May 9, 1967 J. DAVIS 3,319,207

GROOVED TOROIDAL BODY WITH METAL FILLING

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FIG. 1

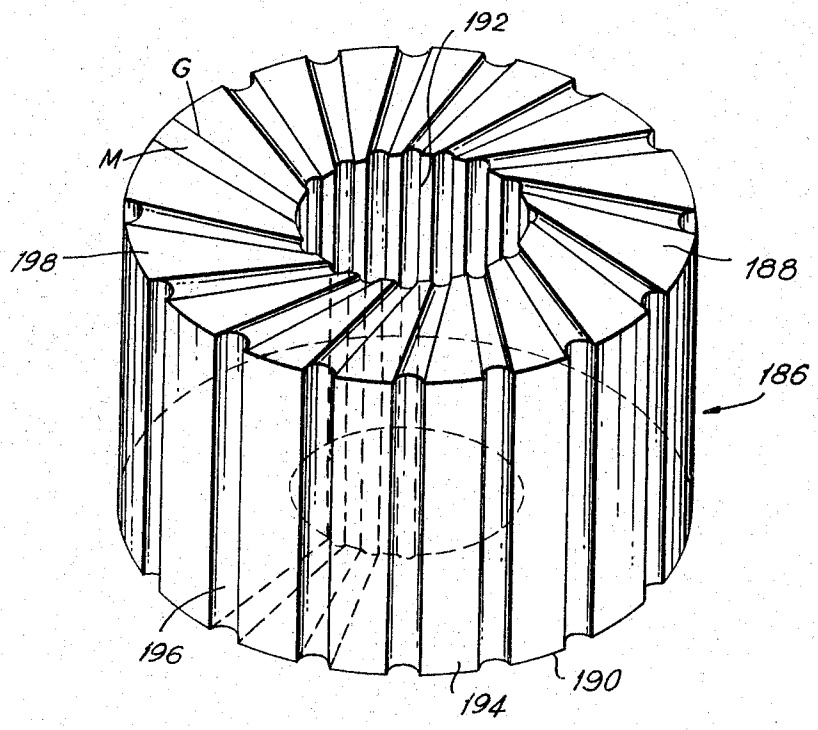
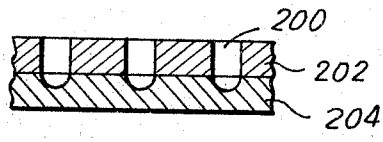


