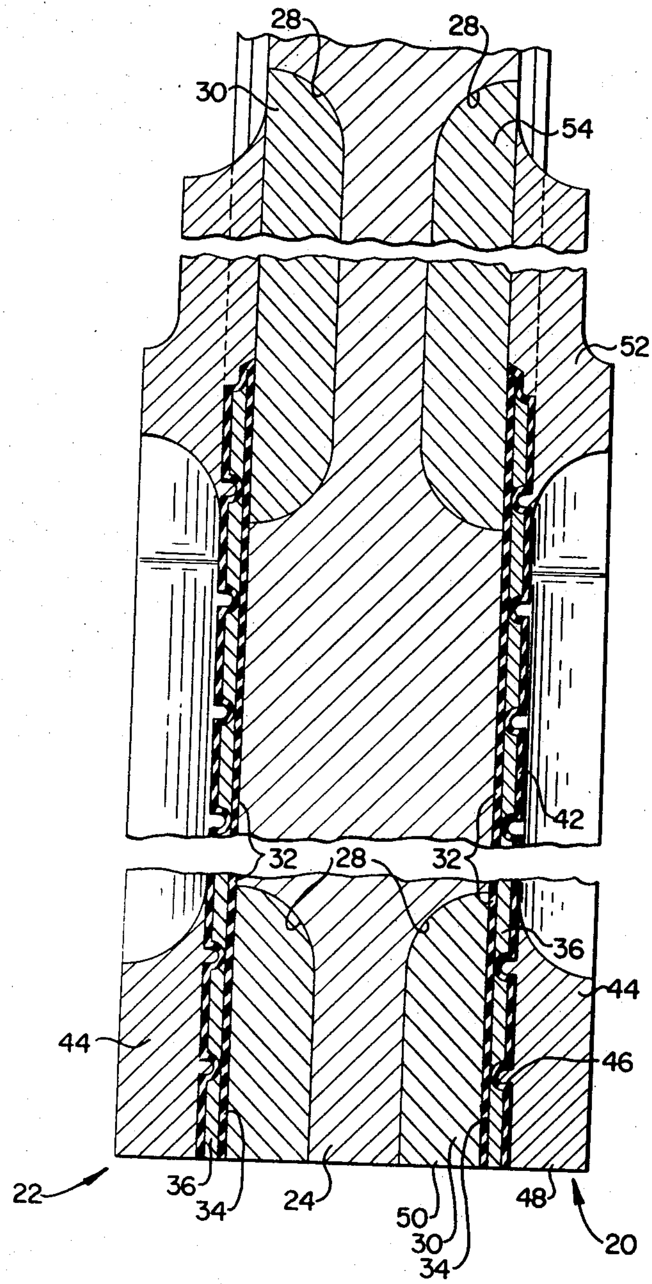

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FIG. 5

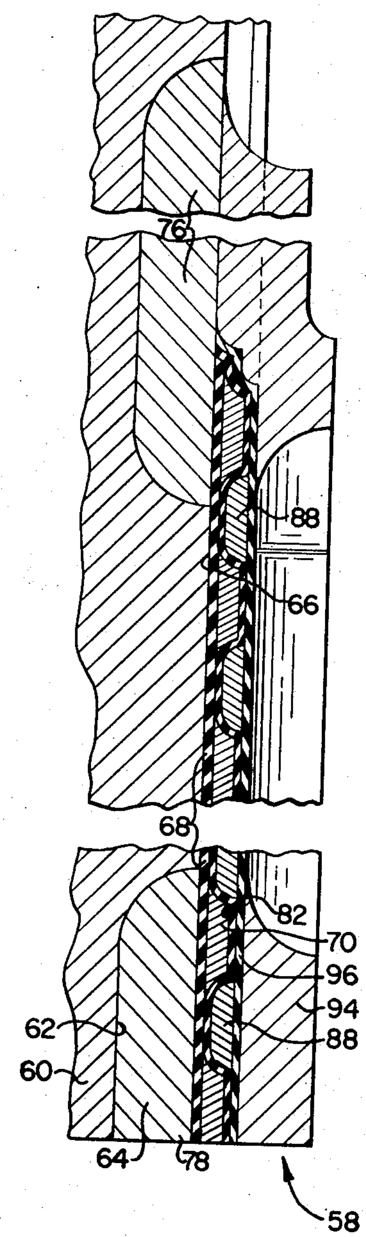
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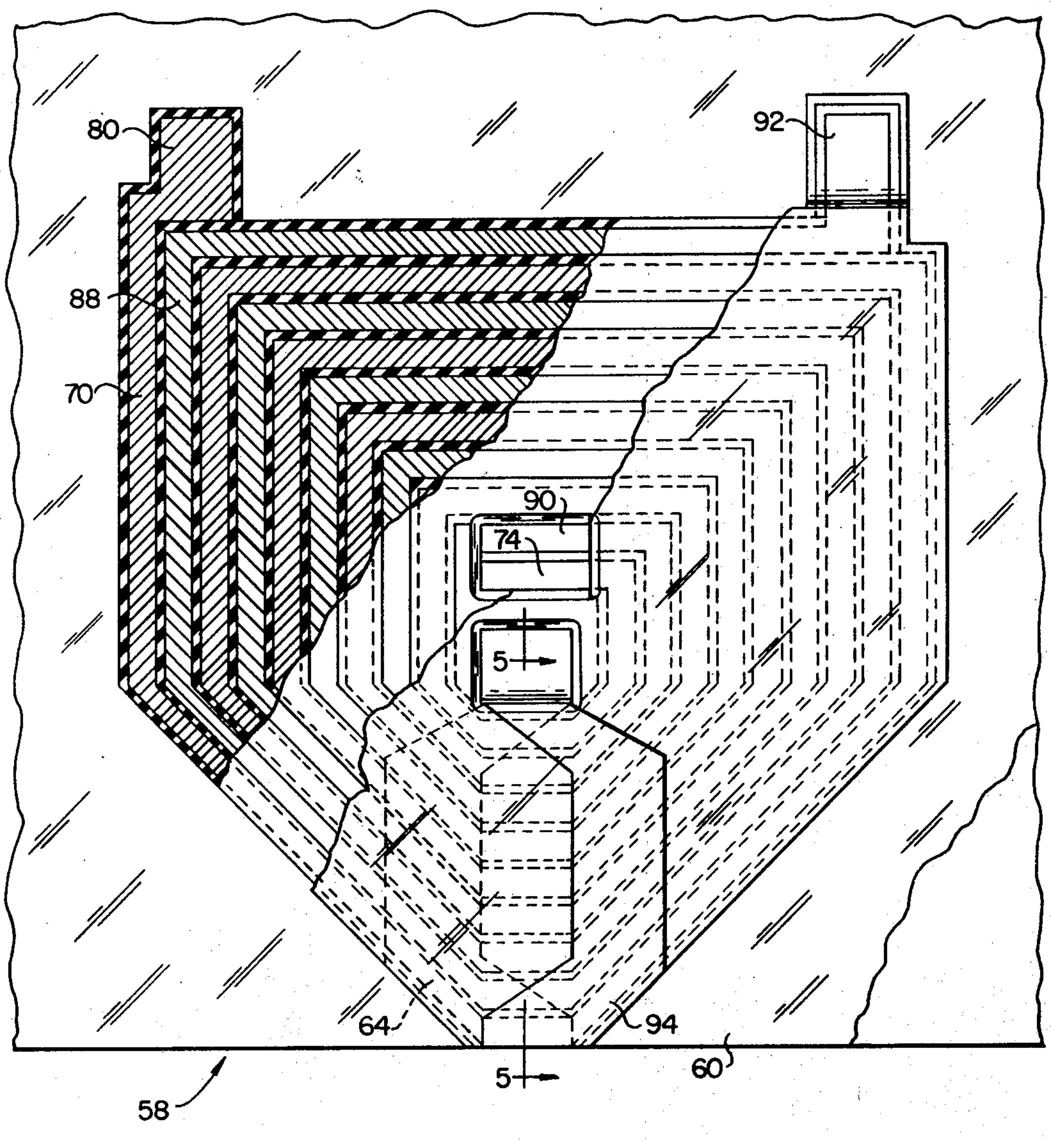
FIG. 4



