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(54) **High voltage resistive structure integrated on a semiconductor substrate**

Auf einem Halbleitersubstrat integrierte Hochspannungs-Widerstandsstruktur

Structure de résistance à haute tension intégrée sur un substrat semi-conducteur

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(73) Proprietor: **STMicroelectronics S.r.l.**
20041 Agrate Brianza (Milano) (IT)

(72) Inventor: **Leonardi, Salvatore**
95025 Aci S. Antonio (Catania) (IT)

(74) Representative: **Botti, Mario**
Botti & Ferrari S.r.l.,
Via Locatelli, 5
20124 Milano (IT)

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- **PATENT ABSTRACTS OF JAPAN vol. 012, no. 020 (E-575), 21 January 1988 -& JP 62 177959 A (NEC CORP), 4 August 1987**
- **PATENT ABSTRACTS OF JAPAN vol. 012, no. 003 (E-570), 7 January 1988 -& JP 62 165352 A (NEC CORP), 21 July 1987**
- **PATENT ABSTRACTS OF JAPAN vol. 098, no. 002, 30 January 1998 -& JP 09 257831 A (NIPPON SEIKI CO LTD), 3 October 1997**

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Description

Field of application

[0001] The present invention relates to an integrated high voltage resistive structure on a semiconductive substrate.

[0002] More specifically the invention relates to a serpentine integrated resistive structure on a semiconductive substrate having a first type of conductivity opposite to that of the semiconductor substrate.

[0003] The invention relates in particular, but not exclusively to a resistive structure at high voltage to be integrated on a semiconductive substrate together with power devices and the following description is made with reference to this field of application with the sole objective of simplifying its disclosure.

Prior art

[0004] As is well known, high voltage resistive structures which are integrated on a semiconductive substrate find ample use in the field of application for power devices formed as integrated circuit, for example VIPower devices.

[0005] VIPower devices integrate on the same chip a region on which the power devices are formed (power region) and a region on which signal devices are formed (signal region). In some applications, it is necessary to arrange, inside the signal region, a division of the substrate voltage. This can be provided by using a resistive structure connected between the substrate and a control region of the signal device. This resistive structure will therefore be subjected to the substrate voltage Vs which as is well known, in devices of the VIPower type, can reach elevated values of up to 2KV (from which the term resistive structure or high voltage resistance HV).

[0006] In figures 1 and 2 the electrical diagrams of two examples of possible applications of the high voltage resistive structures are shown.

[0007] In figure 1 for example, a first circuital structure C1 is shown comprising a bipolar component Q1 of the NPN type connected in series on the emitter region to a first terminal of the resistance R1. A Zener diode D1 is connected, in inverted polarization, between the base terminal of the component Q1 and a second terminal of the resistance R1. A high voltage resistance R_{HV} is connected between the collector region and the base region of the component Q1.

[0008] When a current I1 flows through the resistance RHV, the component Q1 switches on and drives a low voltage circuitry BT connected to an emitter region of the component Q1. The current which flows through the resistance R_{HV} obviously depends on the substrate voltage Vs and on the value of the resistance itself.

[0009] In figure 2, a second circuital structure C2 is shown comprising two circuital branches 1a and 2a having a common node A.

[0010] The first branch 1a comprises a Zener diode chain D2, D3 and D4 connected to the base region of a first bipolar component Q2, which is polarized by a resistance R2.

[0011] The second branch 2a comprises a resistance R3 connected in series to the emitter region of a second bipolar component Q3, which is controlled by a battery Vb. A high voltage resistance RHV is then connected to node A.

[0012] In this configuration the voltage value on node A can be used as a reference value for permitting conduction on branch 1 or on branch 2, depending on the value of Vz of the Zener chain, of the Vb battery voltage as well as from the other components present in the circuitry. In this case, the resistance R_{HV} is used simply as a voltage divider.

[0013] In both examples of application, the voltage of substrate Vs applied to the resistance RHV, as said before, can reach elevated values. The division of voltage used as driver signal for the linear region (circuit C2), as also the current which flows on the resistance HV (circuit C1), assumes values which must be comparable and wherefore not above the maximum voltage of the well inside which the signal circuitry is integrated, and therefore of the maximum current foreseen for a determined circuit structure. This means that the resistance HV must have a resistive value such as to permit the division or the current required by the driving circuitry as foreseen by the circuital structure used.