FIG. 2



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FIG. 3

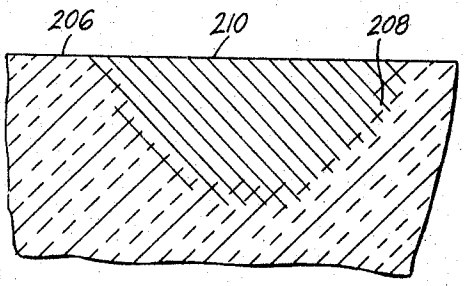


FIG. 4

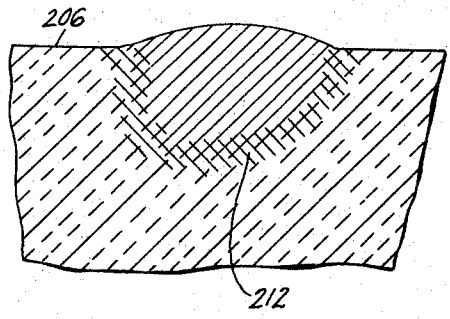


FIG. 5

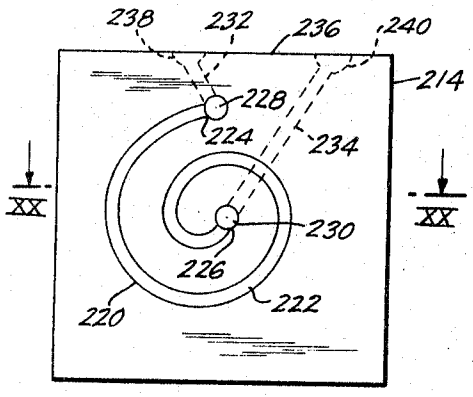


FIG. 6

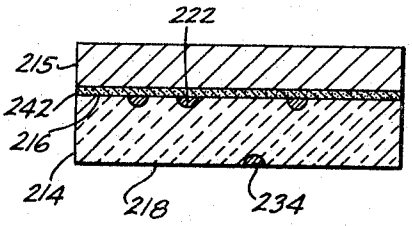
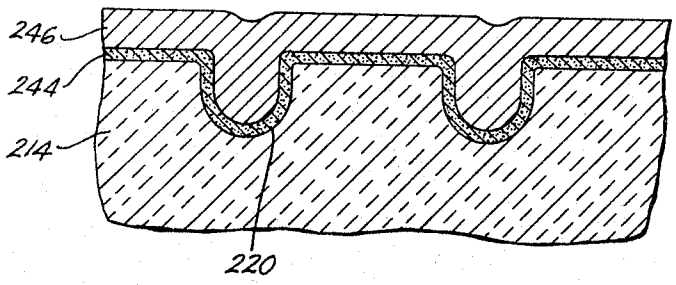


FIG. 7



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FIG. 8

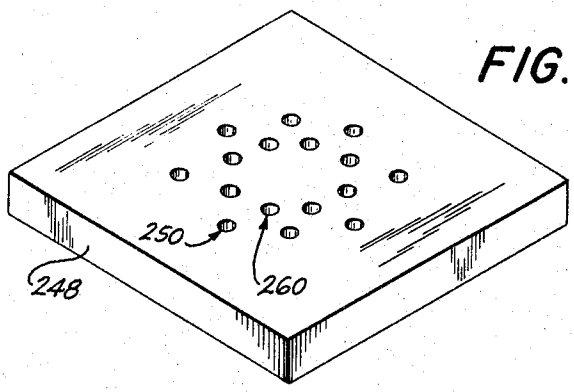


FIG. 9

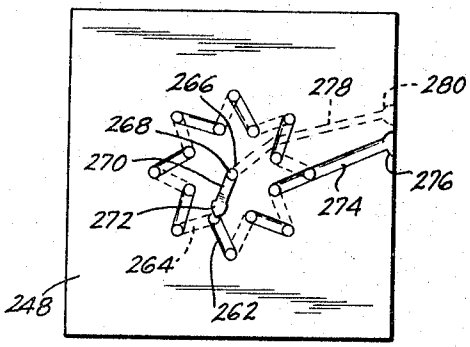


FIG. 10

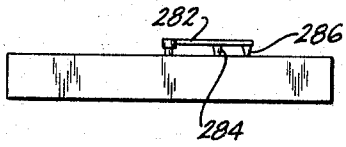


FIG. 11

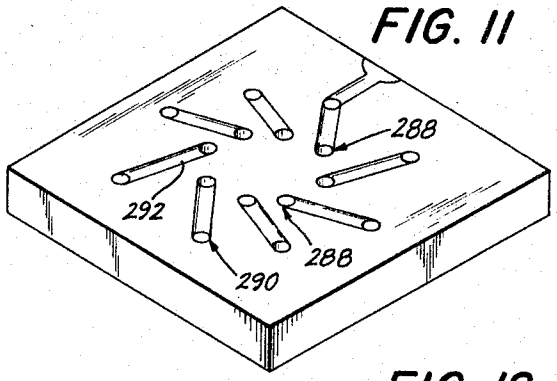


FIG. 13

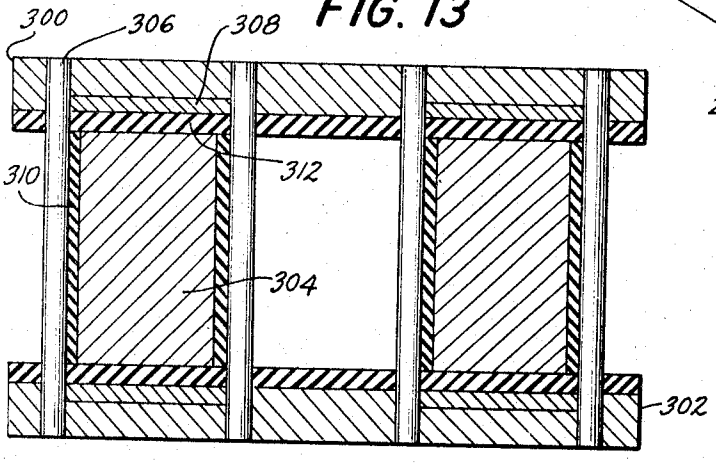
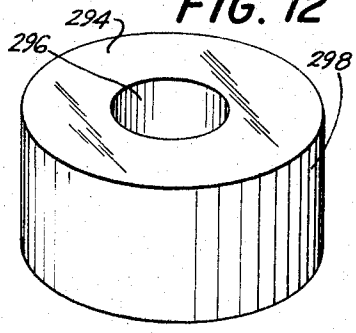


