

Nov. 8, 1960

I. M. ROSS ET AL

2,959,504

SEMICONDUCTIVE CURRENT LIMITERS

Filed May 26, 1958

3 Sheets-Sheet 1

FIG. 1

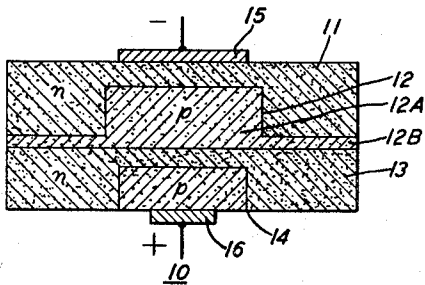


FIG. 2

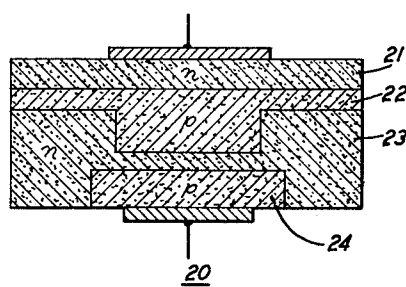


FIG. 3

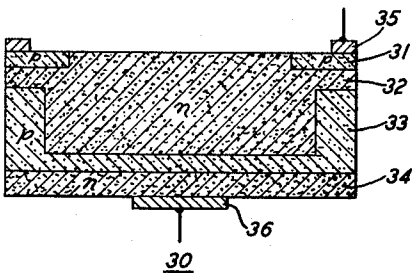


FIG. 4

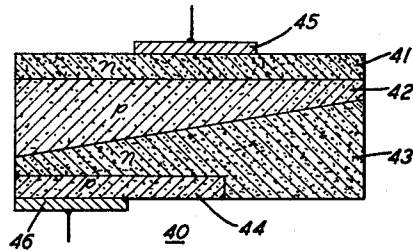


FIG. 6

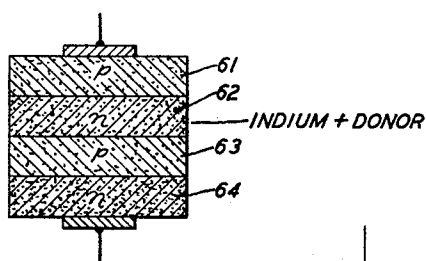


FIG. 8

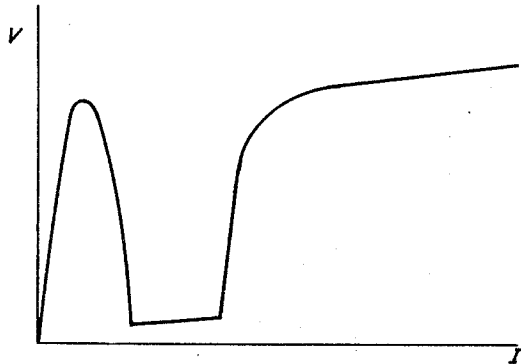


FIG. 7



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FIG. 9

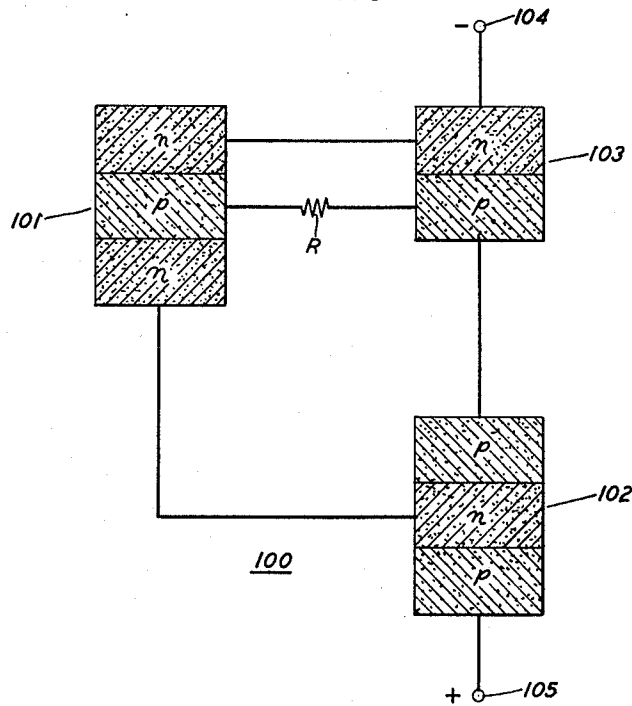
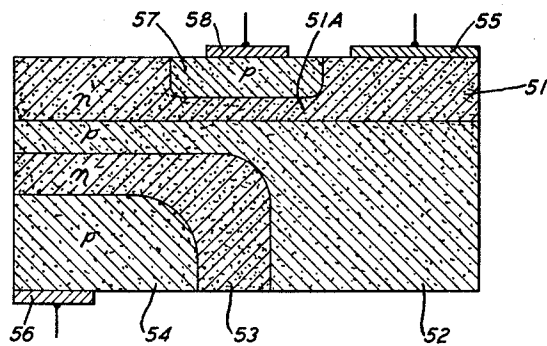


FIG. 5



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FIG. 10A

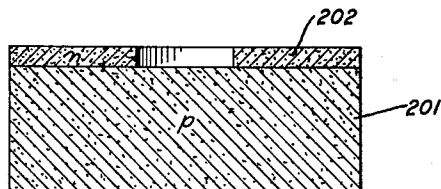


FIG. 10B

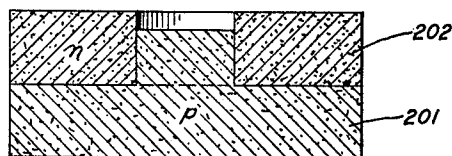


FIG. 10C

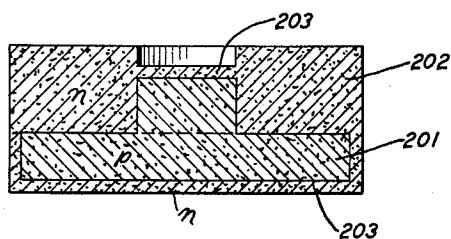
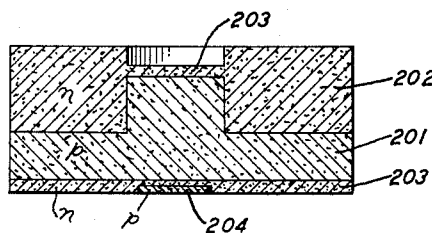


FIG. 10D



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SEMICONDUCTIVE CURRENT LIMITERS

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11 Claims. (Cl. 148—33)

This invention relates to semiconductive devices and more particularly to such devices useful as current limiters.

A current limiter is a device which exhibits a relatively low impedance for currents in a limited range of currents, and beyond which range the device exhibits a relatively high impedance and so tends to limit the flow of current.

Since there is a need in a modern telephone plant of a large number of current limiters, it is desirable to have a current limiter which is inexpensive, reliable and rugged. The present invention is directed primarily to this end.

A feature of the present invention is a diode including a PNPN semiconductive element in which the total current amplification factor, α , of the element has a value of unity or more in the current range in which the diode is to have a low impedance. However, the diode is designed so that the value of α decreases with increasing current such that at the end of this current range it becomes less than unity, at which point the diode provides a high impedance.

Two-terminal PNPN semiconductive elements have previously been known to be useful as switches of the kind which initially exhibit a high impedance to applied voltages below a certain switching level but which, after such level has been exceeded, exhibit a low impedance so long as a relatively small sustaining current is permitted to flow. This switching characteristic is achieved in such known devices by providing that the total α in the element increase with increasing current from a value below unity to a value in excess of unity. Typically, this is achieved by incorporating in the semiconductive element appropriate recombination centers which gradually fill up as the current increases, thereby causing an increase in total α of the element.

