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ELECTRODE SYSTEM COMPRISING CRYSTAL DIODES OR TRANSISTORS

Filed Oct. 20, 1954 2 Sheets-Sheet 1

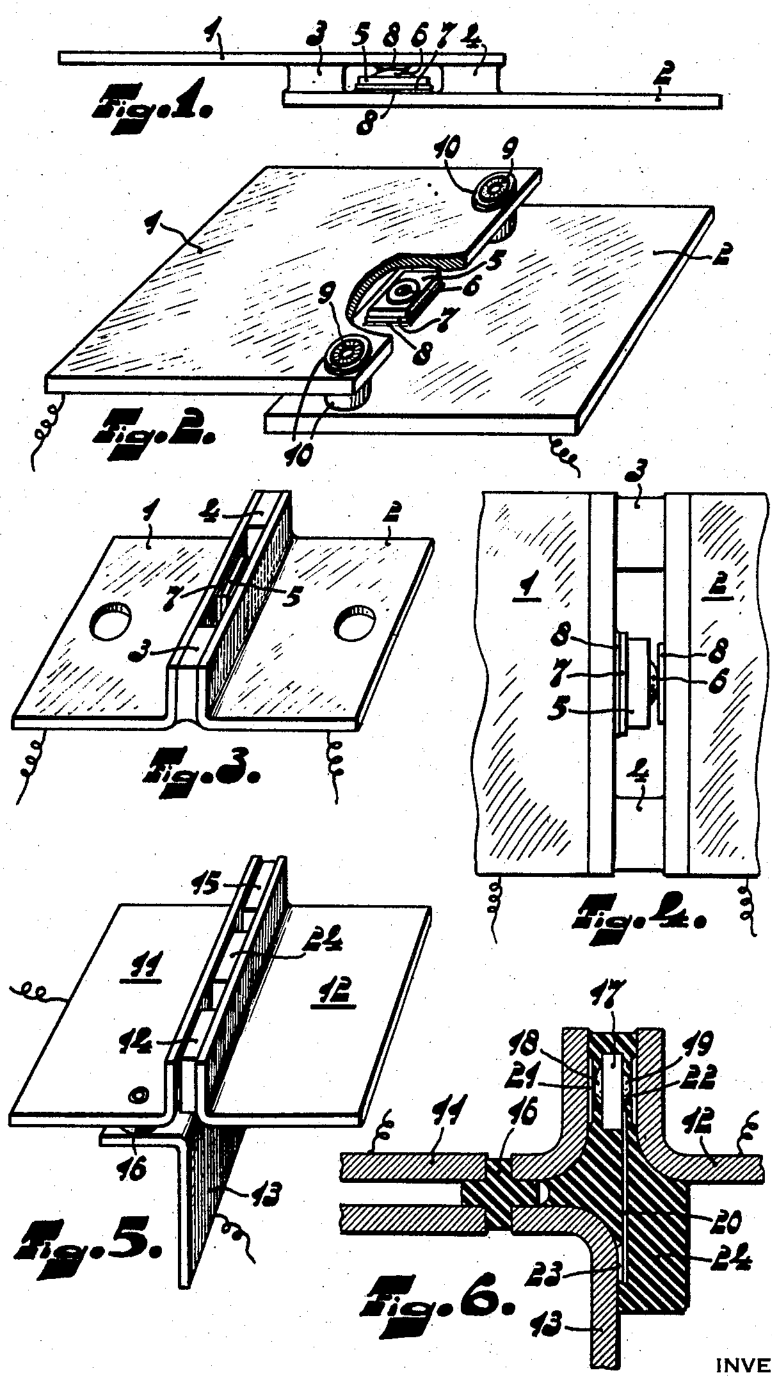

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Fig. 7

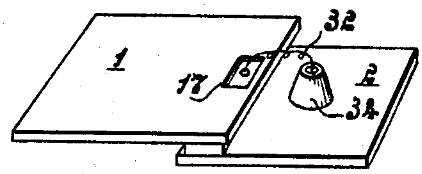

Fig. 8

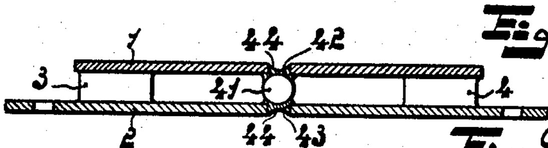

Fig. 9

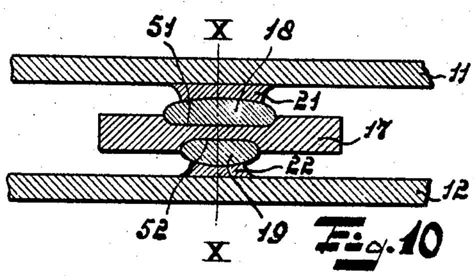

Fig. 10

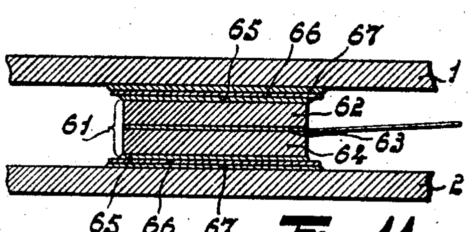

Fig. 11

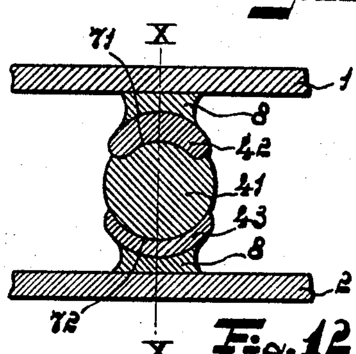

Fig. 12

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ELECTRODE SYSTEM COMPRISING CRYSTAL DIODES OR TRANSISTORS

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4 Claims. (Cl. 317—234)

This invention relates to electrode systems, for example crystal diodes or transistors, comprising a semi-conductive body constituted by at least two parts of different or opposite conductivity types. Said body may be, for example, a mono-crystal manufactured by so-called "growing" from a molten mass, it being possible to obtain layers of different conductivity types by the addition of donors or acceptors to the molten mass of a semi-conductive material, on the surface of which body at one or more areas electrodes are provided by fusion, which are of a material such as to yield parts of different or opposite conductivity types due to alloying with the constitutive material of the body.

The object of the invention is inter alia to improve the dissipation of heat from such a system and thus to permit a higher electrical load.

It is common practice in such systems to secure the semi-conductive body to a carrier and to connect flexible conductors to the other parts, thus preventing the occurrence of mechanical stress in the semi-conductive body, which commonly comprises a very brittle crystal of germanium or silicon.

The invention underlies the recognition that the dissipation of heat by such flexible conductors is unsatisfactory and that it is possible for not only one, but at least two parts of the body to be connected directly, that is to say without the intermediary of flexible conductors, to cooling bodies without detracting from the reliability of the system.

