United States Patent [19]

Yamazaki et al.

[11] **Patent Number: 5,929,527**

[45] **Date of Patent: Jul. 27, 1999**

[54] **ELECTRONIC DEVICE**

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[21] Appl. No.: **08/895,432**

[22] Filed: **Jul. 16, 1997**

[30] **Foreign Application Priority Data**

Jul. 16, 1996 [JP] Japan 8-205417

[51] **Int. Cl.**^{6} **H01L 23/48**; H01L 23/52; H01L 29/40

[52] **U.S. Cl.** **257/771**; 257/765; 257/767; 257/59

[58] **Field of Search** 257/765, 767, 257/771, 59

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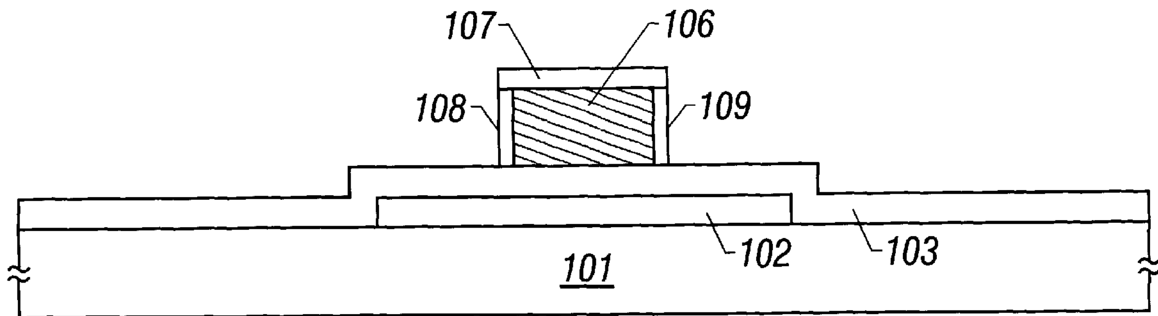
[57] **ABSTRACT**

An electronic device is provided using wiring comprising aluminum to prevent hillock or whisker from generating, wherein the wiring contains oxygen atoms at a concentration of 8×10^{18} atoms·cm^{-3} or less, carbon atoms at a concentration of 5×10^{18} atoms·cm^{-3} or less, and nitrogen atoms at a concentration of 7×10^{17} atoms·cm^{-3} or less; furthermore, a silicon nitride film is formed on the aluminum gate, and an anodic oxide film is formed on the side planes thereof.

