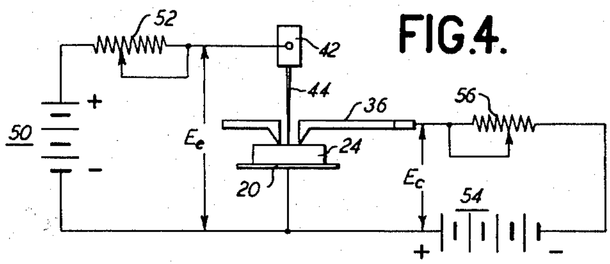
Sept. 9, 1952 A. H. DICKINSON 2,610,234

CRYSTAL TRIODE

Filed May 4, 1950 2 SHEETS—SHEET 1

FIG.4.



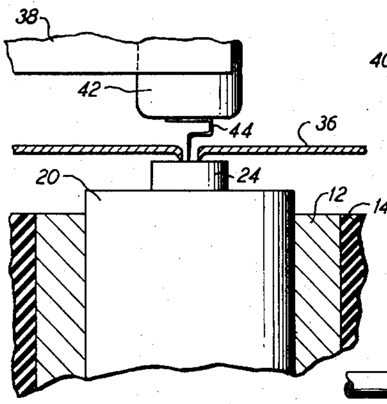
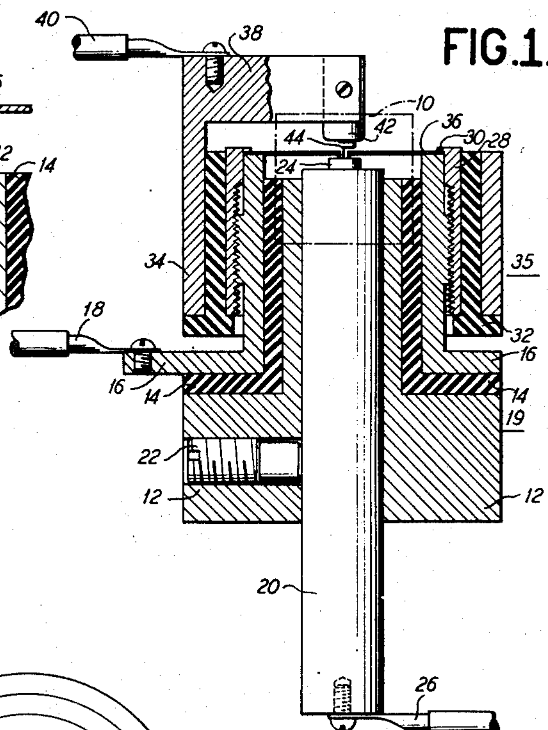


FIG.3.

FIG.1.



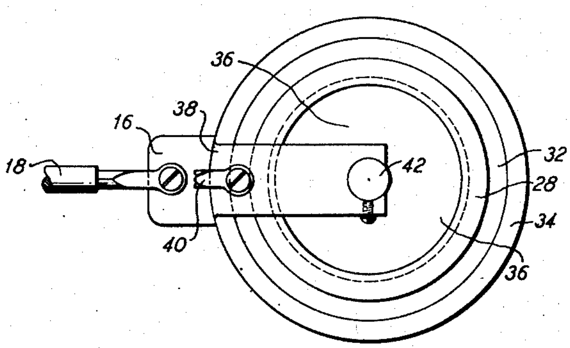


FIG.2.

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FIG. 5.

