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SRAM CELL WITH THIN FILM TRANSISTOR USING TWO POLYSILICON LAYERS

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to semiconductor memory devices and more particularly to the structures of SRAM (Static Random Access Memory) semiconductor memory devices.

2. Description of Related Art

In VLSI semiconductor circuits memories are formed of semiconductor devices, which store data by means of electric charges. Different types of such memories include Static Random Access Memories (SRAM's), Dynamic Random Access Memories (SRAM's), Read Only Memories (ROMs), etc. These semiconductor memory devices can be packed in very large numbers of memory cells with a large storage capacity in a space with very low volume and can be manufactured at a low cost. Among these memories, the static type semiconductor memory has been widely used as a random access memory (RAM), because it can retain stored data without periodically being refreshed during operation.

The static random access memory (SRAM) can be implemented by a large number of bistable flip-flop circuits each of which stores one bit of information. The CMOS flip-flop circuit is composed of a pair of N-channel MOS field effect

transistors and a pair of P-channel MOS Field effect transistors used as a memory cell because of the very low power consumption of the CMOS flip-flop circuit. However, the CMOS flip-flop circuit generally requires a relatively large surface area on a semiconductor substrate, so in the past, there has been a limitation to the capacity of an SRAM by employing the CMOS flip-flop.

Several years ago, a design was adopted in which the cell includes a partial substitution of thin film transistors (TFTs) for the buried FET devices of a pair of P-channel MOS transistors of the CMOS flip-flop circuit in a Silicon-On-Insulator (SOI) structure. According to the TFT or SOI technique, the N channel MOS transistors are formed at a surface of a semiconductor substrate and the P-channel MOS transistors have been fabricated by a polycrystalline silicon layer or a monocrystalline silicon layer which is formed on the surface of the semiconductor substrate over an insulating layer. According to this technique, the P-channel transistors can overlap a part of the N-channel MOS transistors, and therefore the space required by each cell of an SRAM is reduced.

To implement a polysilicon Thin Film Transistor (TFT), with an active load element, typically it is necessary to use three polysilicon layers or four polysilicon layers. Even an SRAM cell with two polysilicon layers and a TFT

requires a metal contact to complete the cross-coupling connection lines required for an SRAM circuit.

SUMMARY OF THE INVENTION

The present invention uses a gate (in a diffused substrate region with a buried contact thereto) below the TFT to overcome the problems described above.

In accordance with this invention a buried contact is included to from the cross-coupling connection lines in an SRAM cell with thin film transistor using two polysilicon layers.

A method of forming a thin film field effect transistor device on a semiconductor substrate of a first conductivity type with the substrate having a surface. The method comprises the following steps. Form field oxide regions on portions of the surface of the substrate and forming a first insulating layer on the surface of the semiconductor substrate between the field oxide regions on the semiconductor substrate. Form a first portion of a polysilicon layer over the field oxide regions and the first insulating layer. Form a buried contact opening through the first portion of a polysilicon layer and the first insulating layer to the surface of the substrate adjacent to one of the field oxide regions exposing a portion of the surface of the semiconductor substrate. Form a second portion of the polysilicon layer over the first portion of the polysilicon layer and

over the portion of the surface of the substrate to form a buried contact between the second portion and the surface of the substrate. Dope the polysilicon layer including the first portion and the second portion. Pattern the polysilicon layer by forming a mask with openings therethrough for patterning the polysilicon layer to form a control gate electrode and to form a conductor from the buried contact. Etch the polysilicon layer to form the control gate electrode and the conductor through the openings in the mask. Form doped source/drain regions in the substrate juxtaposed with the control gate electrode. Form an interelectrode dielectric layer over the control gate electrode and the conductor. Form a gate opening mask for patterning the interelectrode dielectric layer. the gate opening mask having an opening therethrough over a the doped source/drain region in the substrate juxtaposed with the buried contact. Etch the interelectrode dielectric layer through the opening therethrough to form a gate opening therethrough down to the surface of the substrate. Form a gate oxide layer on the surface of the substrate through the gate opening. Form a semiconductor film over the interelectrode dielectric layer and the surface of the substrate through the gate opening. Dope the semiconductor film forming a channel region between source/drain regions in the semiconductor film above the

gate opening, and above the gate opening of a thin film transistor, with the doped region therebelow comprising the control gate of the thin film transistor.

Preferably the method continues with the step of forming a layer of tungsten silicide over the second portion of the polysilicon layer before patterning of the polysilicon layer. It is preferred that the interelectrode dielectric layer comprises an interpolysilicon oxide; the semiconductor layer is formed of a doped polycrystalline silicon layer. The channel of the thin film transistor is an N type and the source/drain regions conductivity type is an N type. The buried contact is connected to the conductor to a control gate electrode of another transistor.

A method is provided for forming a thin film field effect transistor SRAM device on a semiconductor substrate of a first conductivity type, the substrate having a surface The method comprises the following steps. Form a field oxide regions on portions of the surface of the substrate and forming a first insulating layer on the surface of the semiconductor substrate between the field oxide regions on the semiconductor substrate. Form a first portion of a polysilicon layer over the field oxide regions and the first insulating layer. Form a buried contact opening through the first portion of a polysilicon layer and the first

insulating layer to the surface of the substrate adjacent to one of the field oxide regions exposing a portion of the surface of the semiconductor substrate. Form a second portion of the polysilicon layer over the first portion of the polysilicon layer and over the portion of the surface of the substrate to form a buried contact between the second portion and the surface of the substrate. Dope the polysilicon layer including the first portion and the second portion. Pattern the polysilicon layer by forming a mask with openings therethrough for patterning the polysilicon layer to form a control gate electrode and to form a conductor from the buried contact, and etch the polysilicon layer to form the control gate electrode and the conductor through the openings in the mask. Form doped source/drain regions in the substrate juxtaposed with the control gate electrode. Form an interelectrode dielectric layer over the control gate electrode and the conductor. Form a gate opening mask for patterning the interelectrode dielectric layer, the gate opening mask having an opening therethrough over a the doped source/drain region in the substrate juxtaposed with the buried contact. Etch the interelectrode dielectric layer through the opening therethrough to form a gate opening therethrough down to the surface of the substrate. Form a gate oxide layer on the surface of the substrate through the gate opening. Form a semiconductor film over the

interelectrode dielectric layer and the surface of the substrate through the gate opening. Dope the semiconductor film forming a channel region between source/drain regions in the semiconductor film above the gate opening, and above the gate opening of a thin film transistor, with the doped region therebelow comprising the control gate of the thin film transistor.

Preferably, a layer of tungsten silicide is formed over the second portion of the polysilicon layer before patterning of the polysilicon layer; the interelectrode dielectric layer comprises an interpolysilicon oxide; the semiconductor layer is formed of a doped polycrystalline silicon layer; the channel of the thin film transistor is an N type and the source/drain regions conductivity type is an N type; the buried contact is connected to the conductor to a control gate electrode of another transistor.

In accordance with still another aspect of this invention, a thin film field effect transistor circuit is formed on a semiconductor substrate of a first conductivity type, the substrate having a surface. Field oxide regions are formed on portions of the surface of the substrate and a first insulating layer on the surface of the semiconductor substrate between the field oxide regions on the semiconductor substrate. A first portion of a polysilicon layer over the field oxide regions and the first insulating layer. A

buried contact opening is formed through the first portion of a polysilicon layer and the first insulating layer to the surface of the substrate adjacent to one of the field oxide regions exposing a portion of the surface of the semiconductor substrate. A second portion of the polysilicon layer overlies the first portion of the polysilicon layer and extends down into contact with the portion of the surface of the substrate forming a buried contact between the second portion and the surface of the substrate. The polysilicon layer includes the first portion and the second portion which are doped to form conductors. The polysilicon layer is patterned into a control gate electrode and a conductor from the buried contact. Doped source/drain regions in the substrate are juxtaposed with the control gate electrode. An interelectrode dielectric layer overlies the control gate electrode and the conductor. The interelectrode dielectric layer has a gate opening therethrough down to the surface of the substrate. A gate oxide layer on the surface of the substrate through the gate opening. A semiconductor film is formed over the interelectrode dielectric layer and the surface of the substrate through the gate opening. Doped channel region between source/drain regions are formed in the semiconductor film above the gate opening, and above the gate opening of a thin film transistor, with the doped

region therebelow comprising the control gate of the thin film transistor.