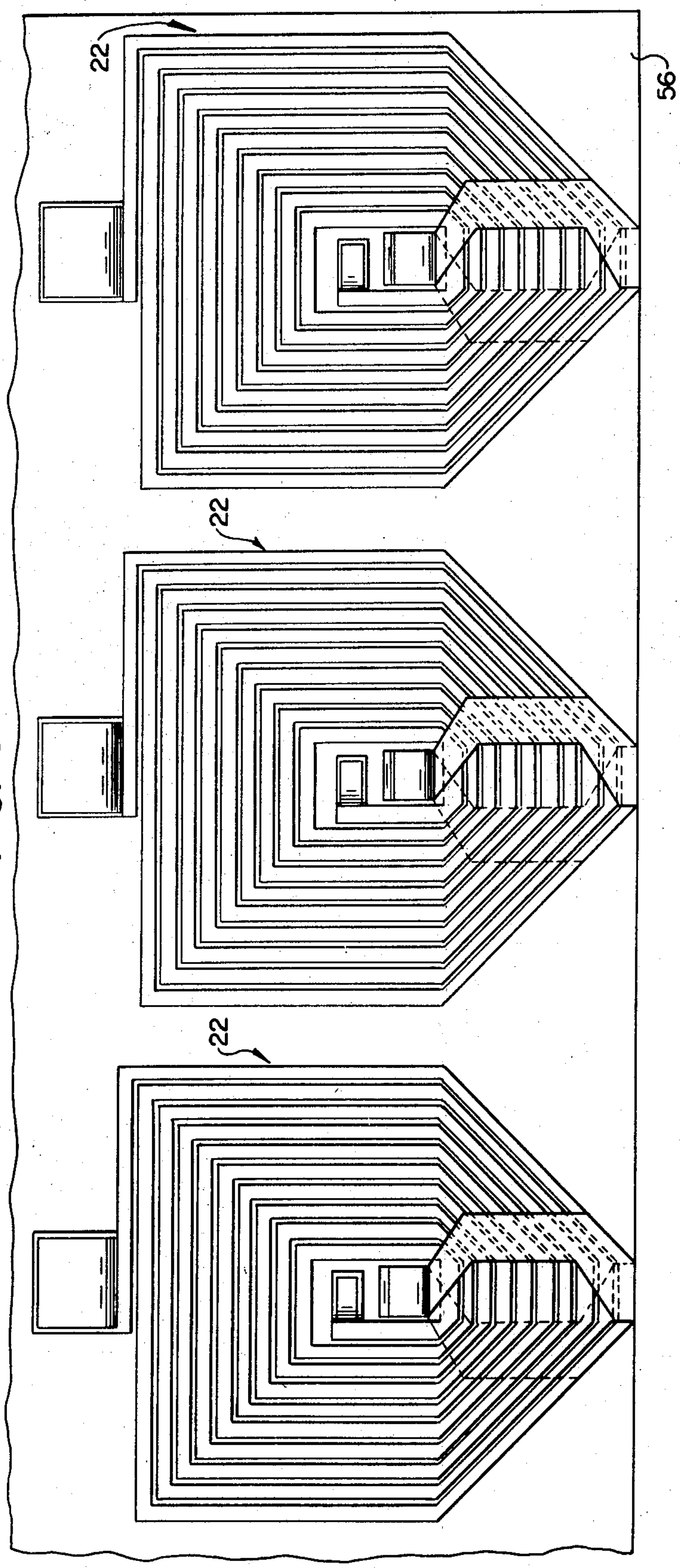


FIG. 6

FIG. 7

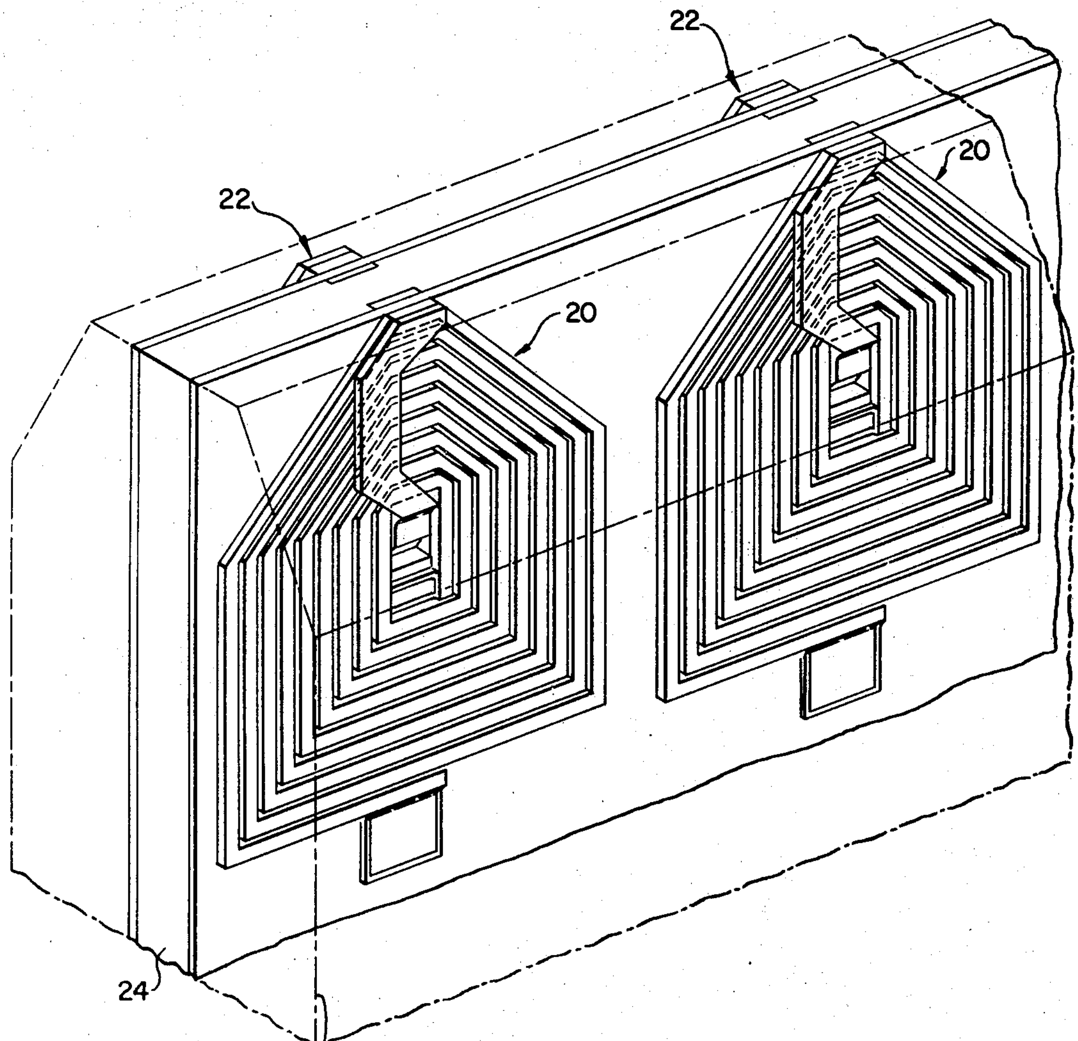


FIG. 8

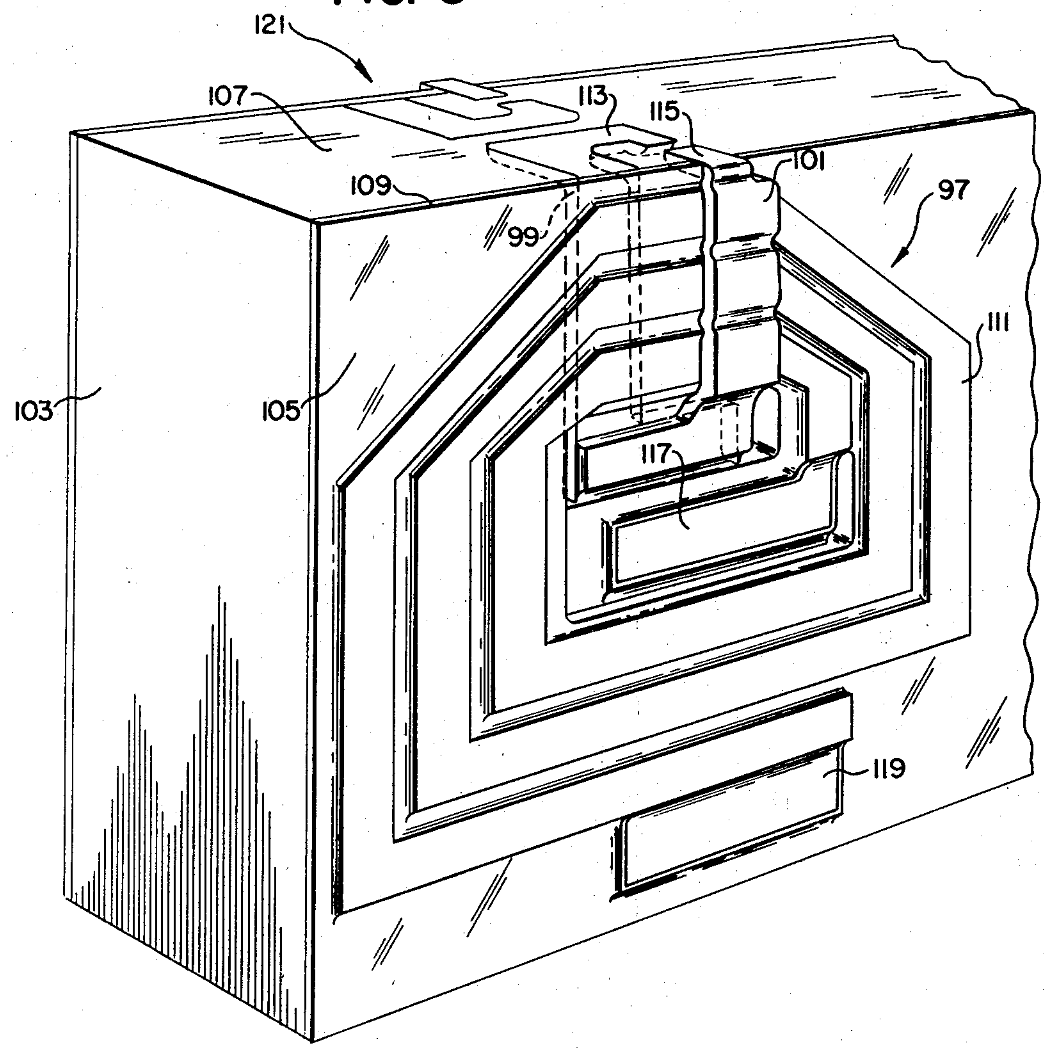


FIG. 9

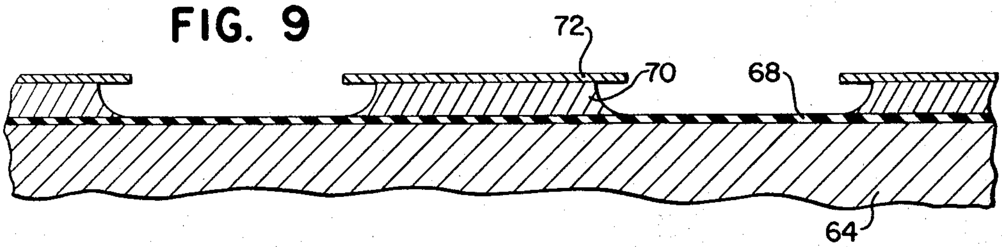


FIG. 10

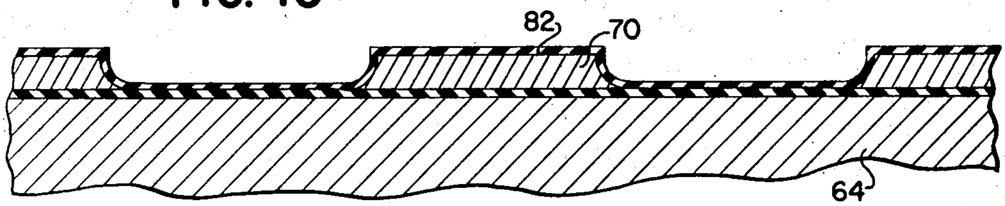
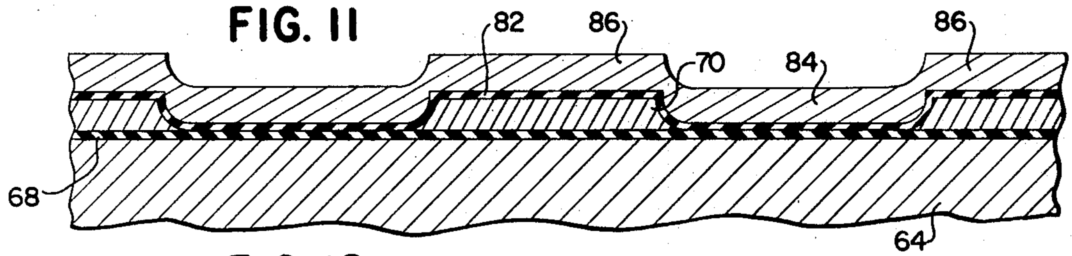


