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MAGNETOSTRICTIVE RELAY

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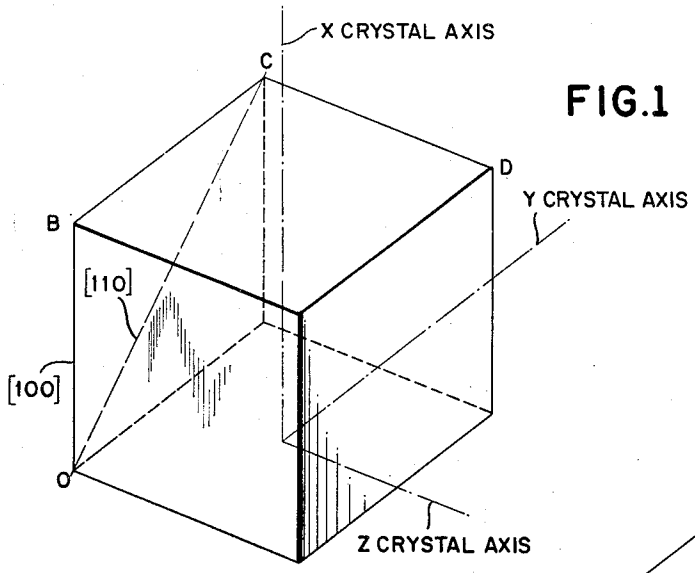


FIG.1

FIG.2

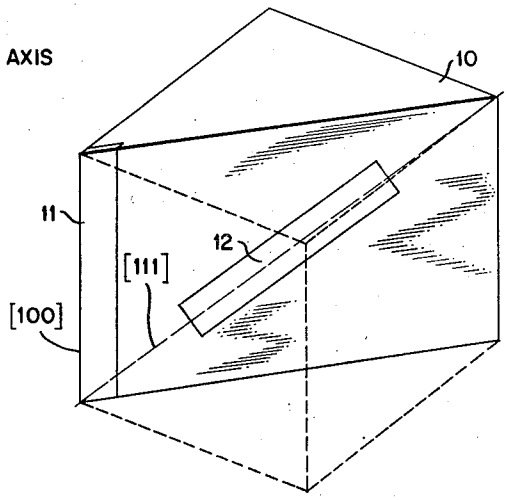
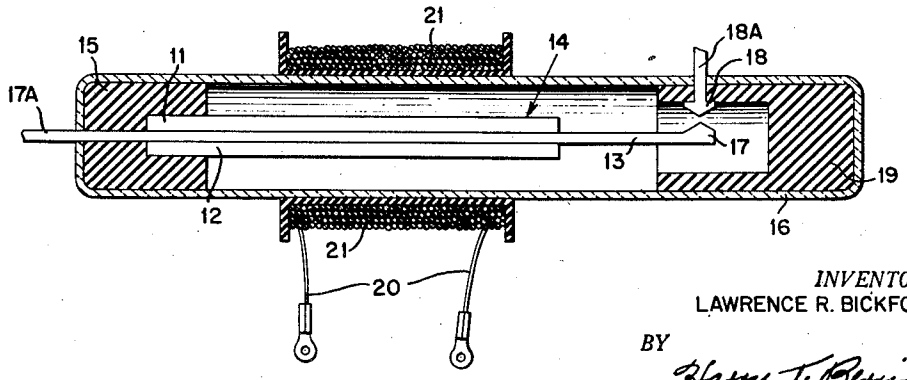


FIG.3



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MAGNETOSTRICTIVE RELAY

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13 Claims. (Cl. 200—87)

This invention relates to relays and more particularly to relays of the magnetostrictive type.

The usual type of magnetostrictive relay uses as a sensitive element two strips of metal fastened together, one of the strips being of a ferromagnetic material, such as steel, which has a positive magnetostrictive coefficient and increases in length with an increase in magnetic flux, while the other strip is also a ferromagnetic material, such as nickel, which has a negative magnetostrictive coefficient and decreases in length with an increase in magnetic flux. The bi-metal element is rigidly supported at one end with the free end having a contact supported thereon. Another contact is supported on a stationary structure adjacent to the first contact. A coil surrounds the bi-metal element and upon energization, subjects the bi-metal element to a magnetic field. The resulting increase in length of the positive magnetostrictive strip and the decrease in length of the magnetostrictive strip, effects a flexing of the bi-metal element such as to engage the contact carried thereon with the mating rigidly supported contact, if the contacts are normally open, or to separate the contacts if they are normally closed. The relay contacts are connected to an external circuit which is accordingly opened or completed dependent upon the state of the relay.

