

A HIGH PRECISION
SEMICONDUCTOR RESISTOR DEVICE

The present invention relates to a high precision resistance element structure used for a semiconductor device.

Fig. 1 is a structural diagram showing a conventional polycrystalline silicon resistance element, and in particular a high resistance element which is formed on a semiconductor substrate. Polycrystalline silicon 2 is formed on the semiconductor substrate 3 and through an insulating (or oxide) film 9 is connected to aluminium electrodes 4 and 6 through the contacts 5 and 7. An insulating film 10 is formed on the top surface of the polycrystalline silicon 2 which overlays only the aluminium signal lines or the oxide protective film 9.

Furthermore, Fig. 2 is a structural diagram showing a conventional resistance element which is formed on a semiconductor substrate using a low concentration diffused region or an ion implanted diffused region. A diffused resistor 12 which is formed on a surface of the semiconductor substrate 13 is connected to the aluminium lines 14 and 16 through the contacts 15 and 17. An insulating film (or an oxide film) is formed over the diffused resistor. The insulating film overlays only either the signal lines of aluminium, or the oxide protective film.

However, in the conventional structure shown in Fig. 2, a depletion layer occurs on the surface of the resistance element due to the electrical field from the signal lines passing through the resistance element, and causes an increase in the resistance value of it. When the depth of the depletion layer reaches a degree that is not able to be ignored with respect to the diffusion depth of the resistance element, it varies largely the resistance value. An ion implanted resistance element with a depth of less $1\mu\text{m}$ and a sheet resistance of 6 to 9 $\text{K}\Omega/\text{m}^2$ suffers

from this phenomenon remarkably, and may vary its resistance value over several to several ten %.

Similarly, when a high value resistance polycrystalline silicon is applied to the structure shown in Fig.1 which is protected only by an oxide film, its resistance value is often varied due to impurity ions invading into the polycrystalline silicon.

A semiconductor element varies naturally in its energy level in response to incident light. Therefore, there has been a disadvantage that the resistance value is varied in response to light such as visible rays, infrared rays, or ultraviolet rays being irradiated onto a semiconductor device.

A semiconductor device structure according to the present invention is characterised in that a low resistance conductor is formed at least over a diffused resistor or a polycrystalline silicon resistance element formed using low concentration diffusion or ion implantation, the conductor having a resistance lower than that of the resistance element, and is kept at a fixed potential with respect to a power source. Thus a conductor connected to a fixed potential is formed at least over a low concentration diffused resistor or an ion implanted resistor, or a high resistance value polycrystalline silicon.

According to the present invention, there is provided a semiconductor device comprising:

- a semiconductor substrate;

- a resistance element diffused in said substrate;

- a conductor which is disposed over said resistance element and to which a fixed potential is applied, wherein the improvement lies in the resistance element being formed of a first diffused region formed by diffusing impurities into said semiconductor substrate, and a second diffused region disposed near to and surrounding said first diffused region in said semiconductor substrate, said second diffused region being supplied with said fixed potential.

According to the present invention, there is provided a semiconductor device comprising:

a semiconductor substrate;

a resistance element formed of polycrystalline silicon disposed over said substrate;

a conductor which is disposed over said resistance element and to which a fixed potential is applied; wherein the improvement lies in the resistance element being formed of a first resistance region and a second resistance region disposed near to and surrounding said first resistance region, said second resistance region also being supplied with said fixed potential.

This structure can stop impurity ions or an electromagnetic field from close signal lines causing a variation in resistance value. Hence, this structure can maintain a low concentration diffused resistor and a polycrystalline silicon resistor to a stable resistance value, and can prevent the resistance value varying due to irradiated light.

The present invention will now be described with reference to the accompanying drawings, of which:

Fig. 1 is a structural diagram showing a conventional polycrystalline silicon resistance element;

Fig. 2 is a structural diagram showing a conventional diffused resistance element;

Fig. 3 is a structural diagram showing a conventional polycrystalline silicon resistance element;

Fig. 4 is structural diagram showing a conventional diffused resistance element;

Fig. 5(a) is a plan view a polycrystalline silicon resistor with the circumference surrounded by the same material as that of the resistance element, and Fig. 5(b) is a cross sectional view thereof;

Fig. 6(a) is a structural diagram showing a polycrystalline silicon resistor element covered with a conductor connected to a potential V_{dd} and Fig. 6(b) shows a circuit diagram where the conductor potential is an output of a transistor;

Fig. 7 is an application circuit diagram showing a pair of resistance elements for dividing an output voltage, using a device according to the present invention;