FIG. 11



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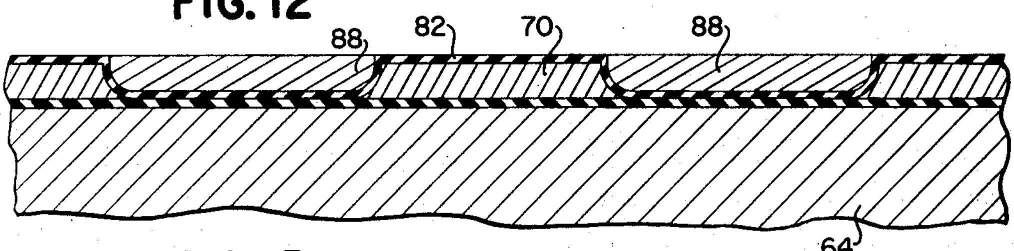

FIG. 13

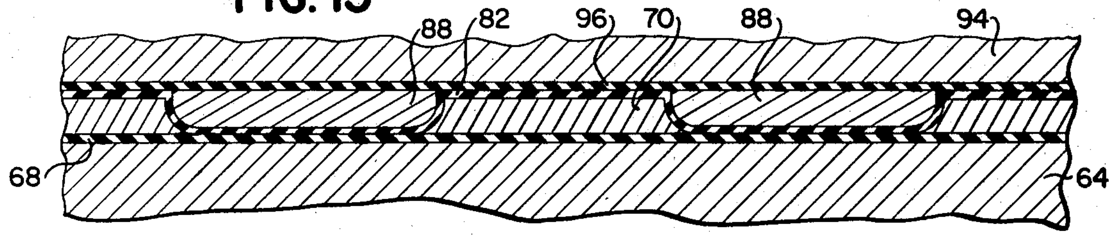

FIG. 14

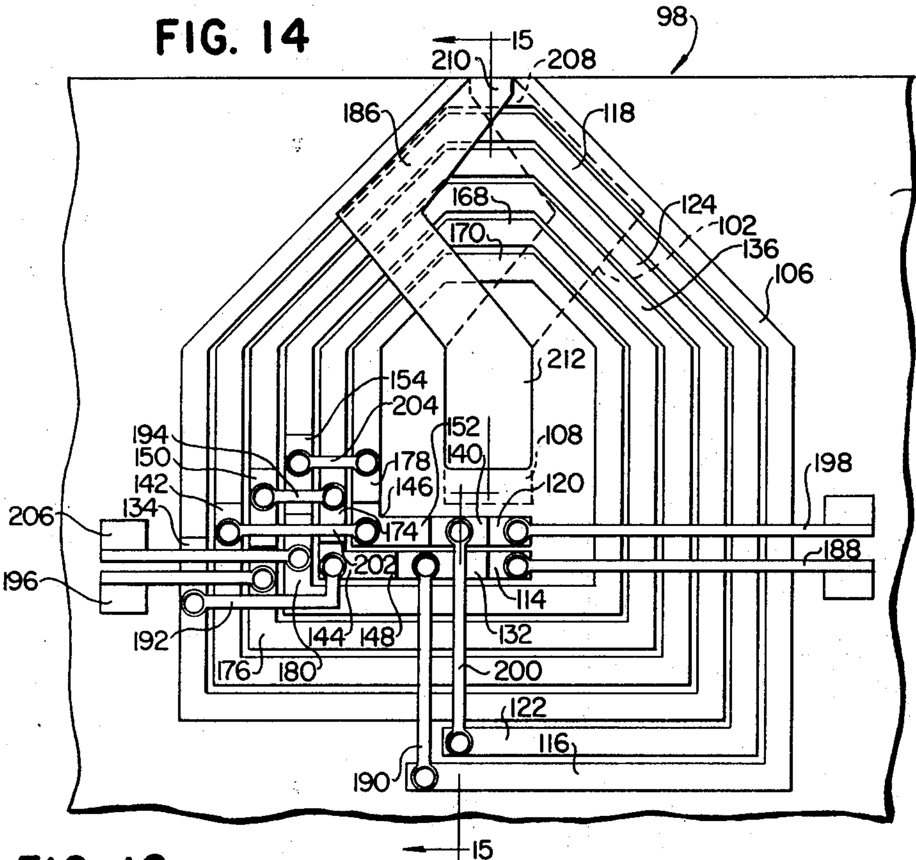
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FIG. 16