[0014] This resistance value can also be in the order of some MΩ and in any case not less than a few tens of KΩ.

[0015] A first known technical solution for the formation of resistive structures with high resistive values foresees forming doped regions having a high resistivity on a semiconductive substrate.

[0016] Though advantageous in many respects, this first solution has various problems, in particular even forming regions of high resistivity, fairly high area dimensions are required for the die.

[0017] Another solution of the prior art foresees the formation of long resistive structures which, according to the area used, minimise the dimensions of silicon occupied thanks to a particular layout.

[0018] One layout embodiment according to the prior art is shown in figure 3.

[0019] In particular, in a substrate of N 1' type a serpentine region 2' of P type is formed.

[0020] This type of layout, nevertheless, can not be used for the resistive structure at high voltage, because it would occupy a fairly large area of silicon.

[0021] This is due to the size of the depletion region 3', outlined in figures 3 and 4, that is inversely proportional to the concentration of dopant (and therefore directly proportional to the resistive value), during inverted polarization of a portion of doped silicon and therefore the size of this depletion region is very important in the resistive structures HV.

[0022] Even if the high voltage resistive structures can be integrated by using to the more resistive layers used in the technology, VIPower devices capable of supporting elevated voltages necessarily have an elevated resistivity of the substrate, in varying degrees of size bigger than the more resistive layers available with current technological processes. This means that, layouts which tend to optimize area availability of silicon on chips such as that of figure 3, have the problem of pinch-off phenomenon.

[0023] In particular, the depletion regions of two or more parallel branches of the resistive structure come info contact, as illustrated on the right side of figure 4, with subsequent alterations in the values of the resistive structure itself and therefore of the functioning of the circuitry of which it is a part.

[0024] In order to overcome this problem, it is necessary in the design phase of the layout for the high voltage resistive structure that the distance between the various branches of the serpentine resistive structure which face each other in parallel, should be more than the total of the widths of the depletion regions which belong to each branch. This means that the branches of the resistive structure subjected to a high voltage must be set apart according to the drop in voltage on the resistive structure itself.

[0025] As a consequence of this, the layout in figure 4, in the case of a high voltage resistance structure, takes the form shown in figure 5 with considerable dimensions of silicon areas.

[0026] Furthermore, the high voltage have on the resistive structure, would require border structures, capable of projecting the more pressing regions against premature breakdowns from the high voltages. Metal field plates or rings with a high resistive structure are used for example in this case, which anyway tend to further increase the area of silicon occupied.

[0027] In order to reduced the lateral depletion region between the various branches of the resistive, structure, a known technique enriches the layer intended for integration of the resistive structure itself.

[0028] Nevertheless this solution reduces the capability of the device to hold the voltage, in that in order to obtain a reduction of the widening of the depletion region it would be necessary to have a concentration of dopant in the surface region which would be very high.

[0029] The same considerations made above can also be repeated in the case in which the high voltage resistive structure is integrated around the region at high voltage which surrounds the device. In this way, above all if the device occupies a large area, a length of the resistive structure equal to a fraction of the entire perimeter of the device or at most equal to one or two perimeters permit the formation of the resistive structure desired.

[0030] In this case, in fact, the distances to be kept in mind in the design phase, involve the distances between the branches of the resistive structure itself and the well in which the power device is formed.

[0031] A known solution of a serpentine resistance region is disclosed in the Patent Abstract of Japan N. 62-165352 of the Nec Corporation. In this document the resistance region is surrounded by gloves filled by an insulator.

[0032] A known solution of resistance regions surround by a dielectric layer is disclosed in the Patent Abstract of Japan N. 62-177959 of the Nec Corporation.

[0033] The technical problem which is at the basis of the present invention is to form a serpentine resistive structure integrated on a semiconductive substrate, having structural and functional features such as to allow high voltage to be sustained without incurring in the pinch-off phenomenon between the parallel branches of the serpentine, overcoming the limitations and drawbacks which limit now the resistive structures formed according to the prior art.