Fig. 8 is a cross sectional view showing a polycrystalline silicon resistor with two-layered metal lines;

Fig. 9(a) is a plan view showing a diffused resistor over which the circumference is covered with the same material as that thereof, according to the present invention, and Fig. 9(b) is a cross sectional view thereof;

Fig. 10 is a cross sectional view showing a diffused resistance element over which the top and under layers are covered with a shielding conductor, according to the present invention;

Fig. 11(a) is a plan view showing a diffused resistance element over which the circumference is covered with a stopper, according to the present invention, and Fig. 11(b) is a cross sectional view thereof; and

Fig. 12 is an equivalent circuit diagram showing a high frequency delay line circuit using a shielding conductor covered resistance element according to the present invention.

Fig. 3 is a structural diagram showing a fundamental structure of a polycrystalline silicon resistance element. A polycrystalline silicon resistance element 2 has two ends, one being derived from the contact 5 and the other being derived from the contact 7. The electrodes 4 and 6 are made of aluminium material. A low resistance conductor 1 is formed over the polycrystalline silicon 2 by way of an oxide film so as to cover at least half the plane area of the polycrystalline silicon 2, and is supplied with a fixed potential (for example, a low power source potential V_{ss} 8, a high power source potential

Vdd, or an intermediate potential). The oxide film 9 provides an insulating film.

Fig. 4 is a basic conventional structural diagram showing a diffused resistor. Contacts 15 and 17 are formed at both the ends of a diffused resistor 12, and aluminium lines 14 and 16 are used as electrodes. The aluminium conductor 11 covers at least a half of the area of the diffused resistor through an oxide, and is supplied with a potential Vss 18. In this structure the aluminium conductor 11 works as a shielding material, and realises effectively a stable and high precision diffused resistor because it can shield electrically external electromagnetic noises, light, and ions, and blocks physically contamination.

Such resistance element structures have advantages as follows. First it can prevent noise entering from the signal line into the resistance element. That means that any electrical and magnetic noise transferred from stray capacitance and stray inductance around the resistance element is removed by the electrostatic shielding effect of the low resistance conductor. Hence, the resistance element does not vary its current vs voltage characteristics (that is, resistance value) during operation of a semiconductor device, and maintains a stable and high precision resistance value.

Next, external positive ions or negative ions can be blocked from invading the resistance element after completion of the manufacturing process. In other words, the ions which are positively charged more than the potential of the low resistance conductor are repelled away from the resistance element, while the negatively charged ions are attracted toward the low resistance conductor. While a semiconductor is energised, the ion distribution is uniform around the low resistance element, and the influence of an electric field due to the external ions can be prevented.

Hence, the resistance value variations due to aging can be prevented. Also, the low resistance conductor can shield the resistance element from being illuminated by externally irradiated light. Since the high resistance value

polycrystalline silicon resistor is made of a semiconductor, light energy of visible rays, infrared rays, or ultraviolet rays transmits the electron energy, thus changing the characteristics thereof. The above mentioned problems can be solved by covering with a low resistance conductor acting as a physical protective material to obtain a stable resistance element.

As described above, the characteristic variations of the resistance element under influence from an external field can be prevented advantageously. Similarly, this countermeasure additionally enables noise, electric field, and magnetic field generated from the resistance element itself to be prevented from affecting the circumference. In particular, in a high speed circuit, the resistance element through which electric charges change abruptly, generates a large thermal noise and unnecessary radiation. In addition to P type polycrystalline silicon and N type polycrystalline silicon used as low resistance materials, and is similarly effective in the case of high resistance non-ion implanted or slightly ion implanted polycrystalline silicon (called "High Resistance") or other semiconductors which are not restricted to silicon and is even effective in the case of semiconductors made of metal compounds.

A metal such as aluminium, tungsten, molybdenum may be generally used as a low resistance material. In addition, a polycrystalline silicon, a gallium and arsenic series compound and a superconductivity material may be used effectively.

The present invention is directed to a wide variety of applications using the resistance element structure. Two divisional applications have also been filed to some of these applications and hold GB application nos. 9301742.4 ^{Ser. No 2262188} and 9301741.6 ^{Ser. No 2262187} which is directed principally to figure 7 and 9301741.6.