Since each of the bi-metal strips of the sensitive element has in general a different coefficient of thermal expansion (and contraction) a shift in the ambient temperature also effects a flexing of the bi-metal element without any energizing magnetic field. The conventional magnetostriction relay is accordingly subject to erroneous opening or closure under the influence of slight changes in ambient temperature.

Certain ferromagnetic single crystals such as iron, magnetite, cobalt ferrite etc. have a positive magnetostriction coefficient along some crystallographic directions and a negative magnetostriction coefficient in other directions. It is accordingly the principal object of the subject invention to provide a magnetostrictive relay having a magnetostrictively sensitive element made of two strips cut from different orientations of a single crystal of a cubic ferromagnetic material the strips having opposite magnetostrictive coefficients. Since both strips of the magnetostrictive element are of the same material and accordingly have the same temperature coefficient, thermal expansion or contraction will not cause flexing of the element, thus preventing erroneous opening or closing of the related contacts due to changes in ambient temperature.

Other objects of the invention will be pointed out in the following description and claims and illustrated in the accompanying drawings, which disclose, by way of example, the principle of the invention, and the best mode, which has been contemplated, of applying that principle.

In the drawings:

Fig. 1 is a diagrammatic representation of a single crystal of a magnetic ferrite.

Fig. 2 is a diagrammatic representation of a portion of the crystal shown in Fig. 1 and illustrates the manner in which a strip of positive magnetostrictive coefficient, and one of negative magnetostrictive coefficient are cut from different orientations of the same crystal.

Fig. 3 is a detail section view through the improved magnetostriction relay structure.

Referring now to Fig. 2 there is shown a diagrammatic representation of a single crystal **10** of a ferromagnetic material, with part of the crystal as indicated in phantom having been cut away in order to illustrate the two different orientations of the crystal from which strips **11** and **12** are cut.

For the particular relay as shown in Fig. 3, the strips **11** and **12** are cut from a single, large, pure, mechanically sound crystal of iron ferrite (Fe_3O_4). The single crystal may be a natural crystal or may be grown by heating (Fe_3O_4) to a melting temperature of 1575° C. in an induction furnace and then allowing the crucible to cool from the bottom up at rate of about 1½ hours per inch. A single ferrite crystal could be obtained also by the well known Verneuil method, the Bridgman method, or the method involving pulling a seed slowly out of a melt of the ferrite in such a way that the solid-liquid interface remains near the surface of the melt, and crystal growth occurs at that point.

After the preparation of the single crystal, the three mutually perpendicular crystallographic axes *x*, *y*, and *z* of the material are determined in any well known manner, such as by X-ray study. To facilitate the explanation of the orientations of the crystal from which the pair of strips **11**, and **12** are cut, each having an opposite magnetostrictive coefficient, it will be assumed that the single crystal is cubic in shape as indicated in Fig. 1 and the *x*, *y*, *z* crystallographic axes thereof are aligned with the geometric axes of the crystal. Starting with point O of the cube as a reference, and always considering the axes as indicated in Fig. 1 in the sequences *x*, *y*, *z*, the crystal directions may be defined as follows. The crystallographic direction coincident with a line connected between the origin O and a point B on a cube edge of the crystal, as shown in Fig. 1, may be defined as the [100] crystallographic direction, that is one increment in the positive direction of the *x* axis (to point B) from point O, zero increments in the positive direction of the *y* axis from point B, and zero increments in the positive direction of the *z* axis from point B. Similarly the crystallographic axis [110] is a left face diagonal between the origin O and point C as indicated in Fig. 1, that is the axis extending between point O and a point located by the direction of one increment in the plus *x* axis direction (to point B), and one increment in the plus *y* axis direction (to point C) from point B, and zero increments in the plus *z* axis direction from point C (5 to 11 at point C). Similarly the crystallographic axis [111] would be coincident with the body diagonal OD in Fig. 1.

With the above orientation description in mind, the crystal is then cut in half along the body diagonal OD as indicated in Fig. 2 whereafter, a strip **11** is cut from the one half of the cube with the longitudinal axis thereof in the so called [100] crystal direction as indicated, the strip having a negative magnetostrictive coefficient. A similar strip **12** is cut from the same half of the crystal with the longitudinal axis thereof in the so called [111] crystal direction, the strip having a positive magnetostrictive coefficient.

Each of the strips **11** and **12** is thereafter lapped to a desired size and then copper plated. The two strips **11** and **12** are then soldered with Woods metal to opposite faces of a brass strip **13**, as indicated in Fig. 3, the resulting structure forming a magnetostrictive sensitive element **14** for the improved relay.