5 Claims, 9 Drawing Sheets



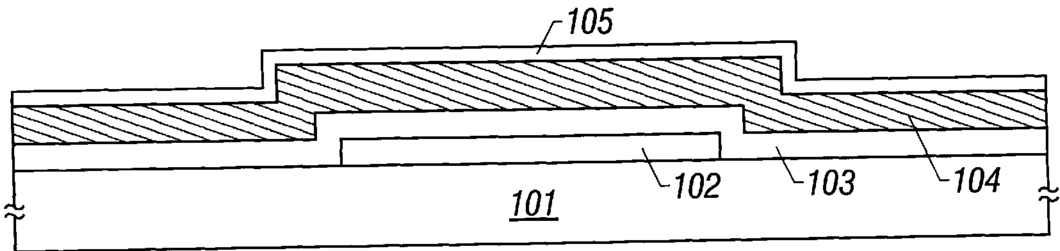


FIG. 1A

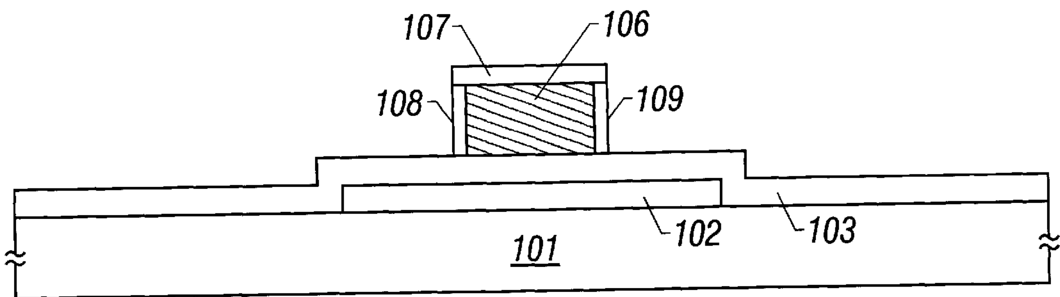


FIG. 1B

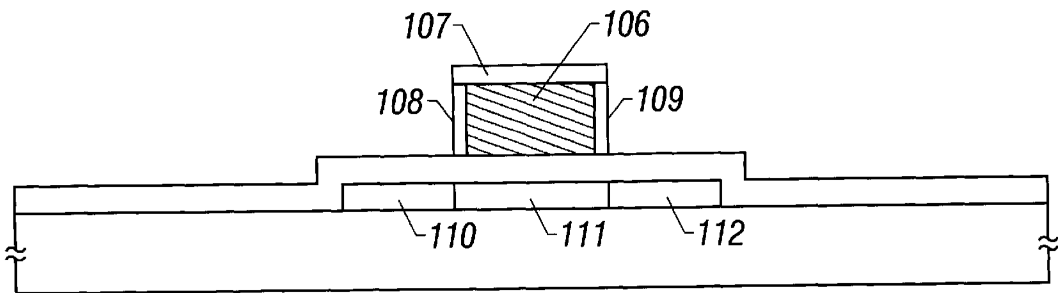


FIG. 1C

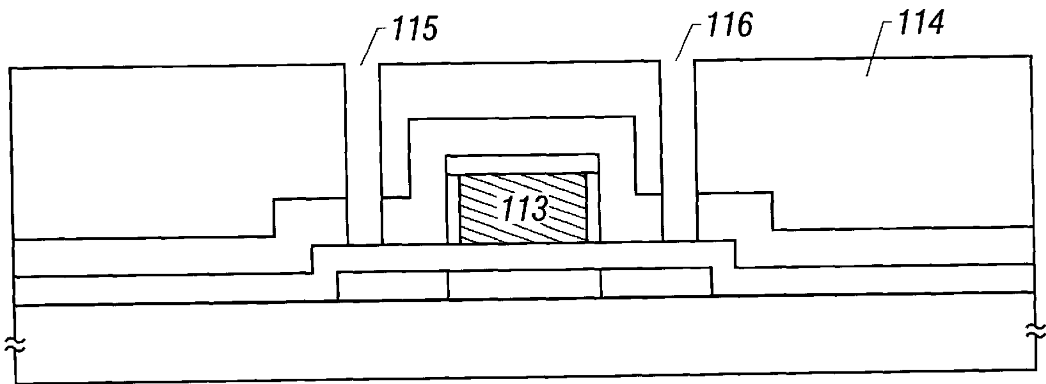


FIG. 2A

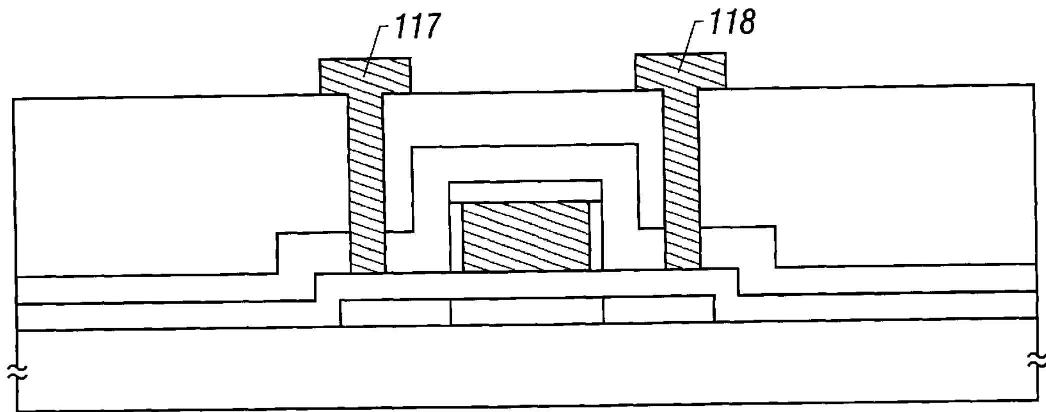


FIG. 2B

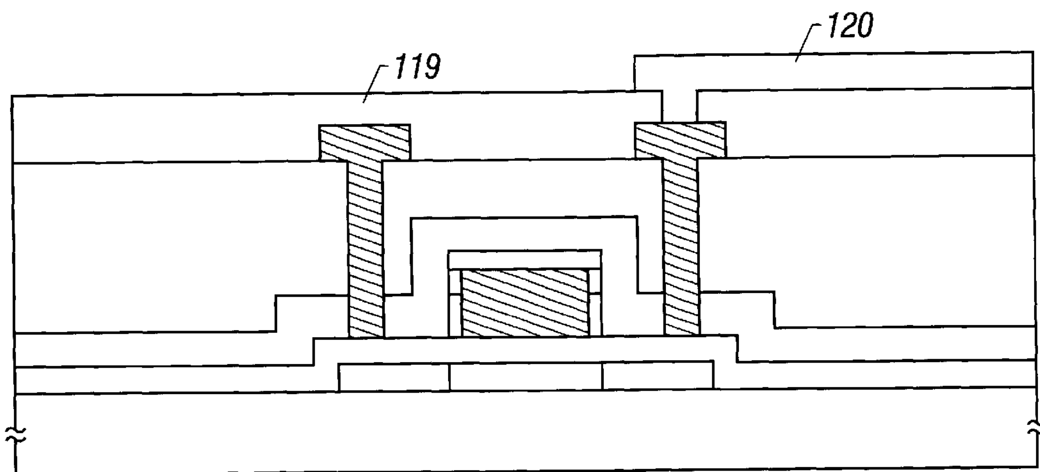


FIG. 2C

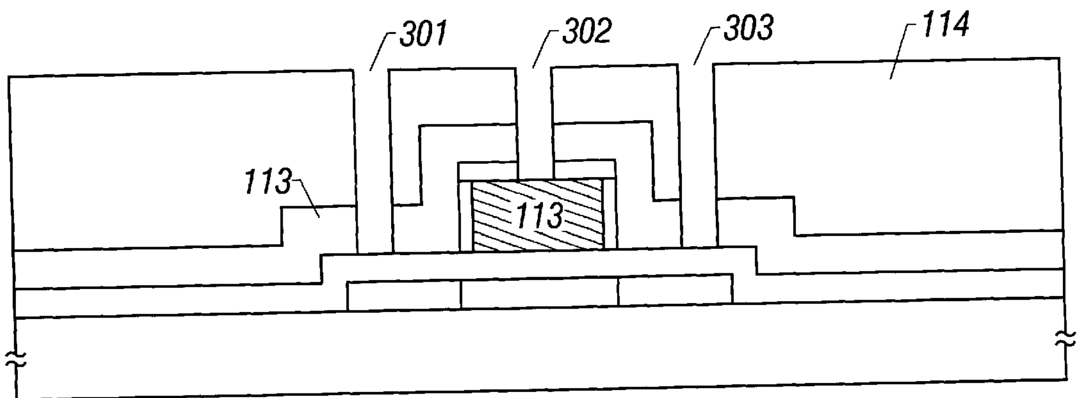


FIG. 3A

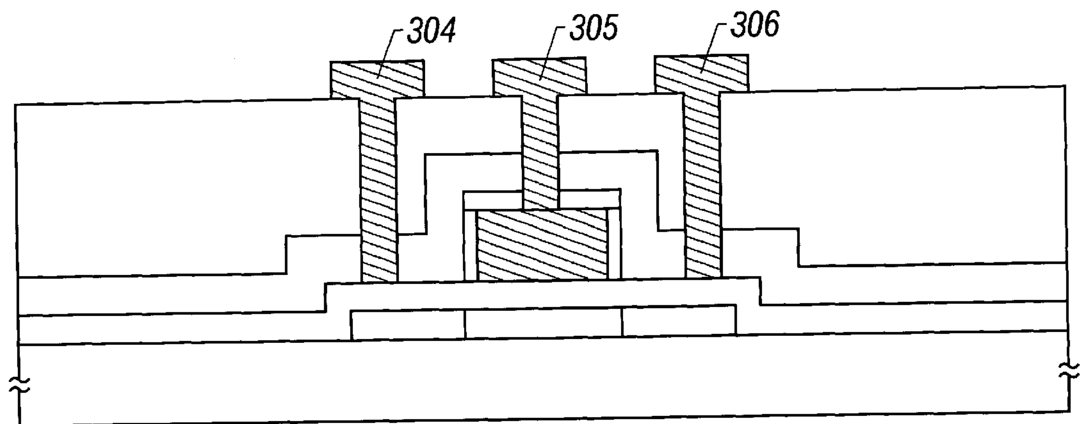


FIG. 3B

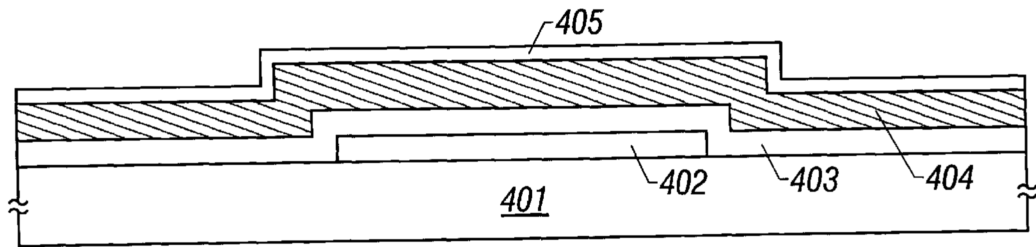


FIG. 4A

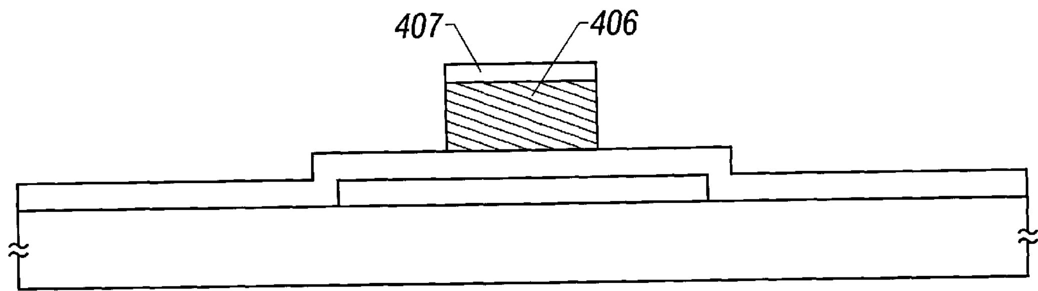


FIG. 4B

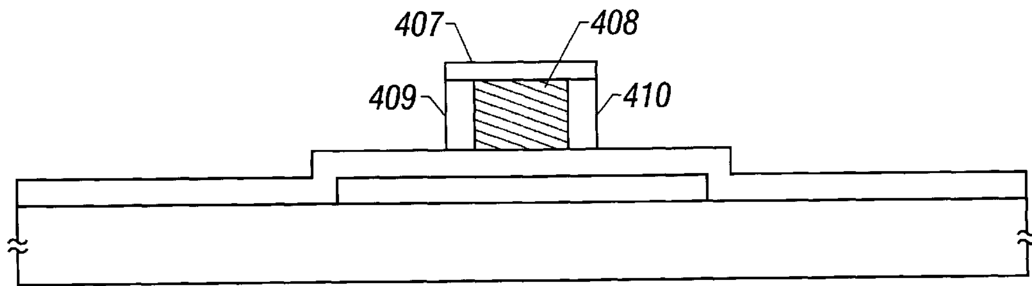


FIG. 4C

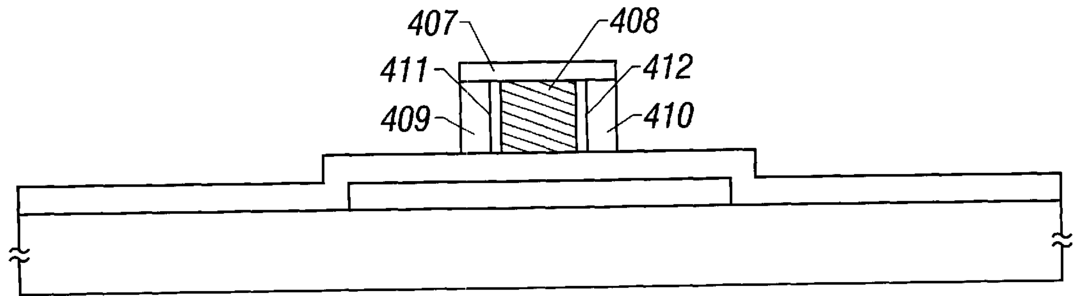


FIG. 5A

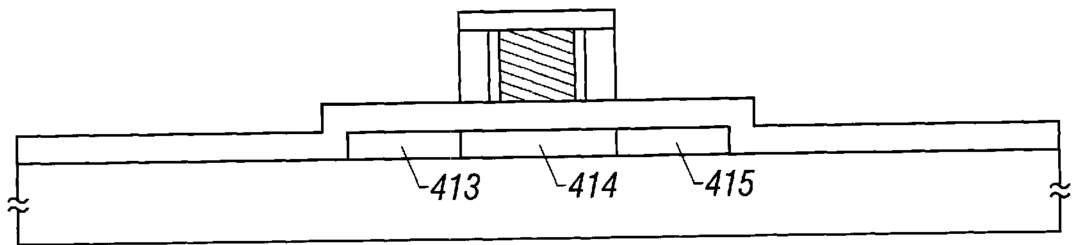


FIG. 5B

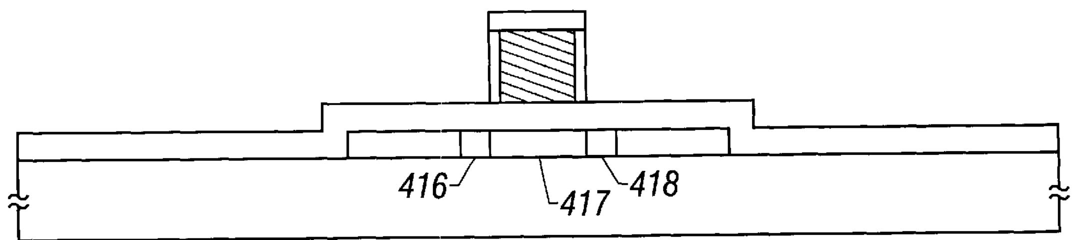


FIG. 5C

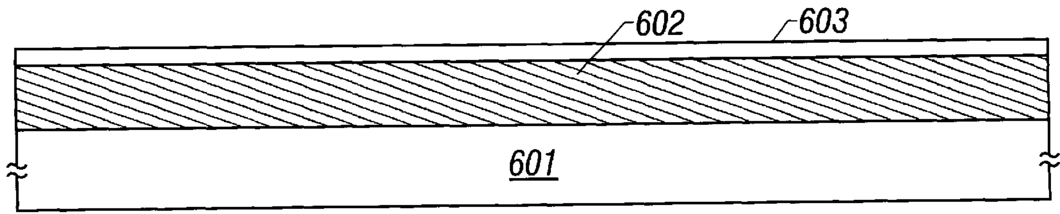


FIG. 6A

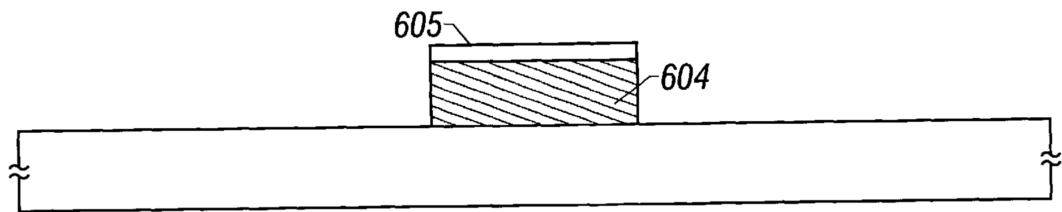


FIG. 6B

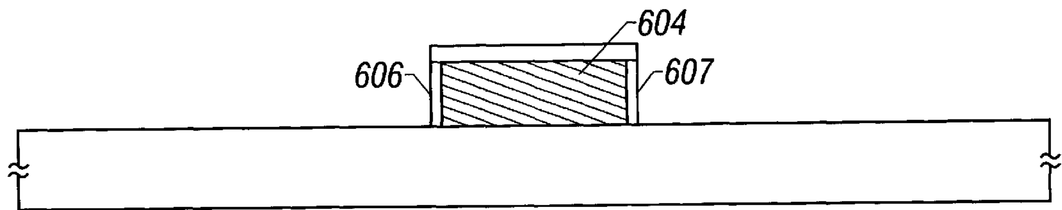


FIG. 6C

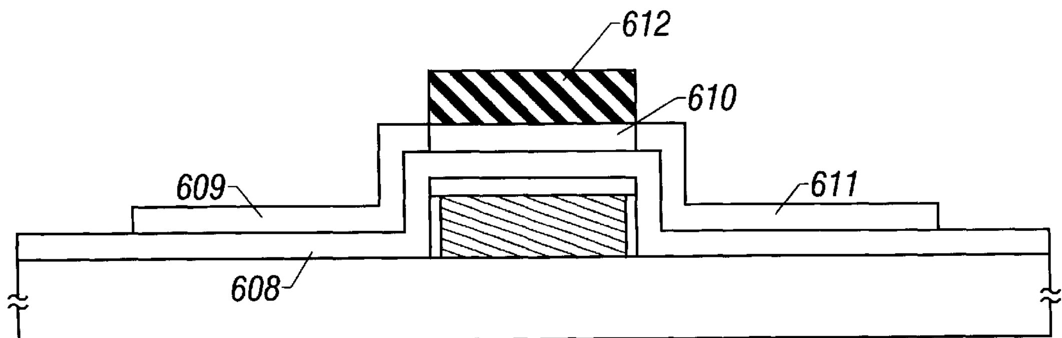


FIG. 6D

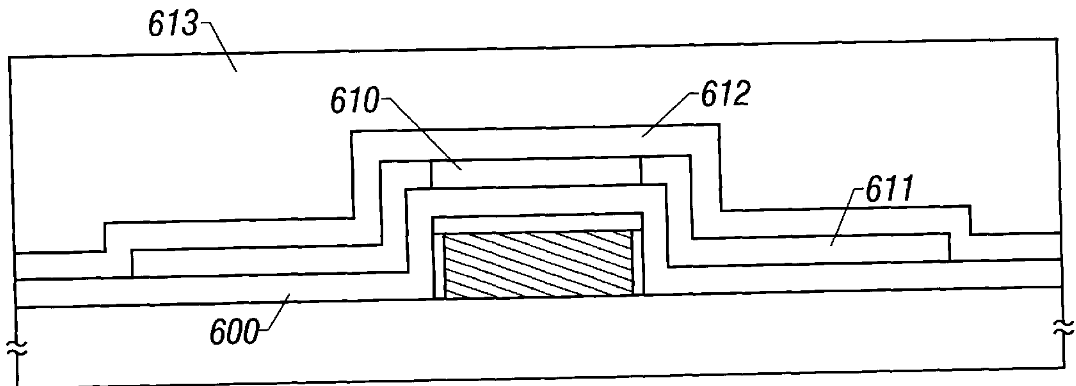


FIG. 7A

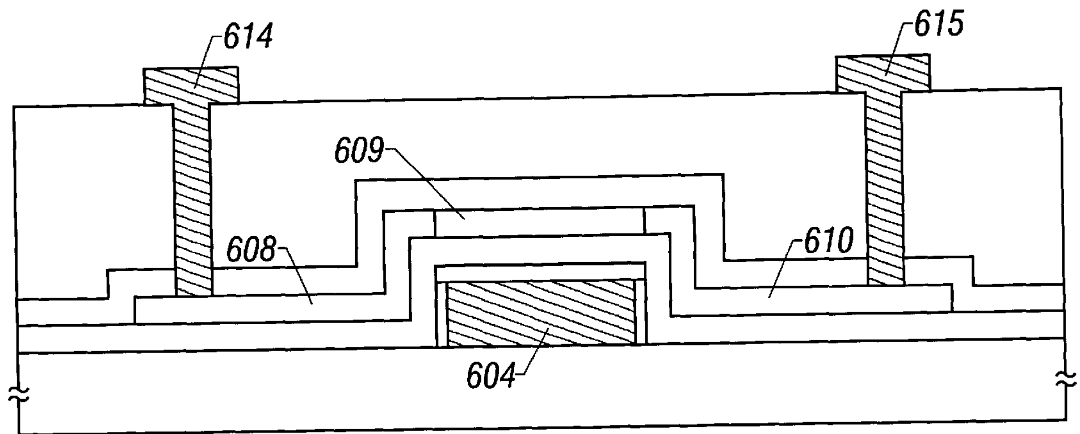


FIG. 7B

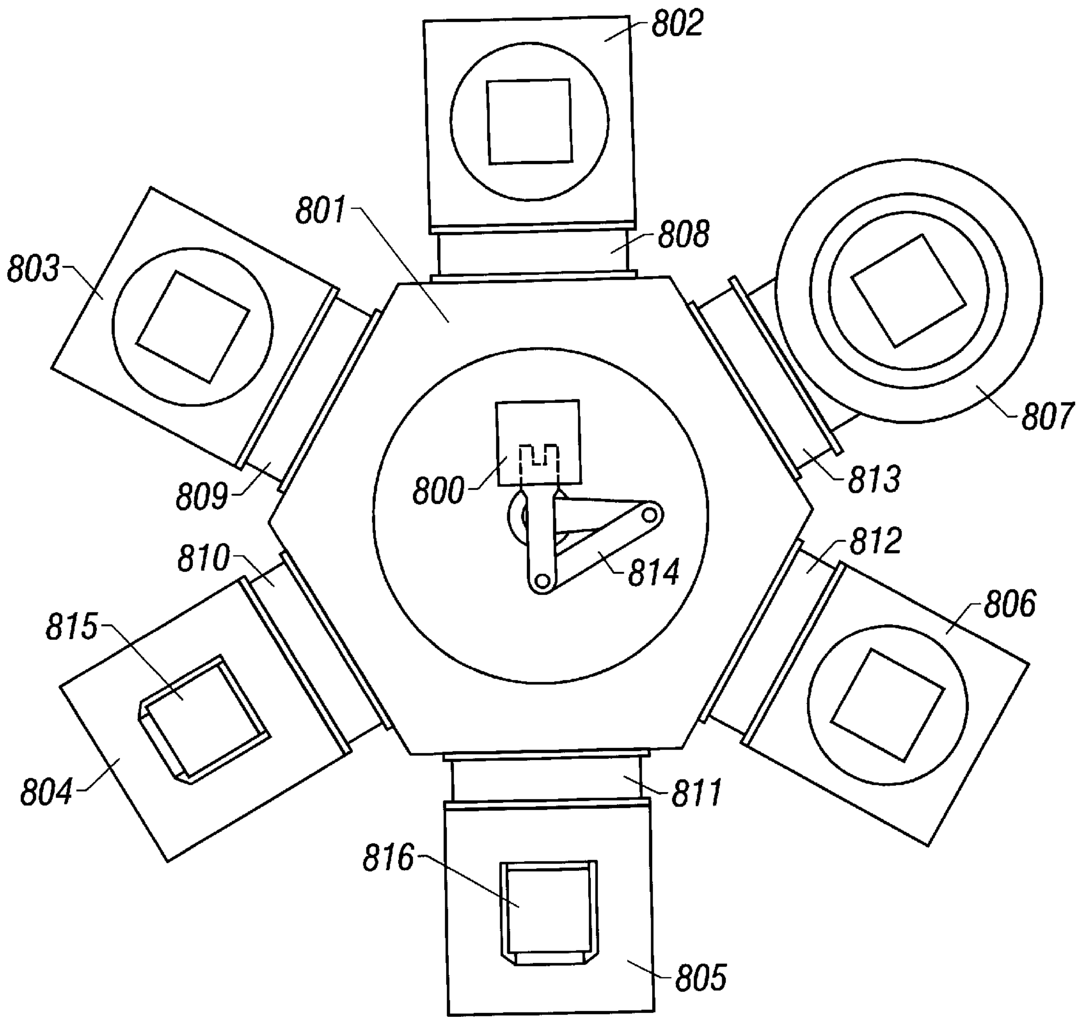


FIG. 8

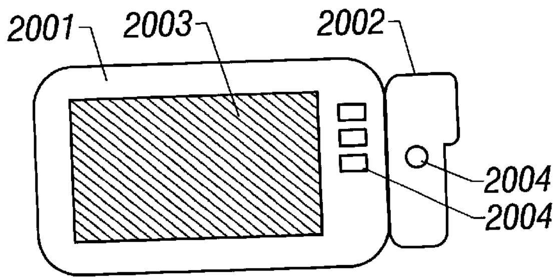


FIG. 9A

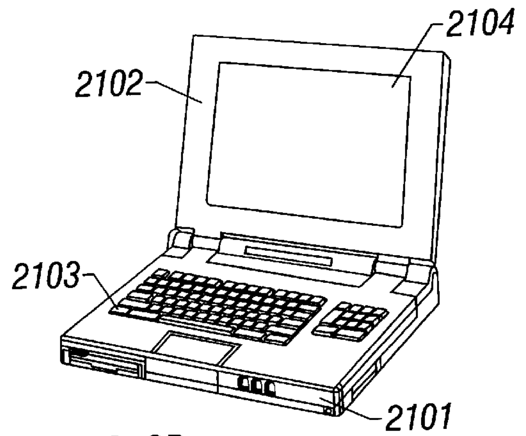


FIG. 9B

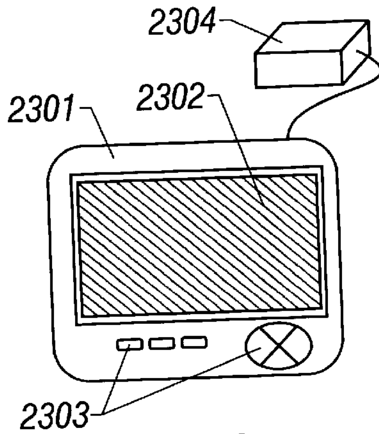


FIG. 9C

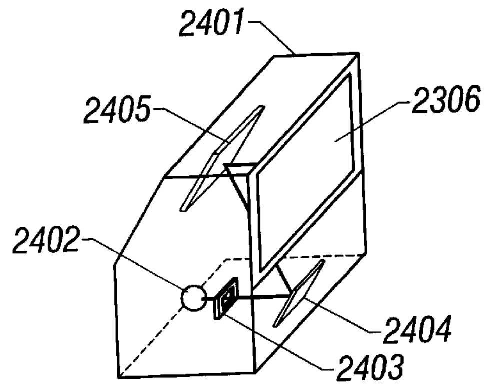


FIG. 9D

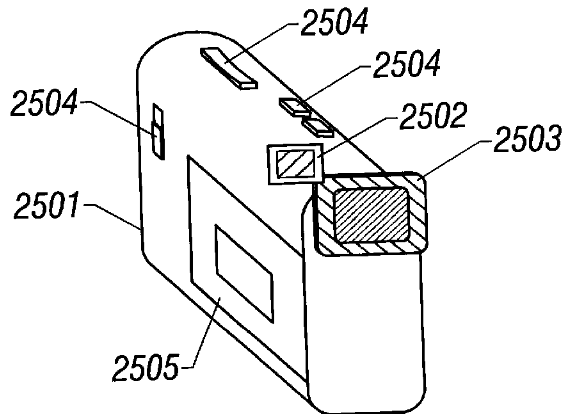


FIG. 9E

ELECTRONIC DEVICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to an electronic device whose electrodes and wiring are constructed by aluminum or a material containing aluminum as the principal component. It also relates to a method for manufacturing the same.

2. Description of the Related Art

Recently, active-matrix liquid crystal devices equipped with large-area image planes are attracting much attention. Such active-matrix liquid crystal devices not only require image planes having larger area, but also demand for finer patterning.