Summary of the invention

[0034] The resolutive idea at the basis of the present invention is that of forming a resistive structure with integrated serpentine on a semiconductive substrate, in which, between at least two parallel portions of the serpentine, insulation regions are formed.

[0035] On the basis of such resolutive idea the technical problem is resolved by a resistive structure of the type previously indicated and defied in the characterising part of claim 1.

[0036] The characteristics and advantages of the device according to the invention result from the description, given hereinbelow, of an example of embodiment given as an indication and not limiting with reference to the attached designs.

Brief description of the drawings

[0037] In such drawings:

- figure 1 shows a schematic view of a driving circuit in which a high voltage resistance of the known type is used;
- figure 2 shows a schematic view of a divider circuit in which a high voltage resistance of the known type is used;
- figure 3 shows a schematic top view of a portion of semiconductive substrate in which a first embodiment of a resistive structure is integrated according to prior art;
- figure 4 shows a schematic view in vertical section along the IV - IV line of figure 3;
- figure 5 shows a schematic top view of a portion of semiconductive substrate on which a second embodiment of a resistive structure has been integrated

according to prior art;

- figure 6 shows a schematic top view of a portion of semiconductive substrate in which an embodiment of a resistive structure not forming part of the claimed invention has been integrated;

- figure 7 shows a schematic view in vertical section along the VII - VII line of figure 6;

- figure 8 shows a schematic top view of a portion of semiconductive substrate in which an embodiment of a resistive structure HV not forming part of the claimed invention has been integrated;

- figure 9 shows a schematic view in vertical section along the IX - IX line of figure 8;

- figure 10 shows a schematic top view of a portion of semiconductive substrate in which an embodiment of resistive structure HV has been integrated according to the invention;

- figure 11 shows a schematic view in vertical section along the XI - XI line of figure 10;

- figure 12 shows a schematic top view of a portion of semiconductive substrate in which another embodiment of a resistive structure HV not forming part of the claimed invention has been integrated;

- figure 13 shows a schematic view in vertical section along the XIII - XIII line of figure 12.

Detailed description

[0038] With reference to figure 6, with 10 a resistive structure not forming part of the claims invention is indicated.

[0039] On a conductive substrate 1 of a first type of conductivity, for example of N type, a serpentine region 2 of a second type of conductivity is formed.

[0040] Such serpentine region 2 comprises at least one portion 3 which is substantially straight.

[0041] In particular, the serpentine region 2 comprises a series of portions 3 parallel to each other.

[0042] Between these parallel portions 3 of the serpentine region 2 at least one dielectric insulation region 4 (trench) is formed.

[0043] These trenches 4 engage on line 5, still of dielectric material, which substantially flows perpendicularly to the portions 3 of the serpentine regions 2.

[0044] As can clearly be seen in figure 6, a series of trenches 4 and line 5 form protective structure 6 which has a comb configuration.

[0045] Two comb configured protection structures 6 are engaged on opposite sides of the serpentine region 2.

[0046] With such configuration the perimeter of region 2 is substantially surrounded by dielectric regions.

[0047] The presence of trenches 4, according to the invention, avoids the formation of the depletion region 3' which, in prior art structures, is located around those portions of the serpentine region 2 which is subjected to high voltage.

[0048] In polarization Vs conditions of the substrate 1, the presence of trenches 4 placed in proximity of the external region to the serpentine region 2, allow the equipotential lines to reach the surface of the substrate along the internal walls of the dielectric region of the trench.

[0049] Though the dimensions of the trench widthwise are (1 ÷ 4 mm) much smaller than those of the depletion region necessary in resistive structures formed according to prior art (and therefore with a higher electric field when the same voltage is applied), the trench structure according to the invention, can withstand higher voltages as long as the critical electric field value in the oxide (about 600 V/mm) is much higher than it is in the silicon (20 V/mm per high voltage structure).

[0050] The vertical dimensions of the trenches 4, must be greater than that of the serpentine resistive structure 2 in order to protect the resistive structure from premature breakdowns.

