

PATENT SPECIFICATION

(11)

1 480 116

(8)

1 480 116

- (21) Application No. 42449/74 (22) Filed 30 Sept. 1974
 (31) Convention Application No. 405 490 (32) Filed 11 Oct. 1973 in
 (33) United States of America (US)
 (44) Complete Specification published 20 July 1977
 (51) INT. CL.² H01L 29/747
 (52) Index at acceptance
 H1K 1CX 2S11G 2S22D 3E1M 3E5C1 3E5CY 3T6A 3T6B
 3TY 5B1 5B2 5B4 5C3A 5C3L 5CY 7K3 8M 8P
 9N1 AB
 (72) Inventors RICHARD WILLIAM KENNEDY
 EDWARD GEORGE TEFFT



(54) IMPROVEMENTS IN OR RELATING TO TRIACS

(71) We, GENERAL ELECTRIC COMPANY, a corporation organized and existing under the Laws of the State of New York, United States of America, of 1 River Road, Schenectady 12305, State of New York, United States of America, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to bidirectional triode thyristors or triacs.

Since its introduction, the bidirectional triode thyristor, or triac, has been growing in popularity among circuit designers. The reasons for this growth are evident; as a single component that can replace several components in many circuit applications, the triac can provide improvements in weight, size and cost. However, improvement is still being sought in some characteristics of triac performance. Consider, for example, the commonly used circuit in which a triac replaces two inversely connected parallel SCR's to selectively pass AC current. When using the SCR's each device has an entire half cycle in a back biased state to turn off. Thus, false firing due to the presence of mobile carriers when forward voltage is reapplied is rarely a problem. However, consider the corresponding triac circuit. One region of the triac pellet is conductive during one half cycle and another region is conductive during the following half cycle. See, for example, the *SCR Manual*, 5th Edition, copyright 1972 by the General Electric Co., or U.S. Patent 3,275,909. Consequently, in the AC application, one region of the triac is in a conductive state at all times except during brief periods near the crossovers of the AC input signal. If mobile charge carriers from the region which is then in a conductive state "spill over" into the region

which is then in a non-conductive state, that region can be inadvertently triggered by those carriers on the reversal of the applied voltage. This effect has limited the frequencies at which triacs can be used.

It is, therefore, an object of this invention to provide a triac which resists carrier spillover from the region in a conductive state to the region in a non-conductive state.

The present invention provides a bidirectional triode thyristor pellet comprising:

a body of semiconductor material that defines two major surfaces and is selectively diffused with impurities so as to define a first conductive region and a second conductive region which can conduct, when triggered, in opposite senses;

means for stimulating carrier recombination comprising an auxiliary impurity diffused into said body at the boundary between said first conductive region and said second conductive region;

and a glass passivation layer on the periphery of said body.

The first conductive region is for conducting current in a first direction, the second conductive region is for conducting current in a second, opposite direction and there is a gate region for receiving triggering signals. The auxiliary impurity that stimulates carrier recombination is diffused into the body of semiconductor material at the boundaries between these three regions for inhibiting the interregion carrier drift discussed above. As disclosed below the auxiliary impurity can be gold and is preferably diffused into the internal layers where the depletion layer is formed. Thereby, a triac capable of operation at higher frequencies in AC applications is provided inasmuch as inadvertent triggering due to carrier spillover is prevented. Inasmuch as the gold is not covering the conductive areas but is selectively diffused, it will be appreciated

that characteristics such as conducting voltage drop are not significantly affected.

A method for making the pellets is disclosed below. A wafer of semiconductor material defining two major surfaces is selectively diffused with impurities in a conventional manner to divide the wafer into a plurality of portions, each portion being properly diffused to form a triac pellet. Each pellet, of course, includes the first and second conductive regions and the gate region. One of the major surfaces of the wafer is masked, leaving exposed only the boundaries between the several regions in each pellet. One preferred method of masking that is described below includes thermally growing a layer of oxide on the wafer and then etching openings over the boundaries. The auxiliary impurity, for example gold, is then diffused through the openings. A preferred diffusion process that is described below includes vapor depositing the gold over the oxide and applying heat to diffuse the impurity into the wafer to a depth at least sufficient to put gold in the interior layers. From the above brief discussion it will be apparent that the method of fabricating improved triac pellets can be practiced with conventional processing equipment.

Following diffusion, the wafers are grooved between the portions and then divided into individual pellets along the grooves. The openings in the oxide that were used during the gold diffusion step are masked at a low temperature with a material such as a lacquer or wax and photoresist techniques are used to locate the positions of the grooves. An advantage of the subject method is that the areas to be grooved and the areas immediately therearound are still covered with oxide. Thus the grooves will be well defined and can be precisely located inasmuch as they are located by openings in the oxide. Simultaneous etching of grooves on each side is performed.