Preferably, a layer of tungsten silicide is formed over the second portion of the polysilicon layer. The inter-electrode dielectric layer comprises an interpolysilicon oxide. The semiconductor layer is formed of a doped polycrystalline silicon layer. The channel of the thin film transistor is an N type and the source/drain regions conductivity type is an N type. The buried contact is connected to the conductor to a control gate electrode of another transistor.

In accordance with another aspect of this invention, a thin film field effect transistor SRAM device on a semiconductor substrate of a first conductivity type, the substrate having a surface. There are field oxide regions on portions of the surface of the substrate and a first insulating layer on the surface of the semiconductor substrate between the field oxide regions on the semiconductor substrate. A first portion of a polysilicon layer is formed over the field oxide regions and the first insulating layer. A buried contact opening exists through the first portion of a polysilicon layer and the first insulating layer to the surface of the substrate adjacent to one of the field oxide regions exposing a portion of the surface of the semiconductor substrate. A second portion of the polysilicon layer

over the first portion of the polysilicon layer and over the portion of the surface of the substrate forming a buried contact between the second portion and the surface of the substrate. The polysilicon layer includes the first portion and the second portion being doped. The polysilicon layer is patterned into a control gate electrode and a conductor from the buried contact. There are doped source/drain regions in the substrate juxtaposed with the control gate electrode. An interelectrode dielectric layer overlies the control gate electrode and the conductor. The interelectrode dielectric layer has a gate opening therethrough down to the surface of the substrate. A gate oxide layer is formed on the surface of the substrate through the gate opening. A semiconductor film overlies the interelectrode dielectric layer and the surface of the substrate, extending through the gate opening. There is a doped channel region between source/drain regions in the semiconductor film above the gate opening, and above the gate opening of a thin film transistor, with the doped region therebelow comprising the control gate of the thin film transistor.

Preferably, a layer of tungsten silicide is formed over the second portion of the polysilicon layer; interelectrode dielectric layer comprises an interpolysilicon oxide; the

semiconductor layer is formed of a doped polycrystalline silicon layer; the channel of the thin film transistor is an N type and the source/drain regions conductivity type is an N type. The buried contact is connected to the conductor to a control gate electrode of another transistor.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other aspects and advantages of this invention are explained and described below with reference to the accompanying drawings, in which:

FIG. 1 shows an electrical schematic circuit diagram of a CMOS type Static Random Access Memory device in accordance with this invention.

FIG. 2 is a plan view of a transistor in accordance with this invention of a MOSFET device formed on a silicon substrate.

FIGS. 3A-3N show a sectional view taken along line 3-3' in FIG. 2 of the process of manufacture of transistors in accordance with this invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. 1 shows an electrical schematic circuit diagram of a CMOS type Static Random Access Memory (SRAM) device in accordance with this invention. In FIG. 1, N-channel MOS pass transistors T1 and T2 and P-channel MOS drive transistors T3 and T4 form a CMOS flip-flop circuit in which the transistors T3 and T1 have control gate electrodes electrically connected to node N1 to form a first CMOS inverter and the transistors T4 and T2 have control gate electrodes electrically connected to node N2 forming a second CMOS inverter. Nodes N1 and N2 of the first and second CMOS inverters are connected to a pair of digit lines DL and DL(bar) via a pair of N-channel transfer gate transistors T5 and T6 having their control gate electrodes controlled by a word line WL respectively.

In this invention, the transistor T1 is a MOSFET device formed on a doped silicon substrate. An FET device in accordance with this invention is shown in a plan view in FIG. 2.

FIGS. 3A-3N show sectional views of a sequence of steps in the process of manufacture of a device in accordance with this invention including the transistors T1 and T4. FIGS. 3A-3N show sectional views taken along line 3-3' in FIG. 2. The transistor T4 is a TFT device which is formed with the

channel above the substrate in a polysilicon film 60 as seen in FIG. 3N.

In FIG. 2 the TFT transistor T4, which is located between buried contact BC1 and conductor line 39 (gate G1 of transistor T1), includes source 60S, channel 60C, and drain 60D, as well as a buried contact BC1 which is connected (FIG. 3N) to the buried N+ doped control gate electrode 46 (gate G4) of TFT transistor T4.

Conductor 39 in FIG. 2 is both the control gate electrode G1 of FET transistor T1 (with source/drain regions 45, 46) and conductor 39 connects to the control gate of transistor T3 and connects to buried contact BC2.
Line 39 is a provides a connection line to node N1 and the source/drain circuits of transistors T4 and T2.

FIG. 3A shows a sectional view of a device 29 in accordance with this invention in an early stage of manufacture after the formation of two field oxidation (FOX) regions 31 on either end of a portion of the surface of- substrate 30.

A Vt ion implantation with ions 33 is performed into P- substrate 30. The concentration of dopant 33 is from about 10^{16} atoms/cm^3 to about 10^{17} atoms/cm^3 with boron (B11) dopant implanted.

FIG. 3B shows the device 29 of FIG. 3A after deposition of two layers. The first is gate oxide layer 32 deposited

on the surface of P- doped substrate 30 between the FOX regions 31 and 31'.

In the next step polysilicon is deposited to form an undoped first polysilicon portion 34 (known in the industry as poly 1-1) of first polysilicon layer (preferably about 500Å thick, within a thickness range between about 300 Å and about 800 Å).

FIG. 3C shows the device 29 of FIG. 3B after forming an opening in the undoped first polysilicon portion 34 (poly 1-1) to form a buried contact region for buried contact BC1 by patterning with mask 35 having opening 35' and etching through the opening 35' to form an opening 37 down to substrate 30 to the left of FOX region 31' by removing the exposed region of undoped first polysilicon portion 34 and the underlying region of gate oxide layer 32 down to the surface of substrate 30. In addition, the etching step removes the exposed surface of FOX region 31' below opening 35'. That surface is partially etched away during the time required to remove the thickness of the thinner gate oxide layer 32 in opening 37. The opening 37 down to the surface of layer 30 permits the formation of a the buried contact BC1 as shown in FIG. 3E by the steps shown in FIGS. 3D and 3E.

Next, the photoresist mask 35 is removed from the device 29 of FIG. 3C at the end of the step shown in FIG. 3C.

FIG. 3D shows the device 29 of FIG. 3C after depositing a second polysilicon portion 38 of first polysilicon layer (known in the industry as poly 1-2) having a thickness between about 1,000 Å thick and about 1,500 Å. Portion 38 comprises a second thickness of polysilicon above first polysilicon portion 34. The polysilicon portion 38 reaches down through the opening 37 in first polysilicon portion 34 made by mask opening 35' into direct contact with the substrate 30 and the exposed surface of FOX region 31'.

The next step is to dope all of the first polysilicon layer including first polysilicon portion 34 and polysilicon portion 38 (both poly 1-1 and poly 1-2) using either:

1) $POCl_3$ (typical temperature of about 850°C) or
2) Ion implantation (typical parameters of 50keV and 5E15 ions/cm^2).

Then a tungsten silicide layer 39 is deposited on the top surface of layer 38 on device 29 (with a thickness from about 1,500 Å to about 2,000 Å.

Next device 29 is covered with a photoresist mask 40 above tungsten silicide layer 39. The mask 40 has openings

40' and 40'' therethrough which are to be used to define the patterns of the gate and conductor seen in FIG. 3E.

FIG. 3E shows the device 29 of FIG. 3D after etching through the openings 40' and 40'' through photoresist mask 40 to pattern layers 34 and 38 to form a conductor 34', 38', 39' and control gate electrode G1 of transistor T1.

Next, the layers 34 and 38 are etched away through openings 40', 40'' through mask 40, as shown in FIG. 3E. The result is the new gate electrode G1 formed of layers 34, 38 and 39 between the FOX regions 31 and 31' and the new conductor C4 formed of layer 34', 38' and 39' above FOX region 31'.