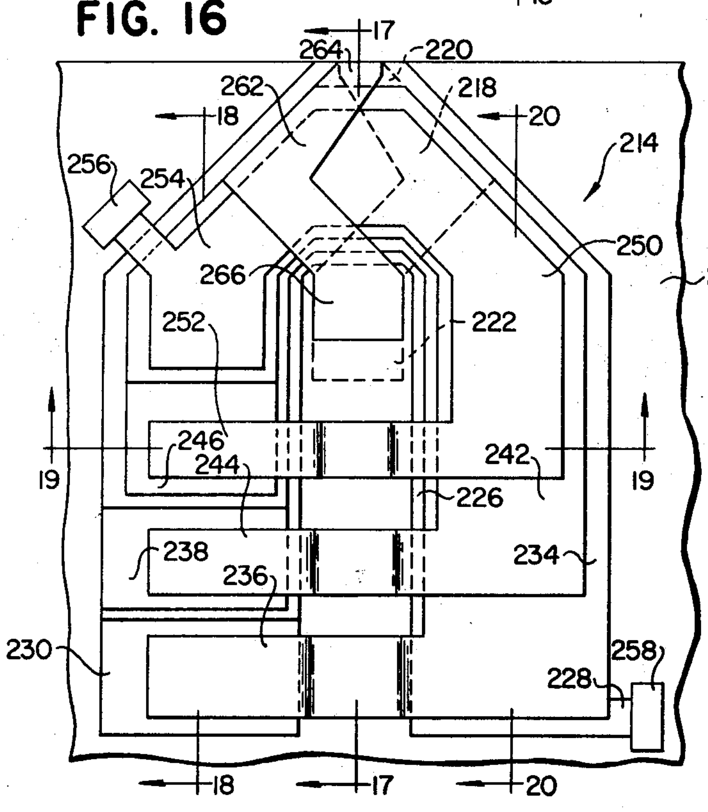
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FIG. 15

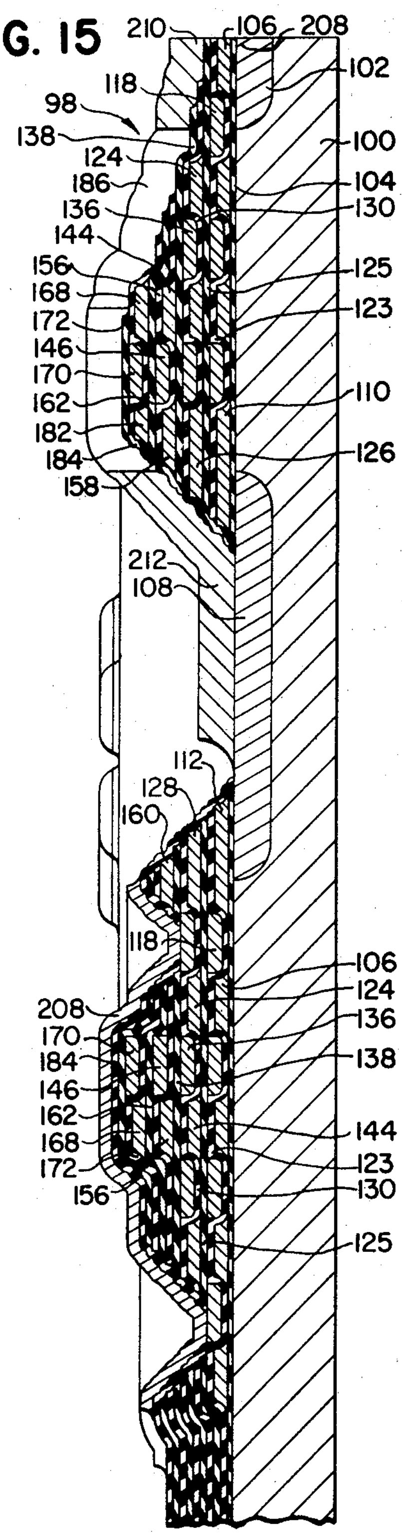
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FIG. 17

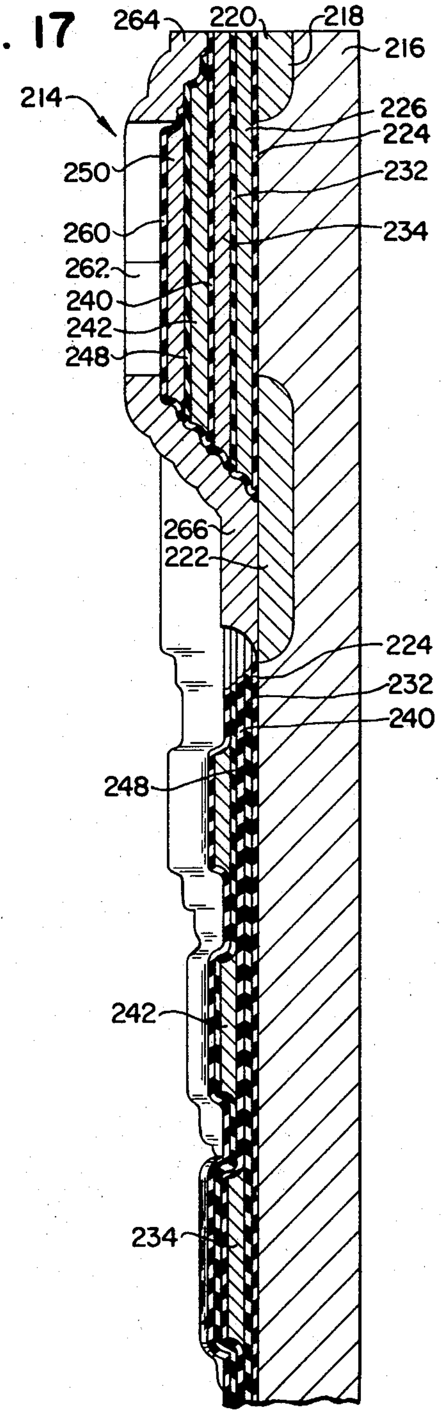
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FIG. 19

