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(54) **Elastomeric material conductive under pressure and application in keyboards.**

(57) An elastomeric material conductive under pressure is suitable for use in a keyboard. When not compressed the material is insulating. When a key (21) is depressed, the pressure renders the material (11) conductive and completes a circuit (14, 11, 16, 17, 15). In order to prolong the life of the material when it is repeatedly compressed, a magnetic field is used during polymerization of an elastomer in which magnetic powder is dispersed. The material becomes piezoconductive in a preferred direction parallel to the applied field.

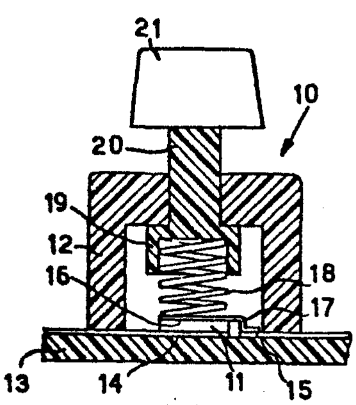

FIG. 2

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TITLE MODIFIED
see front page

ELASTOMERIC MATERIAL CONDUCTIVE UNDER PRESSURE

This invention relates to an elastomeric material which is conductive under pressure and suitable for use in keyboards of data processing equipment.

Elastomeric materials (rubbers) are known which are rendered conductive by adding materials such as carbon black or metal powders to the mix or composition. Some compositions and processes for producing conductive rubbers are given in the book: Conductive Rubbers and Plastics, by R. H. Norman - Elsevier, Amsterdam, London, New York, 1970.

Elements of conductive rubber are used as contact materials in some known types of keyboard.

For application in keyboards, piezoconductive rubbers are more interesting, that is those rubbers which become conductive under the effect of applied pressure, because they allow keyboards without contacts exposed to oxidation to be obtained, inasmuch as contact takes place within the piezoconductive material.

Some piezoconductive elastomers are used for producing fixed contacts. In the known materials the piezoconductive effect disappears after a few thousand actuations of the elastomeric element, for which reason these materials are not suitable for use in keyboards.

The object of the invention is to provide an elastomer which becomes conductive under the effect of pressure and preserves this characteristic for a number of operations of the order of at least some hundreds of thousands.

This problem has been solved by means of the piezoconductive elastomeric material according to the invention, as claimed in claim 1.

The invention will be described in more detail, by way of example, with reference to the accompanying drawings in which:

Fig. 1 is a front view of an apparatus for preparing an elastomer according to the invention;

Fig. 2 shows a key employing the piezoconductive elastomer according to the invention;

Fig. 3 shows a detail of a keyboard employing the elastomer according to the invention;

Fig. 4 is a graph relating to the key of Fig. 2;

Fig. 5 is a diagram of a measuring circuit used for the graph of Fig. 4.

Fig. 2 shows a key 10 which uses a patch 11 of piezoconductive elastomer according to the invention and can be employed to replace a normal contact-type key as an input device for a data processing apparatus, with an interface towards semiconductor electronic circuits of high input impedance.

A housing 12 of the key rests on a printed circuit board 13 on which there is formed an island 14 with a diameter of 8 mm and connected to one end of the contact circuit of the key. The other end of this circuit is connected to another island 15 to which there is soldered a flexible metal plate 17 having a circular end 16 with a diameter of 8 mm.

The patch 11 of piezoconductive material, which has a diameter of 8 mm and a thickness of 0.6 mm, is fixed by means of conductive adhesive between the island 14 and the circular end 16 of the flexible plate 17.

On the end 16 there rests a spring 18 inserted in a recess 19 of a sliding shank 20 of the key 10, which bears a buttom 21. In the inoperative state, the spring 18 bears on the end 16 with a force sufficient to keep the button 21 raised.

When the button 21 is pressed, the force exerted is transmitted through the spring 18 and the end 16 of the flexible plate 17 to the patch 11 of piezoconductive rubber, reaching a value of about 100 g when the button 21 strikes the top of the housway 12 of the key. Under the effect of the applied force, the patch 11 becomes conductive, ensuring a path of low resistivity between the islands 14 and 15.