It will be appreciated that although the strips **11** and **12** as described above are cut from different crystallographic directions of the same single crystal of iron ferrite, each strip could be cut from a separate crystal of iron ferrite provided each is cut from a different crystallographic orientation of its related crystal so that the strips have opposed magnetostrictive coefficients. Referring now to Fig. 3, the sensitive element **14** is rigidly supported at one end by an insulating member **15** which is secured within the one end of a glass envelope **16**. The brass strip **13** of the sensitive element extends beyond a free end of the crystal strips **11** and **12** of the element, and secured to this extension is a contact **17** adapted for cooperation with a mating contact **18** supported by insulating structure **19** secured within the other end of the glass envelope **16**. It will be noted that the brass strip **13** extends through the member **15** and the glass envelope **16** to provide a terminal **17A** by which the contact **17** may be linked to the one side of the external circuit to be controlled by the relay. Similarly, a portion of the contact **18** extends through the glass envelope **16** to provide a terminal **18A** by which the contact **18** may be linked to the other side of the external circuit.

An actuating coil **19** is mounted on the glass envelope and surrounds the midsection of the sensitive element **14**. Upon the passage of a current in a proper direction through leads **20** of the coil, the resulting magnetic flux of the coil acts upon the crystal strips of the sensitive element **14** causing strip **12** to lengthen and strip **11** to shorten. Since the two strips are rigidly secured to each other through the brass strip **13**, the change in dimensions effects a flexing of the sensitive element **14** so as to engage the contact **17** with the contact **18** to complete the external circuit. Upon the removal of the excitation current, the magnetic field collapses and the strips **11** and **12** restore to their normal dimensions to open the contacts **17** and **18**.

It will be appreciated that although the improved magnetostrictive relay, as described above, uses magnetite as the material for the strips **11** and **12**, the strips could be cut from a single crystal of iron, cobalt ferrite or any other suitable material having magnetostriction of opposite signs in different crystal directions.

It will also be appreciated that although the contacts **17** and **18** in Fig. 3 are normally open and adapted to be closed upon the application of a magnetic field to the element **14**, the contacts can be arranged to be normally closed, with the application of the magnetic field opening the contacts. Similarly, the relay contacts may be of the transfer type, in that the application of the field, breaks a normally closed contact and makes a normally open contact. While there have been shown and described and pointed out the fundamental novel features of the invention as applied to a preferred embodiment, it will be understood that various omissions and substitutions and changes in the form and details of the apparatus illustrated and its operation may be made by those skilled in the art, without departing from the spirit of the invention. It is the intention, therefore, to be limited only as indicated by the scope of the following claims.

What is claimed is:

1. A switch device comprising, in combination, a stationary contact, an elongated magnetostrictive element comprised of a pair of mechanically connected members of different magnetostrictive coefficients but both cut from different crystallographic orientations of a single crystal of a ferromagnetic material, means rigidly supporting said elongated element at one end, a contact supported on the free end of said elongated member and adapted for cooperation with said fixed contact, and means including a coil for applying a magnetic flux to said elongated element in a direction to flex the free end of said element so as to engage said contacts.

2. A switch device comprising, in combination, a stationary contact, an elongated magnetostrictive element comprised of a pair of mechanically connected members of different magnetostrictive coefficients but both cut from different crystallographic orientations of a single crystal of a ferromagnetic material, means rigidly supporting said elongated element at one end, a contact supported on the free end of said elongated member and normally engaged with said stationary contact, and means including a coil for applying a magnetic flux to said elongated element in a direction to flex the free end of said element so as to disengage said contacts.

3. A switch device comprising, in combination, a stationary contact including terminal means for linking it to a circuit to be switched, an elongated magnetostrictive element comprised of first and second strip members, said first strip member being cut from a single, cubic crystal of a ferromagnetic material and having a positive magnetostrictive coefficient, said second strip member being cut from a single cubic crystal of the same ferromagnetic material as the first strip member, said second strip member having a negative magnetostrictive coefficient, means rigidly bonding said strips together, with their longitudinal axis aligned, means rigidly supporting said elongated element at one end, a contact supported on the free end of said element and adapted for cooperation with said fixed contact, means for electrically linking said element carried contact to said circuit to be switched, and means including a coil for applying a magnetic field to said element in a direction to flex the free end of said element so as to engage said contacts.

4. A switch device as in claim 3 further characterized in that said means electrically linking said element carried contact to said circuit includes said means bonding said strips together, said bonding means being electrically conductive and forming a terminal at the rigidly supported end of said element.