FIG. 12



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3,319,207

GROOVED TOROIDAL BODY WITH METAL FILLING

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Filed July 18, 1963, Ser. No. 296,121
4 Claims. (Cl. 336—229)

This application is a continuation-in-part based on material divided from my earlier filed copending application, Ser. No. 123,388, filed July 7, 1961.

This invention relates to electrical components inclusive of electronic and magnetic components and the like and further relates to associated methods.

The invention is particularly concerned with electronic and magnetic components of the type wherein a conductive element is supported on a fired and non-etchable substrate such as ceramic and it is an object of this invention to avoid the deficiencies normally inherent in providing such products.

For example, in the conventional type of such structures in which a copper wire is wound on a ferrite toroid, there is an uncontrollable spacing between the wire and the toroid such that the exact electronic and magnetic characteristics are impossible to predict.

This deficiency is, however, exemplary only of the various types of physical relationships which it is impossible to control in conventional products and by the use of conventional techniques, and, with respect thereto, it is an object of the invention to provide a product in which such relationships are very precisely established.

It is a further object of the invention to provide a product wherein a metal is positioned precisely with respect to a ceramic substrate without any possibility of sliding displacement either during fabrication or while the device is in use.

Still another object of the invention is to provide an improved product wherein a metal is related to a ceramic substrate in the form of a winding or coil, but which product requires no winding operations during the fabricating thereof so that the cross section of the metal can be precisely controlled.

Still another object of the invention is to provide a product in which metal may be separated from the associated substrate by a layer of insulation and with respect to which there is no possibility of injuring the insulation during manufacture.

Yet another object of the invention is to provide the advantageous products thereof at minimal cost.

An electronic component of the invention achieving the aforesaid and further objectives of the invention comprises generally a ceramic body defining a surface groove or recess within which is deposited an electrically conductive metal which constitutes with said body a substantially monolithic structure, the ceramic and metal preferably constituting cooperatively and joining along an interspersed migratory phase which bonds the metal to the ceramic.

It will be readily appreciated that a wide variety of products are possible within the aforesaid definition. Certain preferred versions of such products will be described in greater detail hereinafter.

One preferred product, according to the invention, consists of a ceramic or ferrite body within which are provided two circular arrays of bores coupled by surface grooves which, together with the bores, define a toroidal helical path within which is deposited a metal conductor constituting a winding, the physical dimensions of which are very accurately controlled.

According to a feature of the invention, means can be provided on the supporting substrate adapted for selectively engaging the metal conductor in the manner of an adjustable tap or the like.

Yet another preferred product, according to the invention, is a structure wherein a ferrite toroid is sandwiched, with or without the interpositioning of an insulative material, between ceramic or ferrite wafers provided with bores and grooves adapted to constitute the site for conductors constituting a helical winding as will be shown in greater detail hereinafter.

The above and other objects and features of the invention, as well as advantages thereof, will become apparent from the following detailed description of some preferrred embodiments as illustrated in the accompanying drawing in which:

FIGURE 1 illustrates a specific product which is readily fabricated in accordance with the invention;

FIGURE 2 is a longitudinal section of a workpiece illustrating a variation of the technique of the invention;

FIGURE 3 is a cross-section of a portion of a product of the invention illustrating the relationship between a metal conductor and a substrate;

FIGURE 4 is a view similar to that of FIG. 3, illustrating the addition of an insulative layer;

FIGURE 5 is a top plan view of another embodiment of the invention;

FIGURE 6 is a cross-sectional view of the article of manufacture of FIG. 5 with a cover plate added thereto;