The grooves are then glass passivated. A preferred glass passivation process includes depositing glass in a particulate form in the grooves and then applying heat to fuse the glass. A carrier such as alcohol can be used with particulate glass and a temperature of about 700° Centigrade is sufficient to fuse the glass. That is significant inasmuch as the auxiliary impurity diffusion process takes place at 800-900° Centigrade. Thus the glass is fused at a lower temperature and the glass fusion process does not adversely affect the desired distribution of gold within the semiconductor wafer since no significant gold migration takes place at 700° Centigrade.

A better understanding of the present invention may be obtained upon perusal of the following description of a preferred em-

bodiment thereof, taken in conjunction with the accompanying drawings wherein:

Figure 1 is an elevation view of part of a semiconductor wafer;

Figure 2 is a plan view of the part depicted in Figure 1 at a later stage in processing;

Figure 3 is a plan view of a portion of the wafer at a still later stage of processing; and

Figure 4 is an elevation view of a completed triac pellet.

Referring first to Figure 1, there is shown a body of semiconductor material 21 that is a part of a semiconductor wafer which defines a first major surface 22 and a second major surface 23 and is approximately one to three inches in diameter as is conventional in the semiconductor art. In a preferred method of manufacture, the body 21 is initially doped to be of n type conductivity and a dopant that produces a p type conductivity is diffused from the upper major surface 22 to create a p region 24 adjacent thereto and from the lower surface 23 to create a p region 25 adjacent thereto.

The wafer in effect is divided into portions by the diffusion of another impurity in a preselected distribution within each portion. A plan view of a small area of the upper major surface 22 is shown in Figure 2. Two portions and the diffusion patterns thereon are shown. In each portion a large n plus type emitter 26, an n plus type junction gate emitter 27 and an n plus type conductivity control region 28 are diffused. In addition, a second n plus type emitter region 29 is diffused in the lower p type region 25. One of the second n plus type emitter regions 29 is shown by broken lines in Figure 2 so that its juxtaposition can be appreciated. Only one region 29 is shown to preserve clarity. As shown more clearly in Figure 4, the n plus regions 26, 27, 28 and 29 are diffused only approximately halfway through the upper p region 24 and lower p region 25. Thus, it will be appreciated that each portion of the wafer is adapted to form a triac pellet 31. Further information concerning the diffusion of triac pellets to this stage of processing may be had by reference to the above cited patent.

Reference is now made to Figure 3. It will be appreciated that, as is conventional in the triac art, each portion or pellet 31 comprises a first conductive region 32 which is substantially coextensive with the first n plus type emitter region 26 and a second conductive region 33 that is coextensive with most of the second n plus type emitter region 29. Furthermore, a gate region 34 is included in the vicinity of the n plus type junction gate emitter 27. As is well known in the triac art, when a triac is used for selectively passing AC current, the first con-

ductive region 32 conducts during one half of the AC cycle and the second conductive region 33 conducts during the subsequent half cycle. The undesired "spillover" discussed above is carrier migration across the boundary between the regions 32 and 33 that was discussed above.

In order to prevent carrier migration the following process is employed. The first major surface 22 is selectively masked to leave exposed only the region boundaries. A convenient and efficient method of performing the masking operation is to expose the wafer to a temperature of at least 1100° Centigrade to thermally grow a layer of oxide on the surfaces thereof. For the masking operation, the oxide need be on only one of the major surfaces. However, for reasons to be discussed hereinafter, the oxide is preferably grown on each of the major surfaces. Following oxide growth, a generally Y-shaped area of the oxide is removed as shown by the broken lines in Figure 3. It should be pointed out that, of course, this Y-shaped opening is made over each of the several portions in the wafer. The opening is preferably made by conventional techniques such as etching.

An auxiliary impurity which stimulates carrier recombination is then diffused through the openings. Such impurities include, for example, gold and platinum. Thus, gold, for example, is vapor deposited on the first major surface 22. Following vapor deposition, the wafer is exposed to a temperature in the range of from 800 to 900° Centigrade. Only in the Y-shaped openings does the gold contact the semiconductor material. Thus the gold diffuses into the crystal only in the openings as shown in Figure 4. Preferably, the temperature and time of the diffusion operation is controlled such that the gold is diffused into the interior layers. Therefore a region containing gold atoms is created at the boundaries between the first and second conductive regions and the gate region and carrier migration across those boundaries is inhibited. The first and second conductive regions remain substantially gold free.