In contradistinction, in a current limiter in accordance with the present invention the desired current limiting characteristic is achieved by providing that the total α in the semiconductive element, initially in excess of unity, decrease with increasing current over a prescribed current range beyond which it becomes less than unity to provide limiting action at this point. This variation of total α with current is usually realized most advantageously by a structure for the semiconductive element which leads to emission concentration in the element. Alternatively, it is feasible to achieve the desired variation of α with current by the introduction into the body of appropriate impurity centers.

In particular, in illustrative embodiments in accordance with the invention in which the desired variation in total α with current is achieved by geometry effects, the PNPN semiconductive element is characterized by at least one intermediate zone which includes both a portion whose thickness between contiguous zones of opposite conductivity type is significantly more than the diffusion length of minority carriers therein and a

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portion whose corresponding thickness is not significantly more than the diffusion length of minority carriers therein.

In many applications, it is advantageous that the diode used to provide current limiting action also provide initially, until certain current and voltage levels are exceeded, a high impedance to current flow. If this characteristic is desired, it may be more readily achieved by employing silicon rather than germanium as the semiconductive material.

A silicon diode of this kind will exhibit a low impedance for an intermediate range of currents and a high impedance for currents either below or above this range. Because the diode can exhibit a high impedance for the same voltage at two widely separated current ranges, it is also adaptable for use as a storage element.

The invention will be better understood from the following more detailed description, taken in conjunction with the accompanying drawing, in which:

Each of Figs. 1 through 5 shows in section a current limiter illustrative of an embodiment of the invention utilizing geometry effects;

Fig. 6 shows a current limiter illustrative of an embodiment of the invention utilizing conductivity modulation and trapping effects;

Figs. 7 and 8 show the voltage-current characteristics typical of embodiments of the invention;

Fig. 9 shows a conjugate system of two transistors and a diode which is substantially the circuit equivalent of the current limiter shown in Fig. 1; and

Figs. 10A through 10D are sectional views of the current limiter of Fig. 1 in successive stages of one typical fabrication process.

With reference now to the drawing, the diode 10 shown in Fig. 1 comprises a semiconductive element having in succession four zones 11, 12, 13 and 14, contiguous zones being of the opposite conductivity type, and low resistance electrode connections 15, 16 to the two terminal zones 11, 14. It will be convenient throughout to refer to the dimension of a zone parallel to that of the principal current flow between the two electrodes as the thickness of the zone and the dimension transverse to such direction of flow as the width or lateral dimension of the zone. In the element shown, each of zones 11, 12 and 13 has a nonuniform thickness. Of particular import is the fact that the intermediate p-type zone 12 has a centrally located circular portion 12A whose thickness is at least several diffusion lengths of electrons, the minority carriers therein, and a surrounding annular portion 12B whose thickness is less than a diffusion length of the electrons therein. Typically, the ratio of the thicknesses of the two portions should be at least three and preferably at least five. Also of import is the fact that the lateral resistance of the thinner portion 12B is significant, as will be discussed in more detail below. As shown, the n-type zone 13 includes a thinner centrally located circular portion and a thicker surrounding annular portion. The terminal zone 11 extends completely across one major surface, while the terminal zone 14 extends only across a centrally located circular portion of the opposite major surface. Of special import is the fact that the terminal zone 14 extends opposite the thicker central portion 12A of zone 12. The diameter of the terminal zone 14, as well as the diameter of the portion 12A of zone 12 are parameters which permit control of the range over which current limiting action is achieved and accordingly are adjusted to adapt the element to the desired operating range. The resistivities of the intermediate zones 12 and 13 are parameters which control the breakdown characteristics and so these are chosen appropriately. In op-

eration, the diode is interconnected into its work circuit in a manner that the polarities shown are established on electrodes 15 and 16.