The use of a material having low electric resistance for the wiring material is necessary to fulfill the demand above, because the delay of signal propagating on wiring becomes a problem in a device with a size of 10×10 inch^2 or larger.

Concerning a wiring material having low electric resistance, aluminum is the most desirable one. However, aluminum brings about the problem of heat resistance on its use in the manufacturing method (refer to a review paper in *Display and Imaging*, 4 (1996), pp. 199–206; published by Science Communications International).

More specifically, in the steps such as the formation of various types of thin films by deposition and the annealing of the resulting films, or in the irradiation of laser light and the implantation of impurity ions, aluminum undergoes problematic abnormal growth so as to form protrusions called hillock or whisker. These hillock and whisker are believed to be attributable to the poor heat resistance of aluminum.

Those protrusions known as hillock or whisker sometimes grow as long as 1 μm or even longer. This phenomenon leads to the occurrence of short circuit between wirings.

The problem above can be prevented from occurring by forming an anodic oxide film on the surface of the aluminum wiring (see the reference above).

According to the study of the present inventors, it is found that the anodic oxide film (assumably containing Al_2O_3 as the principal component) is robust and is effective for preventing hillock or whisker from generating. On the other hand, however, such a robust material makes it difficult to form contact holes on the aluminum wiring.

SUMMARY OF THE INVENTION

In the light of the aforementioned circumstances, an object of the present invention is to overcome the problem of heat resistance of an aluminum wiring, and to provide a technique which solves the difficulty in forming contact holes on the aluminum wiring having an anodic oxide film formed there-on.