[0051] An embodiment which is particularly advantageous is shown in figures 8 and 9. In the portions of the serpentine regions 2 more subjected to high voltage, two trenches 41 and 42 are formed between parallel portions 3.

[0052] Also a metal contact line formation, for example a metal field plate line suitably formed over the serpentine region 2, can improve the distribution of the potential lines above all in the proximity of the surface regions.

[0053] Also in this embodiment, the depth 8 of the protection structure 6, and therefore the single trenches 41, 42, must be such to reduce the depletion of the regions of substrate 1 which surround the serpentine region 2.

[0054] According to the invention, in fact the depth 8 of the trenches 41, 42 is greater than the depth 9 of the portions 3 of the serpentine region 2. In this way, the side depletion of the substrate region 1 is avoided

[0055] A further embodiment is shown in figures 10 and 11.

[0056] Such embodiment is particularly advantageous in improving voltage hold, above all in the embodiment in which several trenches are used.

[0057] In the substrate 1 of N type, a spacer region 7 of P- type is formed, in which a serpentine region 2 of P type is formed.

[0058] According to the invention, pairs of dielectric trenches 4 are located between parallel portions 3 of the serpentine region 2.

[0059] The depth of the region of spacer 7 is, advantageously, greater than the depth 9 of the serpentine region 2 and smaller than the depth 8 of the trenches.

[0060] The presence of the spacer region 7 forms, in the resistive structure according to the invention, a junction "pn" which allows the entire structure to withstand a

higher voltage, restoring, even though in a smaller way, the depletion effect which occurs in the case of on board structures formed by means of high resistivity rings.

[0061] An embodiment not forming part of the claimed invention is shown in figures 12, 13.

[0062] In a substrate 1 of the N type a first buried region 11 of P type is formed.

[0063] A resistive region 12 of high voltage of the P type is formed above the buried region 11.

[0064] The resistive region 12 and a region 13 of N+ type form a border structure which is formed on the surface of substrate 1.

[0065] A protection structure SI surrounds at least one portion of the resistive structure 12.

[0066] Also in this embodiment the presence of the protection structure SI avoids the side depletion of region 12.

[0067] For example, the protection structure SI comprises a pair of trenches 14 and 15 which are formed on both sides of the resistive region 12.

[0068] Advantageously, these trenches 14 and 15 contact the buried region 11.

[0069] Advantageously, another trench 16 is formed between the resistive region 12 and the region 13 of N+ type.

[0070] As is shown in this fourth embodiment it is possible to produce resistive structures at high voltages integrated in border structures.

[0071] In this way, it is possible to anularly integrate this border structure around the portion of substrate in which power devices have been formed, thereby reducing the area of silicon used.

[0072] In conclusion, the side dimensions of the protection structure 6 which surrounds the serpentine region 2 at high voltage are reduced with respect to the serpentine region 2' at high voltage formed according to the prior art, even when the resistive structure according to the invention comprised several trenches.

[0073] The same silicon area being taken up, these embodiments allow the rather long resistive serpentine region 2 to be integrated, with a corresponding advantage of a higher value of resistive structure. Vice versa, the resistive structure being the same, the silicon area used by the resistive structure according to the invention is smaller with respect to the case of resistive structure formed according to prior art.

Claims

1. High voltage resistive structure (10) integrated on a semiconductive substrate (1) having a first type of conductivity and formed by a serpentine region (2) of conductivity opposite to the substrate conductivity, where between pairs of parallel portions (3) of the serpentine region (2) there is an insulating portion, wherein said insulating portion comprises a plurality of insulating trenches (41, 42), extending more in depth in the substrate than the serpentine region (2), each of said insulating trenches (41, 42) being spaced apart from said parallel portions (3), a first and a second plurality of said insulating trenches (41, 42) engaging a respective insulating trench line (5) to form a first and a second comb configuration that are engaged on opposite sides of the serpentine region (2), and in that said high voltage resistive structure (10) comprises a spacer region (7) having a concentration of dopant which is less than that of the serpentine region (2), said serpentine region (2) being in said spacer region (7).

2. Resistive structure (10) according to claim 1, **characterised in that** said trench (4) extends in depth into the substrate more than the spacer region (7).

