METHODS FOR MANUFACTURING COMPOUND SEMICONDUCTOR AND COMPOUND INSULATOR USING CHEMICAL REACTION AND DIFFUSION BY HEATING, COMPOUND SEMICONDUCTOR AND COMPOUND INSULATOR MANUFACTURED USING THE METHOD, AND PHOTOCELL, ELECTRONIC CIRCUIT, TRANSISTOR, AND MEMORY USING THE SAME

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**Title:** METHODS FOR MANUFACTURING COMPOUND SEMICONDUCTOR AND COMPOUND INSULATOR USING CHEMICAL REACTION AND DIFFUSION BY HEATING, COMPOUND SEMICONDUCTOR AND COMPOUND INSULATOR MANUFACTURED USING THE METHOD, AND PHOTOCELL, ELECTRONIC CIRCUIT, TRANSISTOR, AND MEMORY USING THE SAME

**Abstract:** Provided are methods for manufacturing a compound semiconductor and a compound insulator using chemical reaction and diffusion induced by heating, a compound semiconductor and a compound insulator formed using the methods, and a photocell, an electronic circuit, a transistor, and a memory including the compound semiconductor or the compound insulator. The method for manufacturing a compound semiconductor or a compound insulator involves forming a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and sulfur, interposed between dielectric layers containing oxygen and sulfur and heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the heating is performed at different temperatures for the compound semiconductor and the compound insulator.
METHODS FOR MANUFACTURING COMPOUND SEMICONDUCTOR AND COMPOUND INSULATOR USING CHEMICAL REACTION AND DIFFUSION BY HEATING, COMPOUND SEMICONDUCTOR AND COMPOUND INSULATOR MANUFACTURED USING THE METHOD, AND PHOTOCELL, ELECTRONIC CIRCUIT, TRANSISTOR, AND MEMORY USING THE SAME

Technical Field

The present invention relates to a compound semiconductor, and more particularly, to methods for manufacturing a compound semiconductor and a compound insulator by heating a stacked structure including a rare earth transition metal layer interposed between dielectric layers to induce chemical reaction and diffusion between the intermediate layer and the dielectric layers, and compound semiconductor and compound insulator manufactured using the method, and photocell, electric circuit, transistor, and memory using the same.

Background Art

Compound semiconductors are based on the crystalline properties of materials. A gallium arsenide semiconductor, a typical compound semiconductor, is synthesized by injecting impurities into a crystallized gallium arsenide compound to incorporate free electrons or holes. Compound semiconductors have p-type or n-type semiconductor properties depending on the ratio of constituent materials.

There are various kinds of compound semiconductors: binary compound semiconductors composed of, for example, gallium arsenide or indium phosphide, ternary compound semiconductors composed of, for example, aluminum gallium arsenide or gallium indium arsenide, and quaternary compound semiconductors composed of, for example, gallium indium arsenide phosphide.
Free electrons in gallium arsenide (GaAs) compound semiconductors move faster than those in silicon semiconductors, so that compound semiconductors have been widely used for high-speed operation devices, such as computers. GaAs compound semiconductor has also been widely used for light emitting diodes due to their great light emitting efficiency.

However, such conventional compound semiconductors require complicated manufacturing processes which have low production yield. In addition, it is not easy to control the manufacturing processes such that the final compound semiconductors have properties within a desired range.

Disclosure of the Invention

The present invention is concerned with a new concept of compound semiconductor. The present invention provides methods for manufacturing a compound semiconductor and a compound insulator that involves forming a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur, and heating the stacked structure to induce chemical reaction and diffusion between the intermediate layer and the dielectric layers. The present invention provides a semiconductor compound and a semiconductor insulator manufactured by the above method, and a photocell, an electronic circuit, a transistor, a dynamic random access memory (DRAM), and a flash memory using the semiconductor compound and the semiconductor insulator.

