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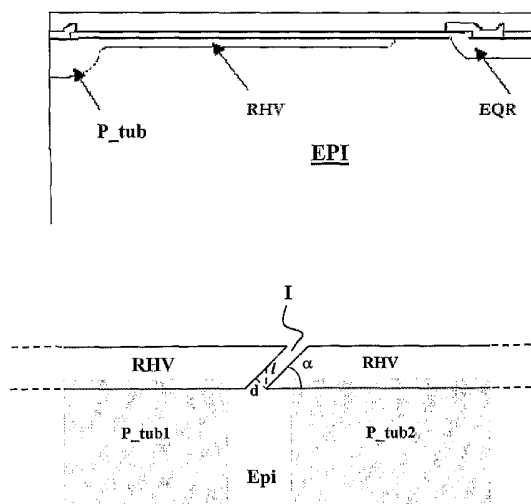
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(54) Title: INTEGRATED HIGH VOLTAGE POWER DEVICE HAVING AN EDGE TERMINATION OF ENHANCED EFFECTIVENESS



(57) Abstract: Instabilities and related drawbacks that arise when interruptions of a perimetral high voltage ring extension implanted regions (RHV) of a main junction (P_tub 1, (P_tub2, ...)) of an integrated device must be realized may be effectively prevented. This important result is achieved by an extremely simple expedient: whenever an interruption (I) of the high voltage ring extension must be created, it is not realized straight across it along a common orthogonal direction to the perimetral implanted region, on the contrary, the narrow interruption is defined obliquely or slantingly across the width of the perimetral high voltage ring extension. In case of a straight interruption, the angle of slant (α) may be generally comprises between 30 and 60 degrees and more preferably is 45 degrees or close to it. Naturally, the narrow interruption is created by masking it from dopant implantation when realizing the perimetral high voltage ring extension region.

WO 2006/030467 A1

“INTEGRATED HIGH VOLTAGE POWER DEVICE HAVING AN EDGE TERMINATION OF ENHANCED EFFECTIVENESS”

FIELD OF THE INVENTION

The present invention relates in general to integrated devices including power
5 transistors of either bipolar junction or MOS type and more in particular to their
edge terminations for enhancing the high voltage breakdown characteristics of the
integrated device.

DISCUSSION OF THE PRIOR ART

When integrating power devices destined to function at relatively high voltages, it
10 is imperative to ensure an adequately high breakdown voltage of main junctions
of the integrated device, for example the base-collector P-N junction of a power
bipolar junction transistor (BJT) or the body-drain junction of a power MOS. This
is done by realizing an appropriate edge termination or edge structure capable of
reducing the effects of the curvature of these junctions at risk around the perimeter
15 of the integrated structure which generally coincide with the edges of the
semiconducting chip. As it is well known to a skilled designer, an appropriate
edge termination may achieve an effectiveness close to perfection, that is it may
ensure a breakdown voltage BV of the device practically coincident or close to the
theoretical BV of an infinite planar parallel junction.

20 According to a well known approach, the edge termination relies on the extension
of the main junction by forming, by ion implantation, a continuous annular
extension of the main junction, commonly referred to as high voltage ring (briefly
RHV) around the perimeter of the integrated device structure or for a substantial
portion of the perimeter.

25 According to common fabrication technologies, such an extension of the main
junction is formed along the perimeter of the active area occupied by an integrated
power transistor and generally also by control circuitry integrated on the same

chip, by introducing, by ion implantation techniques, a controlled dose of dopant such to realize a ring-like implanted extension region electrically connected to a main junction, for example to the current terminal (collector or drain) of an integrated device, represented by a diffused region (for example a P_{tub} diffusion) in the epitaxial layer (EPI) grown on a semiconducting substrate.

The partial cross-sectional view of Figure 1 depicts a typical edge termination of an integrated power BJT.

In this way, upon an increase of the voltage applied to the substrate, the region of the high voltage ring RHV extension of the main junction (P_{tub}) is completely depleted and the potential distributes itself at the surface along the whole length of the high voltage RHV extension with a consequent reduction of the effects of the edge curvature of the main junction as well as of the intensity of the electric field at the surface.

By virtue of this “spreading” mechanism implemented by realizing the high voltage ring extension RHV, the device may reach a breakdown voltage close to the limit case of an infinite planar parallel junction, that is an almost hundred percent effectiveness.