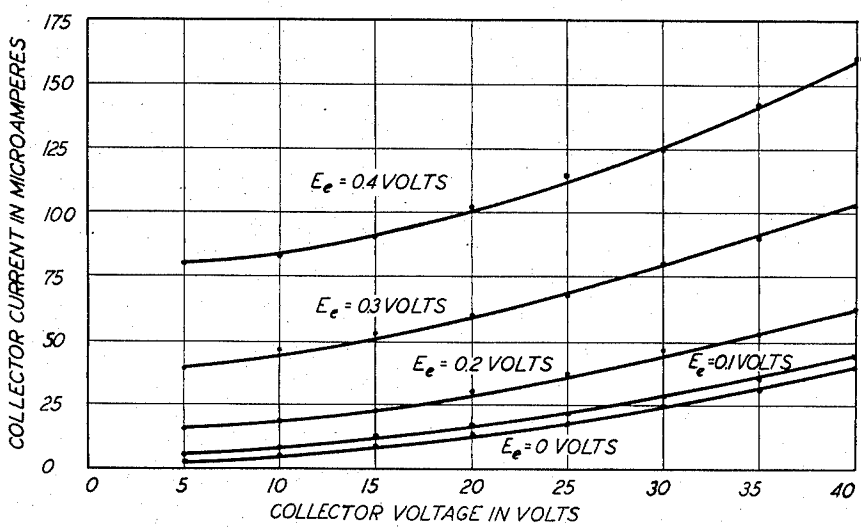
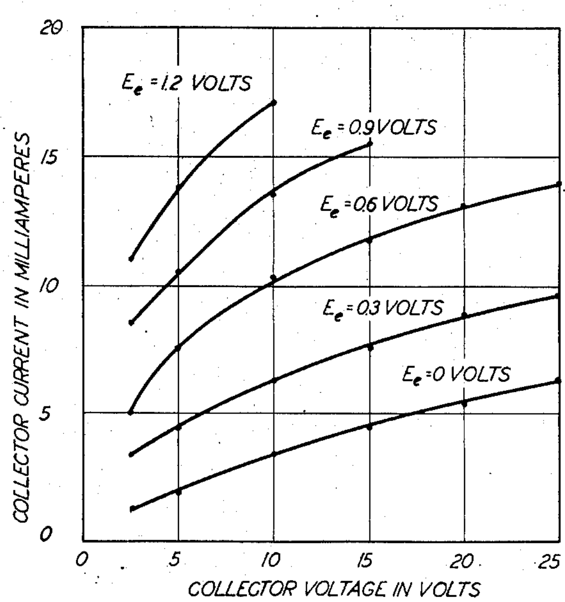


FIG. 6.



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UNITED STATES PATENT OFFICE

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CRYSTAL TRIODE

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Application May 4, 1950, Serial No. 159,980

2 Claims. (Cl. 175—366)

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This invention relates to semi-conductors and more particularly to a novel crystal triode.

A conventional crystal triode or transistor includes two small diameter electrodes in the form of whiskers resting on one face of a crystal, usually of the high back voltage germanium type, and a third or base electrode of relatively large area and low resistance connected to the other face of the crystal. When the two whiskers, termed emitter and collector respectively, are placed in close proximity to each other on the face of the crystal and the proper direct current bias voltages are applied to them there is a mutual influence which permits the device to be used as an amplifier. Such devices have an output impedance of higher value than that of the input impedance. This feature of such crystal triodes requires the use of impedance matching, amplifying or buffer circuits if power gain is required.

It is a principal object of the invention to provide a novel crystal triode which minimizes the above objectionable features.

Another object is to provide a crystal triode having a collector electrode which makes a substantially continuous line contact with one face of the crystal.

Another object is to provide a crystal triode having an electrode arrangement such that the omnidirectional electrical field produced by one electrode is utilized to effect an increased electrical output from the triode.

A further object is to provide a novel crystal triode having a low output impedance so that its use at high frequencies is more feasible.

A still further object is to provide a crystal triode having an output electrode in circumferential spaced relation to an input electrode, the back resistance and the other electrical conditions of the output electrode being variable in response to variations in the electrical conditions of an input electrode.

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 examples, the principle of the invention and the best mode, which has been contemplated, of applying that principle.

In the drawings:

Fig. 1 is a cross sectional view of one embodiment of the invention,

Fig. 2 is a top view of the embodiment shown in Fig. 1,

Fig. 3 is an enlarged view of the portion of Fig. 1 included within the closed dotted line **10**,

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Fig. 4 is a conventional circuit diagram illustrating the character of the invention therein,

Fig. 5 shows a set of characteristic curves for a conventional crystal triode, and

Fig. 6 shows a set of characteristic curves for the crystal triode of the invention.

