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CRYSTAL DIODE FOR MICROWAVES

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Fig. 1

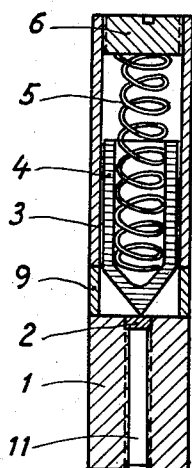


Fig. 2

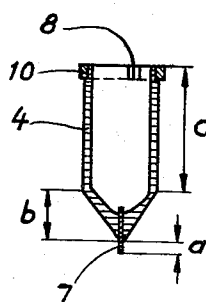


Fig. 3

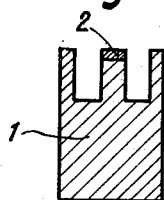


Fig. 4

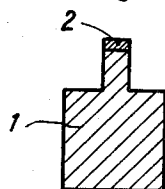
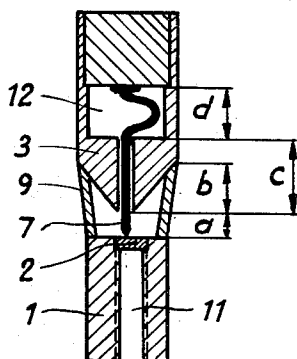


Fig. 5



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## CRYSTAL DIODE FOR MICROWAVES

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12 Claims. (Cl. 250—31)

The object of this invention is to provide a crystal diode for microwaves having a new construction, which is advantageous from the impedance point of view.

Crystal diodes are now generally used for mixing and detecting purposes in the microwave range. Such a diode consists of two electrodes, one of which carries a semi-conducting element, usually a silicon crystal. A thin, bended metal wire is attached to the other electrode, the point of said wire being held against the semiconducting element. The length of the wire is, however, usually not small in comparison to a quarter of a wavelength at the frequencies in the centimeter wave range. Such a wire has an inductance, which causes difficulties in the microwave range, and the value of said inductance ought to be as small as possible for optimum operation.

This invention relates to a crystal diode having the value of said inductance largely reduced. This makes it possible to use the diode with a good result at the highest frequencies of the microwave range.

The crystal diode according to the invention consists of a first electrode comprising a semiconducting element and a second electrode with a point, which is held against the semiconducting element under spring pressure. The diode is mainly characterized by the electrodes being cylindrical with a rather large diameter and by said other electrode being conical with a base diameter approximately equal to the diameter of the diameter of the cylindrical part of the electrode, which diameter is in the order of magnitude of 2–5 millimeters, so that the series inductance of the diode will be as small as possible.

The invention will be closer described in connection with the accompanying drawing, where Fig. 1 shows a crystal diode according to the invention, Figs. 2–4 show some different detail constructions, and Fig. 5 shows another embodiment of a crystal diode according to the invention.

Fig. 1 shows an embodiment of a diode according to the invention. 1 is a metallic electrode, which carries a semiconducting element 2. This may suitably be a silicon crystal, but other semiconducting materials having similar properties, e. g. germanium, may also be used. The other electrode consists of a tubular, metallic cylinder 3, in which another metallic part 4 having a conical point is movable in the axial direction. The point of said part 4 is pressured against the semiconducting element by help of a coil spring 5. The pressure of the conical point against the semiconducting element may be adjusted by a screw 6, which is screwed into the tubular cylinder 3. In order to be able to maintain the pressure at a constant value the conical part 4 shall be able to slide easily in the cylinder 3. It would therefore be advantageous to have a lubricant between the cylinder 3 and the part 4. On the other hand a good electrical contact must exist between them. Therefore the lubricant ought to have a rather high conductivity, and may suitably consist of e. g. graphite. Another way of obtaining a good electrical contact between the cylinder 3