This structure is the electrical equivalent of the conjugate system 100 of two junction transistors and one junction diode shown in Fig. 9. As shown, this conjugate system includes the NPN junction transistor 101, the PNP junction transistor 102 and the NP diode 103, appropriately interconnected between electrodes 104, 105 to which is applied a bias of the polarity shown for achieving current limiting action. The combination of transistor 101, diode 103 and the resistor R can be considered a transistor whose alpha will vary with the amount of shunting of its emitter current through the diode 103. In particular, as the current flowing through the entire system increases, the current flowing through the resistor R also increases. An increase in this current results in a larger increase in the forward bias across the diode 103 than across the emitter junction of the transistor 101, and so an increase in the fraction of current which flows through such diode. This increase will be at the expense of a decrease in the fraction of current flowing through the emitter of the transistor 101. This decrease amounts to a decrease in the alpha of the transistor-diode combination. The total alpha of the system is the sum of the individual alphas of the transistor 102 and the diode-transistor combination. The alpha of the transistor 102 remains fixed but since the alpha of the diode-transistor combination decreases with increasing current as discussed, the total alpha will decrease with increasing current.

In a practical system the various elements would be chosen so that in the range of current in which the impedance is to be low, the total alpha of the system remains at least equal to unity. So long as the total alpha is at least unity, the total impedance of the system viewed between electrodes 104 and 105 is low.

When the total alpha of the system is less than unity the impedance seen between terminals 104 and 105 is high since it then includes the high impedance of a reverse-biased junction. Accordingly, when the current flowing has increased to a value sufficient to cause the total alpha to be less than unity, the system exhibits a high impedance at voltages below the breakdown voltage, and this tends to impede a further increase in current. In Fig. 7 there is plotted the voltage-current characteristic of this system.

By providing additionally that the total alpha be less than unity for currents below a chosen starting value, the impedance of the conjugate system can be made to be high until such starting current is reached. In particular, since silicon transistors typically exhibit low alphas at low currents, their use makes it possible to achieve such a high impedance characteristic at low currents. In such a system, the impedance is low for currents in an intermediate range and high for currents on either side of the range.

In Fig. 8 there is plotted the voltage-current characteristic of such a system.

At this point it seems desirable to point out more clearly the equivalence of the diode shown in Fig. 1 and the conjugate system shown in Fig. 9. The portions of the four zone diode represented by n-type zone 11, the thin portion 12B of p-type zone 12, and the n-type zone 13 correspond to the NPN transistor 101. Because the thickness of the thick central portion 12A of the p-type zone 12 is significantly more than a diffusion length, effectively no transistor action occurs therethrough and the n-type zone 11 is therealong effectively isolated for transistor action from the n-type zone 13. Accordingly, the n-type zone 11 forms effectively only an NP diode with the thick portion of zone 12, analogous to the NP diode 103 of the conjugate system. The high sheet resistance of the thin portion 12B of the p-type zone 12 serves the role of the resistor R connected between the base zone of the

transistor 101 and the diode 103. The thick portion 12A of the p-type zone 12, the n-type zone 13 and the p-type zone 14 form a PNP transistor which corresponds to the transistor 102.

In operation an increase in current between the two electrodes 15 and 16 of the diode causes an increase in the lateral current in the thin portion 12B of the zone 12. Since the sheet resistance of this portion is designed to be high, there results a voltage drop along this portion reducing the effective forward bias on the emitting junction between zone 11 and portion 12B of zone 12 with lateral distance therealong. This effectively reduces the area in which current is flowing across the emitting junction and results in emission concentration in favor of the thick central portion 12A of the zone 12. This results in the desired variation of total alpha as described for the conjugate system.

In particular, for operation in the manner described, it is important that the sheet resistance of the thin portion 12B of the zone 12 be sufficiently high that the voltage drop resulting from the lateral current flow be enough for emission concentration. The element needs to be designed so that in the current range for which the diode is to serve as a low impedance, the total alpha exceeds unity. The principles known to workers for achieving high alphas in junction transistors are here applicable. Electron bombardment may be used to reduce the alpha to achieve a crossover point for the total alpha at a desired current value. An element of this kind can be made to have the characteristic shown in either of Figs. 7 and 8 by appropriate choice of material.