FIG. 3E shows the device 29 of FIG. 3D during formation of source/drain (S/D) lightly doped N- by ion implanting dopant 40' through openings 42', 43' into regions 42 and 43 in the surface of substrate 30. Region 42 is located between the new gate electrode G1 and the FOX region 31. Region 43 is located between the new gate electrode G1 and the FOX region 31' as shown in FIG. 3E. The concentration of dopant 40' in lightly doped N- regions 42 and 43 is from about 10^{17} atoms/cm^3 to about 10^{18} atoms/cm^3.

The buried contact region BC1 is shown extending from region 43 under layer 38' to the lower surface of FOX region 31'. The region BC1 is formed by the conventional step of out-diffusion of dopant from polysilicon layer 38'.

Next in FIG. 3F, spacers 44 of silicon dioxide are formed in a conventional process of blanket deposition followed by etching back the blanket spacer layer to leave spacers 44 adjacent to the control gate G1. In addition, is a spacer 44 adjacent to the layer 38' of conductor C4.

The following step as shown in FIG. 3F is to form S/D N+ doped regions by ion implanting dopant 47 into regions 45, 46 (gate G4) between the new gate electrode G1 and the FOX regions 31, 31' as shown in FIG. 3E. The concentration of dopant 47 in regions 45 and 46 (gate G4) is from about 10^{20} atoms/cm^3 to about 10^{21} atoms/cm^3.

Thereafter, a step is performed of doping with ions of (P++ which is not shown since it is not in regions illustrated in the drawings pertinent to this invention.)

FIG. 3G shows the device 29 of FIG. 3F after depositing an InterPolysilicon Oxide (IPO) silicon dioxide layer 48 which comprises an interconductor dielectric layer for separating the polysilicon layer (34, 38, 39, 34', 38', 39') from the polysilicon film 60. The IPO silicon dioxide layer 48 is formed preferably by a PEOX (Plasma Enhanced Oxide) process of decomposition of TEOS (tetraethylorthosilicate).

In addition a mask 50, 50' has been formed over layer 48, 48' with an opening 50'' over the gate oxide opening to be formed above the gate electrode G4 for the TFT transistor T4.

FIG. 3H shows the device 29 of FIG. 3G after an opening has been made in the layer 48, 48' below the opening 50'' exposing the surface of semiconductor 30, so the TFT gate area 52 has been defined as seen in FIG. 3H above gate electrode region 46 (G4).

FIG. 3I shows the device 29 of FIG. 3H after depositing a conventional gate oxide (silicon dioxide) layer 54 above the N+ region 46 (G4) in the opening made in FIG. 3G. Layer 54 has a thickness from about 200 Å and about 400 Å.

FIG. 3J shows the device 29 of FIG. 3I after depositing a thin film polysilicon layer 60 to form the source/drain and channel of thin film transistor T4.

FIG. 3K shows the device 29 of FIG. 3J with the layer 60 being doped in situ with N- dopant by ion implantation with a concentration of phosphorus (P) or arsenic (As) dopant 47 in regions 45 and 46 (gate G4) from about 10^{16} atoms/cm^3 to about 10^{17} atoms/cm^3.

FIG. 3L shows the device 29 of FIG. 3K with the source region 60S and drain region 60D of layer 60 being doped with P+ dopant by ion implantation with a concentration of dopant 64 except for channel regions 54 above gate G4 which is protected by a mask 64' thereabove. The dopant comprises BF_2 dopant with a concentration of from about 10^{19} atoms/cm^3 to about 10^{20} atoms/cm^3.

In FIG. 3M the device 29 of FIG. 3L is shown after a mask has been placed over the TFT device T4 to protect the channel region 60C and S/D regions 60S and 60D during the etching away of the unwanted portions of the layer 60 by conventional etching techniques.

Conventional backend flow is performed to complete contacts and metal.

In FIG. 3N the device 29 of FIG. 3M is shown after the mask 70 has been removed in the completed form of the device 29 of FIGS. 1 and 2.

Process Steps

The process flow for the process of this invention comprises as follows:

1. Form a conventional set of wells (not shown) in substrate 30 for CMOS devices.
2. Define active regions in substrate 30 and wells (not shown).
3. Form field oxidation regions 31 in FIG. 3A.
4. Perform a Vt implant region 33 in FIG. 3A by I/I with boron ions in a concentration from about 10^{16} atoms/cm^3 to about 10^{17} atoms/cm^3.
5. Deposit gate oxide layer 32 in FIG. 3B.
6. Deposit undoped first polysilicon portion 34 (known in the industry as poly 1-1) of first polysilicon layer

(preferably about 500Å thick, but a maximum thickness range between about 300 Å and about 800 Å).

7. Form opening in (poly 1-1) to form a buried contact region for buried contact BC1 by patterning with mask 35 having opening 35' and etching.

8. Deposit (poly 1-2) which is the second polysilicon portion 38 of first polysilicon layer (known in the industry as poly 1-2) with a thickness range between about 1,000 Å thick and about 1,500 Å thick.

Then dope all of the first polysilicon layer including first polysilicon portion 34 and polysilicon portion 38 (both poly 1-1 and poly 1-2) using either

1) $POCl_3$ (typical temperature of about 850°C) or

2) Ion implantation (typical parameters of 50keV and 5E15 ions/cm^2).

9. Deposit tungsten silicide (within a thickness range between about 1,500 Å thick and about 2,000 Å thick)

10. Gate definition (pattern and etch).

11. Form S/D regions N- regions 42, 43, spacers , N+ regions 45,46 (gate G4) and (P++ regions which are not shown since it is not in regions illustrated in the drawings pertinent to this invention).

12. (FIG. 3G) Deposit InterPolysilicon Oxide (IPO) silicon dioxide layer 48, 48' which comprises an interconductor dielectric layer for separating the polysilicon layer

(34, 38, 39, 39') from the polysilicon film 60. The IPO silicon dioxide layer 48 is formed preferably by a PEOX (Plasma Enhanced Oxide) process of decomposition of TEOS (tetraethylorthosilicate).

13. (FIGS. 3G & 3H) TFT gate area definition.

14. (FIG. 3I) Deposit gate dielectric layer 54 for TFT device T4.

15. (FIG. 3J) Deposit polysilicon film 60.

16. (FIG. 3K) In situ N- ion implant doping of film 60.

17. (FIG. 3L) P+ S/D ion implant doping of regions 60S and 60D as well as other regions aside from the channel 60C of TFT transistor T4. The dopant comprises BF_2 dopant with a concentration of from about 10^{19} atoms/cm^3 to about 10^{20} atoms/cm^3.

Then define TFT device by patterning and etching.

18. Conventional backend flow to complete contacts and metal.

SUMMARY

By including the first buried contact BC1 the advantages are achieved as follows:

1. Reduction in number of polysilicon layers.
2. Current double polysilicon SRAM process may be used with very little modification.

A CMOS SRAM latch is provided with thin-polysilicon transistors in two levels of polysilicon. In this method, use is made of a buried contact structure to form the cross-coupled latch. The process also uses N+ in the substrate to form the gate of the TFT with a buried contact to cross-couple the latch.

While this invention has been described in terms of the above specific embodiment(s), those skilled in the art will recognize that the invention can be practiced with modifications within the spirit and scope of the appended claims, i.e. that changes can be made in form and detail, without departing from the spirit and scope of the invention. Accordingly all such changes come within the purview of the present invention and the invention encompasses the subject matter of the claims which follow.