To complete the processing, the wafer must be divided into triac pellets. An advantageous way of providing such a division is as follows. First, the Y-shaped opening is covered with a protective coating at a relatively low temperature. For example, a wax or lacquer can be coated over the opening. Then, by conventional techniques, such as photoresist techniques, areas where grooves are to be etched to separate the pellets are located. The grooves are preferably etched from both major surfaces, and thus the desirability of growing the oxide coating on each of the major surfaces 22 and 23 will be appreciated. The grooves are

preferably etched deeply enough to intersect all the p-n junctions.

As mentioned previously an advantage of this method is that it permits glass passivation of the pellets. Before glass passivation is performed, the wax or lacquer should be removed from the Y-shaped opening. That is because those organic substances may release vapors during the passivation process that can have deleterious effects on the further processing. Following the removal of the wax, glass, in a particulate form and suspended in a carrier such as alcohol, is deposited in the grooves. The alcohol is quickly evaporated at a low temperature and then the wafer is exposed to a temperature of about 700° Centigrade. At that temperature the glass fuses forming a passivation layer 35 in the grooves. It will be appreciated that the 700° temperature used during the passivation step is lower than the temperature required to mobilize the gold atoms. Thus, the distribution of gold that was previously created is not disturbed.

Following the glass passivation process, the wafer is divided along the grooves to form the pellets 31 as shown in Figures 3 and 4. This division is by conventional techniques.

Thus there has been developed a triac pellet with gold diffused along the boundaries between the first and second conductive regions and the gate region. Consequently, carrier migration across those boundaries is prevented. Furthermore, it has been shown that the process is entirely compatible with glass passivation techniques.

Many modifications and variations of the subject invention will be obvious to those skilled in the art. For example, it is believed that the primary need for the gold is at the boundary between the first and second conductive regions 32, 33. Thus gold diffusion only along the boundary therebetween will result in a substantially improved device.

WHAT WE CLAIM IS:—

1. A bidirectional triode thyristor pellet comprising a body of semiconductor material that defines two major surfaces and is selectively diffused with impurities so as to define a first conductive region and a second conductive region which can conduct, when triggered, in opposite senses; and means for stimulating carrier recombination comprising an auxiliary impurity diffused into said body at the boundary between said first conductive region and said second conductive region; and a glass passivation layer on the periphery of said body.

2. A pellet according to Claim 1 wherein said auxiliary impurity is diffused into an internal portion of an n type conductivity.

ductive region 32 conducts during one half of the AC cycle and the second conductive region 33 conducts during the subsequent half cycle. The undesired "spillover" discussed above is carrier migration across the boundary between the regions 32 and 33 that was discussed above.

In order to prevent carrier migration the following process is employed. The first major surface 22 is selectively masked to leave exposed only the region boundaries. A convenient and efficient method of performing the masking operation is to expose the wafer to a temperature of at least 1100° Centigrade to thermally grow a layer of oxide on the surfaces thereof. For the masking operation, the oxide need be on only one of the major surfaces. However, for reasons to be discussed hereinafter, the oxide is preferably grown on each of the major surfaces. Following oxide growth, a generally Y-shaped area of the oxide is removed as shown by the broken lines in Figure 3. It should be pointed out that, of course, this Y-shaped opening is made over each of the several portions in the wafer. The opening is preferably made by conventional techniques such as etching.

An auxiliary impurity which stimulates carrier recombination is then diffused through the openings. Such impurities include, for example, gold and platinum. Thus, gold, for example, is vapor deposited on the first major surface 22. Following vapor deposition, the wafer is exposed to a temperature in the range of from 800 to 900° Centigrade. Only in the Y-shaped openings does the gold contact the semiconductor material. Thus the gold diffuses into the crystal only in the openings as shown in Figure 4. Preferably, the temperature and time of the diffusion operation is controlled such that the gold is diffused into the interior layers. Therefore a region containing gold atoms is created at the boundaries between the first and second conductive regions and the gate region and carrier migration across those boundaries is inhibited. The first and second conductive regions remain substantially gold free.

To complete the processing, the wafer must be divided into triac pellets. An advantageous way of providing such a division is as follows. First, the Y-shaped opening is covered with a protective coating at a relatively low temperature. For example, a wax or lacquer can be coated over the opening. Then, by conventional techniques, such as photoresist techniques, areas where grooves are to be etched to separate the pellets are located. The grooves are preferably etched from both major surfaces, and thus the desirability of growing the oxide coating on each of the major surfaces 22 and 23 will be appreciated. The grooves are

preferably etched deeply enough to intersect all the p-n junctions.