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and the movable part 4 is as follows. The length  $c$  of the movable part 4 is made equal to an odd number of quarter wavelengths, e. g.  $\frac{1}{4}$  wavelength, at the frequency, at which the diode is intended to be used. Direct electrical contact between the cylinder 3 and the end of said movable part 4, which end is most distant from the conical point, is prevented by a ring 10 of some non-conducting material, e. g. nylon. This open circuit is then transformed by the quarter wavelength  $c$  into a short-circuit between the cylinder 3 and the portion of the movable part 4, where the conicity begins. A ring of some non-conducting material, which ring is similar to the previously mentioned ring 10 may be inserted also round that portion. In these cases the direct current will pass from the movable part 4 through the coil spring 5 and the screw 6 to the cylinder 3. In order to get the diode rather insensitive to mechanical shocks the movable mass, thus mainly the part 4 ought to be made light. This part may suitably be made hollow, as is shown by the figure, and of a light material. The point pressured against the semi-conducting element ought, however, to be made of some hard material, e. g. tungsten. A suitable construction of the movable part 4 is shown by Fig. 2. The conical point is provided with a hole in the axial direction, and a thin, straight metal wire 7 has been inserted into that hole. This construction gives the advantage of the wire 7, which is to be pressured against the semi-conducting element, being able to be made of a suitable, hard material, e. g. tungsten, while the rest of the movable part may be made of some light metallic material. The wire 7 may suitably first be pressed into the hole and then sharpened, so that a suitably formed point will be obtained. The length  $a$  of the portion of the wire, exceeding outside the point of the movable part 4 ought to be considerably less than a quarter of a wavelength. That condition ought not to be difficult to fulfill by this construction. The length  $b$  of the conical portion of the part 4 shall also be short in comparison to half a wavelength and shall preferably not exceed  $\frac{1}{8}$  wavelength. Whether the conical point of the part 4 comprises a metal wire 7 or not, the device makes it possible to obtain a very low inductance in series with the resistance of the barrier layer. Because also the capacitance shunting the resistance of the barrier layer ought to get a small value in the construction according to the invention the diode ought to be useful down to the shortest wavelengths in the microwave range.

It may be desirable at the manufacture of crystal diodes to have a possibility of adjusting the location of the point pressured against the semi-conducting element in order to find a suitable contact point. This may be effected in a very simple manner. The point pressuring against the semi-conducting element may e. g. be placed a little eccentrically. By providing the movable part 4 with two diametrically situated grooves 8 it will be possible easily to change the location of the contact point between the point of the electrode and the semi-conducting element by help of a screwdriver. Another way of obtaining the same result is as follows: The semi-conducting element 2 is fastened at the end of a screw 11. If either the conical point of the previously mentioned part 4 or the semi-conducting element 2 is placed eccentrically, the contact point between them may be easily varied by turning said screw 11. Said variation of the contact point may in this case be effected, although the spring 5 has been previously inserted.

The electrode 1, which carries the semi-conducting element, need not necessarily be constructed as in Fig. 1. In Fig. 3 there is shown another embodiment of said electrode. The construction imports an inductance being obtained in series with the capacitance of the barrier

layer. The value of said inductance is determined by the geometrical dimensions, and at the manufacture of the crystal diode said inductance may easily be given a desired value, contrary to the inductance, which is obtained by the thin, curved contact wire of crystal diodes according to previous constructions. In these previous constructions it is rather difficult to obtain equal values of the inductance at different diodes of one and the same sort of diode. In a construction according to Fig. 3 said inductance shall suitably be given such a value that the capacitance of the barrier layer is compensated in a certain desired frequency range. This shall also be the case if the electrode 1 is constructed according to Fig. 4.

The two electrodes 1 and 3 of the diode are held together by a non-conducting material 9, e. g. glass, ceramic or the like. The space between this non-conducting material, the two electrodes and the semi-conducting element may suitably be filled with wax or some other non-conducting material having small losses and a small dielectric constant.

It may be advantageous to make the two electrodes 1 and 3 with somewhat different diameters, so that the diode may be easily placed e. g. in a waveguide.

Fig. 5 shows another embodiment of a crystal diode according to the invention. 1 is a first electrode of a conducting material, which electrode carries a semi-conducting element 2. The point of a thin metal wire 7 is held against that semi-conducting element. Said wire belongs to the other electrode, the fixed part of which is indicated by 3. The end of the fixed part 3, which faces the semi-conducting element, is conical and has an axial or excentric hole, in which said thin metal wire is movable. The upper portion of this wire is bent or constructed in another manner, so that the point of the wire will be held against the semi-conducting element under spring pressure. The electrode 1 and the fixed part 3 of the other electrode are held together by a non-conducting material 9, e. g. glass, ceramic or the like. The space between this non-conducting material, the two electrodes and the semi-conducting element may suitably be filled with wax or some other non-conducting material having small losses and a small dielectric constant.