FIGURE 7 illustrates a portion of the cross-section of FIG. 6 on enlarged scale with the cover plate removed;

FIGURE 8 illustrates in perspective view a component of the further embodiment of the invention;

FIGURE 9 illustrates in top plan view the component of FIG. 8 further completed;

FIGURE 10 is a side view of the article of FIG. 9 with a slight modification thereof;

FIGURE 11 is a perspective view of a component of a further article of manufacture according to the invention;

FIGURE 12 is a perspective view of a further component of the latter said article of manufacture; and

FIGURE 13 as an axial cross-section of the latter said component.

Reference will be made hereinafter to crystalline and ceramic or ceramic-like substrates in which grooves or slots are formed and this expression shall be considered as applying to alumina, sapphire, glass, steatite and titanates. Other materials of generally similar physical characteristics may also be considered as coming within the scope of this expression, even though the electrical characteristics of these additional materials may differ considerably. Examples of said additional materials are ferrite, tungsten carbide, and other metallic oxide and carbide mixtures.

To form grooves or slots in the materials employed in accordance with the invention, an abrasive can be employed. Depending upon the material of the substrate, the abrasive is propelled at the workpiece being formed to impact against the same with velocities ranging from about 50–1500 feet per second. The depth of the groove or recessed pattern formed in the workpiece is controlled by the time of exposure of the workpiece to the abrasive, in addition to the velocity, weight and volume of the abrasive. These features can be empirically determined depending upon the depth of erosion desired.

The article of manufacture in this intermediate stage is then processed to fill the eroded or recessed pattern with a metal or such other material as is desired be deposited in the substrate. In the case of electrical components, and this expression is intended to cover magnetic and other components as well, the material deposited

will be one having predetermined electrical characteristics.

There are many modes by which metal may be deposited in the grooves in the substrate. For example, metals can be sprayed or otherwise plated onto the substrate and then lapped down so that the only metal remaining is that which is positioned in the recessed pattern, or mixtures of powdered metals in suitable vehicles can be doctored or brushed into the grooves and fired in suitable atmosphere furnaces.

There is, however, one particular procedure which lends itself very well to the production of articles of manufacture suitable for microminatruization and this is a method by which a metal is deposited in the substrate from a readily decomposed and volatile metal bearing compound.

In accordance with this procedure, it is possible to utilize metal carbonyl, nitroxyl compounds, nitrosyl carbonyls, metal hydrides, metal alkyls, metal halides, metal carbonyl halogens, and the like, which are either liquids at normal temperatures and pressure conditions, or gases compressible to liquid under any commercially feasible temperature conditions or solids convertible to liquids at temperatures below the decomposition temperature of the compound, or solutions or carbonyls in volatile solvents such as petroleum ether.

Useful metals which may be deposited from the metallic carbonyl compounds are copper, nickel, iron, chromium, molybdenum, tungsten, cobalt, tellurium, rehenium, and the like.

Illustrative compounds of the other groups are nitroxyls, such as copper nitroxyl, nitrosyl carbonyls, for example, cobalt nitrosyl carbonyl, hydrides, such as tellurium hydride, gelenium hydride, antimony hydride, tin hydride, chromium hydride, the mixed organo-metallo hydrides such as dimethyl alumino hydride, metal alkyls such as tetraethyl lead, metal halides such as chromyl chloride, and carbonyl halogens such as rhodium carbonyl chloride, osmium carbonyl bromide, ruthenium carbonyl chloride, and the like.

The procedure whereby metal may be deposited from a readily decomposed compound is well known for other purposes and will not be described in great detail at this time.

The actual mechanism by which the metal is deposited by decomposition on the substrates involves thermal activation and thus the recessed surfaces of the articles of manufacture are heated. The temperatures required are not very high and for the various materials involved, such temperatures can be found in available literature. Nickel carbonyl, for example, starts to decompose at about 175° F. A preferred range of operation, however, is, for example, a range of about 375–400° F.

According to the invention, the article of manufacture can have its entire recessed surface coated and then subsequently milled down so that the sole remaining metal lies completely within the grooves which have been formed.