In such an edge termination structure including the presence of a high voltage ring extension RHV of the main junction along the whole or at least part of the perimeter of the integrated structure of a power transistor, the implanted high voltage ring RHV region physically encroaches the main diffusion (e.g. the collector or the drain) of the power transistor. In other words the implant mask for the RHV extension region defines an implant window that partially overlap the main diffusion.

In reality, the layout of an integrated circuit may comprise more integrated power transistors along with a control region containing signal processing circuitries. In general, there may be several distinct diffusions of the same type of conductivity, that is forming main junctions that may risk breakdown in case of excessively

high voltage that could be applied to the main junction through the semiconducting substrate, juxtaposed one to the other and separated by the generally lightly doped region of opposite type of conductivity that commonly is the epitaxially grown layer formed on the semiconducting crystal substrate.

- 5 These distinct main diffusions of the same type may generally assume different voltages during operation of the integrated device. In these cases, it is necessary to interrupt the continuity of the high voltage ring extension RHV, by defining in the RHV implant mask a narrow interruption I of the perimetral or ring implanted region diffusion over the lightly doped region of separation between distinct
10 diffusions of the same type likely to assume different voltages, as depicted in Figure 2.

- Of course, the need to realize these necessary narrow interruptions of the continuity of the would-be continuous implanted high voltage ring extension region may determine a sensitivity of the edge termination structure to the
15 presence of electrical charges in the dielectric layers present over the perimetral portion of the mono-crystalline silicon chip coinciding with at least part of the perimeter of an integrated power device, leading to an instability ("walk in/walk out") of the breakdown voltage.

- On another account, such necessary narrow interruptions of the continuity of the
20 dopant implanted high voltage ring extension must be dimensioned such that for a given expected voltage difference between distinct main diffusions of same type of conductivity separated by a lightly doped epitaxial region of opposite type of conductivity, and down to an established maximum reverse voltage that may be applied to such main junctions, the diffusions remain effectively isolated from one
25 another, that is any passage of current by punch-through through the bridging parasitic transistor along the implanted high voltage ring extension of the diffusions is effectively prevented.

While during normal operating voltages the interruption of the continuity of the implanted extension region RHV prevent such a flow of current from our

diffusion to the neighbouring one, in terms of breakdown voltage characteristic, once a certain reverse voltage applied to the main junction is exceeded and even more so upon approaching the breakdown voltage, the widening of the depleted region renders relatively neglectable the physical interruption of the high voltage
5 ring extension, which results in practice electrically continuous, notwithstanding the presence of a narrow interruption.

SUMMARY OF THE INVENTION

An effective way of overcoming the noted instabilities of the breakdown voltage that are likely to occur in presence of narrow interruptions of the implanted high
10 voltage ring extension has now been found.

According to this invention, it has been found that said instabilities and related drawbacks that arise when interruptions of the perimetral high voltage ring extension must be realized may be effectively prevented.

This important result is achieved by an extremely simple expedient: whenever an
15 interruption of the high voltage ring extension must be created, it is not realized straight across it along a common orthogonal direction to the perimetral implanted region, on the contrary, the narrow interruption is defined obliquely or slantingly across the width of the perimetral high voltage ring extension. In case of a straight interruption, the angle of slant may be generally comprised between 30 and 60
20 degrees and more preferably is 45 degrees or close to it. Naturally, the narrow interruption is created by masking it from dopant implantation when realizing the perimetral high voltage ring extension region.

It has been demonstrated that by realizing, where required, a slanting narrow interruption across the width of the high voltage ring implanted region, instead of
25 a straight across orthogonal interruption as it is commonly done according to the prior art, conditions are created by virtue of which in correspondence of the interruption the equipotential lines lie in a region, the average dopant concentration of which can be considered in practice much closer to the dopant

concentration of the high voltage ring diffusion than in the case of a straight across, orthogonal interruption where the equipotential lines lie in a region of relatively low dopant concentration (typically in the epitaxial region EPI).

By so doing, the electrical conditions that would be determined by the presence of an uninterrupted high voltage ring extension are more closely reproduced, notwithstanding the physical interruption in the continuity of the high voltage ring extension, because of the above-discussed reasons.

The invention is defined in the annexed claims.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows a partial cross-section of a typical edge termination of a device comprising an integrated power transistor structure as discussed above.