Referring more particularly to Figs. 1, 2 and 3, there is shown a crystal receptacle suitable for use with the novel crystal triode of the invention. A hexagonal member **12** is formed to receive the insulating member **14** and externally threaded member **16** having a lug **18** secured thereto by any suitable means to insure a good electrical connection. The members **12**, **14** and **16** are joined together, as shown, to prevent any relative movement between them by any suitable means such as cement. The members **12**, **14** and **16** thus form a single inner member generally designated **19** which has its inner portion bored out to receive a rod **20**. Screw **22** is threaded through member **12** to bear against the rod **20** to hold it securely in place. A crystal **24** is soldered on the upper end of rod **20** and terminal **26** is secured to the lower end of rod **20** by any suitable means such as a screw.

Sleeve **28** is internally threaded to snugly engage the external threads of member **16** and includes an inwardly extending lip **30**. Insulating member **32** and conductive member **34** are mounted outward from sleeve **28**, members **32** and **34** and sleeve **28** being joined together by any suitable means to prevent relative movement between them and form a single outer member generally designated **35**.

A disc shaped collector electrode **36** having a diameter approximating that of member **16** is placed over the upper end of the inner member **19** and the outer member **35** screwed thereon until the lip **30** clamps the disc **36** firmly against member **16**. An arm **38** extends inwardly from the member **34** and includes a terminal **40** conductively connected thereto. A rod **42** is attached to and extends downward from the arm **38** and terminates near the crystal **24**.

A conventional type whisker **44** is affixed to rod **42** and extends downward in line with the center of disc **36** to serve as an emitter electrode. The electrode disc **36** may be formed by pricking it at its center and then drilling it to form a continous line or circular knife-edge. Obviously the whisker passes between the circular knife-edge at the center defined by the circumference thereof and makes contact with the crystal **24**. The rod **20** is moved within the member **12** until both the knife-edge of the electrode disc **36** and the point of the whisker 44 are in contact with the upper face of the crystal 24. The screw 22 is tightened to hold the rod 20 firmly in place and thereby maintain the adjustment of the crystal 24 relative to the electrodes 36 and 44. A typical diameter of the knife-edge may be 0.004 to 0.005 inch.

Referring to Fig. 4, a battery 50 in series with a potentiometer 52 is connected between the emitter electrode 44 and the base electrode 20. The battery 54 in series with a potentiometer 56 is connected between the base electrode 20 and the collector electrode 36. As seen from the circuit arrangement, the emitter electrode 44 is biased in a positive or forward direction so that a D. C. current flows into the crystal 24. The collector electrode 36 is biased in a negative or reverse direction with a higher voltage than the bias voltages on the emitter electrode so that a D. C. current flows into the collector electrode.

It is well known that current through the collector electrode is sensitive to and may be controlled by changes of current from the emitter electrode. A change in the emitter voltage E_e may be effected by conventional movement of the arm of potentiometer 52 to change the emitter current and if the collector voltage E_c is kept constant the change in collector current may be larger than the change in emitter current. If desired, after proper adjustment of the potentiometers 52 and 56 an A. C. voltage may be superimposed in any conventional manner on the D. C. voltage E_e to thereby vary the emitter current to cause an increased variance of the collector current.

A change in the collector current as a result of a change in the emitter current is attributed to several phenomena. Within the crystal, the emitter current is thought to be provided largely by positive charges, referred to as holes. The collector current, in the absence of any emitter current, is provided exclusively by electrons. The electric field associated with the collector current attracts the holes toward the collector and they affect the collector current in two ways. Firstly, the contact between the collector and crystal does not impede the flow of holes so that they add directly to the collector current. Secondly, the positive charge is believed to modify the contact between the collector and crystal so that it becomes easier for electrons to flow out of the collector.