It is also possible to fill the recessed pattern to less than complete extent and to cover the metal so deposited with an insulator and finally cover the insulator with additional metal.

A particular form of a product of the invention is illustrated in FIGURE 1 wherein is illustrated a toroid which is adapted for having spirally wound thereupon a metal "wire."

In FIGURE 1 is more particularly illustrated a toroid **186** having parallel flat faces **188** and **190** and further having concentric inner and outer walls **192** and **194**. Toroid **186** may be cast or extruded, but in any event is formed with corresponding axially disposed grooves **196**. In fact the axially disposed grooves can be eroded in accordance with the invention which, in contrast to the known art, can be applied to curved surfaces as well as flat surfaces.

In accordance with the invention, connecting grooves **198** are formed in the faces **188** and **190** in an offset relationship such that strips or grooves **198** and grooves **196** form a continuous spiral-like path around the body of the toroid. This spiral-like path has deposited therein a metal M or other such material by one of the methods which have been discussed above as indicated by way of example in specific groove G as well in FIG. 3 as discussed below.

As shown in FIGURE 2, the process is applicable to cameo as well as intaglio types of processes whereby holes **200** can be cut into a metal coating **202** previously positioned on a substrate **204**.

With respect to the above, as well as the following embodiments of the invention, a characteristic feature thereof is the uniting of a metallic conductor and a ceramic substrate into a monolithic structure wherein there is no measurable spacing between the metal conductor and the substrate or else the metal conductor is separated from the substrate by an electrically insulative material of determinable thickness. It will be appreciated that in products of the invention, the shape of the ceramic substrate is determinative of the shape of the metal conductor so that the shape of the metal conductor is not dependent upon manufacturing techniques and thus may be very precisely controlled as to physical configuration. It will further be appreciated that in products of the invention the metal conductor is so related to the ceramic substrate that physical movement therebetween is nearly impossible so that these products may be readily subjected to high magnitudes of acceleration and/or impact shock without fear of disturbing the electronic and/or magnetic characteristics.

It is also to be understood that the controlling features of the ceramic substrate may be provided subsequent to the firing and thermal shrinkage thereof so that very precise final dimensions are assured.

The cross-section of FIGURE 3 shows generally the monolithic relationship referred to above in accordance with which a ceramic substrate **206**, which may be from the toroid of FIGURE 1 or from the article of FIGURE 2 as well as from the products to be described hereinunder, is provided with a groove or surface recess **208** within which is deposited a metal conductor **210**.

In products of the invention, the cross-section of the metal conductor will conform closely to the cross-section of the accommodating groove, this resulting from the method and technique of fabrication.

It will be understood that the ceramic **206** and metal conductor **210** constitute a monolithic or one-piece structure in contrast to the products heretofore available which include substrates with windings mounted thereon as physically independent components.

FIGURE 3 further illustrates that the metal **210** and ceramic **206** may be bonded or joined along an interspersed migratory phase constituted by the ceramic and metal penetrating or migrating into one another due to the respective porosities thereof, this affording the monolithic feature referred to above.

The metal may have its surface flush with that of the associated ceramic substrate or the metal may be depressed with respect thereto and covered with an insulator as noted above. Alternatively, the metal may be raised with respect to the ceramic substrate as shown in FIGURE 4 which further illustrates the incorporation of an interposed electrically insulative coating **212** which is so deposited as will be indicated hereinafter to have interspersed migratory phases with the metal conductor and with the ceramic.

In the general embodiment illustrated in FIGURE 4, it may be considered that the metal conductor fills the groove provided in the substrate **206** for all practical purposes despite the presence of the electrically insulative coating **212** which occupies a generally nominal percentage of the volume of the groove.

In FIGURE 5 is illustrated an embodiment of the

invention preferably employing the migratory phase noted above with a metal conductor being deposited in a surface groove in a ceramic body. More particularly, FIGURE 5 is a top plan view of a right parallelepiped body **214** fabricated of a ceramic such as aluminum oxide or ferrite.

Body **214** has spaced and parallel surfaces **216** and **218** (FIG. 6) of which the surface **216** is provided with a spiral groove **220** wherein is deposited a metal conductor **222**. Spiral groove **220** has spaced ends **224** and **226** whereat are provided bores **228** and **230** extending completely through body **214** to the face **218**, said bores being coupled to the spiral grooves at the ends thereof.