It can be seen from the foregoing explanation of the principles of operation that nonuniformities in the thicknesses of zones other than zone 12 are not necessary for achieving limiting action, although it is found that the range over which such limiting action occurs can be controlled by the geometry of such other zones. The particular structure shown has been found advantageous because it is readily achieved by known fabrication techniques.

A typical process employed successfully for the fabrication of the NPNP element shown in Fig. 1 was as follows. Figs. 10A through 10D show the element in cross section in different stages of fabrication. A monocrystalline p-type silicon wafer of 0.3 ohm-centimeter resistivity was subjected to a phosphorus-rich atmosphere at 1250° C. for about one hour to form a phosphorus-diffused n-type shallow layer over the surface of the wafer. This phosphorus-diffused layer was thereafter removed completely both from all the surfaces of the wafer except one and from a centrally located circular portion of this face to leave only an annular diffused portion 202 on the wafer, as shown in Fig. 10A. The wafer was then heated for about 50 hours at about 1300° C. in air to increase the depth of penetration of phosphorus-diffused layer 202 as shown in Fig. 10B. The wafer was then subjected to heating first in a phosphorus atmosphere for about 40 minutes at 900° C. and then in air for about two hours at 1300° C. to form a phosphorus-diffused layer 203 over the entire surface of the wafer as shown in Fig. 10C. The phosphorus-diffused layer was removed from the edges of the wafer and the surface of the wafer was thereafter completely masked except for a centrally located circular portion of the major face opposite that on which layer 202 had previously been formed. Boron was diffused into this unmasked central portion to form a p-type region 204, as shown in Fig. 10D in a two step process including heating in a boron-rich atmosphere for one hour at 1300° C. followed by heating in air at this temperature for the same time. Electrode connections were then made to the opposite terminal zones.

An element fabricated by the process outlined was formed from a wafer which was substantially 80 mils square and 5.5 mils thick. The intermediate p-type zone 12 had a centrally located circular portion 12A about 4

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mils thick and 16 mils in diameter. The annular outer portion 12B was .55 mil thick. The specific resistivity of the p-type starting material, which was the resistivity of this zone 12, was about 0.3 ohm-centimeter. The n-type intermediate zone 13 had a circular portion of 10 mils diameter and 0.25 mil thickness and an annular surrounding portion of 0.45 mil thickness. The surface of this n-type zone exposed at the major face had a sheet resistivity of 20 ohms and a surface concentration of 4×10^{18} phosphorus atoms per cubic centimeter. The terminal p-type zone 14 was of 10 mils diameter, and had a depth of about 0.2 mil, a sheet resistivity of 5.5 ohms and a surface concentration of 6×10^{19} boron atoms per cubic centimeter. The terminal n-type zone 11 had a centrally located circular portion of 25 mils diameter and 0.45 mil thick, recessed about 0.6 mil with respect to the remainder of this surface. The surrounding annular portion of the n-type terminal zone had a thickness of 4.5 mils, a sheet resistivity of .16 ohms and a surface concentration of 6×10^{19} phosphorus atoms per cubic centimeter.

The diode incorporating this element exhibited an impedance in the megohms range until the initial breakdown voltage of approximately 44 volts was exceeded, after which its impedance switched to a value of a few ohms, which it maintained so long as a minimum current of about 4 milliamperes was permitted to flow. Current limiting action was achieved at approximately 9 milliamperes beyond which its impedance increased sharply. The second breakdown occurred at a voltage slightly above the first breakdown. The voltage-current characteristic for this element is shown in Fig. 8.

It can be seen that the characteristic depicted has for a range of voltages two stable high impedance states, one corresponding to a low current and the other to a high current. It will be obvious to a worker in the art that such a characteristic adapts the element for use as a binary storage element.

The principles of the invention can be embodied in a wide variety of diode structures. In the embodiment depicted in Fig. 2, terminal zones 21 and 24 are of uniform thickness while the intermediate zones 22 and 23 have a thickness which is nonuniform. In particular, zone 22 has a central portion at least several diffusion lengths thick and a surrounding portion less than a diffusion length thick, the lateral resistance of said outer portion being sufficiently high to provide effective emission concentration.