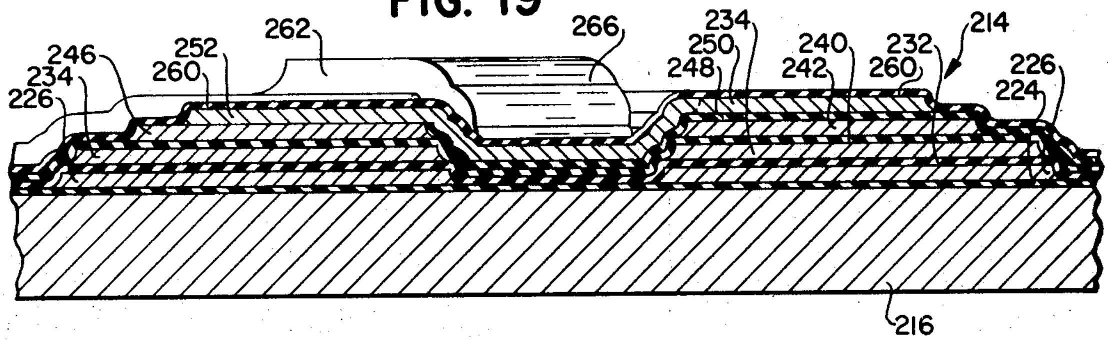


FIG. 18

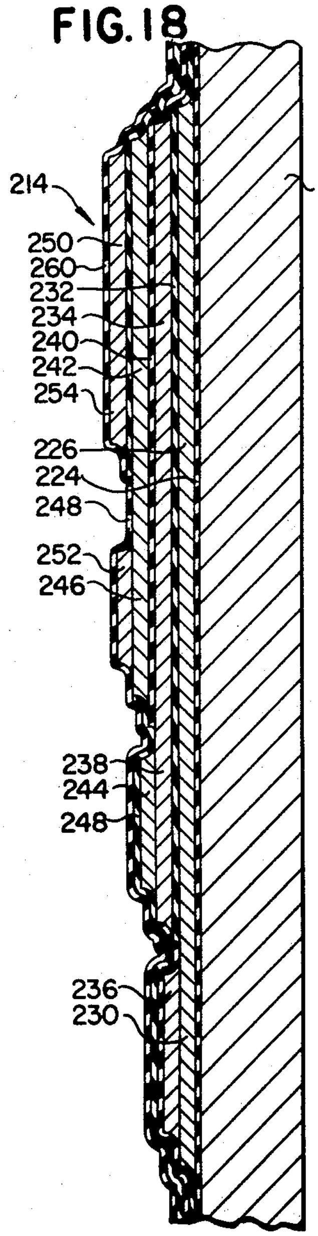
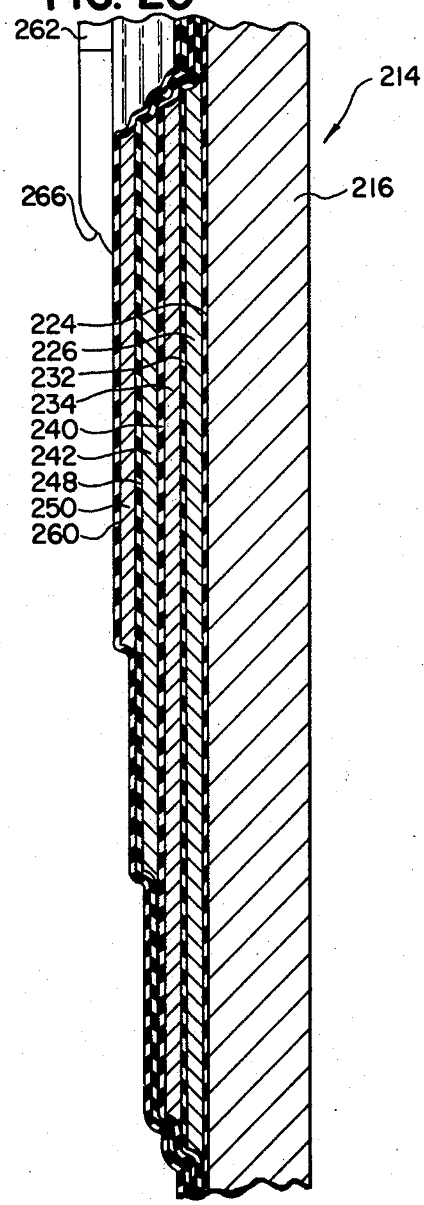


FIG. 20



METHOD OF MAKING A MAGNETIC TRANSDUCER

This application is a division of application Ser. No. 668,528, filed on Sept. 18, 1967, U.S. Pat. No. 3,549,825 by Cebern B. Trimble for Magnetic Transducer with Planar Spiral Coil Extending into the Gap.

BACKGROUND OF THE INVENTION

This invention relates to magnetic transducers for use in magnetic recording and reproduction and to the method of making the same.

One of the problems encountered in magnetic transducers of the prior art is the high cost of producing them. The high cost is due primarily to the watchmaker type of mechanical precision required in fabricating said transducers.

The bulk of prior-art magnetic transducers are generally cubic in form with the coil thereof being wound around at least one of the legs of the magnetic core thereof. While this type of transducer provides adequate performance when properly utilized, a considerable amount of leakage flux is present between the pole tips thereof and across the many faces of the transducer core. Leakage flux is redundant, and the only useful flux in the transducer is that which extends beyond the core area to the area of the recording media with which the transducer is used. Leakage flux, however, in this prior-art transducer is of little concern because the core reluctance is small in comparison to the total leakage field reluctance. The core reluctance is relatively small in these prior-art transducers because of the large cross-sectional area of the core, compared to the mean flux path length, and because the permeability of the core material is high. When such prior-art transducers are used in magnetic switching arrangements where the information transfer rate is increased to enhance system performance, the increased switching rate results in a reduction of the permeability of the core material thereof, which in turn results in an inadequate performance of the transducer.

In contrast with the prior-art transducers, the transducers of this invention have a reduced high frequency fall-off in applications involving increased information transfer rates. The transducers of the instant invention also have several redundant leakage flux circuits requiring a relatively low core reluctance. Inherently, the core reluctance will be small in the transducers of this invention because of a short flux path length resulting from the miniaturization of the transducers.

The transducers of the present invention are batch fabricated through the use of high resolution optical masks along with advanced chemical machining and thin film deposition techniques which provide for reduced costs of fabrication and result in accurately formed, high performance transducers having a deposited coil of high winding density. In addition, the batch-fabrication techniques mentioned facilitate the production of multi-head transducers.

SUMMARY OF THE INVENTION

The magnetic transducers of this invention include generally a first magnetic circuit plate which is deposited on a non-magnetic substrate. A conductor coil means, in the general shape of a spiral, is then deposited on said first magnetic plate and said substrate and is insulated therefrom. Over the coil means is deposited a second magnetic circuit plate which is insulated therefrom. The first and second magnetic circuit plates have pole ends which are spaced apart to receive at least a portion of said coil means therebetween and to provide the gap for the transducer. The coil means include modifications for a single conductor coil, a bifilar coil construction, and a multi-layered bifilar coil construction. The invention also includes a modification in which the first and second magnetic circuit plates lie in planes which intersect each other.

The general method of producing the transducers of this invention utilizes chemical machining and deposition techniques to batch fabricate the transducers. The first magnetic circuit plate previously mentioned is deposited on a non-magnetic substrate, and a layer of conductor material is deposited thereover, with insulation layers being deposited where necessary. The layer of conductor metal is then masked to delineate the shape of the coil required. Chemical machining techniques are then employed to etch away the unwanted conductor material to leave the desired coil configuration. On top of the coil there is deposited the second magnetic circuit plate, having a pole end which is spaced from the pole end of the first magnetic circuit plate to produce the gap for the transducer. Additional steps, to be described later, are required for the various modifications of transducers disclosed herein.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a general perspective view of a magnetic transducer of the prior art.

FIG. **2** is a plan view of one embodiment of the magnetic transducer of this invention, showing the deposited magnetic plates and the generally, spirally shaped coil.

FIG. **3** is generally a cross-sectional view taken along the line **3—3** of FIG. **2**, showing more details of the transducer construction.

FIG. **4** is a plan view of another embodiment of this invention, showing a transducer having a bifilar coil construction.

FIG. **5** is generally a cross-sectional view taken along the line **5—5** of FIG. **4**, showing more details of the bifilar coil construction.

FIG. **6** is a plan view of another embodiment of this invention, showing a plurality of transducers mounted in side-by-side relation for multi-track operation.

FIG. **7** is a general view in perspective of one embodiment of this invention, showing a plurality of transducers arranged on a substrate for multi-track, read-write operation.

FIG. **8** is a general view in perspective of another embodiment of this invention, showing a transducer with its magnetic circuit plates lying in two different planes which are at right angles to each other.

FIGS. **9** to **13** inclusive are cross-sectional views showing various stages in the method of producing a bifilar transducer according to this invention.

FIG. **14** is a plan view of another embodiment of this invention, showing a bifilar transducer with its coils produced in a plurality of layers.

FIG. **15** is a cross-sectional view taken along the line **15—15** of FIG. **14**, showing more details of the bifilar coil construction.

FIG. **16** is a plan view of another embodiment of this invention, showing a transducer having a plurality of multi-layered single turns connected together to form a single coil.

FIG. **17** is a cross-sectional view taken along the line **17—17** of FIG. **16**, showing more details of the transducer shown therein.

FIG. **18** is a cross-sectional view taken along the line **18—18** of FIG. **16**, showing more details of the transducer shown therein.

FIG. **19** is a cross-sectional view taken along the line **19—19** of FIG. **16**, showing more details of the transducer shown therein.

FIG. **20** is a cross-sectional view taken along the line **20—20** of FIG. **16**, showing more details of the transducer shown therein.