5. In a magnetostrictive switch, a stationary contact, a movable contact cooperating with said stationary contact to open and close a circuit through the switch, a magnetostrictive element controlling said movable contact, said element comprising a pair of mechanically connected members of different magnetostrictive coefficients but both cut from different crystallographic orientations of single cubic crystals of a ferromagnetic material so that said pair have identical temperature coefficients, and means including a coil adjacent said magnetostrictive element for applying a magnetic flux thereto to alter the physical dimensions thereof in a manner to engage said movable contact with said stationary contact.

6. A magnetostrictive element comprised of a first elongated portion of substantially uniform thickness cut from a crystal of a ferromagnetic material in a direction orientated to the crystallographic axis so that it has positive magnetostrictive coefficient, a second elongated portion of substantially uniform thickness cut from a single crystal of the same ferromagnetic material as said first portion and cut in a direction orientated to the crystallographic axis so that it has a negative magnetostrictive coefficient, said portions being bonded together, means for clamping one end of element, said element being adapted to be driven at its free end, and magnetic polarizing means including said magnetostrictive element in its magnetic circuit for driving said element.

7. A magnetostrictive element comprising an assembly made up of a strip of brass, a first elongated member of substantially uniform thickness cut from a single crystal of a ferromagnetic material in a direction orientated to the crystallographic axis so that it has a positive magnetostrictive coefficient, a second elongated member of substantially uniform thickness cut from a single crystal of the same ferromagnetic material as said first member and in a direction orientated to the crystallographic axis so that it has a negative magnetostrictive coefficient, each said elongated members being bonded to opposite faces of said strip, means for clamping the one end of the element, the element be adapted to be driven at its free end, and coil means surrounding said element for apply-

ing a magnetic flux thereto to effect a displacement of said free end.

8. A magnetostrictive relay comprising, in combination, a stationary contact including terminal means for effecting an electric connection thereto, a magnetostrictive element comprised of a first strip cut from a single crystal of iron ferrite in a crystallographic direction so that it has a positive magnetostrictive coefficient, a second strip cut also from a crystal of iron ferrite in a crystallographic direction thereof so that it has a negative magnetostrictive coefficient, and means mechanically bonding said strips together; means rigidly clamping the one end of said element, the other end being free and adapted to be driven, a contact secured to said free end for cooperation with said stationary contact, means for making an electrical connection to said contact secured to said element, and circuit means including a coil surrounding said element for applying a magnetic flux thereto to effect a displacement of said free end so as to engage said contacts.

9. A magnetostrictive relay as in claim 8 further characterized in that said contacts are normally engaged and said magnetic flux when applied to said element flexes it to disengage said contacts.

10. A magnetostriction relay as in claim 8 further characterized by a second stationary contact including terminal means for effecting an electrical correction thereto, said second contact being normally engaged by said contact associated with said element, the operational path of said free end of said element being such as to break contact between said second contact and said element associated contact upon the application of the magnetic flux to the element.

11. A magnetostrictive relay comprising in combination, a stationary contact terminal means for effecting an electrical connection thereto, a magnetostrictive element comprised of a first strip cut from a single crystal of a ferromagnetic material with the longitudinal axis in the [100] crystal direction, a second strip cut from a single crystal the same ferromagnetic material as said first strip and with the longitudinal axis in the [111] crystal direction, and means mechanically bonding said strips together, means rigidly clamping the one end of said element, the other end being free and adapted to be driven, a contact

secured to said free end for cooperation with said stationary contact, means for making an electrical connection to said contact secured to said element, and magnetic polarizing means including a coil surrounding said element for applying a magnetic field thereto to displace said free end to engage said contacts.

12. A magnetrostrictive relay as in claim 11 further characterized in that said ferromagnetic material is iron ferrite.

13. A magnetostrictive relay comprising, in combination, an elongated glass housing, a stationary contact rigidly supported within one end of said housing, said contact including a terminal portion which extends through said housing so that an electrical connection may be made to one side of a circuit to be switched, a magnetostrictive element comprising a strip of brass and first and second elongated members bonded to opposite faces of said strip, said members each being cut from different orientations of a single crystal of a ferromagnetic material, said first and second members having positive and negative magnetostrictive coefficients, respectively, means rigidly supporting one end of said element within the other end of said housing, said brass strip portion extending through said housing so that an electrical connection may be made to the other side of the circuit to be switched, said element extending within said housing with the free end proximate said stationary contact, a contact secured to the brass strip portion of the free end of said element and adapted for cooperation therewith, and means including a coil mounted on the exterior of said housing for applying a magnetic field to said element in a direction to flex the free end of said element so as to engage said contacts.

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