Figure 2 is a detail layout view of a physical interruption of the implanted high voltage ring extension region of main diffusions to prevent a flow of current from one diffusion to another juxtaposed main diffusion of the same type of the integrated device, according to known art.

Figure 3 is a detail layout view of a physical interruption created in the implanted high voltage ring extension region, according to the present invention.

DESCRIPTION OF AN EMBODIMENT OF THE INVENTION

With reference to Figure 3, the narrow interruption I of an implanted high voltage ring extension RHV of an edge termination structure of an integrated device, in order to prevent flow of current from one main diffusion, P_{tub1}, to another juxtaposed main diffusion of the same type, P_{tub2}, of the integrated device.

As observed by comparing the prior art layout of Figure 2 with the novel layout of Figure 3, the narrow interruption I is defined substantially obliquely to the longitudinal direction of the high voltage ring extension RHV.

Similarly to the common practice represented in Figure 2, the interruption I of the implanted perimetral RHV region is realized in correspondence of the epitaxial layer region EPI of separation between the two main diffusions P_tub1 and P_tub2, one of which may belong or constitute an epitaxial collector or drain region of a power transistor and the other belong to a region of control circuitry,
5 and which may, during operation, be at different potentials.

In these situations, it is imperative to interrupt the perimetral high voltage ring extension RHV that merges with both distinct diffusions, P_tub1 and P_tub2, by determining in practice the presence of narrow EPI channel across the width of the
10 perimetral high voltage diffusion RHV.

Of course, the narrow interruption I must be wide enough to ensure that the distinct diffusions: P_tub1 and P_tub2, remain electrically isolated up to a nominal maximum difference of voltage between them and up to a certain reverse voltage, during normal functioning conditions of the device, such that the flow of
15 current through the RHV region from one main diffusion to the other by punch-through of the parasite PNP transistor that is created in case of the illustrated example, be prevented.

By contrast, under breakdown conditions, as already noted that is, once a certain maximum admissible reverse voltage is exceeded, the broadening of the depletion
20 region makes in fact the doped high voltage ring extension RHV behave as if there were no interruptions along it.

In the sample embodiment shown in Figure 3, the interruption I is defined with an angle of inclination α of about 45°.

As may be readily noted, by comparing the prior art layout of the narrow
25 interruption I of the RHV extension of Figure 2 with the layout of a functionally similar interruption I made according to the present invention of Figure 3, under breakdown conditions, the equipotential lines that in case of the prior art layout of the interruption I extend in the EPI channel of separation between the juxtaposed

ends of the annular high voltage ring doped extension RHV for the whole width of the perimetral RHV extension region, in the case of the layout of interruption of the present invention, the equipotential lines extend in the EPI channel for a length that is considerably less than the whole width of the RHV diffusion,
5 approximately for a length $l=d/\cos\alpha$.

In this way, even if one or more interruptions of the perimetral RHV extension need to be formed, the electrical behaviour of a continuous RHV extension are more closely reproduced. This effectively prevents the observed decline of effectiveness of the so interrupted RHV extension under breakdown conditions.

10 Notwithstanding the fact that the illustrated embodiment shows a slanting of the narrow interruption I of the perimetral RHV extension by an angle of about 45° , practically similar results can be obtained also with angles of inclination different from 45° . Generally, any angle comprised between 30° and 60° produces evident improvements.

15 Of course, any comparable slanting of the interruption I, even if not along a straight line but slightly curved, would equally be effective in preserving a good effectiveness of the edge termination under breakdown conditions while ensuring in any case an electrical isolation of distinct junctions under normal working conditions.

CLAIMS

1. An integrated device including at least a power transistor, a diffusion of which constitutes a main junction and a current terminal of the transistor, an edge termination including a high voltage ring extension implanted region partially overlapping said main junction diffusion and extending along at least part of the perimeter of the integrated device and at least another diffusion of the same type of said main junction diffusion also partially overlapped by said high voltage ring extension implanted region, and wherein the continuity of said perimetral high voltage ring extension implanted region must be interrupted over a region of lesser dopant concentration of the dopant concentration of said implanted extension region, characterized in that
narrow interruption of the continuity of said perimetral high voltage ring extension implanted region is not defined orthogonal to the perimetral ring extension but slanted for preserving effectiveness of said edge termination including said high voltage ring extension under breakdown voltage conditions.
2. The integrated device of claim 1, wherein said narrow interruption is inclined by an angle comprised between 30° and 60° .
3. The integrated device of claim 2, wherein said angle of inclination is 45° .
4. The integrated device of claim 1, wherein said region of lesser dopant concentration is an epitaxially grown layer formed on a semiconducting crystal substrate of the integrated device and at least said first main junction of the power transistor is the base-collector junction of a bipolar junction power transistor.
5. The integrated device according to claim 4, wherein said main junction of the power transistor is the body-drain junction of a power MOS transistor.