3. Resistive structure (10) according to claim 1, **characterised in that** said insulating trenches (4) are made of oxide.

4. Resistive structure (10) according to claim 1, **characterised in that** said serpentine region (2) and said spacer region (7) are of P type.

Patentansprüche

1. Hochspannungs-Widerstandstruktur (10), die auf einem Halbleitersubstrat (1) eines ersten Leitfähigkeitstyps integriert ist und die durch einen Serpentinenbereich (2) mit entgegengesetzter Leitfähigkeit zu der Leitfähigkeit des Substrats gebildet ist, wobei zwischen Paaren von parallelen Bereichen (3) des Serpentinenbereichs (2) ein Isolierbereich vorhanden ist, wobei der Isolierbereich eine Mehrzahl von isolierenden Gräben (41, 42) aufweist, die sich in dem Substrat auf eine größere Tiefe als der Serpentinenbereich (2) erstrecken, wobei jeder der isolierenden Gräben (41, 42) von den parallelen Bereichen (3) beabstandet ist, wobei eine erste und eine zweite Mehrzahl der isolierenden Gräben (41, 42) mit einer jeweiligen Isoliergraben-Leitung (5) zusammenwirken, um eine erste und eine zweite Kammkonfiguration zu bilden, die auf gegenüberliegenden Seiten des Serpentinenbereichs (2) eingreifen, und dass die Hochspannungs-Widerstandsstruktur (10) einen Abstandshalterbereich (7) mit einer Dotierstoff-Konzentration aufweist, die geringer ist als die des Serpentinenbereichs (2), wobei der Serpentinenbereich (2) in dem Abstandshalterbereich (7) vorgesehen ist.

2. Widerstandsstruktur (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** sich der Graben (4) auf eine größere Tiefe in dem Substrat als der Abstandshalterbereich (7) erstreckt.

3. Widerstandsstruktur (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** die Isoliergräben (4) aus Oxid gebildet sind.

4. Widerstandsstruktur (10) nach Anspruch 1, **dadurch gekennzeichnet, dass** der Serpentinenbereich (2) und der Abstandshalterbereich (7) p-leitend sind.

Revendications

1. Structure résistive à haute tension (10) intégrée sur un substrat semiconducteur (1) présentant un premier type de conductivité et formée par une région en serpentin (2) de conductivité opposée à la conductivité de substrat, où entre des paires de parties parallèles (3) de la région en serpentin (2), il existe une partie isolante, où ladite partie isolante comprend une pluralité de tranchées isolantes (41, 42), s'étendant davantage en profondeur dans le substrat que la région en serpentin (2), chacune desdites tranchées isolantes (41, 42) étant espacée desdites parties parallèles (3), une première et une seconde pluralités desdites tranchées isolantes (41, 42) s'engageant avec une ligne de tranchées isolantes respective (5) pour former des première et seconde configurations en peigne qui s'engagent sur les côtés opposés de la région en serpentin (2), et en ce que ladite structure résistive à haute tension (10) comprend une région d'espacement (7) ayant une concentration de dopant qui est inférieure à celle de la région en serpentin (2), ladite région en serpentin (2) se trouvant dans ladite région d'espacement (7).

2. Structure résistive (10) selon la revendication 1, **caractérisée en ce que** ladite tranchée (4) s'étend davantage en profondeur dans le substrat que la région d'espacement (7).

3. Structure résistive (10) selon la revendication 1, **caractérisée en ce que** lesdites tranchées isolantes (4) sont constituées d'oxyde.

4. Structure résistive (10) selon la revendication 1, **caractérisée en ce que** ladite région en serpentin (2) et ladite région d'espacement (7) sont du type P.