CLAIMS

Having thus described the invention, what is claimed as new and desirable to be secured by Letters Patent is as follows:

1. A method of forming a thin film field effect transistor device on a semiconductor substrate of a first conductivity type, said substrate having a surface; said method comprising the steps as follows:

forming field oxide regions on portions of said surface of said substrate and forming a first insulating layer on said surface of said semiconductor substrate between said field oxide regions on said semiconductor substrate;

forming a first portion of a polysilicon layer over said field oxide regions and said first insulating layer,

forming a buried contact opening through said first portion of a polysilicon layer and said first insulating layer to said surface of said substrate adjacent to one of said field oxide regions exposing a portion of said surface of said semiconductor substrate,

forming a second portion of said polysilicon layer over said first portion of said polysilicon layer and over said portion of said surface of said substrate to

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form a buried contact between said second portion and said surface of said substrate,

doping said polysilicon layer including said first portion and said second portion,

patterning said polysilicon layer by forming a mask with openings therethrough for patterning said polysilicon layer to form a control gate electrode and to form a conductor from said buried contact, and etching said polysilicon layer to form said control gate electrode and said conductor through said openings in said mask,

forming doped source/drain regions in said substrate juxtaposed with said control gate electrode,

forming an interelectrode dielectric layer over said control gate electrode and said conductor,

forming a gate opening mask for patterning said interelectrode dielectric layer, said gate opening mask having an opening therethrough over a said doped source/drain region in said substrate juxtaposed with said buried contact,

etching said interelectrode dielectric layer through said opening therethrough to form a gate opening therethrough down to said surface of said substrate,

forming a gate oxide layer on said surface of said substrate through said gate opening,

forming a semiconductor film over said

interelectrode dielectric layer and said surface of said substrate through said gate opening,

doping said semiconductor film forming a channel region between source/drain regions in said semiconductor film above said gate opening, and above said gate opening of a thin film transistor, with the doped region therebelow comprising the control gate of said thin film transistor.

2. A method of forming a semiconductor device according to claim 1, wherein a layer of tungsten silicide is formed over said second portion of said polysilicon layer before patterning of said polysilicon layer.

3. A method of forming a semiconductor device according to claim 1, wherein said interelectrode dielectric layer comprises an interpolysilicon oxide.

4. A method of forming a semiconductor device according to claim 1, in which said semiconductor layer is formed of a doped polycrystalline silicon layer.

5. A method of forming a semiconductor device according to claim 1, in which said channel of said thin film transistor is an N type and said source/drain regions conductivity type is an N type.

6. A method of forming a semiconductor device according to claim 1, wherein said buried contact is connected to said conductor to a control gate electrode of another transistor.

7. A method of forming a semiconductor device according to claim 2, wherein said interelectrode dielectric layer comprises an interpolysilicon oxide.

8. A method of forming a semiconductor device according to claim 7, in which said semiconductor layer is formed of a doped polycrystalline silicon layer.

9. A method of forming a semiconductor device according to claim 8, in which said channel of said thin film transistor is an N type and said source/drain regions conductivity type is an N type.

10. A method of forming a semiconductor device according to claim 9, wherein said buried contact is connected to said conductor to a control gate electrode of another transistor.

11. A method of forming a thin film field effect transistor SRAM device on a semiconductor substrate of a first conductivity type, said substrate having a surface; said method comprising the steps as follows:

forming field oxide regions on portions of said surface of said substrate and forming a first insulating layer on said surface of said semiconductor substrate between said field oxide regions on said semiconductor substrate;

forming a first portion of a polysilicon layer over said field oxide regions and said first insulating layer,

forming a buried contact opening through said first portion of a polysilicon layer and said first insulating layer to said surface of said substrate adjacent to one of said field oxide regions exposing a portion of said surface of said semiconductor substrate,

forming a second portion of said polysilicon layer over said first portion of said polysilicon layer and over said portion of said surface of said substrate to form a buried contact between said second portion and said surface of said substrate,

doping said polysilicon layer including said first portion and said second portion,

patterning said polysilicon layer by forming a mask with openings therethrough for patterning said polysilicon layer to form a control gate electrode and to form a conductor from said buried contact, and

etching said polysilicon layer to form said control gate electrode and said conductor through said openings in said mask,

forming doped source/drain regions in said substrate juxtaposed with said control gate electrode,

forming an interelectrode dielectric layer over said control gate electrode and said conductor,

forming a gate opening mask for patterning said interelectrode dielectric layer, said gate opening mask having an opening therethrough over a said doped source/drain region in said substrate juxtaposed with said buried contact,

etching said interelectrode dielectric layer through said opening therethrough to form a gate opening therethrough down to said surface of said substrate,

forming a gate oxide layer on said surface of said substrate through said gate opening,

forming a semiconductor film over said interelectrode dielectric layer and said surface of said substrate through said gate opening,

doping said semiconductor film forming a channel region between source/drain regions in said semiconductor film above said gate opening, and above said gate opening of a thin film transistor, with the doped region therebelow comprising the control gate of said thin film transistor.

12. A method of forming a semiconductor SRAM device according to claim 11, in which a layer of tungsten silicide is formed over said second portion of said polysilicon layer before patterning of said polysilicon layer.

13. A method of forming a semiconductor SRAM device according to claim 11, wherein said interelectrode dielectric layer comprises an interpolysilicon oxide.

14. A method of forming a semiconductor SRAM device according to claim 11, in which said semiconductor layer is formed of a doped polycrystalline silicon layer.

15. A method of forming a semiconductor SRAM device according to claim 11, in which said channel of said thin film transistor is an N type and said source/drain regions conductivity type is an N type.

16. A method of forming a semiconductor SRAM device according to claim 11, wherein said buried contact is connected to said conductor to a control gate electrode of another transistor.

17. A method of forming a semiconductor SRAM device according to claim 12, wherein said interelectrode dielectric layer comprises an interpolysilicon oxide.

18. A method of forming a semiconductor SRAM device according to claim 17, in which said semiconductor layer is formed of a doped polycrystalline silicon layer.

19. A method of forming a semiconductor SRAM device according to claim 18, in which said channel of said thin film transistor is an N type and said source/drain regions conductivity type is an N type.

20. A method of forming a semiconductor SRAM device according to claim 9, wherein said buried contact is connected to said conductor to a control gate electrode of another transistor.

21. A thin film field effect transistor circuit on a semiconductor substrate of a first conductivity type, said substrate having a surface; said transistor comprising as follows:

field oxide regions on portions of said surface of said substrate and a first insulating layer on said surface of said semiconductor substrate between said field oxide regions on said semiconductor substrate;

a first portion of a polysilicon layer over said field oxide regions and said first insulating layer,

a buried contact opening through said first portion of a polysilicon layer and said first

insulating layer to said surface of said substrate adjacent to one of said field oxide regions exposing a portion of

said surface of said semiconductor substrate,

a second portion of said polysilicon layer over said first portion of said polysilicon layer and over said portion of said surface of said substrate forming a buried contact between said second portion and said surface of said substrate,

said polysilicon layer including said first portion and said second portion being doped,

said polysilicon layer patterned into a control gate electrode and a conductor from said buried contact,

doped source/drain regions in said substrate juxtaposed with said control gate electrode,

an interelectrode dielectric layer over said control gate electrode and said conductor,

said interelectrode dielectric layer having a gate opening therethrough down to said surface of said substrate,

a gate oxide layer on said surface of said substrate through said gate opening,

a semiconductor film over said interelectrode dielectric layer and said surface of said substrate through said gate opening,

a doped channel region between source/drain regions in said semiconductor film above said gate opening, and above said gate opening of a thin film transistor, with the doped region therebelow comprising the control gate of said thin film transistor.

22. A device according to claim 21, in which a layer of tungsten silicide is formed over said second portion of said polysilicon layer.

23. A device according to claim 21, wherein said interelectrode dielectric layer comprises an interpolysilicon oxide.

24. A device according to claim 21, in which said semiconductor layer is formed of a doped polycrystalline silicon layer.

25. A device according to claim 21, in which said channel of said thin film transistor is an N type and said source/drain regions conductivity type is an N type.

26. A device according to claim 21, wherein said buried contact is connected to said conductor to a control gate electrode of another transistor.

* C L M S *

27. A device according to claim 22, wherein said interelectrode dielectric layer comprises an interpolysilicon oxide.

28. A device according to claim 27, in which said semiconductor layer is formed of a doped polycrystalline silicon layer.

29. A device according to claim 28, in which said channel of said thin film transistor is an N type and said source/drain regions conductivity type is an N type.

30. A device according to claim 29, wherein said buried contact is connected to said conductor to a control gate electrode of another transistor.