For use of the key in a data entry keyboard, it is required that the patch 11 behave as a practically perfect insulator until the pressure applied reaches a predetermined value of about 80 g and to assume a low resistance when this pressure is exceeded, and then to reacquire the insulating properties on release of the key, presenting a certain hysteresis, but with a negligible delay. It is moreover essential that the patch preserves these characteristics for at least 100,000 operations of the same key, with a contact resistance always below 10,000 ohms.

According to the known literature (B. E. Spingett: Conductivity of a system of metallic particles dispersed in an insulating medium - J. A. Phys., Vol. 44, No. 6, June 73, pp. 2925 - 26, and C. H. Kuist: Anisotropic conduction in elastomeric composites - Proc. 7 Am. Conn. Symposium, June 1974, pp. 203 - 209), on varying the percentage of metal powder in a matrix of insulating elastomer the conductivity of the whole shows a distinct transition from insulating material to conductive material for a well-defined percentage by volume (V_m) of metal powder close to 0.2 and dependent to a certain extent on the grain size and on the shape of the metal granules, presenting piezo-conductive characteristics for percentages by volume of metal powders a little lower than V_m.

In particular in the article by C. H. Kuist, percentages of metal (nickel) powder by volume ranging between 0.08 and 0.18 are suggested for the piezoconductive rubbers.

It is known that the application of a magnetic field during the polymerization of rigid epoxy plastics materials containing metal powders (see the said book Conductive Rubbers and Plastics, page 82) brings a considerable increase in the conductivity of the whole in the direction of the magnetic field; it could therefore be expected from this that also with elastomers the application of a magnetic field during the polymerization would lead to a lowering of the transition percentage V_m between the piezoconductive condition and the conductive condition in the preferred direction established by the magnetic field.

Surprisingly, it has been found that on dispersing nickel powders in a matrix of elastomeric binder, for example of the type Silastic E manufactured by Dow Corning, and maintaining the composition under the effect of a magnetic field during the polymerization of the binder, the rubber proves to be insulating in the absence of pressure even with percentages of powder between 15 and 27%, which greatly exceed the indicated limit values. On the other hand, the endurance of the piezoconductive characteristics improves decisively and passes from a few thousand operations of the key to several hundreds of thousands before irregularities of operation not tolerated by noraml electronic utilization circuits are encountered.

It has also been found that on exceeding these percentages, the piezoconductive characteristics become worse again and that the optimum value is found for percentages around 21%.

The preferred metal material is a nickel powder consisting of spherical grains and having the maximum hardness compatible with preservation of the magnetic characteristics. More particularly, good results have been obtained with a nickel powder known by the trade name of Alloy 79 GS, supplied by the Baudier Company, of Liancourt (France).

The powder consists of 93.94% of nickel, 3.5% of silicon, 1% of iron, 1.6% of boron and 0.05% of carbon and has a Rockwell C hardness of 18-22; the spherical granules have a diameter between 100 and 150μ.

A preferred composition of the piezoconductive elastomer is constituted by:

Silastic E silicone rubber from Dupont: by weight: 30 parts;
79 GS nickel powder from Baudier: 70 parts;
Silastic E hardener from Dupont: 3 parts.

Preparation of the piezoconductive elastomer requires careful mixing of the powder and silicone rubber, addition of the hardener, a first degassing of the mix under vacuum and casting in the mould followed by a second degassing under vacuum and introduction into the magnetizer, which applies a magnetic field with a direction perpendicular to the faces of the sheet during the polymerization of the binder.

The thickness of the sheet or film of piezoconductive elastomer may vary from 0.4 to 0.8 mm, the preferred thickness being 0.6 mm.

The intensity of the magnetic field during the polymerization is not critical, provided that the field reaches an intensity of at least 500 oersteds. Above this value no appreciable variations are found in the results.