According to one constitution of the present invention, there is provided an electronic device characterized in that it comprises a film pattern made of aluminum or a material containing aluminum as the principal component thereof, wherein the film made of aluminum or a material containing aluminum as the principal component contains oxygen atoms at a concentration of 8×10^{18} atoms·cm^{-3} or less, carbon atoms at a concentration of 5×10^{18} atoms·cm^{-3} or less, and nitrogen atoms at a concentration of 7×10^{17} atoms·cm^{-3} or less. By employing the constitution above, the maximum height of the generated protrusions such as hillock and whisker can be suppressed to 500 Å or less.

According to another constitution of the present invention, there is provided a method for manufacturing an electronic device comprising a film pattern made of aluminum or a material containing aluminum as the principal component thereof, wherein the film made of aluminum or a material containing aluminum as the principal component contains oxygen atoms at a concentration of 8×10^{18} atoms·cm^{-3} or less, carbon atoms at a concentration of 5×10^{18} atoms·cm^{-3} or less, and nitrogen atoms at a concentration of 7×10^{17} atoms·cm^{-3} or less; and the film pattern is subjected to a process whose process temperature is 400° C. or lower.

By controlling the process temperature to 400° C. or lower, it is possible to make the best of the effect of controlling the concentration of oxygen, carbon, and nitrogen atoms to a desired low level.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**A to **1**C are diagrams showing the steps of manufacturing a thin film transistor;

FIGS. **2**A to **2**C are diagrams showing the steps of manufacturing a thin film transistor;

FIGS. **3**A and **3**B are diagrams showing the steps of manufacturing a thin film transistor;

FIGS. **4**A to **4**C are diagrams showing the steps of manufacturing another thin film transistor;

FIGS. **5**A to **5**C are diagrams showing the steps of manufacturing another thin film transistor;