31. A thin film field effect transistor SRAM device on a semiconductor substrate of a first conductivity type, said substrate having a surface; said transistor comprising as follows:

field oxide regions on portions of said surface of said substrate and a first insulating layer on said surface of said semiconductor substrate between said field oxide regions on said semiconductor substrate;

a first portion of a polysilicon layer over said field oxide regions and said first insulating layer,

a buried contact opening through said first portion of a polysilicon layer and said first insulating layer to said surface of said substrate adjacent to one of said field oxide regions exposing a portion of said surface of said semiconductor substrate,

a second portion of said polysilicon layer over said first portion of said polysilicon layer and extends into contact with said portion of said surface of said substrate forming a buried contact between said second portion and said surface of said substrate,

said polysilicon layer including said first portion and said second portion being doped,

said polysilicon layer patterned into a control gate electrode and a conductor from said buried contact,

doped source/drain regions in said substrate juxtaposed with said control gate electrode,

an interelectrode dielectric layer over said control gate electrode and said conductor,

said interelectrode dielectric layer having a gate opening therethrough down to said surface of said substrate,

a gate oxide layer on said surface of said substrate through said gate opening,

a semiconductor film over said interelectrode dielectric layer and said surface of said substrate through said gate opening,

a doped channel region between source/drain regions in said semiconductor film above said gate opening, and above said gate opening of a thin film transistor, with the doped region therebelow comprising the control gate of said thin film transistor.

32. A device according to claim 31, in which a layer of tungsten silicide is formed over said second portion of said polysilicon layer.

33. A device according to claim 31, wherein said interelectrode dielectric layer comprises an interpolysilicon oxide.

34. A device according to claim 31, in which said semiconductor layer is formed of a doped polycrystalline silicon layer.

35. A device according to claim 31, in which said channel of said thin film transistor is an N type and said source/drain regions conductivity type is an N type.

36. A device according to claim 31, wherein said buried contact is connected to said conductor to a control gate electrode of another transistor.

37. A device according to claim 32, wherein said interelectrode dielectric layer comprises an interpolysilicon oxide.

38. A device according to claim 37, in which said semiconductor layer is formed of a doped polycrystalline silicon layer.

39. A device according to claim 38, in which said channel of said thin film transistor is an N type and said source/drain regions conductivity type is an N type.

40. A device according to claim 39, wherein said buried contact is connected to said conductor to a control gate electrode of another transistor.

ABSTRACT OF THE DISCLOSURE

SRAM CELL WITH THIN FILM TRANSISTOR USING TWO POLYSILICON LAYERS

A TFT formed on a semiconductor substrate of a first conductivity type, includes a first doped portion of a polysilicon layer over FOX regions and a first insulating layer. A buried contact extends through the first portion of a polysilicon layer and the first insulating layer to the surface of the substrate adjacent to a FOX region. A second doped portion of the polysilicon layer overlies the first portion and forms a buried contact between the second portion and the substrate. The polysilicon layer forms a gate electrode and a conductor from the buried contact. Doped source/drain regions in the substrate are juxtaposed with the gate electrode. An interelectrode dielectric layer over the gate electrode and the conductor has a gate opening therethrough down to the substrate. A gate oxide layer is formed on the surface of the substrate at the gate opening. A semiconductor film extends over the interelectrode dielectric layer and over the surface of the substrate through the gate opening. A doped channel region is formed between source/drain regions in the semiconductor film above the gate opening, and above the gate opening of a TFT, with the doped region therebelow comprising the gate of the TFT.

(FIGURE 1 IS SUGGESTED FOR PUBLICATION)

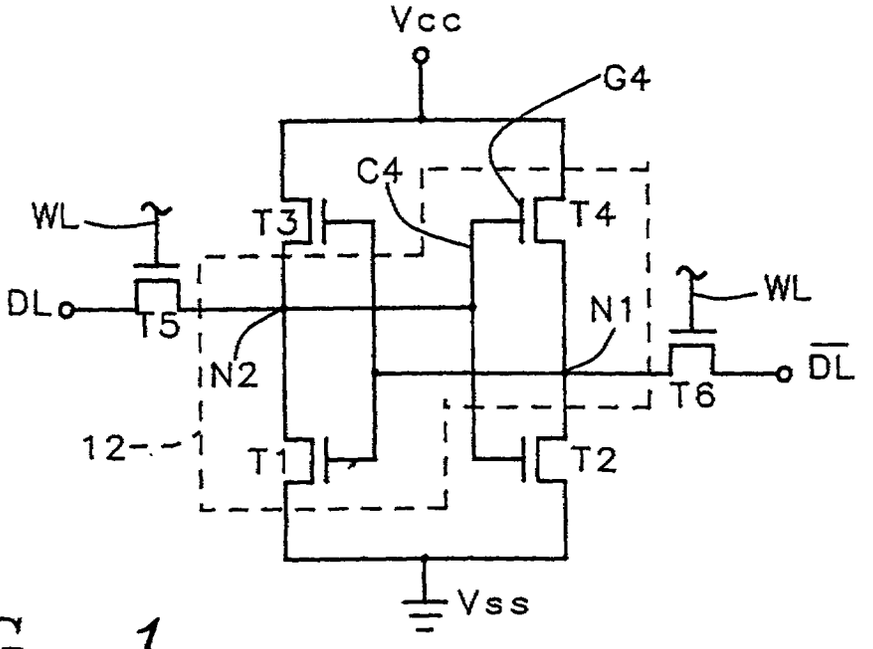

Vcc
G4
C4
WL
T3
T4
DL
T5
N1
WL
N2
T6
DL
12
T1
T2
Vss

FIG. 1

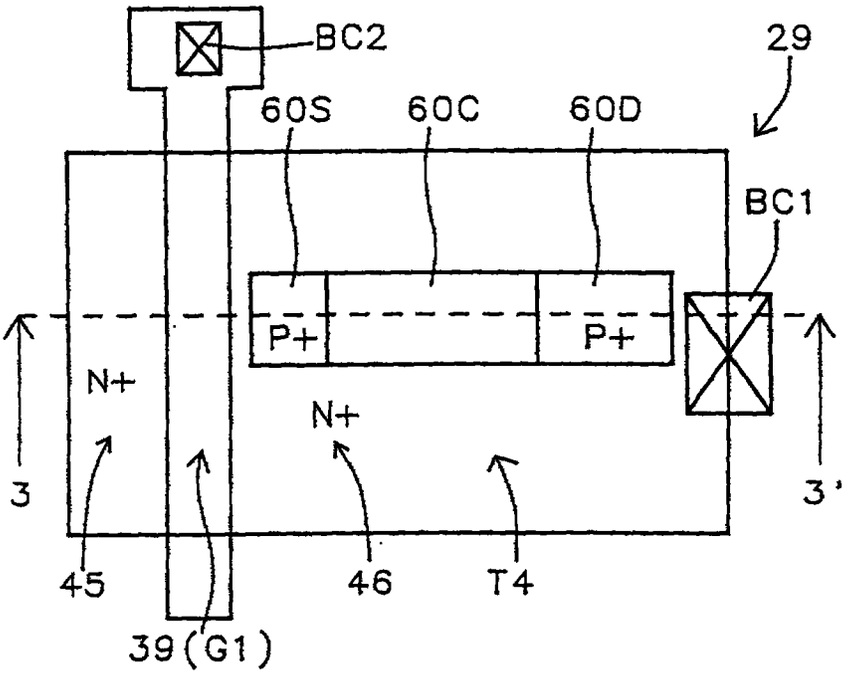

BC2
29
60S
60C
60D
BC1
P+
P+
N+
N+
3
3'
45
46
T4
39(G1)