The apparatus used for preparing the elastomer is shown diagrammatically in Fig. 1, in which a mould 31 of non-magnetic material, in which the elastomer mix 36 is cast, is between two pole pieces 32 and 33 a magnetizer 37 which are interconnected by an external magnetic circuit (not shown). The magnetic flux is maintained throughout the time of polymerization of the elastomer by the current flowing in two windings 34 and 35. During the polymerization, the elastomer is kept at room temperature. Under these conditions, complete polymerization requires about 18 hours.

The time required for preparing the piezoconductive elastomeric material can be reduced to 10 minutes, still in a magnetic field, if the temperature of the mould 31 is brought to 100°C.

All the samples tested have exceeded the prescribed minimum life of 100,000 operations, with peaks of more than 1,000,000 operations.

Fig. 5 shows a simple circuit used for detecting the characteristics of the key of Fig. 2, comprising a DC voltage generator 41 producing 5 V and a 50 KΩ limiting resistor 42 in series with the key 10.

Fig. 4 is a graph of the voltage drop detected across the terminals 43 and 44 of the resistor 42 as a function of the force F applied to the key. The phenomenon of hysteresis between actuation and release of the key is obvious from the graph.

An alternative embodiment of a keyboard employing the piezoconductive rubber according to the invention is shown in Fig. 3.

In the keyboard 23, a single sheet 24 of piezoconductive material produced in a magnetic field in accordance with the invention is used, instead of individual patches of piezoconductive elastomer as in the key of Fig. 2. The sheet 24 is stuck by means of a conductive adhesive to islands 26 of a printed circuit board 25 which constitute one of the contact terminals of the keys 27.

A second, flexible, printed circuit board 28 is stuck by means of conductive adhesive on top of the sheet 24 of piezoconductive material at islands 29 in line with the islands 26. The islands 26 and 29 constitute contact terminals of the keys 27..

Springs 30, in combination with the movement of buttons 22, transmit the force applied to the buttons 22 to the piezoconductive sheet 24, causing locally the formation of passages of relatively low resistivity between the islands 26 and 29, while the material of the piezoconductive sheet 24 interposed between the keys 27 and not subjected to pressure maintains its insulating properties. The solution of Fig. 3, which is functionally equivalent to the modular solution of Fig. 2, is more convenient for producing keyboards with a large number of keys inasmuch as it drastically reduces the number of parts.

As regards the value of the actuating force applied to the key, a maximum value of 100 g is required. Since it has been verified that the number of operations which can be obtained before the occurrence of irregularities increases with the value of the force applied, the maximum number of operations in keyboards employing the piezoconductive elastomer according to the invention can be further increased if, instead of the actuating force being obtained directly from the key, it is obtained from a lever system which presses on the piezoconductive rubber with a force higher than, for example double, that applied to the key, with a proportionally smaller stroke.

With this solution, it is possible to construct keys which simultaneously close a plurality of independent circuits by using a plurality of separate and insulated patches of piezoconductive material according to the invention or acting simultaneously on different points of the same sheet of piezoconductive material by means of actuating elements insulated from one another.

It is possible to make numerous variations in the solutions exemplified here as regards the type of elastomer and of magnetic conductive material, the form of the key, the level of modularity, that is the manner of grouping the keys, the actuating mechanism, and the production of contact between the piezoconductive material and the encoding circuit, without departing from the scope of the invention as claimed.

CLAIMS

1. Piezoconductive elastomeric material containing a magnetic metal powder dispersed in a matrix of polymerized elastomer, characterised in that the material is subjected to the action of a magnetic field during the polymerization, whereby it becomes piezoconductive in a preferred direction parallel to the direction of the magnetic field.

2. Material as in claim 1, characterised in that the percentage by volume of the powder is between 15% and 27%.

3. Material as in claim 1 or 2, characterised in that the magnetic metal material is substantially a hard nickel powder with spherical granules having a diameter between 100 and 150 μ.

4. Key for data processing equipment without movable contacts, characterised in that the force of actuation of the key acts on a piezoconductive material according to any one of the preceding claims.