FIGS. **6**A to **6**D are diagram showing the steps of manufacturing a still other film transistor;

FIGS. **7**A and **7**B are diagrams showing the steps of manufacturing a still other thin film transistor;

FIG. **8** is a schematic of a film deposition apparatus; and

FIGS. **9**A to **9**E schematically show devices utilizing liquid crystal panels.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. **1**B, an embodiment of the present invention comprises forming a silicon nitride film **107** on the upper plane of a patterned aluminum film **106** containing 8×10^{18} atoms·cm^{-3} or less of oxygen atoms, 5×10^{18} atoms·cm^{-3} or less of carbon atoms, and 7×10^{17} atoms·cm^{-3} or less of nitrogen atoms, and also forming anodic oxide films (oxide films) **108** and **109** on the side planes of the patterned aluminum film **106**.

By utilizing the constitution above, the formation of protrusions such as hillock and whisker can be suppressed, and contacts can be formed more easily.

The present invention is described in detail referring to the preferred embodiments according to the present invention. It should be understood, however, that the present invention is not to be construed as being limited to the examples below.

EXAMPLE 1

FIGS. **1**A to **1**C schematically show the fabrication process (cross section) of the present example. The present example refers to a fabrication process of a thin film transistor provided to the pixel matrix portion of an active matrix-type liquid crystal display (generally known as "pixel transistor").

Referring to FIG. **1**A, a base film (not shown) is formed on the surface of a glass substrate **101**. As the base film (not

A three-layered film consisting of titanium film, aluminum film, and titanium film is formed by sputtering. A source electrode **304**, a gate lead electrode **305**, and a drain electrode **306** are formed by patterning the resulting three-layered film. The structure shown in FIG. **3**B is obtained in this manner.