Body **214** is further provided with grooves **232** and **234** coupled respectively to bores **228** and **230** and extending to the edge **236** of body **214**.

The aforesaid grooves and bores are filled with a metal conductor such as silver, gold, platinum, or the like, the metal in groove **220** constituting a winding connected via the metal in bores **228** and **230** to the metal in grooves **232** and **234**, there being further provided terminals **238** and **240** constituted by recesses with metal deposited therein, these terminals constituting means for coupling the spiral winding into an electrical circuit.

FIGURE 6 shows the body **214** provided with a ferrite cover **215** separated from body **214** and the metal conductors therein by an electrically insulative sheet **242**.

FIGURE 7 illustrates a slight modification on an enlarged scale, wherein the body **214** having the grooves **220** provided therein is given a coating of electrically insulative material **244** such as magnesium oxide, a layer **246** of metal being deposited thereon and subsequently milled down to remove all of the metal except that reposed in the groove.

In the above embodiment the body **214** and the cover **215** are preferably fabricated of ferrite, the grooves therein being provided after the firing of these respective bodies so that there will be no subsequent dimensional instability. A coating of insulative material may be provided on these bodies by dipping the same in or spraying the same with magnesium oxide or by a known technique involving hydrolysis with magnesium methylate.

The deposition of the metal can be provided for by the use of gas plating as aforesaid, or by depositing amalgams or by electroplating, or by any other known and suitable techniques whereby such metals as copper, silver, gold, platinum, rhodium, or other such conductor may be intimately deposited on the supporting ceramic substrate.

For the type of article illustrated in FIGURES 8–10, a ceramic body **248**, preferably in the form of a right parallelepiped having 3 pairs of opposed and parallel faces, is provided with two concentric circular (or inner and outer) arrangements **250** and **260** of bores extending between the upper and lower faces of this body.

Said bores are spaced equi-angularly so that there are an equal number of bores in the inner and outer circular arrays. The bores of the inner array **260** are however staggered with respect to the bores of the outer array **250**. Preferably, the bores of the inner array are centered between the corresponding bores of the outer array.

The upper face of body **248** is provided with a plurality of grooves **262** extending between corresponding bores of the inner and outer arrays. The lower face of the body **248** is provided with a plurality of grooves **264** connecting corresponding bores of the aforesaid arrays so that grooves **262** and **264** together with the bores of arrays **250** and **260** cooperatively constitute a circular or toroidal helical path within which a metal is deposited preferably in such a manner as to constitute with the ceramic an interspersed migratory phase.

In said body **248** is provided a further bore **266** in which is mounted a pivot pin **268** supporting an arm **270** having at the free extremity thereof a contact **272**. Pivot pin **268** extends completely through body **248**. In the upper surface of body **248** is provided a groove **274** connected to the aforesaid helical path and to a recess **276** at the periphery of body **248**, the grooves **274** and **276** having deposited therein an electrically conductive metal. In the lower face of body **248** is provided a groove **278** coupled to bore **266** and to a recess **280**, there being a metal conductor deposited in this groove and recess.

The metal in recesses **276** and **280** constitutes two terminals or means for coupling the aforesaid helical path and the metallic deposit therein to an electrical circuit. Arm **270** represents a means whereby more or less of the conductive winding in the body **248** may be coupled into said circuit.

It will be understood from what has been stated above that current flow will be between terminals **276** and **280** such as, for example, from terminal **276** via the metal in groove **274** and thence via the electrical winding to contact **272** and arm **270** to pivot **268** and thence via the metal in groove **278** to terminal **280**.

FIGURE 10 illustrates a slight modification of the invention wherein an arm **282** is provided with two contacts **284** and **286** whereby the winding in the body **248** can be selectively incorporated into an associated electrical circuit by making contact with the winding at the innermost or outermost portions thereof by appropriate alignment of contacts **284** or **286** as desired.

The embodiment of the invention illustrated in FIGURES 11–13 consists of two end pieces or plates such as shown in FIG. 11 and a toroid such as shown in FIG. 12, these components being preferably fabricated of ferrite or alumina.