As mentioned previously an advantage of this method is that it permits glass passivation of the pellets. Before glass passivation is performed, the wax or lacquer should be removed from the Y-shaped opening. That is because those organic substances may release vapors during the passivation process that can have deleterious effects on the further processing. Following the removal of the wax, glass, in a particulate form and suspended in a carrier such as alcohol, is deposited in the grooves. The alcohol is quickly evaporated at a low temperature and then the wafer is exposed to a temperature of about 700° Centigrade. At that temperature the glass fuses forming a passivation layer 35 in the grooves. It will be appreciated that the 700° temperature used during the passivation step is lower than the temperature required to mobilize the gold atoms. Thus, the distribution of gold that was previously created is not disturbed.

Following the glass passivation process, the wafer is divided along the grooves to form the pellets 31 as shown in Figures 3 and 4. This division is by conventional techniques.

Thus there has been developed a triac pellet with gold diffused along the boundaries between the first and second conductive regions and the gate region. Consequently, carrier migration across those boundaries is prevented. Furthermore, it has been shown that the process is entirely compatible with glass passivation techniques.

Many modifications and variations of the subject invention will be obvious to those skilled in the art. For example, it is believed that the primary need for the gold is at the boundary between the first and second conductive regions 32, 33. Thus gold diffusion only along the boundary therebetween will result in a substantially improved device.

WHAT WE CLAIM IS:—

1. A bidirectional triode thyristor pellet comprising a body of semiconductor material that defines two major surfaces and is selectively diffused with impurities so as to define a first conductive region and a second conductive region which can conduct, when triggered, in opposite senses; and means for stimulating carrier recombination comprising an auxiliary impurity diffused into said body at the boundary between said first conductive region and said second conductive region; and a glass passivation layer on the periphery of said body.

2. A pellet according to Claim 1 wherein said auxiliary impurity is diffused into an internal portion of an n type conductivity.



3. A pellet according to claim 1 or claim 2 comprising a thermally grown oxide on one of said major surfaces.

4. A pellet according to any of the preceding claims wherein said auxiliary impurity is gold.

5. A pellet according to any of the preceding claims comprising a layer of thermally grown oxide on each of said major surfaces.

6. A pellet according to any of the preceding claims comprising a gate region at least partially bounded by said first conductive region and said second conductive region and wherein said auxiliary impurity is also diffused into the boundaries between said gate region and said first conductive region and said second conductive region.

7. A method for fabricating bilateral thyristor pellets in accordance with any of the preceding claims comprising the steps of providing a wafer of semiconductor material defining two major surfaces and selectively diffused with impurities so as to define a plurality of portions each of which, when the wafer is divided, can provide a pellet body and each portion comprising a first conductive region and a second conductive region which can conduct, when triggered, in opposite sense; applying a mask to one of said major surfaces, wherein said mask defines an opening at the boundary between said first conductive region and said second conductive region in each portion; diffusing an auxiliary impurity through said openings, wherein said auxiliary impurity stimulates carrier recombination at said boundaries; masking the openings at a temperature at which no significant migration of said auxiliary impurity takes place; forming fresh openings in the mask defining the boundary openings where intersecting grooves that will separate said portions are to be formed; forming grooves in the wafer surface through said fresh openings; coating the grooves with glass; and dividing the wafer along the grooves so as to separate the wafer into pellets.

8. A method according to Claim 7 wherein said step of applying a mask to define boundary openings comprises the steps of thermally growing a layer of oxide on said one major surface and selectively re-

moving the portions of said layer of oxide that overlie said boundaries.

9. A method according to either of Claims 7 or 8 wherein said step of diffusing an auxiliary impurity comprises vapor depositing said auxiliary impurity on said semiconductor material.

10. A method according to any one of claims 7 to 9 wherein said step of coating said grooves comprises depositing said glass in said grooves in a particulate form and applying heat to fuse said glass.

11. A method according to any one of claims 8 to 10 wherein said step of thermally growing a layer of oxide is carried out at a temperature of at least 1100° Centigrade, said step of diffusing an auxiliary impurity is carried out at from 800-900° Centigrade and said step of applying heat to fuse said glass is carried out at about 700° Centigrade.

12. A method according to any one of Claims 7 to 11 wherein said auxiliary impurity is gold.

13. A method according to any one of Claims 7 to 12 wherein each of said portions comprises a gate region at least partially bounded by said first conductive region and said second conductive region and wherein said boundary mask defines openings at the boundaries between said gate region and said first conductive region and said second conductive region.

14. A method according to any one of claims 7 to 13 wherein the openings are masked with wax or lacquer.

15. A method according to any one of claims 7 to 14 wherein the fresh openings are formed by selectively applying photoresist and etching.

16. A method for fabricating bidirectional triode thyristors substantially as hereinbefore described with reference to and as shown in the accompanying drawings.

17. A triac made by the method according to claim 16.

P. M. TURNER,

Agent for the Applicants.

Reference has been directed in pursuance of section 9, subsection (1) of the Patents Act 1949, to patents No. 1 327 203 and No. 1 214 180.