Then, a hydrogenation step similar to that described in Example 1 is performed to complete a thin film transistor.

Steps for manufacturing an N-channel type thin film transistor are described in the description above. In general, an N-channel type thin film transistor and a P-channel type thin film transistor disposed in a complementary arrangement are used for a peripheral drive circuit.

EXAMPLE 3

The present example refers to a process for manufacturing a thin film transistor comprising a low concentration impurity region interposed between a channel region and a drain region.

FIGS. **4**A to **4**C and FIGS. **5**A to **5**C show the steps for manufacturing a thin film transistor according to the present example. First, a base film (not shown) is formed on the surface of a glass substrate **401**. Then, an amorphous silicon film is formed, and is crystallized by irradiating a laser radiation. Thus is obtained a crystalline silicon film. The resulting crystalline silicon film is patterned to form an active layer **402** for the thin film transistor.

Then, a silicon oxide film **403** which functions as a gate insulating film is formed, and an aluminum film **404** is formed thereafter.

A silicon nitride film **405** is formed on the aluminum film. Thus is obtained a structure shown in FIG. **4**A.

An aluminum pattern **406** is obtained by applying patterning to the structure with reference to FIG. **4**A. The resulting aluminum pattern is the base pattern of the gate electrode that is to be formed later. A remaining silicon nitride pattern is also shown by a reference numeral **407**. Thus is obtained a structure as is shown in FIG. **4**B.

Anodic oxidation is performed thereafter to form anodic oxide films **409** and **410** by using the aluminum pattern **406** as the anode.

In the present example, an aqueous 3% oxalic acid solution is used as the electrolytic solution. The anodic oxide film formed in this step is porous, and can be grown to a growth length of several micrometers. The growth length can be controlled by adjusting the duration of anodic oxidation. Thus is obtained a structure as is shown in FIG. **4**C, in which the pattern **408** becomes the gate electrode.

Then, anodic oxidation is performed again. In this case, anodic oxidation is performed under the same conditions as those employed in forming dense anodic oxide films in Example 1. Thus are obtained dense anodic oxide films **411** and **412** as shown in FIG. **5**A.

The dense anodic oxide films **411** and **412** are formed at a thickness of 500 Å. The dense anodic oxide films are formed selectively on the side planes of the gate electrode **408**, because a silicon nitride film **407** is formed previously on the upper plane of the gate electrode **408**. Furthermore, because the electrolytic solution permeates the porous anodic oxide films **409** and **410**, dense anodic oxide films **411** and **412** are formed as shown in FIG. **5**A.

Phosphorus (P) atoms are implanted thereafter by employing plasma doping in the present example. Thus are formed a source region **413**, an I-type region **414**, and a drain region **415** in a self-aligned manner as is shown in FIG. **5**B.

Then, the porous anodic oxide films **409** and **410** are removed selectively. Referring to FIG. **5**C, a part of the silicon nitride film **407** on the upper portion of the anodic oxide films **409** and **410** is removed together with the anodic oxide films.

Subsequently, doping of P atoms is performed again. In the present step, the doping is carried out at a dose lower than that employed in the previous doping step. In the present step, low concentration impurity regions **416** and **418** are formed in a self-aligned manner, and a channel forming region **417** is also formed in a self-aligned manner.

The low concentration impurity regions **416** and **418** contain phosphorus (P) at a concentration lower than that for the source region **413** or the drain region **415**.

In general, the low concentration impurity region **418** on the drain region side is called as "LDD (lightly doped drain) region".

Once a structure as shown in FIG. **5**C is obtained, laser light is irradiated to thereby anneal the region subjected to doping.

In the constitution described in the present example, the upper plane of the gate electrode (and the gate line extending therefrom) is covered by a silicon nitride film, and the side plane thereof is covered by a dense anodic oxide film. By employing such a constitution, the generation of hillock or whisker on the surface of the gate electrode can be suppressed during the steps of doping impurity and irradiating laser radiation. Moreover, in such a structure, contacts to gate electrodes (or gate lines) can be formed more easily.

EXAMPLE 4

The present example refers to a thin film transistor of a so-called bottom-gate type constitution, in which the gate electrode is provided between the active layer and the substrate.

FIGS. **6**A to **6**D and FIGS. **7**A and **7**B show the steps for manufacturing a thin film transistor according to the present example. First, a 3,000Å-thick aluminum film **602** is formed on the surface of a glass substrate **601** by means of sputtering. The resulting aluminum film constitutes the gate electrode in the later steps.

Once the aluminum film **602** is formed, a 500-Å-thick silicon nitride film **603** is formed thereon by plasma CVD. Thus is obtained a structure shown in FIG. **6**A.

A gate electrode **604** is formed thereafter by patterning. Silicon nitride film **605** remains on the gate electrode **604**. The structure shown in FIG. **6**B is obtained in this manner.

Dense anodic oxide films **606** and **607** are each formed at a thickness of 500 Å by effecting anodic oxidation using the gate electrode **604** as the anode.

Because silicon nitride film **605** still remains in this step, anodic oxide films are formed on only the side planes of the gate electrode **604**. Thus is obtained a structure as shown in FIG. **6**C.

A 1,000-Å-thick silicon oxide film **608** which functions as a gate insulating film is formed thereafter by means of plasma CVD. In order to form an active layer, a 500-Å-thick amorphous silicon film (not shown) is formed by plasma CVD. A crystalline silicon film (not shown) is obtained thereafter by irradiating a laser light to the amorphous silicon film.

Once the crystalline silicon film (not shown) is obtained, patterning is performed to form an active layer pattern comprising regions **609**, **610**, and **611**.

Then, a resist mask **612** is formed by performing exposure from the back side of the substrate **601** while using the gate electrode **604** as a mask (see FIG. **6**D).

In this state, plasma doping is performed to dope P atoms. Thus, a source region **609**, a drain region **611**, and a channel region **610** are formed in a self-aligned manner in the present doping step. Thus is obtained a structure shown in FIG. **6**D.

Upon completion of the doping step above, laser light is irradiated to the structure to activate the doped atoms and to anneal the doped regions.

Then, a 2,000-Å-thick silicon nitride film is formed by plasma CVD to provide a first interlayer insulating film **612**, and a polyimide film is formed thereafter to obtain a second interlayer insulating film **613**. The structure thus obtained is shown in FIG. **7**A.

After perforating contact holes, a source electrode **614** and a drain electrode **615** are formed. Hydrogenation is performed finally to complete the transistor.

Although not shown, another contact to the gate electrode **604** is formed by perforating a contact hole on the upper portion of wiring extended from the gate electrode **604** in a separate portion. Thus is obtained a structure shown in FIG. **7**B.

Also in the constitution of the present example, hillock and whisker are prevented from generating as a whole because an anodic oxide film is formed on the side planes of the gate electrode **604** and because a silicon nitride film is formed on the upper plane of the gate electrode **604**. Moreover, because a silicon nitride film is formed on the upper plane of the gate electrode, the formation of contact holes is facilitated.

EXAMPLE 5

The relation between the concentration of impurities in an aluminum film containing 0.18% by weight of scandium and the generation of hillock is shown in this example. A 3,000-Å-thick aluminum film was formed by sputtering, and was subjected to heat treatment at 350° C. for a duration of 1 hour under gaseous hydrogen atmosphere. Table 1 shows the relation between the observed height of the hillock and the concentration of impurities in the thus obtained film.