FIG. 2

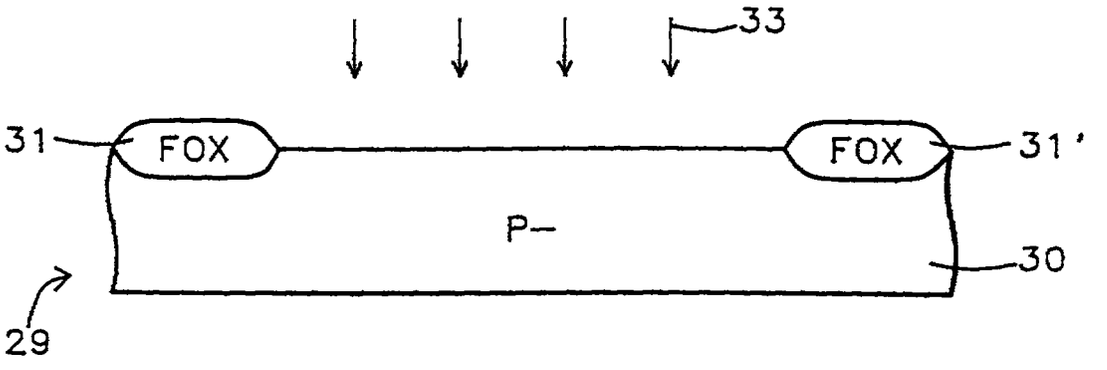


FIG. 3A

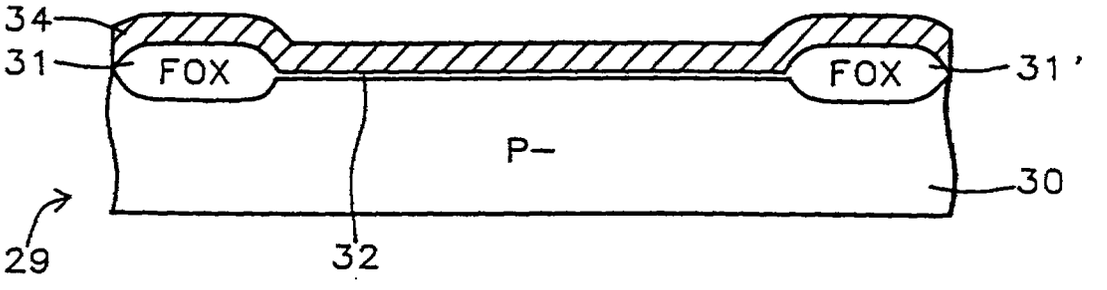


FIG. 3B

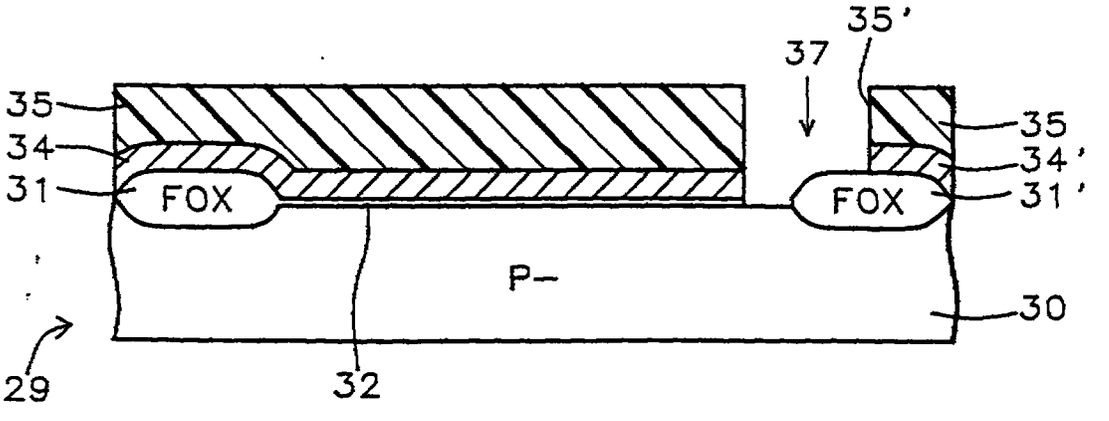


FIG. 3C

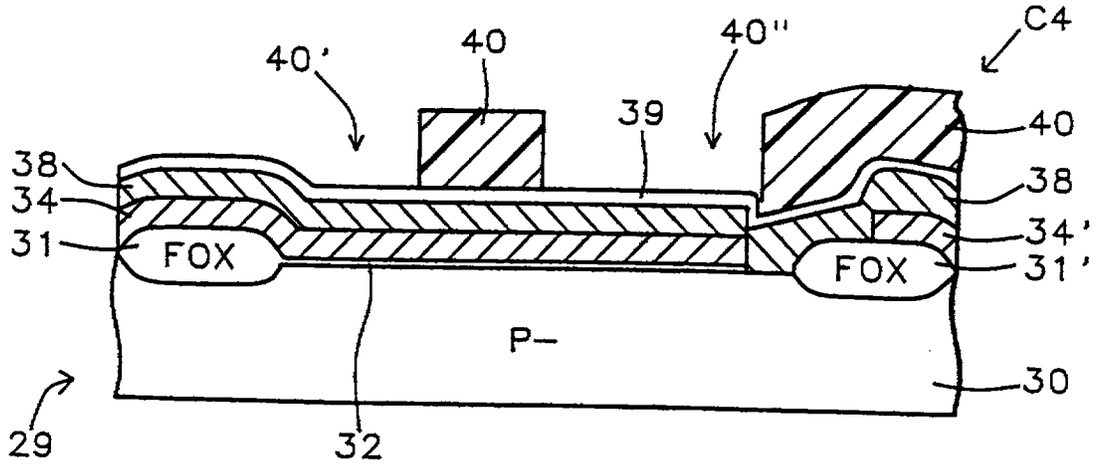


FIG. 3D

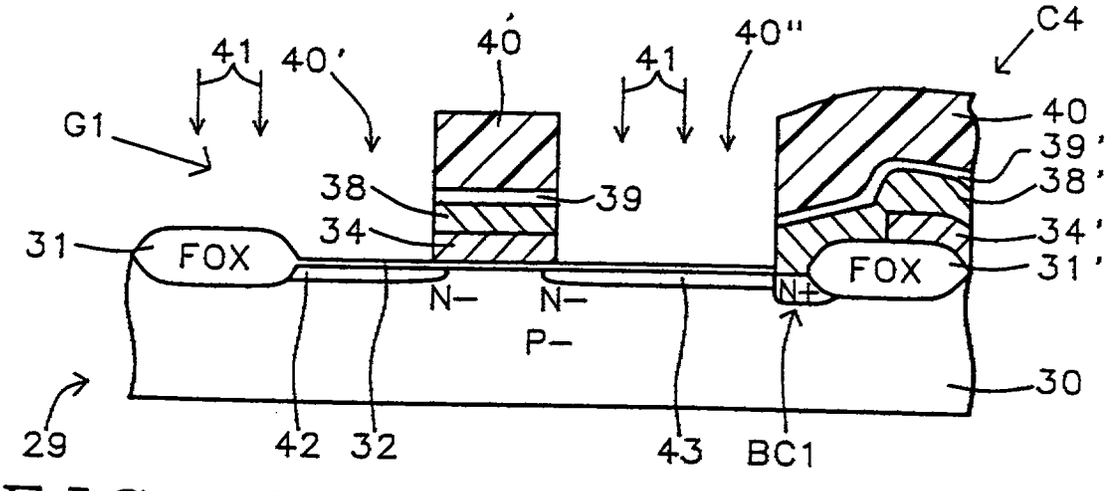


FIG. 3E

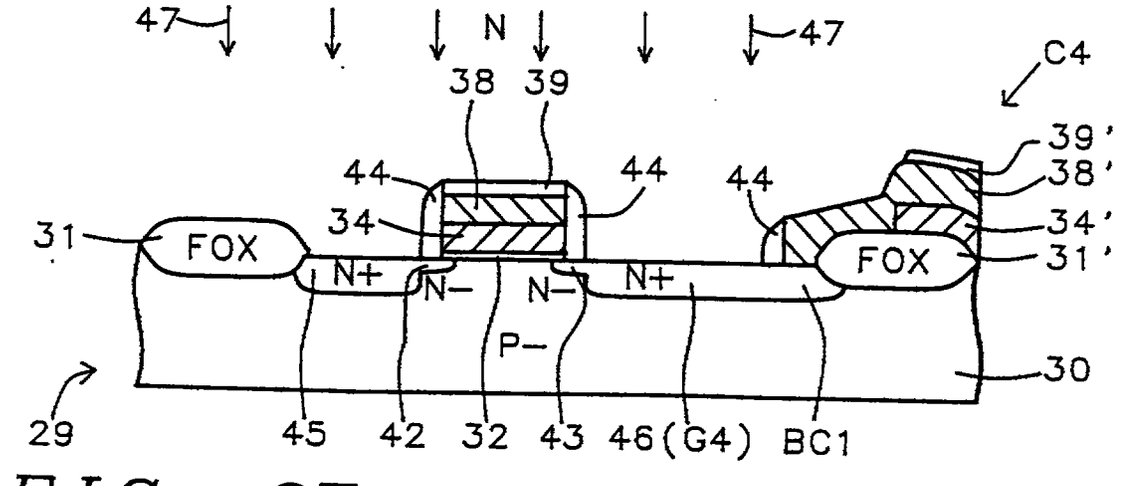


FIG. 3F