Fig. 3 shows an alternative embodiment 30 in which the effect of emission concentration is to favor the outer portion of the wafer. The wafer comprises the annular terminal zone 31, an intermediate zone 32 of nonuniform thickness, an intermediate zone 33 of nonuniform thickness and a terminal zone 34. An annular electrode 35 makes a low resistance connection to the terminal zone 31 and the electrode 36 makes a low resistance connection to the terminal zone 34. In this instance, the intermediate zone 33 in which emission concentration occurs includes an inner circular portion whose thickness is less than a diffusion length of minority carriers therein, and an annular surrounding portion whose thickness is at least several diffusion lengths. In this case, it is important that the terminal zone 31, which is the terminal zone separated from the intermediate zone in which emission concentration occurs, be annular since such terminal zone must extend opposite the thicker region favored by emission concentration of such intermediate zone.

In the embodiment shown in Fig. 4, the terminal zones 41 and 44 are of uniform thickness while each of the intermediate zones 42 and 43 are tapered in thickness. In this instance too, it is important to displace the terminal zone 44 from a central location toward the thicker end of the intermediate p-type zone 42, the region of emission concentration.

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In Fig. 5 there is shown an embodiment which is adapted for electronic control of the value of current beyond which the element acts to limit further increase. First, the element comprises a succession of four zones 51, 52, 53 and 54 which together with electrodes 55 and 56 form an NPNP diode, basically similar to those discussed in connection with Figs. 1, 2 and 3. However, in this embodiment, the terminal zone 51 includes an intermediate region 51A of reduced thickness and significant lateral resistance. The intermediate zone 52 is made to have a region many diffusion lengths thick opposite the region of zone 51 to which the electrode 55 connects and a region less than a diffusion length thick. It can be seen that the device formed by the four zones 51, 52, 53 and 54 and electrodes 55 and 56 is substantially the equivalent of the conjugate system shown in Fig. 9 after modification to insert the resistor R between the emitter of junction transistor 101 and the n-type zone of the diode 102 and to short together the base of junction transistor 101 and the p-type zone of the diode 102.

To achieve the electronic control mentioned above, the element includes a fifth zone 57, to which is connected electrode 58 and which is positioned contiguous to the region 51A of restricted thickness of zone 51. By biasing electrode 58 negative with respect to electrode 55, the rectifying junction between zones 51 and 57 is biased in reverse, creating a space charge layer which penetrates into region 51A. Variation of the voltage applied to electrode 58 permits variation of the depth of penetration of this space charge layer into region 51A and a consequent change of its conductivity. This is analogous to variation of the value of the resistor R in the conjugate system shown in Fig. 9 modified as discussed. As a consequence, the potential maintained on electrode 58 is a parameter for control of the current beyond which limiting occurs.

A decrease of alpha with increasing current in a transistor can also be obtained without utilizing emission concentration. For example, it is known that at high injection levels the emitter efficiency of a transistor can decrease provided the base region becomes conductivity-modulated. Conductivity modulation results when there is a significant increase in the majority carrier density in the base region because of the need to neutralize a high density of injected minority carriers. The increased density of majority carriers in the base region tends to an increased injection of such carriers from the base region into the emitter region, which, in turn, results in a decrease in alpha. To utilize this effect in a PNP diode in accordance with the invention, it is important that either one or both of the intermediate regions have a low impurity concentration corresponding to a high specific resistivity since this is necessary to achieve conductivity modulation with reasonable injection levels.