According to the invention, at least two parts of the semi-conductive body are each connected directly to a cooling body, the cooling bodies furthermore being rigidly interconnected by one or more insulating bridges. The term "rigid connection" is to be understood in this case to mean a connection which is mechanically much stronger than that brought about by the semi-conductive body.

The cooling bodies may have the shape of plates which extend in parallel with one another through part of their surfaces, it being possible for the semi-conductive body, together with one or more insulating bridges, to be provided between the parallel parts. The semi-conductive body is preferably so positioned that the boundaries between the parts of different conductivity type extend as far as possible in parallel with the said parts of the plates.

In many cases it may be advantageous to fold the cooling plates in part, in order to improve the thermal contact with the surroundings.

In order that the invention may be readily carried into effect, it will now be described with reference to the accompanying drawing, given by way of example, in which:

Fig. 1 is a side view of a crystal diode arranged between two parallel cooling plates.

Fig. 2 is a perspective view of a variant of the construction shown in Fig. 1.

Fig. 3 is a perspective view of a third embodiment of a crystal diode.

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Fig. 4 is a plan view of the said diode on an enlarged scale.

Fig. 5 is a perspective view of a transistor comprising cooling plates.

Fig. 6 is a sectional view of the transistor of Fig. 5.

Figs. 7 and 8 are a side view and a perspective view respectively of two transistors.

Fig. 9 is a sectional view of one embodiment of a crystal diode.

Figs. 10 to 12 are sectional views of the semi-conductive body with adjoining parts on an enlarged scale.