In accordance with one aspect of the present invention, as recited in claim 1, there is provided a method for manufacturing a compound semiconductor, the method comprising: forming a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and heating the stacked structure to
induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

According to one embodiment of the method for manufacturing a compound semiconductor according to the present invention, as recited in claim 2, there is provided a method for manufacturing a compound semiconductor, the method comprising: forming a stacked structure including an intermediate layer comprising alloys of rare earth metal and transition metal, both of which are highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

According to another embodiment of the method for manufacturing a compound semiconductor according to the present invention, as recited in claim 3, there is provided a method for manufacturing a compound semiconductor, the method comprising: forming a stacked structure including a rare earth metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

According to another embodiment of the method for manufacturing a compound semiconductor according to the present invention, as recited in claim 4, there is provided a method for manufacturing a compound semiconductor, the method comprising: forming a stacked structure including a transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

According to specific embodiments of the method for manufacturing a compound semiconductor according to the present invention, the heating is performed by laser beam irradiation, as recited
in claim 5. The heating may be performed by electron beam irradiation, as recited in claim 6. The heating is performed at a temperature ranging from 753°C to 783°C, as recited in claim 7. The dielectric layers and the intermediate layer are simultaneously formed as a single mixed layer, as recited in claim 8.

In accordance with another aspect of the present invention, as recited in claims 9 through 16, there are provided compound semiconductors manufactured by the methods of claims 1 through 8.

In accordance with other aspects of the present invention, as recited in claims 17 through 24, there are provided methods for manufacturing a compound insulator, which are performed in the same manner as the methods of manufacturing a compound semiconductor according to claims 1 through 16, with the exception of the temperature of heating. As recited in claims 25 through 32, the present invention also provide compound insulators manufactured by the methods of claims 17 through 24.

In accordance with another aspect of the present invention, as recited in claims 33 through 40, there are provided photocells using any compound semiconductor according to claims 9 through 16.

In accordance with another aspect of the present invention, as recited in claims 41 through 49, there are provided methods for manufacturing an electronic circuit, which involves a compound semiconductor manufacturing method according to claims 1 through 8, a compound insulator manufacturing method according to claims 17 through 24, and a conductor manufacturing method performed at a temperature range different from that of the compound semiconductor manufacturing and compound insulator manufacturing methods. One embodiment of the method for manufacturing an electronic circuit comprising at least one of a conductor, a semiconductor, and an insulator comprises: forming a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen
and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the heating is performed at less than 753°C to form the conductor, at a temperature ranging from 753°C to 783°C to form the semiconductor, and above 783°C to form the insulator.

In accordance with another aspect of the present invention, as recited in claims 50 through 58, there are provided electronic circuits manufactured by the methods according to claims 41 through 49.

In accordance with another aspect of the present invention, there are provided transistors as recited in claims 59 through 67, which can be implemented as an example of electronic circuits according to claims 50 through 58. One embodiment of a transistor according to the present invention comprises a conductor having a source, a drain, and a gate, and a semiconductor forming a channel between the source and the drain when electric current is applied to the gate, wherein the conductor is formed from a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating at less than 753°C to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the semiconductor is formed from the stacked structure by heating at a temperature ranging from 753°C to 783°C to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

In accordance with another aspect of the present invention, as recited in claim 68, there is provided a DRAM using a transistor according to claims 59 through 67, the DRAM comprising an insulator formed by heating the stacked structure above 783°C to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer in order to form a capacitor in the stacked structure between the source and the drain of the transistor.
In accordance with another aspect of the present invention, as recited in claim 69, there is provided a flash memory using a transistor according to claims 59 through 67, the flash memory comprising a floating gate forming semiconductor formed by heating the stacked structure at a temperature ranging from 753°K to 783°K to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer in order to form the floating gate in the stacked structure between the source and the drain of the transistor; and an insulator formed by heating the stacked structure at a temperature above 783°K to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer in order to insulate the region between the floating gate forming semiconductor and the source and the region between the floating gate forming semiconductor and the drain.