TABLE 1

No.	Impurity concentration Sample in film Nos. (atoms · cm^{-3}) (max. value) Oxygen	Carbon	Nitrogen	Maximum height of Hillock (Å)
1	2×10^{20}	9×10^{19}	1×10^{19}	1552
2	7×10^{19}	4×10^{19}	7×10^{18}	1627
3	7×10^{19}	2×10^{19}	5×10^{18}	2472
4	1×10^{19}	8×10^{18}	2×10^{18}	837
5	8×10^{18}	4×10^{18}	6×10^{17}	322
6	7×10^{18}	4×10^{18}	7×10^{17}	481
7	7×10^{18}	5×10^{18}	7×10^{17}	373

Referring to Table 1, the concentration of impurities differs from a sample to another. The difference arises due to factors such as the varied duration of evacuation during sputtering, whether or not cleaning of chamber of the sputtering apparatus was performed, and how maintenance was carried out on the evacuation pump.

The height of the hillock was determined by observation under cross section SEM (scanning electron microscope) and AFM (atomic force microscope). The concentration of impurity elements is given by the maximum value measured by using SIMS (secondary ion mass spectroscopy).

It is apparent from Table 1 that the generation of hillock can be suppressed by decreasing the concentration of oxygen (O), carbon (C), and nitrogen (N) contained in the film.

By taking into consideration the film thickness of the interlayer insulating film and the like, hillock not greater than 500 Å in height are allowable in view of practical use. Conclusively, Table 1 reads that the allowable concentration of the impurities is 7×10^{18} atoms·cm^{-3} or lower for oxygen, 5×10^{18} atoms·cm^{-3} or lower for carbon, and 7×10^{17} atoms·cm^{-3} or lower for nitrogen.

Care should be taken in using SIMS for the measurement of the impurity concentration, because a false value is sometimes measured in the vicinity of the interface of the film.

Explanation of the Apparatus

The apparatus for use in an embodiment of the present invention is described below. FIG. **8** schematically shows the apparatus. Referring to FIG. **8**, the apparatus is of a multichamber type in which a plurality of processes are performed continuously without exposing the sample to the atmosphere. Each of the chambers is equipped with the necessary evacuation system, and maintains the airtight environment.

Referring to FIG. **8**, the apparatus comprises a substrate feeding chamber **804** and a substrate discharging chamber **805**. A plurality of substrates (samples) set in a cassette **815** are wholly fed into the substrate feeding chamber **804** from the outside. The substrates subjected to the process are set again in a cassette **816**, and once process for a predetermined number of substrates are finished, the cassette **816** with such substrates is wholly drawn again from the chamber.

A substrate transportation chamber **801** transports a substrate **800** to a desired chamber by using a robot arm **814**.

A chamber **803** is provided to form aluminum films by means of sputtering. The chamber **803** is equipped with a cryo pump to control the concentration of impurities in the aluminum film to a predetermined level or lower.

A sputtering apparatus **802** is used to form a germanium (or silver) film to realize favorable electric contact in forming contacts. The chamber **802** is also equipped with a cryo pump to prevent the incorporation of impurities as much as possible.

A chamber **807** is provided to perform heat treatment. In this chamber, heating is effected by irradiating a light emitted from a lamp.

A chamber **806** is further provided to form a silicon nitride film by using plasma CVD.

Gate valves, which are gate-type sections or partitions **810**, **809**, **808**, **813**, **812**, and **811**, are provided between the substrate transportation chamber **801** and each of the peripheral chambers for performing various types of processes.

An example of operating the apparatus with reference to FIG. **8** is described below. The present operation comprises sequential processes of forming an aluminum film by film deposition, forming a germanium film, heat treatment, and forming a silicon nitride film.

In the processes, the gate valves are all closed except for the one through which the sample is passed. First, a plurality of substrates (samples) for forming thereon an aluminum film are set inside a cassette **815**, and are transported into the substrate feeding chamber **804**. A substrate is then transported into the chamber **803** by using the robot arm **814**.

Upon completion of the formation of the aluminum film inside the chamber **803**, the substrate is transferred to the chamber **806** to form thereon a silicon nitride film. Then, the substrate is placed inside the cassette **816** of the substrate discharging chamber **805** to complete the entire process.

In case of forming an aluminum film for use as the contact after the formation of contact holes, a germanium film is formed inside the chamber **802** after forming the aluminum film in the chamber **803**, and thereafter heat treatment is carried out in the heating chamber **807** to perform reflow treatment, i.e., the annealing for forming the contact.

Reflow treatment provides a favorable electric contact between aluminum and the electrode to be brought into contact therewith (i.e., the electrode exposed at the bottom portion of the contact hole), because the melting point drops at the contact portion between aluminum and germanium, and germanium thereby diffuses into the aluminum film by the heat treatment.

EXAMPLE 6

The present example relates to a case of employing, in the place of anodic oxidation, plasma oxidation for the formation of a metallic oxide film on the surface of aluminum. Plasma oxidation can be performed by effecting high frequency discharge under a reduced-pressure oxidizing atmosphere.

EXAMPLE 7

The present invention disclosed in the present specification is applicable to an active matrix electro-optical device. Electro-optical devices include, for instance, a liquid crystal display device, an EL (electro-luminescent) display device, and an EC (electro-chromic) display device.

Application examples of the commercially available products include TV cameras, personal computers, car navigation systems, TV projection systems, video cameras, etc. Those products are briefly described below with reference to FIGS. **9**A to **9**E.

FIG. **9**A shows a TV camera comprising a main body **2001**, a camera **2002**, a display device **2003**, and operation switches **2004**. The display device **2003** is also used as a view finder.

FIG. **9**B shows a personal computer comprising a main body **2101**, a cover **2102**, a keyboard **2103**, and a display device **2104**. The display device **2104** is used as a monitor, and a diagonal of ten and several inches in size is required.

Referring to FIG. **9**C, a car navigation system comprises a main body **2301**, a display device **2302**, operation switches **2303**, and an antenna **2304**. The display device **2302** is used as a monitor, but the main usage thereof is to display a map. Thus, the allowance in resolution is relatively large.

Referring to FIG. **9**D, a TV projection system comprises a main body **2401**, a light source **2402**, a display device **2403**, mirrors **2404** and **2405**, and a screen **2406**. Because the image displayed in the display device **2403** is projected to the screen **2406**, the display device **2403** must have high resolution.

Referring to FIG. **9**E, a video camera comprises a main body **2501**, a display device **2502**, an eye piece **2503**, operation switches **2504**, and a tape holder **2505**. Since the real time view of the photographed image can be seen through the eye piece **2503**, a user may take pictures while viewing the image.

As described above, by using the present invention, not only the problem concerning the heat resistance of an aluminum wiring is overcome, but also the problematic formation of contacts is facilitated in case an anodic oxidation film is formed.

Although aluminum is used for the gate electrode and the gate line in the foregoing embodiments, the present invention is applicable to anodic oxidizable metals such as tantalum in place of aluminum.

While the invention has been described in detail, it should be understood that the present invention is not to be construed as being limited thereto, and that any modifications can be made without departing from the scope of claims.

What is claimed is:

1. An electronic device comprising a film pattern made of aluminum or a material containing aluminum as a principal component thereof, wherein,

the film made of aluminum or a material containing aluminum as a principal component contains oxygen atoms at a concentration of 8×10^{18} atoms·cm^{-3} or less, carbon atoms at a concentration of 5×10^{18} atoms·cm^{-3} or less, and nitrogen atoms at a concentration of 7×10^{17} atoms·cm^{-3} or less.