Fig. 5 (a) is a plan view showing a first embodiment wherein the circumference is shielded with the same material as that of the resistor. Fig. 5 (b) is a cross sectional view of the above structure taken along the line A to B. In order to boost the shielding effect derived from the present invention, it is

desirable to form a shielding material with the same height as that of the resistance element. A polycrystalline silicon 77 is arranged around the polycrystalline silicon resistance element 70, and an aluminium conductor 75 is formed so as to cover completely the above structure. If possible, contacts 76 and 78 should be formed into the aluminium conductor 75 and the polycrystalline silicon 77. The structure maintains the resistance value of the polycrystalline silicon resistive element 70, by providing a good shielding effect from the low resistance conductor. In Figure 5 (a), numerals 73 and 74 represent the aluminium conductor 75 and an aluminium line on the same level connected to the polycrystalline silicon 70 through the contacts 71 and 72.

Fig. 6 (a) is a structural diagram showing a conventional resistance element modified wherein a potential Vdd 90 is supplied to the low resistance conductor shown in Fig. 1. The potential Vdd 90 may be replaced for the potential Vss in light of the shielding effect.

Fig. 6 (b) is an example showing a transistor producing an intermediate potential between the potentials Vdd and Vss to the low resistance conductor. It is assumed that the driving capabilities of the MOS transistors 91, 92, 93, and 94 are β_{P1} , β_{P2} , β_{N1} , and β_{N2} , respectively and the potential of the signal 96 is expressed as follows:

$$V_2 = V_{dd} - \sqrt{\frac{\beta_{N2} \cdot \beta_{P1}}{\beta_{P2} \cdot \beta_{N1}}} \times (V_{TP2} - V_{TP1})$$

where $\beta_{P1} = \beta_{P2}$,

$\beta_{N1} = \beta_{N2}$,

$V_{TN1} = V_{TN2}$,

$V_{dd} - V_2 = V_{TP2} - V_{TP1}$.

Hence, the output voltage is expressed below by taking V_{dd} as a reference voltage:

$$V_{out} = V_2.$$

In order to improve the shielding effect, it is necessary to lower the output impedance for the intermediate potential. In Fig. 8(b), the output 97 is obtained by using a differential pair circuit as a V_2 voltage follower.

The depletion effect which is one cause in variations to the shielded resistance element can be compensated by varying the potential of the shield in cooperation with the temperature characteristics of the shielded resistance element.

Fig. 7 is an application circuit diagram which uses two resistors. Two polycrystalline silicon resistors 114 and 115 are serially connected between the potential V_{dd} 110 and V_{ss} 111. The operational amplifier 117 receives the signal 116 at the intermediate node thereof, and provides an output voltage V_0 118.

In order to obtain $V_0 = V_{dd} / 2$, the resistors 114 and 115 have the same structure as previously, the aluminium conductors 113 and 112 are formed on the resistors 114 and 115 to prevent any influence due to ambient noise and magnetic fields, and are supplied with the same potential. Such a structure outputs a stable voltage V_0 .

The above voltage divider has a wide variety of applications. A potential $V_{dd}/3$ or $V_{dd}/4$ can be easily obtained with a three or four serially connected resistor configuration.

In order to design a layout of a semiconductor integrated device using a standard cell process, an automatic arranging and wiring process can be performed by registering predeterminingly the resistors and aluminium conductors covering them as one cell.

According to the present invention, a polycrystalline silicon resistor structure with a one layered aluminium wiring has been explained above as an

embodiment. The present invention can be applied to a two or three layered wiring structure in a semiconductor device.

Fig. 8 is a structural diagram showing a two layered aluminium structure. A polycrystalline silicon resistor 120 is formed over the substrate 121 through an oxide film 122. The resistor 120 with the electrodes 124 and 125 acts as a resistance element. Both the electrodes 124 and 125 are made of a first aluminium wiring layer. A second aluminium wiring layer 127 is formed over the polycrystalline silicon resistor 120 through the oxide films 123 and 126, and is supplied with the potential V_{ss} . In this case, the shielding effect may be reduced somewhat, because of distant spacing between the resistance element 120 and the shield material 127 in comparison with that of the single layered aluminium wiring. However, the lack of the shield pattern when not directly providing the contacts to the resistance element makes the design easy.

In the above mentioned embodiments, polycrystalline silicon has been used as a silicon material. However, a diffused resistor buried in a semiconductor substrate may be applied to form a stable resistor using the shielding effect.

As a material applied to a diffused resistor according to the present invention, the following may be used, a low concentration diffused resistor including a P^- well resistor formed into an N^- substrate, and N^- well resistor formed into a P^- substrate, and a high concentration diffused resistor including ion implanted P^+ and N^+ resistors.

For a low resistance conductor material, a metal -semiconductor compound and superconductive material may be used, in addition to aluminium and polycrystalline silicon.

A variety of combinations of the diffused resistor and the shield material can be performed.