Each end piece is, as illustrated in FIG. 11, provided with an inner array **288** of bores and an outer array of **290** of corresponding bores. These bores are equidistantly spaced and staggered relative to one another as in the above described embodiments. Between corresponding of the bores are provided grooves **292** which function to accommodate a metal deposit forming part of a helical winding.

The toroid element of FIG. 12 is conventionally provided with two flat end pieces of which the top face **294** is visible, there being further provided inner and outer concentric faces **296** and **298** of generally cylindrical form.

The cross-section of FIG. 13 illustrates the complete component inclusive of the upper end piece **300**, the lower end piece **302** and the toroid **304** sandwiched therebetween. Metal risers **306** are employed extending through the respective bores and in contact with the metal in grooves **292** and the risers cooperatively constitute a helical winding encompassing the toroid **304**.

In accordance with the invention, the arrays **290** and **292** are of such respective diameters as to be able to accommodate the toroid **304** therebetween with the risers **306** being spaced from the toroid. Accordingly, it is possible to accommodate between the risers and the toroid an electrically insulative coating **310**, a further electrically insulative coating **312** being provided between the toroid **304** and end pieces **300** and **302** as well as between end pieces **300** and **302** and the metallic deposits in the aforesaid end pieces.

The electrically insulative coating illustrated in FIG. 13 may be sprayed onto elements **300**, **302** and **304** or, alternatively, these elements may be dipped into a liquid dispersion of magnesium oxide or the like in conventional manner. Still further, the coatings may be provided in the form of sheets or such.

In the above described embodiments of the invention, the element is preferably such that a monolithic structure is constituted by a ceramic substrate and a metal deposited in grooves or recesses therein. Preferably the metal is locked to the ceramic substrate or to an insulative

coating thereon by a connecting migratory phase which results when a ceramic is metallized.

In the various embodiments of the invention it will be readily appreciated that the intimate juxtapositioning of the metal with the associated ceramic avoids the possibility of air gaps of uncontrolled dimensions.

It will further be appreciated that relative movement between the metal and the ceramic substrate is impossible either during manufacture or while the resulting component is in use.

Since fabricating steps such as the winding of a coil on a ceramic substrate are avoided, the conventional difficulties with wire strain are not present in products of the invention. Similarly, other problems such as insulation strippage are avoided.

Experience has shown that products of the type disclosed herein may be produced in great volume at low cost and that such products are eminently suited for precision applications despite the prospects of being subjected to high magnitudes of acceleration and impact shocks.

There will now be obvious to those skilled in the art many modifications and variations of the methods, articles of manufacture and apparatus set forth above. These modifications and variations will not, however, depart from the scope of the invention if defined by the following claims.

What is claimed is:

1. An article of manufacture comprising a toroidal body with substantially flat radial faces and inner and outer walls extending between said faces, there being provided grooves extending substantially axially in said walls and further grooves connecting the grooves in the inner wall with respective grooves in the outer wall, said further and first said grooves constituting a spiral path around said body, and a metal filling in the grooves.

2. An electrical component comprising a solid toroidal body with substantially flat radial faces and circular inner and outer walls extending between said faces, said body being provided with evenly spaced axially extending

grooves in said walls and further grooves connecting the grooves in the inner wall with respective grooves in the outer wall, the further and first said grooves constituting a spiral path around said body, and a metal in said grooves in intimately contacting relation with said body.

3. An article of manufacture comprising a ferrite toroid having end faces and concentric inner and outer cylindrical faces extending between said end faces, an electrically insulative material covering said end faces, end pieces of ceramic material sandwiching said material against said ferrite toroid, said end pieces being provided with aligned bores arranged in concentric circles substantially tangential to said concentric faces, said end pieces being provided with grooves adjacent said insulative material connecting corresponding bores of said concentric circles, electrically conductive risers extending through said bores and adjacent said toroid, and an electrically conductive metal in and filling the grooves in the end pieces and connecting the associated risers to constitute a helical winding, said ceramic and metal cooperatively constituting an interspersed migratory phase connecting the metal and ceramic.

4. An article as claimed in claim **3** comprising means pivotally supported on one of said end pieces for selectively engaging said winding.

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