In addition to a decrease in the emitter efficiency, a decrease in the transport factor can be utilized in a transistor to decrease alpha with current. For this effect it is necessary to have the lifetime of minority carriers in the base region decrease with increasing injection level. This is an effect opposite to that employed in PNP diodes intended for use as switches. Such a decrease in lifetime with increasing injection level can be achieved by the introduction of appropriate recombination centers into the base region, the transport factor of which is to decrease with current. The condition for the effect desired is that the Fermi level under equilibrium in the material of this zone be closer to the center of the gap than is the trap level. Since most recombination levels are deep levels, this condition also tends to require high resistivity base regions. To incorporate this effect into a PNP diode in accordance with the present invention, selected impurities have to be introduced into either one or both of the intermediate regions.

It is preferable ordinarily to utilize both of the last-described effects to achieve a decreasing alpha with increasing injection level.

A typical impurity which can be used in silicon in this way is indium. Indium in silicon has a trapping level which lies closer to the valence band than to the conduction band. Since indium is an acceptor, it is necessary that the indium-rich region be overcompensated by a donor to obtain n-type conductivity. Indium in silicon is known to have a significant capture rate for both the capture of electrons from the conduction band and the capture of holes from the valence band. It has a trapping level which is fairly close to the valence band, and therefore not too close to the center of the gap. In n-type silicon of a resistivity range in which the Fermi level is closer to the center of the gap is this trapping level, a substantial decrease of lifetime with increasing injection level becomes feasible.

Fig. 6 shows a PNP diode in accordance with this aspect of the invention. The diode comprises the four zones 61, 62, 63 and 64 of which the n-type intermediate zone 62 includes both indium and a donor such as phosphorus. Typically, the indium concentration is 3.0×10^{16} atoms per cubic centimeter and the phosphorus concentration is 3.1×10^{16} atoms per cubic centimeter. For such concentration, a thickness of 10^{-3} centimeters for this zone is suitable and the decrease in transport factor with increasing injection level will occur for current densities between one and ten amperes per square centimeter. With current densities in this range, conductivity modulation of the intermediate zone 62 also will occur with a resultant decrease in emitter efficiency with increasing injection level, as desired. It is then further necessary to provide only that the alpha associated with the other intermediate region 63 have a value such that the total alpha diode remains at least unity in the range of currents below the onset of current limiting action.

It is obvious that the principles of the invention may be embodied in a wide variety of structures of which those described herein are merely illustrative. Moreover, it is feasible to introduce an electrode connection to either one or both of the intermediate zones of the succession of four zones to achieve an additional measure of control both of the onset of limiting current action and also of the initial breakdown point in devices having the characteristic shown in Fig. 8.

What is claimed is:

1. A semiconductor device comprising a semiconductor wafer including a succession of at least four zones, contiguous zones of the succession being of opposite conductivity type, and electrode connections to the two end zones of the succession, characterized in that one of the intermediate zones of the succession has a first region which has a thickness at least several diffusion lengths of minority carriers therein and a second region which has a thickness of less than a diffusion length of minority carriers therein, and the end zone spaced from said one intermediate zone extends primarily opposite the first region of said one intermediate zone.

2. A semiconductor device in accordance with claim 1 further characterized in that the semiconductor wafer consists of a succession of only four zones and electrode connections are made only to the two end zones of the succession, the two intermediate zones being free of electrode connections.

3. A semiconductor device in accordance with claim 1 further characterized in that the semiconductor wafer includes a fifth zone contiguous with and of opposite conductivity type to an end zone of the succession of four zones and a third electrode is connected to said fifth zone, the second and third zones of the succession being free of electrode connections.

4. A semiconductor device comprising a substantially monocrystalline PNP diode silicon wafer and electrode connections to the terminal zones of the wafer, characterized in that at least one of the two intermediate zones of the wafer is of nonuniform thickness, having a thickness in

one region significantly more than the diffusion length of minority carriers therein, and a thickness in another region not significantly more than said diffusion length, whereby the ratio of thicknesses of the two regions is at least three to one, and the terminal zone spaced from said one intermediate zone extends primarily opposite said one intermediate zone.