The crystal diode shown in Fig. 1 comprises two metallic cooling plates **1** and **2**, for example of brass, which are rigidly interconnected by insulating bridges **3** and **4**. Said bridges may each comprise an insulating body, for example a ceramic disc, which is connected to the plates with the use of a thermosetting cement. The plates are separated by the semi-conductive body **5** with an electrode **6** provided thereon by fusion. The body may consist of germanium of the N-type and the electrode may consist of indium. The body **5** has soldered to its lower side a metallic plate **7** having a coefficient of expansion similar to that of germanium, which plate serves to prevent the semi-conductive body from cracking as a result of its different coefficient of expansion with respect to that of copper. The plate may consist of an alloy containing 54% of iron, 29% of nickel and 17% of cobalt, which alloy is known under the name "Fernico."

The assembly is secured between the plates **1** and **2** with the use of a low-melting solder such as Wood's metal. The securing operation is preferably effected by first providing each plate with a thin layer of Wood's metal **8** and subsequently pushing the body **5**, together with the electrode **6** and the plate **7**, between the plates **1** and **2**, the Wood's metal at the same time being fused by means of hot air.

It has been found that at normal temperatures the mechanical stress in the body **5** and the electrode **6** has no harmful consequences.

The supply of current is to be effected in this case through the plates **1** and **2**.

Fig. 2 shows a similar diode, but in which the plates **1** and **2** are interconnected with the use of flanged sleeves **9** and several insulating discs **10**.

It will be evident that the body **5** and the electrode **6** may be protected from the action of the atmosphere surrounding them by casting with a sealing mass. Ethoxyline resins, also known under the mark "Araldit," are very suitable for this purpose.

The construction shown in Fig. 3, a plan view of which is shown again in Fig. 4 on an enlarged scale, substantially corresponds to that of Fig. 1, except the plates **1** and **2** are bent rectangularly along their edges so as to facilitate the securing thereof on a base plate.

Figs. 5 and 6 show a transistor comprising three plates **11**, **12** and **13** which are bent along their edges and rigidly secured to one another. Insulating discs **14** and **15** are shown between the plates **11** and **12** as an example of securing and fixed in position between the plates by cementing. Ceramic bodies **16** shown between the plates **11** and **13** may likewise be fixed in position by cementing. The transistor proper comprises a semiconductive body **17** having two electrodes **18** and **19**. The body **17** furthermore carries a current supply conductor **20** which may be soldered to the body.

The transistor is manufactured in a manner similar to that described with reference to Figs. 1 and 2. After the plates **11**, **12**, **13** have been interconnected and locally provided with thin layers of low-melting solder **21**, **22**, **23**, the body **17**, together with the parts **18**, **19**, **20**, is carefully pushed between the plates, the solder at the same time being fused by means of hot air. Afterwards, the body is cast in a protective mass **24**.

The transistor shown in Fig. 7, as the diode shown in Fig. 1, is built up with the use of two cooling plates **1** and **2** which are rigidly interconnected along their edges at **3**. However, the semi-conductive body **17**, instead of being secured between the plates **1** and **2**, is in this case secured to the edge of plate **1** through the intermediary of the "Fernico" plate **31**. The electrode **18** is soldered to the plate **1** with the use of Wood's metal **21**, whereas the electrode **19** is connected through a conductor **32** to a contact **33** which is secured to an insulator **34** carried by the plate **2**.

The transistor shown in Fig. 8 is distinguished from the preceding ones in that the semi-conductive body **17** is soldered in an aperture of the plate **1**. The dissipation of heat may thus be more favourable.

The transistors shown in Figs. 7 and 8 afford the advantage that the capacity between the electrode **19** and the conductors connected therewith may be low with respect to that of the other parts.

It will be evident that in these transistors and also in the diodes shown in Figs. 3, 4 and 7 the semi-conductive body may be cast in a sealing mass.

Finally, Fig. 9 again shows a diode. In this diode the semi-conductive body is constituted by a small ball **41** which may consist of, for example, germanium of the N-type. On one side thereof a thin layer **42** of a metal such as indium is provided by fusion, which layer brings about a p-n transition, whereas on the other side a soldered joint **43** provided therein yields an ohmic contact, for example of tin. The plates **1** and **2** may exhibit apertures **44**, which can accommodate the ball and the solder.