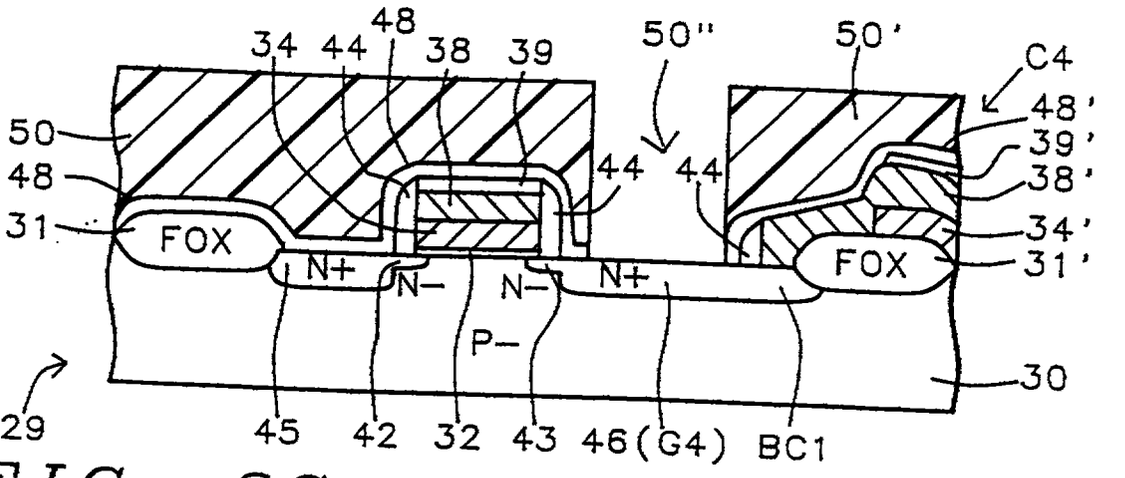


FIG. 3G

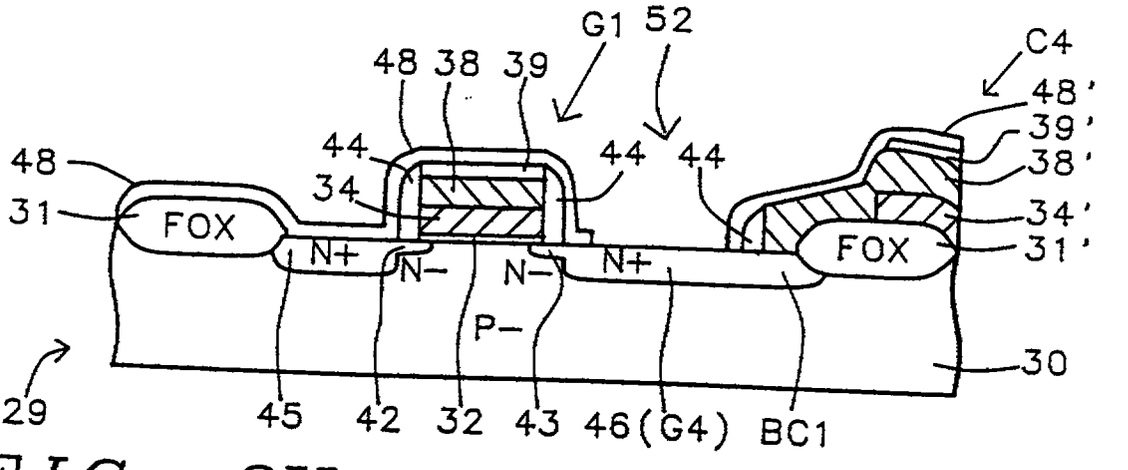


FIG. 3H

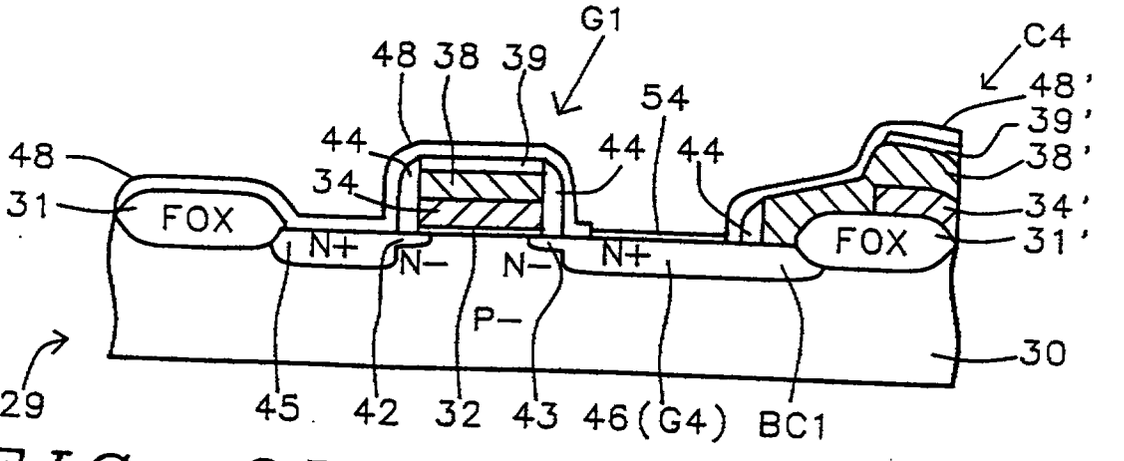


FIG. 3I

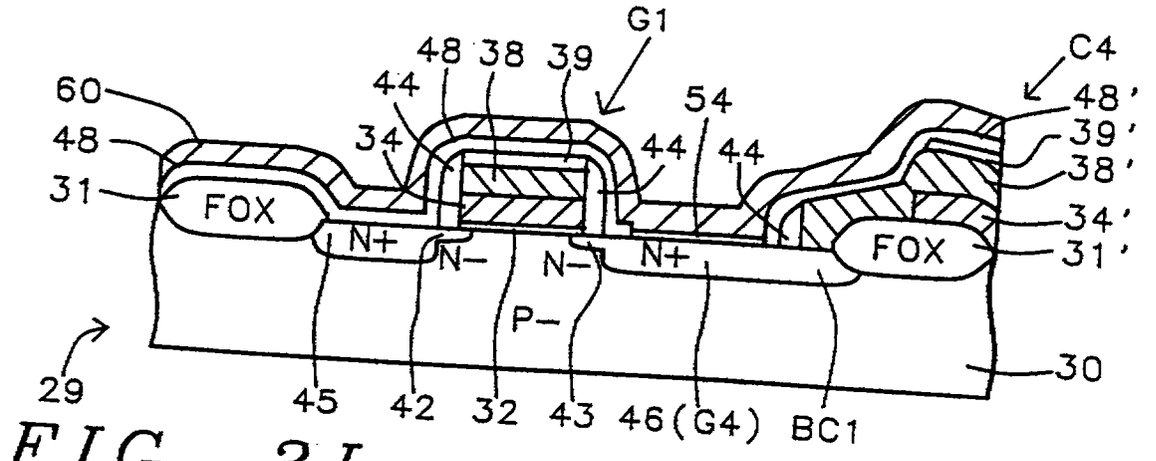


FIG. 3J

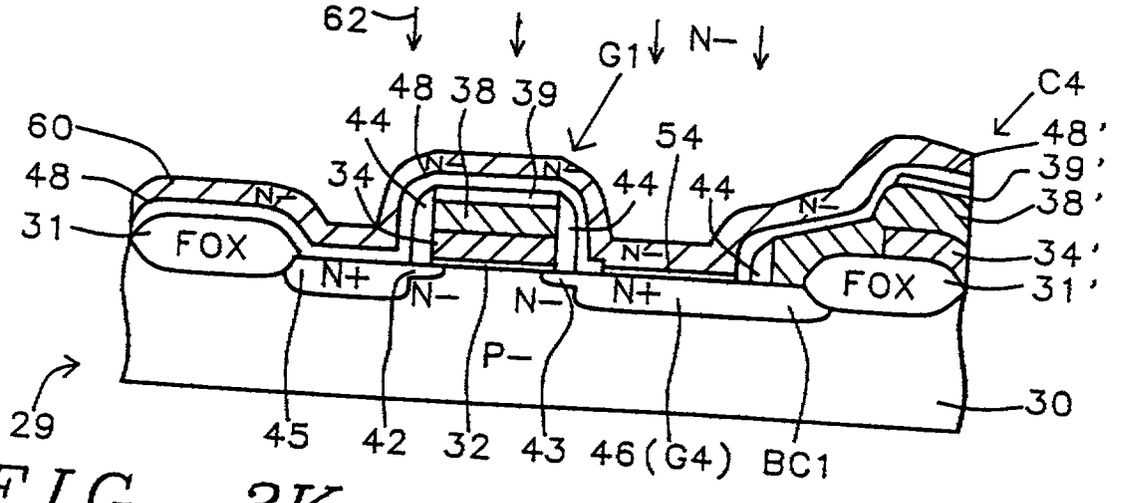


FIG. 3K

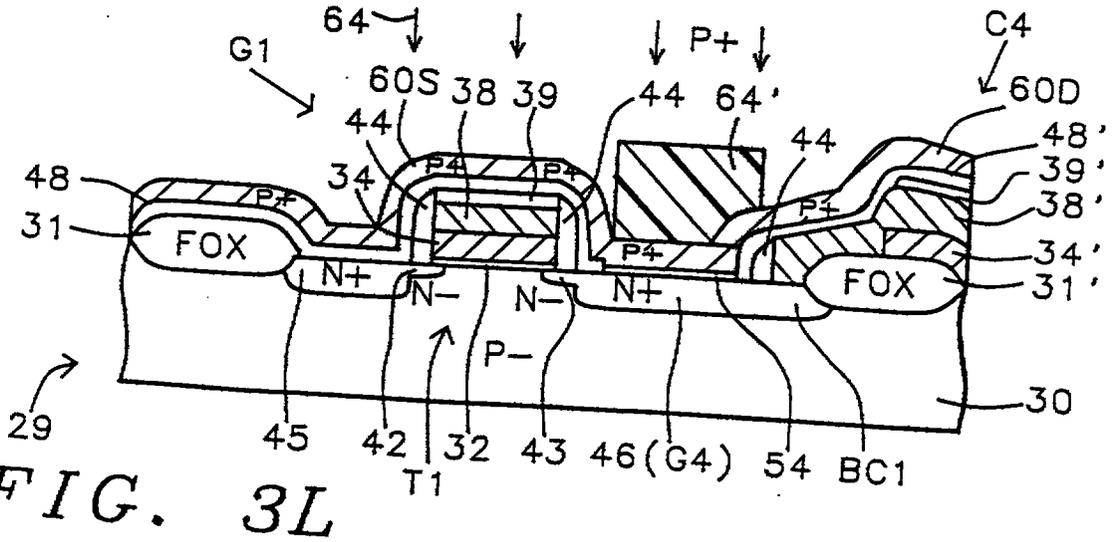


FIG. 3L

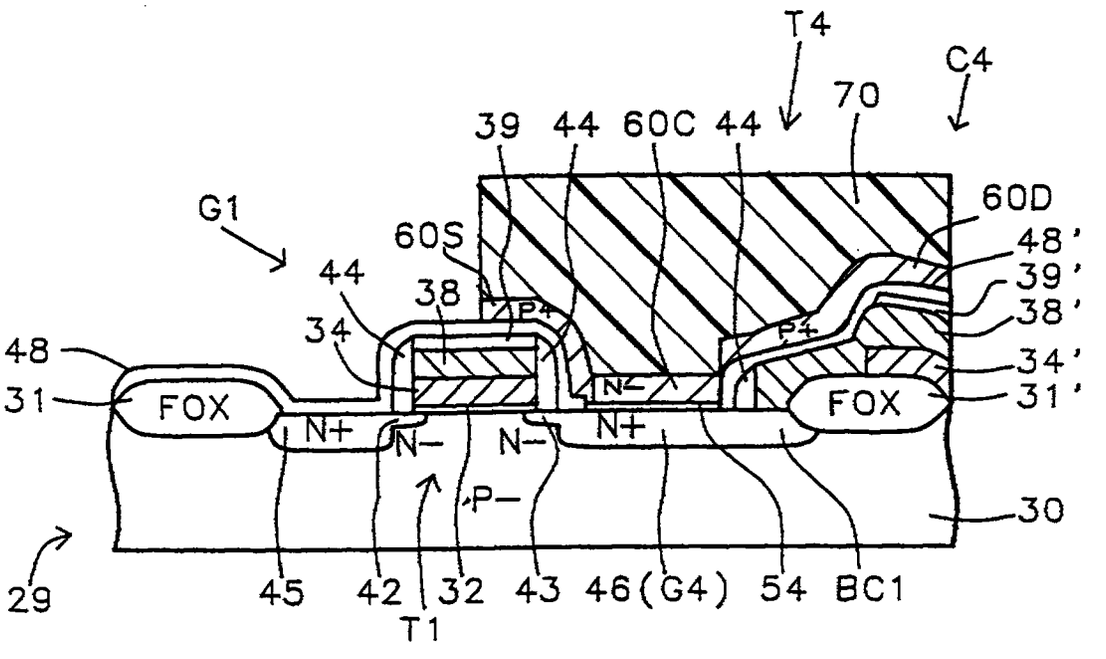

