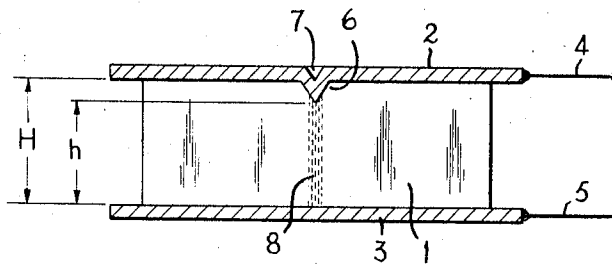


Sept. 10, 1968

A. JENSEN
SWITCHING ELEMENT HAVING ACCURATELY SET
THRESHOLD POTENTIAL
Filed Dec. 20, 1965

3,401,318



1

3,401,318

SWITCHING ELEMENT HAVING ACCURATELY SET THRESHOLD POTENTIAL

Arne Jensen, Havnbjerg, Als, Denmark, assignor to Danfoss A/S, Nordborg, Denmark, a company of Denmark
Filed Dec. 20, 1965, Ser. No. 514,956

Claims priority, application Germany, Dec. 22, 1964, D 46,118

2 Claims. (Cl. 317—235)

ABSTRACT OF THE DISCLOSURE

A switching element having parallel electrodes between which is disposed a body of semiconductor material having a negative temperature coefficient of resistance. When a potential is applied across the semiconductor body a very small current will flow therethrough. If the potential exceeds a certain threshold value the resistance between the electrodes drops sharply to a very low value. The threshold potential is accurately determined by a projection, preferably conical, formed by a punched mark on one of the electrodes and extending toward the other electrode. The projection determines the position of a current path between the electrodes and makes it possible to make similar switching elements with similar threshold potentials.

The present invention relates to a semiconductor switching element, and more particularly to a semiconductor switching element utilizing semiconductor material having a negative temperature coefficient of resistance.

Switching elements containing a body of switching material consisting of a semiconductor material having a negative temperature coefficient of resistance operates in this manner: when a potential is applied across the semiconductor material, a very small current will flow therethrough; if the potential exceeds a certain threshold value, the resistance between the electrodes drops sharply to a very low value. It is believed that the current through the switching material causes heating thereof which is less than the heat dissipation of the material between the electrodes itself, that is the current through the material itself does not cause heating, which results in a decrease of resistance. When the threshold value of voltage, however, is exceeded, so that the current therethrough increases to such an extent that the heat losses can no longer be dissipated, then very quickly a negative temperature coefficient of resistance will cause a lowering of resistance at a certain region between the electrodes; this in turn causes a larger current, an even greater heating, and a rapid drop of resistance.

Elements of this kind are known; they consist essentially of tellurium, with additives from elements of groups IV and V of the Periodic Table of Elements. They can be made by vapor deposition, by sintering, or by permitting a melt of the semiconductor material to solidify on an electrode plate. In their high resistance state, the resistance between coplanar parallel electrodes may be several megohms; in their low resistance state the resistance may drop to the order of 1 ohm. A suitable composition is, for example, 67.5% tellurium, 25% arsenic, and 7.5% germanium.

When such coplanar, parallel electrodes are used, the particular region where the semiconductor material breaks down is indeterminate; that is, the breakdown occurs at random, somewhere between the parallel electrodes. The threshold voltage at which the material itself would break down depends to a large extent on the thickness of the material between the electrodes. Since it is very difficult to manufacture such switching elements which have perfectly flat, parallel electrodes, separated

2

by a precise distance from each other, it is difficult to duplicate such elements having precisely set threshold potentials.

It is thus an object of the present invention to provide a semiconductor switching element of the type described which is cheaper and easier to manufacture, and in which the threshold potential can be more accurately determined.

Briefly, in accordance with the present invention, the semiconductor switching element is so arranged, that semiconductor material is arranged to be sandwiched between a pair of electrodes. One of the electrodes is provided with a projection, which is preferably conical and may be formed by a punch mark, which projection extends in the direction of the other electrode.

The structure, organization and operation of the invention will now be described more specifically in the following detailed description with reference to the accompanying drawings, in which the sole figure illustrates, schematically, a cross sectional view through a semiconductor switching element of the present invention, which may, in plan view, for example, be circular.

A body of semiconductor material 1 is arranged between a pair of electrodes 2 and 3, both of which are preferably plane and circular; lead wires 4 and 5 are soldered to electrodes 2 and 3. One of the electrodes is formed with a projection, which is preferably conical and may be made by a punch mark, 7, which projects within a matching depression 6 of the semiconductor material 1. Upon application of a small potential to the connections 4 and 5, a small current will flow through the semiconductor body 1 which is essentially evenly distributed across the cross section thereof. The thickness of the material, through which the current has to pass, is indicated in the drawing by H. Below projection 7, however, where the thickness is only h, the resistance will be slightly less. So long as the dissipation of heat of the material is sufficient to prevent any localized heating, the resistance of the semiconductor material 1 will remain high. When the potential applied is increased and exceeds a certain threshold, increased heating below the point 7 is to be expected, and a low-resistance current path 8 is formed. The current through this path 8 will very quickly rise to a high value, and the current density will be great, which is typical for this kind of semiconductor switching element. Thus, the projection 7 determines the location of the current path 8 within the switching element. The difference between dimensions H and h, for a given material, determines the threshold potential. Thus, even if the surfaces of electrodes 2 and 3 should show irregularities, causing spurious current paths or non-reproducibility of threshold potential, provision of a projection which is greater than such irregularities would determine the threshold potential and definitely locate current path 8. When the material of the electrode is harder than that of the semiconductor body, a subsequent adjustment of the depth of the projection 7 can be made, for example by slight additional punching, screw pressure against a housing, or the like. Locating this projection 7 within the center of the switching element, that is at the center of the circle in a preferred construction, provides for best utilization of material, and for most accurate reproducibility of elements.

The construction according to the present invention permits manufacture by the cheapest method, that is by vapor deposition or sintering of the semiconductor material on either one of the electrodes 2, 3. Any irregularities of the material which may occur due to the method of manufacture, and which are not compensated by pressure of the other electrodes, are overcome by the extent of the projection 7. The construction of the switching element with the projection is also suitable when the elec-

trodes are applied against a semiconductor body having preformed depressions, which depressions however should not be as deep as the extent of the projection 7, and the matching depression 6 of the semiconductor element itself.

Adjustment of the threshold potential can be made not only by suitable arrangement of the extent of projection of projection 7, but also by suitable choice of the electrode material. Preferably, the electrode material consists of good heat conductive material so that the heat generated by current through the semiconductor material, when the applied potential is below the threshold value, can be readily dissipated.

I claim:

1. A semiconductor switching element comprising, a pair of connecting, parallel electrodes, and semiconductor material having a negative temperature coefficient of resistance located between said electrodes and in contact therewith, wherein one of said electrodes is formed with a conical projection extending in the direction of said other electrode to form a path within said semiconductor

material of lesser length, and said projection is larger than irregularities in the surface of the electrodes adjacent the semiconductor material.

2. An element as claimed in claim 1 wherein said electrodes are of good heat conductive material.

References Cited

UNITED STATES PATENTS

10	3,017,520	1/1962	Maupin	317—235
	3,056,100	9/1962	Warner	317—235
	3,309,585	3/1967	Forrest	317—235
	3,331,432	7/1967	Cotton	317—235

FOREIGN PATENTS

15	107,795	7/1939	Great Britian.
	953,339	3/1964	Great Britian.

JOHN W. HUCKERT, *Primary Examiner.*

20 A. J. JAMES, *Assistant Examiner.*