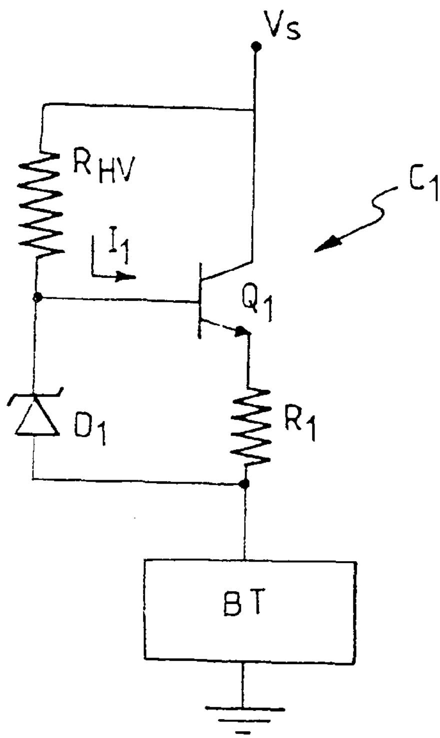


FIG.1

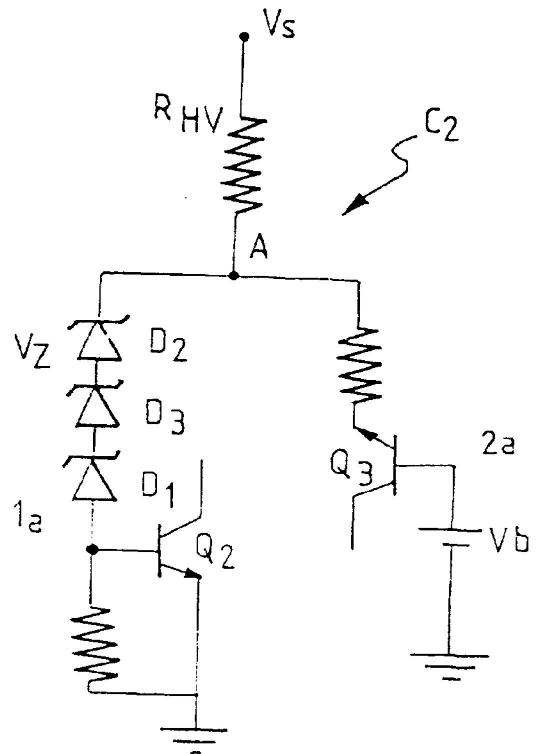
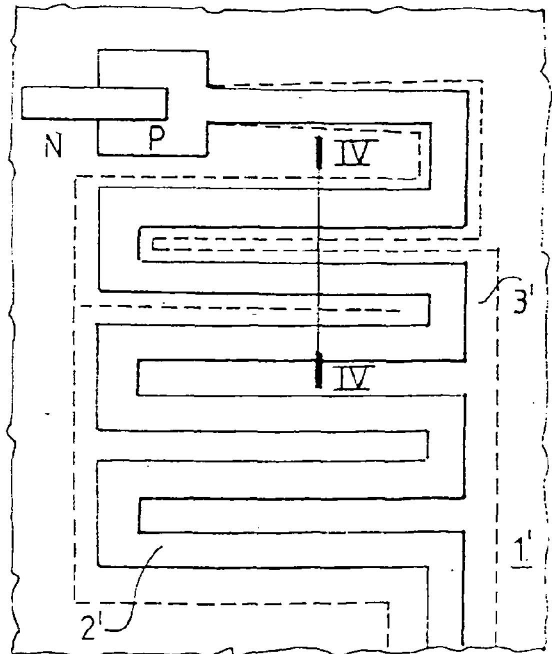