T4
C4
70
39
44
60C
44
60D
G1
60S
48'
44
39'
38
38'
34
34'
48
31
FOX
N+
N-
N-
N+
FOX
31'
P-
30
29
45
42
32
43
46(G4)
54
BC1
T1

FIG. 3M

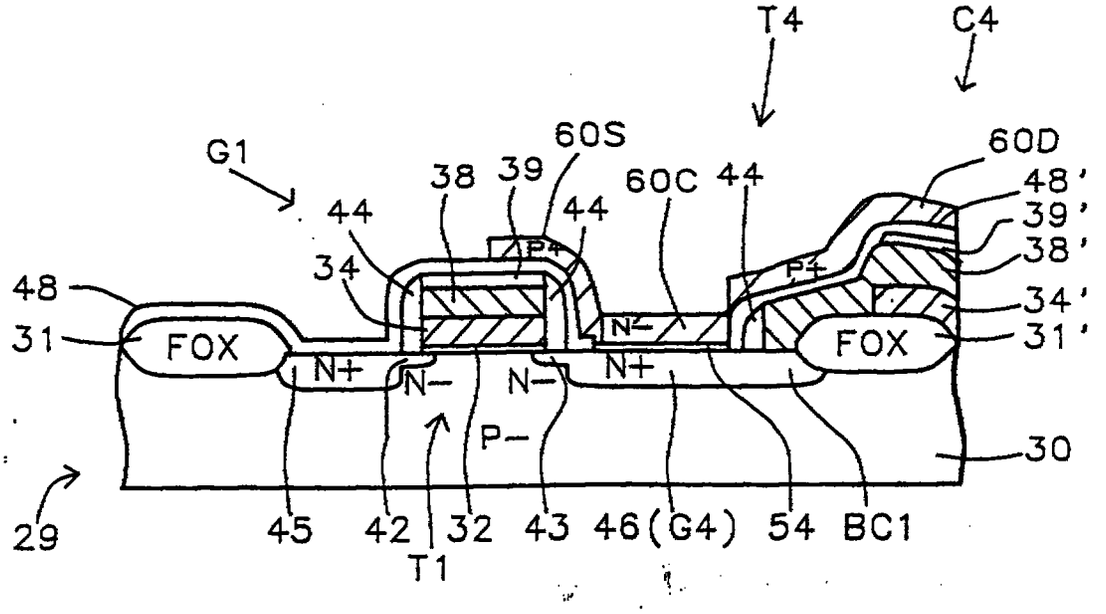

T4
C4
60S
G1
60D
38
39
60C
44
48'
44
44
39'
38'
34
34'
48
31
FOX
N+
N-
N-
N+
FOX
31'
P-
30
29
45
42
32
43
46(G4)
54
BC1
T1

FIG. 3N