6. The integrated device according to claim 1, wherein said other diffusion of the same type of said main junction diffusion of the power transistor belongs to a region containing control circuitry of the power transistor.

1/1

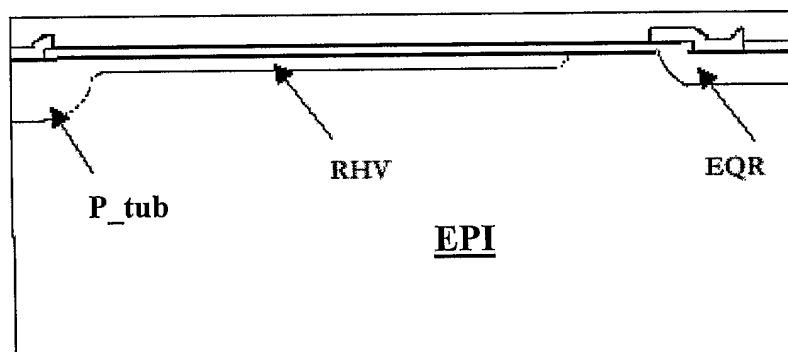


FIG. 1

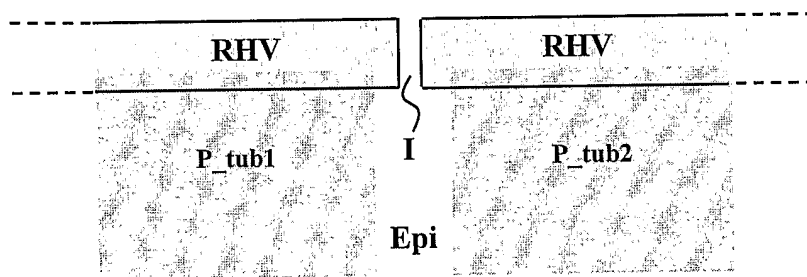


FIG. 2

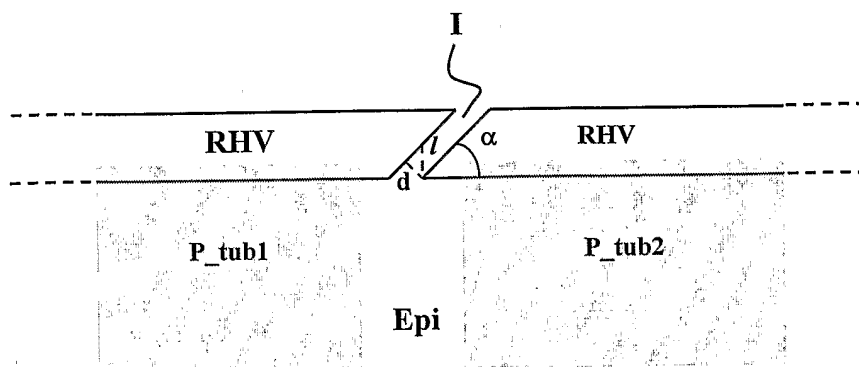


FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/112005/000515

A. CLASSIFICATION OF SUBJECT MATTER
H01L29/06 H01L27/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 667 393 A (FERLA ET AL) 26 May 1987 (1987-05-26) the whole document figure 2	1-6
A	EP 0 637 846 A (SILICONIX INCORPORATED) 8 February 1995 (1995-02-08) the whole document figure 2	1-6
A	EP 0 632 502 A (CONSORZIO PER LA RICERCA SULLA MICROELETTRONICA NEL MEZZOGIORNO - CORI) 4 January 1995 (1995-01-04) the whole document figure 1	1-6
A	US 2002/017647 A1 (BAKOWSKI MIETEK ET AL) 14 February 2002 (2002-02-14) the whole document	1-6

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

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