DESCRIPTION OF THE PREFERRED EMBODIMENTS:

FIG. **3** shows a first embodiment of this invention, which includes two magnetic transducers **20** and **22**, which are mounted on the same substrate **24** to form a read-write transducer. Because these transducers **20** and **22** may be identical, a discussion of the construction of the transducer **20** will follow.

The transducer **20** (FIGS. **2** and **3**) has a generally planar construction when compared with the prior-art transducer **26** shown in FIG. **1**. The transducer **20** includes the substrate **25** having a recess **23** formed therein to receive the first magnetic circuit plate **30**. The top of the plate **30** (as viewed in FIG. **3**) lies in the same plane as does the surface **32** of the substrate **24**, which may be of glass. A layer of insulation **34** is then deposited on the surface **32** and the plate **30** to insulate the plate **30** from the individual turns of the coil **36**. If the magnetic circuit plate **30** is made of ferrite material, the insulation layer **34** is generally not needed; however, if said plate is made of permalloy material, the layer **34** is needed.

After the insulation layer **34** is deposited on the surface **32** and the plate **30**, the coil **36** is formed thereon as shown in FIGS. **2** and **3**. The coil **36** is generally spiral in shape, with its innermost turn beginning at **38** (FIG. **2**) and its outermost turn ending at **40**. The techniques used for producing the various elements of the transducer **20** will be later described in detail.

After the coil **36** is formed on the insulation layer **34** (FIG. **3**), a layer of insulation **42** is deposited on the coil **36**, so as to fill the spaces between adjacent turns thereof and to insulate the coil from the second magnetic circuit plate **44**. The plate **44**, when deposited, also has projections **46**, which fill the spaces in the pockets of insulation formed between adjacent turns of the coil **36**. The second plate **44** has a pole end **48**, which is positioned opposite the pole end **50** of the first magnetic plate **30**, as shown in FIG. **3**, and the second plate **44** has a back end **52**, which is in contact with the back end **54** of the first magnetic plate. When looking at the first and second magnetic plates **30** and **44** respectively (as viewed in FIG. **2**), it is apparent that they are offset from each other. Being offset from each other in this manner reduces the leakage flux across the plates **30** and **44**. The reluctance of the magnetic path in the plates **30** and **44** is lower with no gap at the back ends **54** and **52** as shown, although the transducer is operative with a gap at said back ends.

The transducer **22** shown in FIG. **3** is identical to the transducer **20** just described; however, it is placed on the opposite side of the substrate **24**. When so positioned, the transducers **22** and **24** together provide a read-write magnetic transducer head. FIG. **6** shows a plurality of transducers **22** positioned in side-by-side relation on a common substrate **56** for multi-track applications. FIG. **7** shows a plurality of transducers **20** and **22** arranged on opposite sides of a common substrate **24** to form a plurality of read-write transducers for multi-track applications. The entire arrangement shown in FIG. **7** may be encapsulated in plastic **57** (shown in dashed lines) to form a flying platform which may be moved relative to the record media.

FIGS. **4** and **5** show a second modification of this invention, in which the transducer **58** is bifilar. The method for producing this modification and the modification shown principally in FIG. **2** is substantially the same; however, more of the details of the method are brought out in a discussion of the second modification. Therefore, a detailed discussion of the method for producing the transducer **58** of this invention will now be presented.

The transducer **58** (FIGS. **4** and **5**) is produced on the substrate **60** as follows. The substrate **60** may be made of glass, as previously explained, and a thin layer of tantalum (not shown) is R. F. sputtered on the substrate by conventional techniques. A thin layer of gold (not shown) is similarly sputtered on the layer of tantalum. A conventional photo resist is then positioned over the gold layer to delineate the shape of the recess **62** into which the first magnetic circuit plate **64** will be positioned. The photo resist is then exposed and developed, conventionally, leaving the gold layer exposed for the area where the recess **62** will be formed. The exposed gold layer is then etched away by a conventional solution of aqua regia to expose the layer of tantalum, where the recess **62** will be formed. The layer of tantalum is then etched away by a conventional solution of hydrofluoric nitrate, which also etches the glass substrate **60** to the desired depth to form the recess **62**. The tantalum and gold layers mentioned in this paragraph are utilized to form a strong bond to the substrate **60**.

After the recess **62** is formed in the substrate **60**, a layer of tantalum, followed by a layer of gold, is R. F. sputtered on the surface of the recess **62** by the techniques already explained. The layer of gold serves as a plating electrode for electrode positioning a permalloy material in the recess **62**, which is overfilled. After overfilling, the excess permalloy is abraded down, so that the top thereof (as viewed in FIG. **5**) of the first magnetic plate **64** lies in the same plane as the top surface **66** of the substrate **60**. A layer of glass insulation **68** is then R. F. sputtered over the surface **66** and the plate **74** by conventional techniques.

Once the layer of glass insulation **68** (FIGS. **5** and **9**) is deposited on the magnetic circuit plate **64**, a layer of conductor material is adhered thereto as follows. First, a layer of tantalum is sputtered on the layer **68**, and over the tantalum, a layer of gold is deposited by the techniques already explained. This layer of gold (not shown) is actually a plating electrode for the layer of conductor material, such as copper, which is deposited thereon to the desired thickness, the copper layer being used to form the first coil **70**, shown in FIGS. **4**, **5**, and **9** through **13**.

The first coil 70 is produced as follows. After the layer of conductor material is deposited on the insulation layer 68 (best shown in FIG. 9), a photo resist mask 72 is placed over the layer of conductor material to delineate the desired shape of the coil 70, and the chemical machining techniques already described are used to remove the unwanted portions of conductor material, leaving the individual turns of the coil 70 separated from one another. The insulating layer 68 serves as a stop for said machining techniques. The coil 70 has the general shape of a spiral, with its inner turn 74 starting near the back gap 76 (FIG. 5) of the first magnetic plate 64, and the outer turn thereof being located near the pole end 78 of the circuit plate 64 and ending at the terminal 80 (FIG. 4).

After the first coil 70 is deposited and formed, the photo resist mask 72 (FIG. 9) is removed by conventional techniques, and the transducer 58 is cleaned in preparation for depositing a second layer 82 of glass insulation by the R. F. sputtering technique already mentioned. After the layer 82 is deposited, a thin layer of tantalum (not shown) is deposited thereon, which is followed by a thin layer of gold, which is deposited thereover by said sputtering technique. The gold layer (not shown) serves as a plating electrode for the layer of conductor metal 84, which is deposited thereover to the desired thickness, as shown in FIG. 11.

After the layer of conductor metal 84 is deposited, those areas 86 which are positioned above the turns of the coil 70 (as viewed in FIG. 11) are abraded down to the level of the glass insulation 82 above said turns, so that the top of the metal layer 84 lies in the same plane as the top of the glass layer 82, as shown in FIG. 12. The abrasion operation produces the discrete turns of the second coil 88, and, as can be seen from FIG. 12, the turns of the second coil 88 are insulated from the turns of the first coil 70 and lie between adjacent turns of the first coil 70. As can be seen from FIG. 4, the second coil 88 has one terminal 90 near the back end of the first magnetic circuit plate 64 and the other terminal at 92, with the outer turn of said coil positioned near the pole end 78 of the first magnetic plate 64.

Prior to forming the second magnetic circuit plate 94, the portion of the transducer 58 near the back gap end 76 of the first magnetic circuit plate 64 is cleared away by using photo resist masks (not shown) and conventional chemical machining techniques to expose the end 76 of the plate 64 (FIG. 5). After the back gap end 76 is exposed, a third layer of glass insulation 96 (FIG. 5) is deposited over the entire second coil 88 and the substrate 60 except for the area of of the back gap end 76. A suitable mask (not shown) can be positioned over the back gap end 76 to prevent the deposition of the glass layer 96 thereon, and it can be removed after the layer 96 is deposited to expose the end 76.

The second magnetic circuit plate 94 (FIGS. 5 and 13) is formed as follows. After the third layer 96 of insulation is deposited, a thin layer of tantalum (not shown) is deposited thereover, and a thin layer of gold (not shown) is deposited over the tantalum. The gold layer serves as a plating electrode for depositing a layer of desired thickness of permalloy material thereon, the permalloy material being formed into the second magnetic circuit plate 94 through utilizing a photo resist mask and the chemical machining techniques already described. The second magnetic circuit plate 94 has the general shape shown in FIG. 4. As shown in FIG. 4, the plates 64 and 94 are generally "C" shaped, with their pole ends overlapping to form the transducer gap, with portions of the first and second coils 70 and 88, respectively, lying between said pole ends, as better shown in FIG. 5.