5. Key as in claim 4, characterised in that the force of actuation acts on a patch of piezoconductive material.

6. Key as in claim 5, characterised in that the force of actuation acts to establish a contact at a predetermined point of a sheet of piezoconductive material.

7. Key as in claim 5 or 6, characterised in that the said force of actuation acts simultaneously on a plurality of patches of piezoconductive material or at a plurality of predetermined points of the sheet of piezoconductive material, closing a plurality of independent electric circuits.

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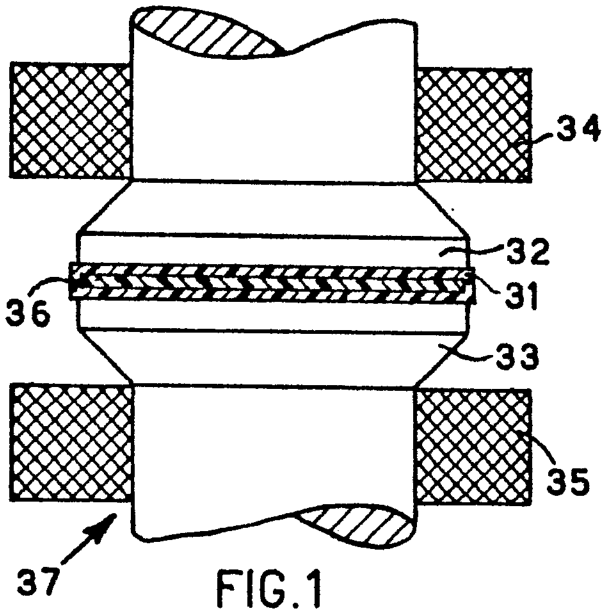