2. A device according to claim **1**, wherein an oxide film is formed on a side plane of the film pattern, and a silicon nitride film is formed on an upper plane of the film pattern.

3. A device according to claim **1**, wherein an oxide film is formed in contact with a side plane of the film pattern.

4. A device according to claim **1**, wherein a silicon nitride film is formed in contact with an upper plane of the film pattern, and a contact to the film pattern is formed via an aperture formed in the silicon nitride film.

5. A device according to claim **1**, wherein a protrusion is formed on a surface of the film pattern, and a maximum height of the protrusion is 500 Å or lower.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 5,929,527
DATED : July 27, 1999
INVENTOR(S) : Yamazaki et al.

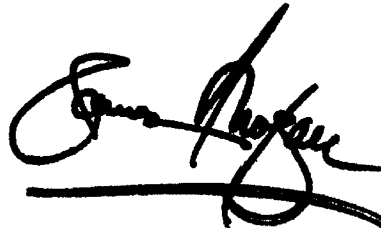
It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Drawings,
Please substitute the attached FIGs. 2A, 2B, and 2C (Sheet 2 of 9); and FIGs. 3A and 3B (Sheet 3 of 9) as shown on the two attached pages.

Signed and Sealed this

Ninth Day of July, 2002

Attest:



JAMES E. ROGAN

Attesting Officer *Director of the United States Patent and Trademark Office*

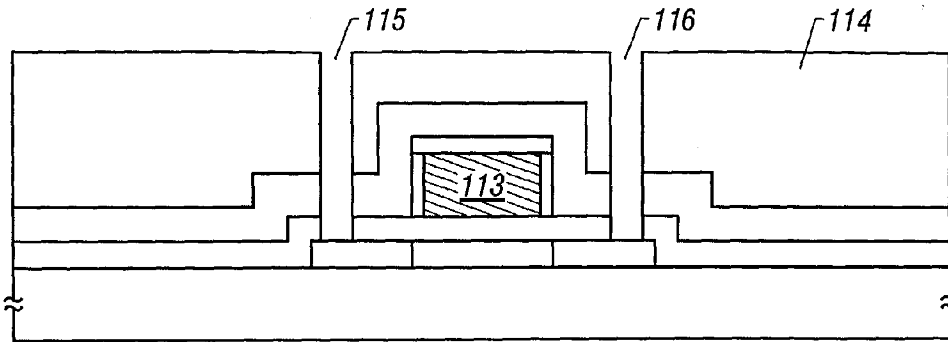


FIG. 2A

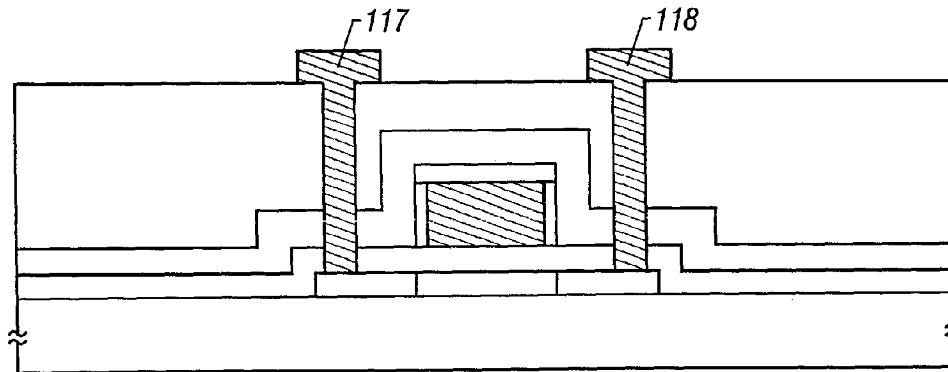
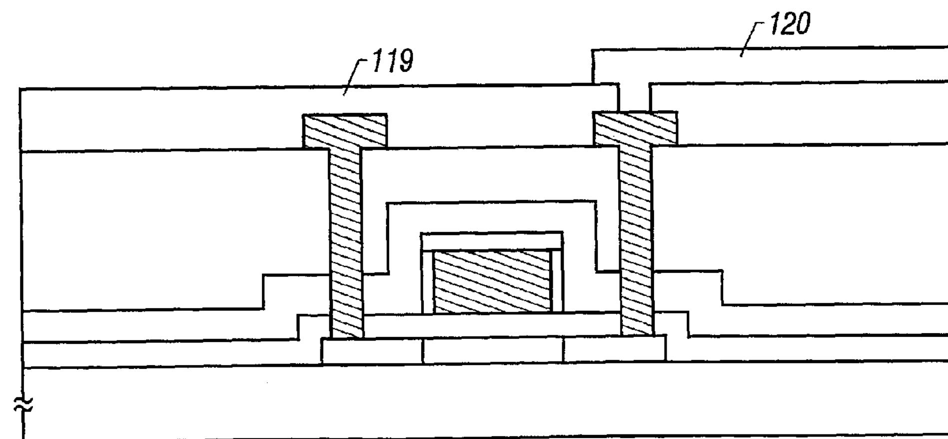


FIG. 2B



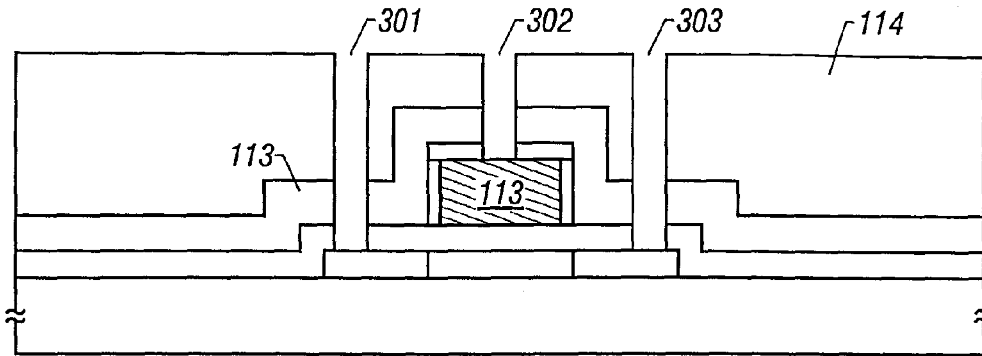


FIG. 3A

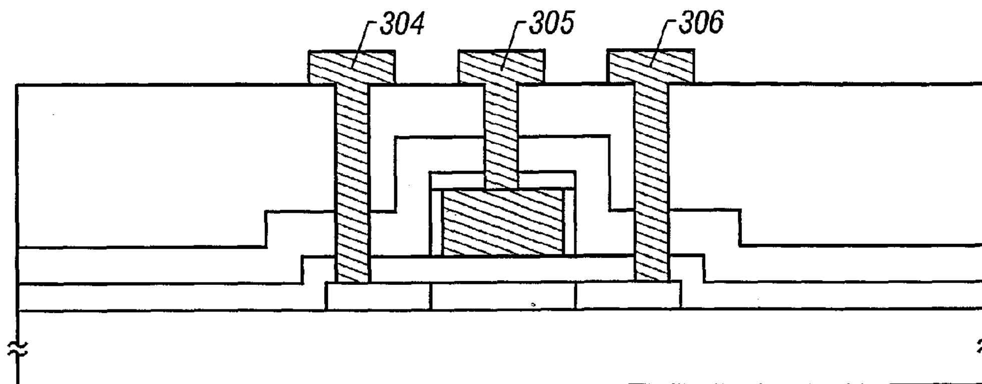


FIG. 3B