The upper end of the thin wire 7 is fastened to the fixed part 3 of said other electrode in such a manner, that a good electrical and mechanical contact will be obtained. The direct current through the diode will then pass this fastening point. High frequency currents shall, however, be able to pass from the thin wire 7 directly to the conical end of the fixed part 3 of said other electrode. This may be effected in two different manners. Either the sliding surfaces between the thin wire 7 and the hole, in which the wire is movable, are coated with a lubricant with a good electrical conductivity, e. g. graphite, or said sliding surfaces may also be coated with an insulating material, so that a direct contact between the metal surfaces of the hole and the wire 7 will be prevented. In the latter case the length  $c$  (more exactly the electrical length) of said hole shall be chosen so as to be an odd number of quarter wavelengths, e. g.  $\frac{1}{4}$  wavelength, at the frequency at which the diode is intended to be used. Because the upper end of said hole is open, the lower end of said hole will act as if it were shortcircuited from the high frequency point of view. In order to make the upper end of said hole act exactly as an open circuit, the length  $d$  (i. e. more exactly the electrical length) of the cavity 12 above said hole shall be an odd number of quarter wavelengths at the frequency, at which the diode is intended to be used.

In order to make the location of the contact point between the point of the wire 7 and the semi-conducting element 2 adjustable, the point of said wire and the semi-conducting element may also in this construction be located excentrically in relation to each other. According to the figure the semi-conducting element is carried by a screw 11, by means of which the semi-conducting ele-

ment may be turnable, so that the location of the contact point may be adjusted.

The length  $a$  of the portion of the wire 7, which portion exceeds the conical part of said other electrode ought to be small and preferably considerably less than a quarter of the smallest wavelength, at which the diode is intended to be used.

The length  $b$  of the conical portion of said other electrode part 3 also ought to be small and preferably less than one eighth of the smallest wavelength, at which the diode is intended to be used.

The crystal diode may of course also in this embodiment be constructed according to Fig. 3 or 4 so that the electrode, which carries the semi-conducting element, is constructed to form a reactance of such a value and sign, that the capacitance of the barrier layer will be compensated in a certain frequency range.

It may be advantageous to make the two electrodes 1 and 3 with different diameters as is shown by Fig. 5 in order to make the diode easily insertable into a waveguide.

I claim:

1. A crystal diode for use in connection with the mixing and detecting of microwaves of different lengths, comprising a first and a second cylindrical electrode, said first electrode including a semi-conductive member and said second electrode including a conical member fixedly mounted relative to the first electrode and having a longitudinal bore, and a metal wire having a diameter thin relative to the diameters of said cylindrical electrodes, the said wire being secured to one end of said second electrode and extending axially movable to said bore, the other end of the wire being pointed and engaging said semi-conducting member with a pressure contact.
2. A crystal diode according to claim 1, wherein the portion of the wire protruding from said conical member is of a length considerably less than one quarter of the shortest wave length with which said diode is usable.
3. A crystal diode according to claim 1, wherein an electrically conductive lubricating material is interposed between said metal wire and the wall defining said bore through the respective electrode thereby effecting low mechanical friction and low electric resistance between the metal wire and the said wall.
4. A crystal diode according to claim 3, wherein the said lubricating material comprises graphite.
5. A crystal diode according to claim 1, wherein the bore through said conical member has an electrically effective length of an odd number of quarter wave lengths, and wherein the wire portion within said bore is electrically insulated from the surrounding wall of the conical member.
6. A crystal diode according to claim 5, wherein the said movable wire is coated with insulation material.
7. A crystal diode according to claim 1, wherein the said electrodes are mounted axially rotatable relative to each other, and wherein said point of contact between said wire and said semi-conducting member is eccentric relative to the rotational axis of at least one of said electrodes for varying the location of said contact point on the semi-conducting member by rotating said electrodes relative to each other.
8. A crystal diode according to claim 7, wherein the electrode including said semi-conducting member is axially rotatable and said contact point is eccentric relative to the rotational axis of the said electrode.
9. A crystal diode according to claim 1, wherein the said electrodes have diameters different one from the other so as to facilitate insertion of the diode in a wave guide.
10. A crystal diode according to claim 1, wherein a sleeve member made of electrically non-conducting material is disposed between said two electrodes for joining the same, the said protruding wire portion extending through said sleeve member.

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11. A crystal diode according to claim 10, wherein the space bounded by said sleeve member and said electrodes is filled with a non-conductive material having a low dielectric constant.

12. A crystal diode according to claim 1, wherein the said electrode including the non-conductive member is of a configuration such as to form a reactance having a value and sign compensating for the capacitance of the barrier layer of the diode within a predetermined range of frequency.

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