5. A semiconductor device comprising a PNP diode semiconductor wafer of which at least one of the two intermediate zones is of resistivity sufficiently high for the conductivity modulation of said zone and at least one of the two intermediate zones includes a concentration of recombination centers for decreasing the transport factor of such zone with increasing current, such that the wafer has a total alpha in excess of unity for a range of currents flowing therethrough and such total alpha decreases with increasing current so that a value of current is reached beyond which the total alpha is less than unity whereby the wafer exhibits a low impedance in the first-mentioned range of currents and a high impedance beyond this range.

6. A semiconductor device comprising a substantially monocrystalline PNP diode silicon wafer characterized in that the intermediate n-type zone includes indium overcompensated by a donor impurity and the wafer has a total alpha in excess of unity for a range of currents flowing therethrough and such total alpha decreases with increasing current so that a value of current is reached beyond which the total alpha is less than unity whereby the wafer exhibits a low impedance in the first-mentioned range of currents and a high impedance beyond this range.

7. A semiconductor device comprising a semiconductor wafer having a succession of four zones, contiguous zones being of opposite conductivity type and electrode connections to the two terminal zones, the wafer being characterized in that one intermediate zone has a first region whose thickness is at least several times the diffusion length of minority carriers therein and a second region whose thickness is less than the diffusion length of minority carriers therein, the sheet resistivity of such second region being sufficiently high to cause emission concentration in favor of said first region, and the terminal zone spaced from said intermediate zone extending primarily opposite said first region.

8. A semiconductor device according to claim 6 further characterized in that the semiconductor wafer is substantially monocrystalline silicon and the ratio of the thickness of said first region to the thickness of said second region is at least three to one.

9. A semiconductor diode comprising a PNP diode semiconductor wafer and electrode connections to the two terminal zones of the wafer, characterized in that the first terminal zone extends laterally completely across the wafer and has a central region of reduced thickness and a surrounding region of increased thickness, the second zone extends laterally completely across the wafer and has a centrally located region whose thickness is at least several diffusion lengths of minority carriers therein and a surrounding portion whose thickness is less than a diffusion length in minority carriers, the third zone extends laterally completely across the wafer and has a centrally located region of reduced thickness and the surrounding portion of increased thickness, and the fourth zone is centrally located and extends laterally across only a limited portion of the wafer.

10. A semiconductor diode comprising a PNP diode semiconductor wafer and electrode connections to the two terminal zones characterized in that the first zone is annular and extends laterally across only a limited portion of the wafer, the second zone extends laterally completely across the wafer and includes a thicker centrally located portion and a thinner surrounding portion, the third zone extends laterally completely across the wafer and includes a central portion of thickness less than the diffusion length of minority carriers therein and a sur-

rounding portion of thickness at least several diffusion lengths of minority carriers therein, and the fourth zone extends laterally completely across the wafer.

11. A semiconductive diode comprising a monocrystal-
line PNP silicon wafer and electrode connections to the
two terminal zones, the wafer being characterized in that
it includes an intermediate zone which extends laterally
completely across the wafer and has a first extended
region whose thickness is at least several times the dif-
fusion length of minority carriers therein and a second
extended region whose thickness is less than the diffusion
length of minority carriers therein, the sheet resistance
of said second extended region being sufficient to cause
emission concentration in favor of the first extended
region with increasing currents through the diode and the

terminal zone spaced from said intermediate zone extends
laterally across only a limited portion of the wafer and
is located substantially opposite the second extended
region of the intermediate zone, whereby the diode ex-
hibits a total alpha which is greater than unity for an
intermediate range of current and less than unity for
currents outside said intermediate range.

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UNITED STATES PATENT OFFICE
CERTIFICATION OF CORRECTION

Patent No. 2,959,504

November 8, 1960

Ian M. Ross et al.

It is hereby certified that error appears in the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 8, line 44, for the claim reference numeral "6"
read -- 7 --.

Signed and sealed this 2nd day of May 1961.

(SEAL)
Attest:

ERNEST W. SWIDER
Attesting Officer

DAVID L. LADD
Commissioner of Patents

UNITED STATES PATENT OFFICE
CERTIFICATION OF CORRECTION

Patent No. 2,959,504

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