FIG.2

FIG.3



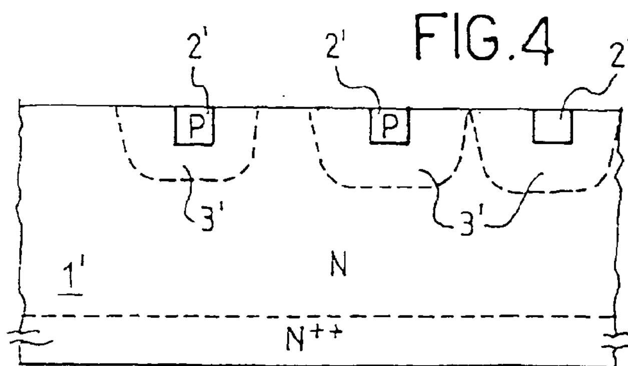


FIG.4

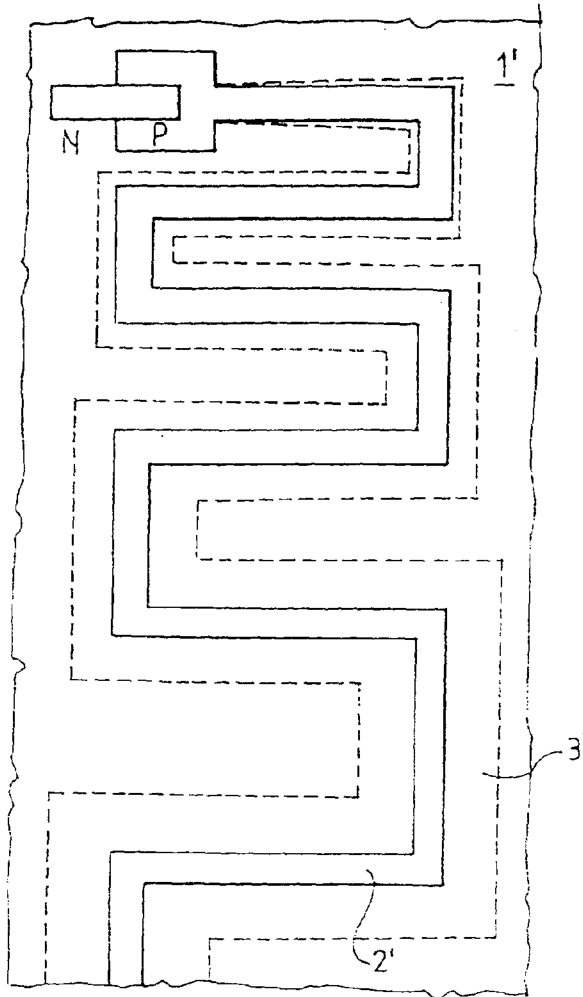


FIG.5

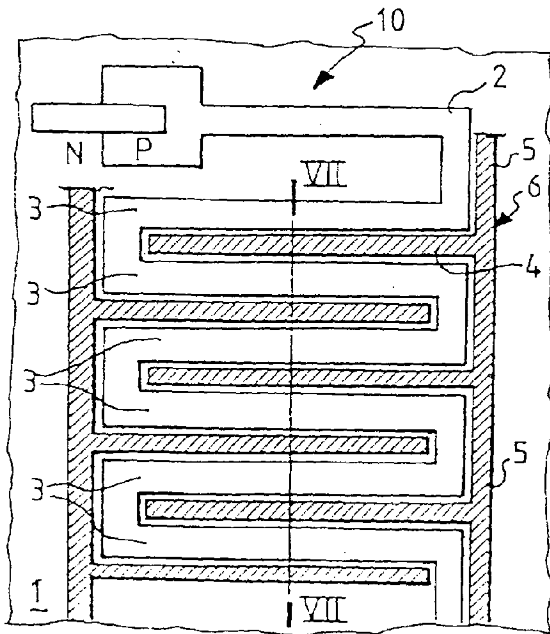


FIG.6

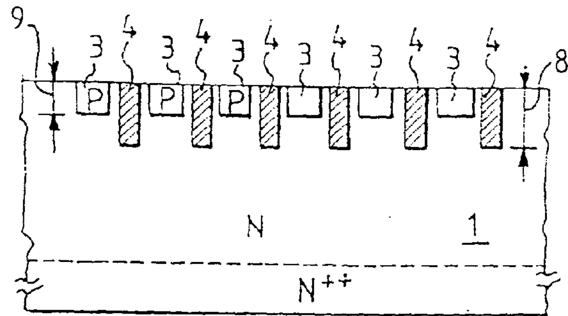


FIG.7

FIG.8

FIG.9

FIG.10

FIG.11

FIG.12

FIG.13

REFERENCES CITED IN THE DESCRIPTION

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Non-patent literature cited in the description

- *PATENT ABSTRACTS OF JAPAN,* 62-165352 **[0031]**
- *PATENT ABSTRACTS OF JAPAN,* 62-177959 **[0032]**