FIG.1

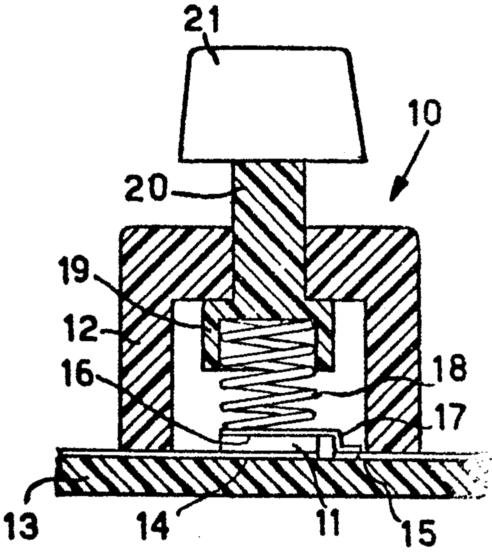

FIG.2

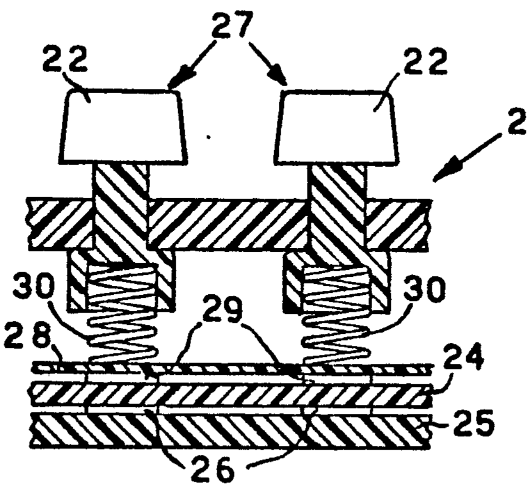

FIG. 3

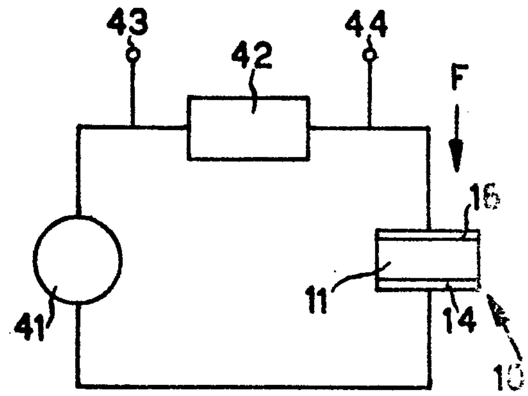

FIG. 5

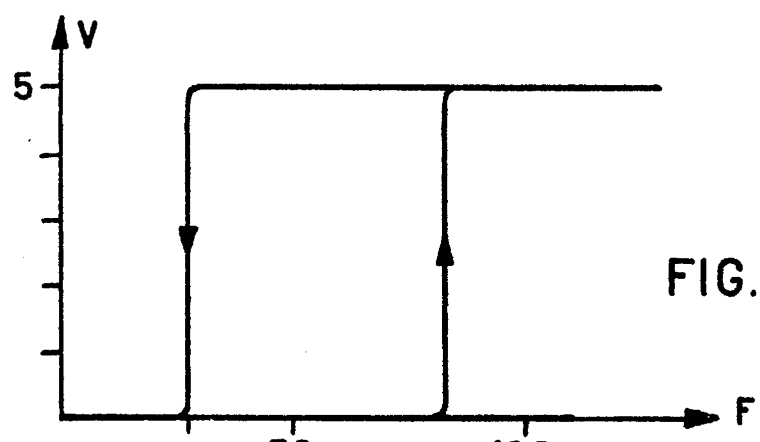

FIG.4

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EUROPEAN SEARCH REPORT

Application number
EP 78 300 393.2

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim
X,P	DE - A - 2 729 959 (JAPAN SYNTHETIC RUBBER) * claim 1, 7, 8, 12; page 7, break 2; fig. 6 * --	1-3
-	CH - A - 547 007 (WIFO) * subclaims 4, 5; column 3, lines [illegible] to 36; fig. 1 to 4 * --	1-3
-	DE - B - [illegible]39 642 (STANDARD ELEKTRIK LOREN[illegible]) * claim 1; [illegible]g. * --	4,5
-	DE - B - 2 [illegible] 176 (W.B. SUDDUTH) * claim 1; f[illegible] 1, 5 * --	4,6,7
A	FR - A - 2 18[illegible]99 (BATTELLE MEMORIAL INS[illegible]UTE) * claims 1, 2; [illegible]. 2 to 4 * --	
D	JOURNAL OF APPLIE[illegible] PHYSICS vol. 44, no. 6, Ju[illegible] 1973 B.E. SPRINGETT "Co[illegible]ctivity of a system of metalli[illegible] particles dispersed in an insu[illegible]ting medium" pages 2925 to 2926 -- ./..	

CLASSIFICATION OF THE APPLICATION (Int. Cl.²)

H 01 H 1/02
H 01 B 5/16
H 01 H 13/10
H 01 H 13/70
H 01 H 35/00

TECHNICAL FIELDS SEARCHED (Int.Cl.²)

H 01 B 5/16
H 01 H 1/02
H 01 H 11/04
H 01 H 13/00
H 01 H 13/10
H 01 H 13/12
H 01 H 13/70
H 01 H 35/00
H 01 L 41/22

CATEGORY OF CITED DOCUMENTS

X: particularly relevant
A: technological background
O: non-written disclosure
P: intermediate document
T: theory or principle underlying the invention
E: conflicting application
D: document cited in the application
L: citation for other reasons

&: member of the same patent family, corresponding document

X The present search report has been [illegible] up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	[illegible]-01-1979	RUPPERT

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DOCUMENTS CONSIDERED TO BE RELEVANT			CLASSIFICATION OF THE APPLICATION (Int. Cl.²)
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	
D	SEVENTH ANNUAL CONNECTOR SYMPOSIUM PROCEEDINGS October 1974 Camden, New Jersey, USA CH. KUIST "Anisotropic Conduction in Elastomeric Composites pages 203 to 209 ----		
			TECHNICAL FIELDS SEARCHED (Int. Cl.²)