Heating to a temperature of about 500° C. is commonly required for manufacturing the p-n transition. This thermal treatment may be carried out before the ball is secured between the plates, in which event the insulating bridges 3 and 4 need not be resistant to high temperatures. It is alternatively possible to carry out the thermal treatment after the ball has been provided and in this case the insulating bridges must be capable of withstanding a high temperature. They may then be manufactured, for example, from ceramic material, glass or similar material.

As previously mentioned, it is preferable that the semi-conductive bodies should be so arranged that the boundaries between the parts of different conductivity types are as far as possible parallel to the cooling plates. This is shown in detail in Figs. 10 to 12, which illustrate several embodiments of the semi-conductive body on an enlarged scale.

In the transistor shown in Fig. 10, the semi-conductive body **17** comprises two electrodes **18** and **19** which are provided in opposition by fusion. If the body consists of germanium of the N-type, the electrodes may be of indium. After the assembly has been subjected to a thermal treatment, for example at 500° C., the indium has alloyed with the germanium so strongly that the electrodes have penetrated the surface of the latter. After freezing, at least those parts of the electrodes **18**, **19** which adjoin the material of the original body comprise a semi-conductor of the P-type. In order that the mechanical stress may be distributed through the body **17** as favourably as possible, it is desirable that the boundaries **51** and **52** between the parts **17**, **19** should be parallel to the cooling plates **11** and **12**.

Fig. 11 shows a transistor of the "grown junction" type. The semi-conductive monocrystal **61** comprises three parts **62**, **63**, **64** of opposite conductivity type, viz. of

the p-n-p or the n-p-n type. The crystal is connected with the use of solder **65** to two "Fernico" plates **66** which, in turn, are secured with the use of Wood's metal **67** to the cooling plates **11** and **12**. As before, the boundaries between the parts **62**, **63**, **64** are parallel to the said plates.

The diode shown in Fig. 12 is substantially similar to that shown in Fig. 9, except the parts **42** and **43**, which may be of indium and tin respectively, are secured to the cooling plates **1** and **2** with the use of a low-melting metal **8**. The boundaries **71** and **72** between the parts **41**, **42** and **41**, **43** are as far as possible parallel to the cooling plates **1** and **2**.

If in cases as shown in Figs. 10 and 12 the said boundaries are curved, more or less, this implies that the axis of symmetry X—X of the semi-conductive body is at right angles to the adjoining parts of the cooling plates.

What is claimed is:

1. A semi-conductor device comprising a pair of cooling plates having parallel, spaced portions, a semi-conductive body containing at least two portions of opposite conductivity type material and secured directly to and between said parallel portions of said cooling plates with one conductivity type portion secured to one of said plates and with the other conductivity type portion secured to the other of said plates and with the opposite-conductivity-type portions extending substantially parallel to the parallel spaced portions of the cooling plates, and insulating supporting means secured and bonded directly to and between said parallel portions of said cooling plates and rigidly interconnecting the latter together.

2. A semi-conductor device as set forth in claim 1 wherein the insulating supporting means includes a pair of insulating members disposed on opposite sides of the semi-conductive body.

3. A transistor device comprising first and second cooling plates having parallel, spaced portions, a semi-conductor body containing emitter, collector and base electrodes mounted between said parallel portions of the cooling plates, one of said electrodes being secured directly to one of the parallel portions, another of said electrodes being secured directly to the other of said parallel portions, insulating means disposed between the parallel portions and secured thereto and rigidly interconnecting them together, a third cooling plate connected to at least one of the other cooling plates, and means connecting the third of said electrodes to said third cooling plate.

4. A transistor device comprising first and second cooling plates having parallel, spaced portions, a semi-conductor body secured edgewise to the edge of said first cooling plate, rectifying connections on opposite surfaces of said semi-conductor body, one of said rectifying connections being secured directly to said second cooling plate, insulating means secured to and between said parallel portions of said cooling plates and rigidly linking them together, terminal means insulatingly mounted on said second terminal plate, and means interconnecting said cooling means and the other of said rectifying connections.

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