FIG. 8 is a general view in perspective of another embodiment of this invention, showing a transducer 97 having portions of its magnetic circuit plates 99 and 101 lying in two mutually perpendicular planes. The transducer 97 is mounted on a substrate 103 by the techniques already mentioned, with a few following exceptions. Instead of being mounted in one plane, the first magnetic circuit plate 99 is deposited in a recess which extends into the mutually perpendicular facer 105 and 107 of the substrate 103, these faces joining along a common edge 109. The transducer 97 includes a coil 111, which is similar to the coil 36 (shown in FIG. 2) and which is positioned between the magnetic circuit plates 99 and 101 by the techniques already described. The circuit plate 99 has one portion lying in the face 105 and a second portion 113 lying in the face 107. The circuit plate 101 has a portion positioned generally parallel to the face 105 and a second portion 115 lying in the face 107. The portions 113 and 115 are spaced apart to form the transducing gap of the transducer 97, and the tops of the portions 113 and 115 are in the same plane as the top of the face 107 as viewed in FIG. 8. The coil 111 is provided with terminals 117 and 119 to connect it to external circuitry. A transducer 121, identical to the transducer 97, may be positioned in opposed relation on the substrate 103 to provide a read/write transducer.

FIGS. 14 and 15 show another modification of a bifilar transducer made according to this invention; however, in this transducer 98, each individual coil thereof is composed of a plurality of multi-layered windings, each winding being in the general shape of a spiral and said windings being interconnected to form said coil. The transducer 98 is supported on a substrate 100, which may be glass and which has recesses formed therein to receive the first magnetic circuit plate 102 according to the techniques already explained. An insulating layer 104 is then deposited over the entire substrate 100 and the first plate 102. On top of the layer 104, the first winding 106 of the first conductor coil is formed as previously explained, with this one exception. Near the back end 108 of the first plate 102, certain portions (like 110 and 112 in FIG. 15) of the conductor material from which the winding 106 was formed are not removed when the winding 106 is formed. These portions 110 and 112 are isolated from the winding 106 and are used merely as fillers to facilitate the construction of the transducer 98, as will be explained later. The beginning of the first winding of the first coil starts at 114 and ends at 116 (FIG. 14).

As can best be seen in FIG. 14, the first winding 118 of the second coil of the transducer starts at 120 and ends at 122. The individual turns of the winding 118 are located slightly above and between the individual turns of the winding 106 of the first coil, as shown in FIG. 15, by the techniques already described in relation to the embodiment shown in FIGS. 4,5, and 9 through 13 inclusive. The winding 118 is insulated from the winding 106 by a layer 123 of glass insulation. The top of the winding **118** and the top of the insulation layer **123** lie in the same plane, over which another layer **125** of glass insulation is deposited.

After the layer **125** of glass insulation is deposited, a second winding **124** of the first coil of the transducer **98** is formed thereon, as shown in FIGS. **14** and **15**, with the filler portions **126** and **128** (FIG. **15**) being formed at the same time. After the second winding **124** is formed, it is insulated by a layer **130** of glass insulation. The winding **124** begins at **132** (FIG. **14**) and ends at **134**.

After the second winding **124** of the first coil of the transducer **98** is formed, the second winding **136** of the second coil is formed on the layer **130** of glass insulation already deposited by the techniques already described. The top of the winding **136** lies in the same plane as the top of the insulation layer **130**, as viewed in FIG. **15**, and another layer of glass insulation **138** is deposited over this plane. The winding **136** starts at **140** and ends at **142** (FIG. **14**) and has the generally spiral shape shown.

The third winding **144** of the first coil and the third winding **146** of the second coil (FIGS. **14** and **15**) are formed in the same manner as the other windings of the transducer **98**. The winding **144** starts at **148** and ends at **150** (FIG. **14**). The winding **146** starts at **152** and ends at **154**. Both windings **144** and **146** are generally spiral in shape and generally overlie the other windings of their respective coils, and are insulated from each other by a layer **156** of glass insulation. The filler portions **158** and **160** are formed at the same time that the winding **144** is formed. The top of the winding **146** lies in the same plane as the top of the layer **156** of glass insulation, and another layer **162** of glass insulation is deposited over this plane.

The fourth winding **168** of the first coil and the fourth winding **170** of the second coil of the transducer **98**, as shown in FIGS. **14** and **15**, are formed by the same techniques as the other windings thereof, and the windings **168** and **170** are insulated from each other by the layer **172** of glass. The fourth winding **168** starts at **174** and ends at **176** (FIG. **14**), and the fourth winding **170** starts at **178** and ends at **180**, both said windings having the generally spiral shape shown. The filler portion **182** (FIG. **14**) is formed when the winding **168** is formed.

After the windings **168** and **170** are formed, a layer **184** of glass is deposited over all the safe windings of the transducer **98**, as shown in FIG. **15**. The filler portions **110**, **126**, **158**, and **182**, previously mentioned, provide a gradual slope for better supporting the back end of the second magnetic circuit plate **186** on the layer **184** of insulation.

In order to connect the individual windings of the first and second coils of the bifilar transducer **98** shown in FIGS. **14** and **15**, the following construction is used. The individual windings (**106**,**124**,**144**, and **168**) of the first coil are connected together as follows. A terminal conductor strip **188** is connected to the starting end **114** of the first winding, as shown in FIG. **14**. In order to expose the end **114** prior to securing the strip **188** thereto, it was necessary to take steps to remove the various layers of glass insulation which may have been deposited thereover during the process of producing the transducer **98**. These steps are conventional and need not be recited here in detail. The remaining end **116** of the first winding **106**, after being exposed, is connected to the beginning end **132** of the second winding **124** by the conductor strip **190**, which may be deposited by conventional techniques. The remaining end **134** of the second winding **124** is connected to the beginning end **148** of the third winding **144** by the conductor strip **192**. In a similar manner, the remaining end **150** of the third winding **144** is connected to the beginning end **174** of the fourth winding **168** by the conductor strip **194**. The remaining end **176** of the fourth winding **168** has a terminal conductor strip **196** connected thereto, as shown in FIG. **14**.

The individual windings (**118**,**136**, **146**, and **170**) of the second coil of the bifilar transducer **98** are connected to form one continuous coil as follows. The first winding **118** has a terminal conductor strip **198** connected to the beginning end **120** thereof, as shown in FIG. **14**. The ends of the several windings of said second coil are exposed by removing any insulation layers which may be present thereover, as previously explained. The remaining end **122** of the first winding **118** is connected to the beginning end **140** of the second winding **136** by the conductor strip **200**. The remaining end **142** of the second winding **136** is connected to the beginning end **142** of the third winding **146** by the conductor strip **202**. In a similar manner, the remaining end **152** of the third winding **146** is connected to the beginning end **178** of the fourth winding **170** by the conductor strip **204**. The remaining end **180** of the fourth winding **146** has a terminal conductor strip **206** connected thereto as shown.

After the first and second coils of the bifilar transducer **98** are connected as just explained, a protective layer **208** (FIG. **15**) of glass insulation may be deposited thereover to protect the individual windings and conductor strips. The second magnetic circuit plate **186** is then formed on the transducer **98** by the techniques already explained. As is apparent from FIG. **15**, portions of the first and second coils lie between the first and second magnetic circuit plates **102** and **186**, respectively, and the pole ends **208** and **210**, respectively, thereof are spaced apart to produce the transducer gap. The back ends **108** and **212** of the plates **102** and **186**, respectively, may be joined as shown in FIG. **15**, or they may be spaced apart according to design requirements.

FIGS. **16** through **20** show another transducer **214** of this invention; however, this transducer has a single coil, which is made of a plurality of multi-layered, single-turn conductor windings as follows. The transducer **214** is supported on a substrate **216**, which may be glass, and the substrate has recesses formed therein into which the first magnetic circuit plate **218** (having a pole end **220** and a back end **222**) is positioned and formed according to the techniques previously described. A thin planar layer **224**, of glass insulation, is then deposited over said substrate **216** and circuit plate **218**. The first turn **226** is formed on the glass layer **224** and has terminal ends **228** and **230** and the general shape shown in FIG. **16**. On top of the first turn **226**, there is deposited a second layer **232** of glass insulation. The second turn **234** is formed on the second layer **232** and has the general shape best shown in FIG. **16**. The second turn **234** of the coil has one end **236** thereof connected to the end **230** of the first turn **226**, and its other end terminates at **238**. It is apparent from FIG. **16** that the individual turns (**226, 234**) of the coil, when connected in series, conform to the general shape of a spiral.

