

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 either formed of polycrystalline silicon disposed over said substrate or diffused therein.

- a conductor which is disposed over said resistance element and to which a fixed potential is applied, wherein the improvement lies in that said resistance element has two terminals connected across a power source, and an intermediate node for obtaining a divided voltage of said power source.

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 structural diagram showing a polycrystalline silicon resistor element covered with a conductor connected to a potential Vdd and Fig. 5(b) is an embodiment showing a circuit diagram where the conductor potential is an output of a transistor;

Fig. 6 is an application circuit diagram showing an intermediate tap for dividing an output voltage, according to the present invention;

Fig. 7 is an application circuit diagram showing a pair of resistance elements for dividing an output voltage; and

Fig. 8 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 V_{dd} , 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 V_{ss} 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. Indeed the present invention described in this application is a divisional of GB Patent Application No. 9015141.6. Ser. No. 2232530

Fig. 5 (a) is a structural diagram showing a resistance element 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. 5 (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 Vdd 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. 9(b), the output 97 is obtained by using a differential pair circuit as a V2 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. 6 is an application circuit diagram showing a first embodiment of the resistor with an intermediate tap. This circuit outputs an intermediate voltage

through an output operational amplifier 107 by dividing the resistor in two. This invention is applied to a resistance element divided accurately in two.

The polycrystalline silicon resistor 101 has a contact 102 connected to the potential Vdd 100, a contact 104 connected to the potential Vss 105, and a contact 103 formed at the intermediate portion thereof to output a signal potential Vdd/2. An aluminium conductor 109 which is connected to the potential Vss covers the upper portion of the polycrystalline silicon resistor 1001. Hence, the resistor is shielded from ambient noise of magnetic field, and a partial resistance variation can be prevented. The output V_0 108 is accurately at Vdd/2.

Fig. 7 is an application circuit diagram which uses two resistors for the same purpose as that in Fig. 6. Two polycrystalline silicon resistors 114 and 115 are serially connected between the potential Vdd 110 and Vss 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 115 and 116 have the same structure as the resistor 116, the aluminium conductors 113 and 112 are formed on the resistors 115 and 116 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 Vdd/3 or Vdd/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.

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. 8 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, voltage sensing circuits, and oscillation halt detecting circuits which require a mutual resistance precision between a plurality of resistors; static RAMs,

EPROMs, and E²PROMs which require high value resistors with suppressed leak current.

Furthermore, the art according to the present invention in which a resistance element is shielded with a conductor can be applied to capacitors, transistors, or other related devices to improve the stabilities of them.

The present invention has an extremely wide range of applications because the stable and high precision resistance element can be formed by using existing manufacturing processes and requiring little peripheral structural patterns.

An improved resistance stability and precision means that an absolute resistance value of a resistor and a mutual resistance ratio between a plurality of resistance elements are less likely to be effected by ambient electromagnetic noise. The structure according to the present invention also is unlikely to be affected by ions and prevents resistance value variations due to aging, because the surface potential (generally of an oxide) of a resistance element is not floated electrically. Also, the structure can prevent variations in resistance element characteristics due to light, and can suppress electromagnetic noises generated from the resistance element itself. Furthermore, a lightly diffused high resistance element with high precision occupies a small area which ultimately leads to a highly integrated semiconductor device.

CLAIMS

1. A semiconductor device comprising:
a semiconductor substrate;
a resistance element either formed of polycrystalline silicon disposed over said substrate or diffused therein.
a conductor which is disposed over said resistance element and to which a fixed potential is applied, wherein the improvement lies in that said resistance element has two terminals connected across a power source, and an intermediate node for obtaining a divided voltage of said power source.
 2. A semiconductor device as claimed in claim 1, in which there are n resistance elements, where n = an integer of two, three or four, serially connected together with the intermediate node arranged so as to provide the divided voltage V/n .
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