Fig. 9 is a structural diagram showing a second embodiment wherein the same diffusion material covers around the diffused resistor. Fig. 9(a) is a plan view. Fig. 9(b) is a cross sectional view taken along the line A to B. A

diffused resistor 130 is formed in a shallow portion of the semiconductor substrate 139. The same material 137 forms the ambient (horizontal) portion of the resistor 130. An aluminium conductor 135 covers the top portion of the diffused resistor 130 through the oxide film, and is connected to the diffused material 137 via the contacts 136 and 138 to receive the power source potential V_{ss} . The structure improves the shielding effect against electromagnetic noise generated from the source and drain of an ambient transistor or a diffused resistor. In Figure 9(a), the aluminium electrodes 133 and 134 are in the same layer as that of aluminium conductor 135 which are connected to diffused resistor 130 through contacts 131 and 132.

Fig. 10 is a structural diagram showing a shield conductor formed on the under portion of a diffused resistor. The N^+ buried layer 142 and the high impurity concentration N type epitaxial layers 144 and 145 are formed in the P^- substrate 143. The contact 146 is connected to the potential V_{dd} . An aluminium conductor 141 covers the P^+ diffused resistor 140 through an oxide film 147, and receives the potential V_{dd} . The structure provides a stable and extremely high precision diffused resistance element because of a complete shielding.

In the embodiments shown in Figs. 9 and 10, the resistance element is shielded horizontally and vertically, so that it is possible to prevent effectively any influence of a substrate current generated by a switching operation of a transistor near to a current path when light or α rays is irradiated onto a semiconductor integrated device.

Fig. 11(a) is a plan view showing a diffused resistor surrounded by a stopper, and Fig. 11(b) is a cross sectional view taken along the line A to B. An N type diffused resistor 150 is formed on a surface of the P^- well 159 in an N^- substrate. A P^+ stopper 157 is formed so as to surround the N type diffused resistor 150, and is supplied with the potential V_{ss} from the aluminium conductor 155 through the contracts 156 and 158. This structure can effectively

prevent a latch-up phenomenon in addition to the shielding effect to ambient electromagnetic noise.

In case of an inverted type semiconductor, a P type diffused resistor is formed on an N^- substrate, and surrounded by a N^+ stopper. An aluminium conductor is formed over the diffused resistor and the N^+ stopper, and connected to the potential Vdd. This structure also can effectively prevent electromagnetic noise and latch-up. In Figure 11(a), aluminium electrodes 153 and 154 are in the same layer as the aluminium conductor, and are connected to the resistor 150 by way of the contacts 151 and 152.

In the above mentioned electrostatic shielding effect in which a conductor surrounds a diffused resistor and is supplied with a fixed potential, the fixed potential power source may be Vss, Vdd, or an intermediate potential in the similar manner as that in the polycrystalline silicon resistor. In case a single diffused resistance voltage divider with an intermediate tap is used, the resistance value stability is effectively improved by covering the circumference of divider with a conductor connected to a fixed potential. The present invention can be applied to a voltage divider using a plurality of diffused resistance elements.

Fig. 12 is an equivalent circuit diagram showing a high frequency delay line using a shielded resistor according to the present invention. A conductor which is connected to a fixed potential surrounds the resistors 160 to 163, and the capacitors 164 to 167 have a stable capacitance value. The shielded resistors provide good resistance value stability. A signal is input from the resistance terminal at the side V_i , and issued from the resistance terminal at the side V_{out} .

As described above, the present invention has a wide range of applications. A resistance element is one of most fundamental passive elements for circuit technologies, and various circuits requires high precision resistors. Particularly, the present invention can be widely applied in the following semiconductor integrated electronic devices: oscillation circuits, A/D converters, and sensor circuits which require resistors with absolute resistance value; D/A converters,



4. A semiconductor device as claimed in claim 1, 2 or 3, in which said resistance element has two terminals connected across a power source and an intermediate node for obtaining a divided voltage of said power source.
5. A semiconductor device as claimed in claim 4, in which there are two three or four resistance elements serially connected together with the intermediate node arranged so as to provide the divided voltage $V/2$, $V/3$ or $V/4$.
6. A semiconductor device as claimed in any one of the preceding claims when dependent on claim 1, further comprising a buried layer which is the same conductivity type as that of said second diffused region, and is of a conductivity type opposite to that of said semiconductor substrate, said buried layer being formed below said first diffused region in said semiconductor, so as to contact said second diffused region in said semiconductor substrate.
7. A semiconductor device as claimed in any one of the preceding claims when dependent on claim 1, in which both said first and second diffused regions are of the same conductivity type.
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