It is known that the effectiveness of this action is dependent among other things upon impurities in the crystal, the bias voltage, the magnitude of the collector current, the temperature, the electrode arrangement, the electrode spacing and the contact between the crystal and the electrodes.

Referring to Figs. 5 and 6, there is demonstrated the superior performance of the semiconductors of the invention as compared to that of the conventional semi-conductors using whisker type electrodes as emitters and collectors.

Fig. 5 shows the collector current in microamperes for various values of collector voltage in volts when the emitter voltage E_e is varied from 0 volt to 0.4 volt in 0.1 volt intervals. These curves represent the curves normally obtained when a germanium type crystal was used and both the emitter and collector electrodes were in the form of whiskers.

Fig. 6 shows the curves obtainable when using a similar type crystal, a whisker type emitter electrode and a collector electrode in continuous line contact with the crystal and in circumferential spaced relationship with the emitter electrode as taught by the invention. Here, the collector voltage is drawn to the same scale as in Fig. 5 but the collector current is given in milliamperes and so drawn that the current represented by a given distance along the ordinate is equal to 125 times that represented by the same distance along the ordinate of Fig. 5. In Fig. 6 the emitter voltage curves represent emitter voltage values from 0 to 1.2 volts in intervals of 0.3 volt.

The tremendous increase in output obtained by a practice of the invention can be readily appreciated by considering, as an example, the curves representing an emitter voltage of 0.3 volt when the collector voltage is 20 volts. It is seen that for these values the collector current indicated by Fig. 5 is approximately 60 microamperes and that indicated by Fig. 6 is approximately 9 milliamperes or 9000 microamperes. In other words, the current output made possible by the novel collector electrode of the invention is approximately 150 times that obtained by a comparable crystal triode using conventional type whisker electrodes.

The circumferential arrangement of the collector electrode of the invention with respect to the emitter electrode provides an increased area of contact between the collector electrode and the crystal as compared to that of the crystal triodes of the two whisker type. The current flowing through a crystal triode contact is substantially proportional to the area of the contact provided other features effecting such current flow remain unchanged. Such is demonstrated by the curves of Fig. 6 as compared to those of Fig. 5.

The higher collector current provided by a practice of the invention, when the emitter voltage is 0, also provides a collector current having a greater rate of change with a changing emitter voltage than that obtained by the two whisker type crystal triode using a similar crystal. This is attributed to the greater utilization by the invention of the holes introduced at the emitter. This increased utilization is made possible because the increased magnitude of the field of the collector current causes an increased number of holes to reach the collector before they combine with electrons. The larger the collector current, the larger the number of holes it can carry without the positive space charge of the holes reducing the field to such an extent that a large fractional part of additional holes is attracted to the base rather than to the collector.

Also in the two whisker type crystal triode the path of traverse of the holes between the emitter and collector is of different length because of the unsymmetrical effect of the field produced by the collector current on the holes as they are injected by the emitter. As a result, many of the holes combine with electrons before the holes reach the collector and can therefore make no contribution toward increasing the collector current. In the novel crystal triode of the invention the holes at the emitter are influenced by a substantially uniform field created as a result of the geometric configuration of the collector electrode. Accordingly, a larger number of the holes are utilized to increase the effect of the emitter voltage on the collector current.

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 device illustrated and in 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. In a crystal triode; a crystal having a plurality of planar surfaces; a base electrode electrically and mechanically connected to a first face of the crystal; an emitter electrode mounted in point contact with a second face of said crystal; a resilient disc-shaped collector electrode in spaced relation to said emitter electrode and having a substantially continuous line contact surface substantially parallel to said second face; mechanical means for holding said disc-shaped collector electrode and said emitter electrode in a preselected spaced relationship; and a member having said base electrode affixed thereto, said member being longitudinally movable relative to said mechanical means so that the selected movement thereof causes a preselected pressure to be exerted between said emitter and collector electrodes and said second face of said crystal.

2. The crystal triode set forth in claim 1 wherein said member is rotatable relative to said mechanical means so that said line contact is movable on the face of said crystal to utilize particular electrical characteristics thereat.

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