After the second turn **234** of the transducer **214** is formed, a layer **240** of glass insulation is deposited thereover, and the third turn **242** is then formed on the layer **240** (FIGS. **16, 17, 18, 19**, and **20**). The turn **242** has the general shape shown in FIG. **16** and has one end **244** connected to the end **238** of the second turn **244**, and the remaining end thereof terminates at **246**. On top of the third turn **242** is deposited a layer **248** of glass insulation, over which is deposited the fourth turn **250** of the coil. The fourth turn **250** has one end **252** connected to the end **246** of the turn **242** and its other end terminating at **254**. A suitable connecting terminal **256** (FIG. **16**) is connected to the end **254** of the fourth turn **250**, and a similar terminal **258** is connected to the beginning end **228** of the first turn **226** to enable the transducer to be connected to external circuitry. A layer **260** of glass insulation is then deposited over the fourth turn **250**.

The second magnetic circuit plate **262** is then formed on the layer **260** according to the techniques already described. The plate **262** has a pole end **264** (best shown in FIG. **17**) and a back gap end **266**. The pole end **264** is spaced from the pole end **220** of the first plate **218** to form the gap of the transducer **214**, with portions of its coil positioned between said pole ends. The back ends **222** and **266** of the plates **218** and **262**, respectively (FIG. **17**), may be connected as shown, or they may be spaced apart according to design requirements.

While the forms of the invention shown and described herein are admirably adapted to fulfill the requirements primarily stated, it is to be understood that it is not intended to confine the invention to the forms or embodiments disclosed herein, for it is susceptible of embodiment in various other forms.

I claim:

1. The method of producing a magnetic transducer comprising the steps of:

a. forming a recess on one side of a non-magnetic substrate;

b. forming a generally planar first magnetic plate in said recess, with said plate having a pole end and a back end;

c. insulatingly supporting and forming over said plate and one side a coil means in the general shape of a spiral so that the outer turn thereof lies near said pole end, and the inner turn of said coil means lies near said back end;

d. and insulatingly supporting and forming a second magnetic plate over said coil means with said second plate having a pole end positioned opposite the pole end of said first plate and having a back end magnetically coupled to the back end of said first magnetic plate, and with at least the outer turn of said coil means being positioned between said pole ends.

2. The method as claimed in claim **1** in which said step c) comprises the steps of:

(e) forming the first of a plurality of generally spirally shaped coil windings so as to position the outermost portion thereof near said pole end of said first magnetic plate;

(f) forming the second winding of said plurality in superposed relationship with said first winding while simultaneously joining one end of said first winding with one end of said second winding; and

(g) forming additional windings as required according to the technique of step (f) so as to join one end of each preceding winding with one end of the winding being currently formed so as to form said coil means into a multilayered single coil.

3. The method of producing a magnetic transducer comprising the steps of:

a. forming a first magnetic plate on a non-magnetic substrate, with said plate having a pole end and a back end;

b. depositing a first thin film of insulation over the entire surface of said substrate and plate;

c. depositing a layer of conductor metal over said insulation;

d. forming a coil means in the general shape of a spiral of said conductor metal;

e. depositing a second thin film of insulation over said first film of insulation and said coil means;

f. removing portions of said second film of insulation near said back end of said first plate to expose said back end and to expose the ends of said coil means; and

g. forming a second magnetic plate on said second film of insulation and said back end to magnetically couple said back end with said second magnetic plate, said second plate having a pole end which is spaced from said pole end of said first magnetic plate to produce a transducer gap with an outer portion of said coil means being positioned between said pole ends.

4. The method as claimed in claim **3** in which said forming step (a) comprises:

h. etching a recess in the surface of said substrate:

i. depositing a permalloy to overfill said recess; and

j. abrading the excess permalloy so that the top thereof lies in the plane of said surface to form said first magnetic plate.

5. The method as claimed in claim **4** in which said forming step (d) comprises the steps of:

k. delineating the portions of said conductor metal to be removed so that upon the removal thereof said coil means will be produced; and

L. etching away said portions of step (k) down to said first film of insulation to produce said coil means.

6. The method of producing a bifilar magnetic transducer comprising the steps of:

a. forming a first magnetic plate on a non-magnetic substrate with said plate having a pole end and a back end;

b. depositing a first thin film of insulation over the entire surface of said substrate and plate;

c. depositing a layer of conductor metal over said insulation;

d. delineating portions of said conductor metal to be removed so that, upon the removal thereof, a desired first coil in the general shape of a spiral will be produced by the metal remaining;

e. etching away said portions of step (d) down to said first film of insulation to produce said first coil with spaces between adjacent turns thereof;
f. depositing a second thin film of insulation over said first coil and said first film of insulation from step (e);
g. depositing a second layer of conductor metal over said second film of insulation;
h. delineating portions of said second layer of conductor metal to be removed so that upon the removal thereof, a desired second coil in the general shape of a spiral will be produced by the metal remaining;
i. removing said portions of said second layer of metal down to said second film of insulation while leaving said metal of step (g) in said spaces between the turns of said first coil to thereby form discrete turns of said second coil of said transducer;
j. depositing a third thin film of insulation over said second coil;
k. depositing a layer of permalloy metal on said third film of insulation;
L. delineating portions of said permalloy metal of step (k) to be removed so that, upon the removal thereof, a desired second magnetic plate having a pole end and a back end will be produced by the permalloy metal remaining; and
m. joining said back ends of said first and second plates and exposing the ends of said coils for making connections thereto.

7. The method as claimed in claim **6** in which said forming step (a) comprises the steps of:
n. etching a recess in the surface of said substrate;
o. depositing a permalloy to overfill said recess; and
p. abrading the excess permalloy so that the top thereof lies in the plane of said surface to form said first magnetic plate.

8. The method of producing a bifilar magnetic transducer comprising the steps of:
a. forming a recess on one side of a non-magnetic substrate;
b. forming a generally planar first magnetic plate in said recess, with said plate having a pole end and a back end;
c. insulatingly supporting and forming over said plate and one side a plurality of spirally shaped, planar coil windings for first and second multi-turn coils, the windings of said first and second coils being alternated in generally superposed relationship, with at least the outermost turn of the windings of said first and second coils being positioned near said pole end;
d. forming a second magnetic circuit plate over said plurality of windings, with said second plate having a pole end positioned opposite the pole end of said first plate and having a back end magnetically coupled to the back end of said first plate, and with at least one of the outermost turns of the windings of said first and second coils being positioned between said pole ends; and
e. connecting the ends of the windings of said first coil to form one continuous multilayered winding, and similarly connecting the ends of the windings of said second coil to form one continuous multilayered winding.

9. The method of producing a magnetic transducer comprising the steps of:
a. etching a recess in a surface of a non-magnetic substrate;
b. depositing a permalloy to overfill said recess;
c. abrading the excess permalloy so that the top thereof lies in the plane of said surface to form a first magnetic plate;
d. depositing a thin film of insulation over the entire said surface of said substrate;
e. depositing a thin layer of metal over the entire surface of said insulation to form a plating electrode;
f. electro-plating a conductor metal over said thin layer of metal to a desired thickness;
g. delineating the portions of said conductor metal to be removed so that, upon the removal thereof, a desired coil configuration will be produced by the conductor metal remaining;
h. etching said portions down to said film of insulation to produce said coil configuration;
i. depositing a second thin film of insulation over said surface of said substrate and said coil configuration;
j. delineating an area near one end of said first plate to be removed;
k. etching said area of step (j) to expose said first magnetic plate thereat;
L. depositing a second thin layer of metal over the surface of said second film of insulation and the portion of the first magnetic plate as exposed from step (k);
m. depositing a layer of permalloy metal on said second thin layer of metal; and
n. delineating portions of said permalloy metal of step (m) to be removed so that, upon the removal thereof, a desired second magnetic plate will be produced by the permalloy metal remaining.

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