Brief Description of the Drawings

FIG. 1 is a sectional view of a stacked structure including a rare earth transition metal intermediate layer interposed between dielectric layers according to the present invention;

FIGS. 2A through 2C illustrate changes in the physical and chemical properties of the stacked structure according to the present invention at different temperatures, in which FIG. 2A shows the degree of diffusion at different temperatures, FIG. 2B is a graph of transparence and magnetic hystereses versus temperature, and FIG. 2C illustrates the degree of diffusion in the TbFeCo intermediate layer at different temperatures;

FIG. 3 is a graph of resistance versus voltage;

FIG. 4 is a graph of change in resistance versus temperature;

FIG. 5 is a graph of current versus voltage in a diode formed by connecting an n-type semiconductor according to the present invention and a conventional p-type silicon semiconductor;

FIG. 6 is a graph of quantization efficiency versus light wavelength
in a photocell manufactured using an n-type semiconductor according to the present invention and a p-type silicon semiconductor.

FIG. 7 shows the variation of carrier to noise ratio (CNR) with mark length, in which (a) shows various mark lengths of semiconductors manufactured according to the present invention, and (b) is a graph of CNR versus mark length in the semiconductors manufactured according to the present invention; and

FIG. 8 shows a flash memory according to the present invention and a laser beam irradiation temperature profile applied to manufacture the flash memory, in which (a) is a top view of a flash memory according to the present invention, and (b) is a laser beam irradiation temperature profile applied to form the flash memory of (a).

Best mode for carrying out the Invention

Embodiments of the present invention will be described in greater detail with reference to the appended drawings.

FIG. 1 is a sectional view of a stacked structure including a rare earth transition metal intermediate layer interposed between dielectric layers according to the present invention. Referring to FIG. 1, a dielectric layer 110, an intermediate layer 120 formed of a rare earth transition metal, and a dielectric layer 130 are sequentially stacked upon one another. The dielectric layer 110, the intermediate layer 120, and the dielectric layer 130 may be simultaneously formed as a single mixed layer. Although the dielectric layers 110 and 130 in the stacked structure of FIG. 1 are formed of ZnS-SiO₂, any dielectric material containing oxygen and/or sulfur can be used for the dielectric layers 110 and 130. Although the intermediate layer 120 in the stacked structure of FIG. 1 is formed of TbFeCo, any rare earth transition metal having high reactivity to oxygen and/or sulfur, for example, Tb₂S₃, Tb₂O₃, TbO₂, FeS, FeO, Fe₂O₃, Fe₃O₄, CoS₂, Co₂S₃, CoS, CoO, and Co₃O₄, can be used for the intermediate layer 120. Also, the intermediate layer may be composed of rare earth metal, transition metal, or alloys of rare earth
metal and transition metal having high reactivity to oxygen and/or sulfur.

As shown in FIG. 1, a local heating region 140 of the stacked structure is irradiated with a laser beam or an electron beam to induce chemical reaction between the dielectric layers 110 and 130 formed of ZnS-SiO₂ and the intermediate layer 120 formed of TbFeCo, thereby forming a Si-Zn-TbFeCo-O-S compounds. Besides the chemical reaction, sulfur and oxygen diffuse into the intermediate layer 120 at the same time. The compounds formed in the local heating region 140 as a result of the laser beam or electron beam irradiation has conductive, semi-conductive, or insulating properties depending on the heating temperature. When the laser beam or electron beam irradiation is performed to a temperature of 753°K or less, the resulting Si-Zn-TbFeCo-O-S compounds have electrically conductive properties. The resulting Si-Zn-TbFeCo-O-S compounds have electrically semi-conductive properties at a heating temperature of 753°K ~ 783°K and electrically insulating properties at a heating temperature of above 783°K.

FIGS. 2A through 2C illustrate changes in the physical and chemical properties of the stacked structure according to the present invention at different temperatures, in which FIG. 2A shows the degree of diffusion at different temperatures, FIG. 2B is a graph of transparence and magnetic hystereses versus temperature, and FIG. 2C illustrates the degree of diffusion in the TbFeCo intermediate layer at different temperatures.

As is apparent from the scale of FIG. 2, a sequential stacked structure of a 100-nm-thick ZnSiO₂ dielectric layer, a 20-nm-thick TbFeCo intermediate layer, and a 50-nm-thick ZnSiO₂ dielectric layer was used for the experiments. FIG. 2A includes transmission electron microscopic (TEM) photographs and electron diffraction pattern (EDP) photographs showing the degree of diffusion at different temperatures. For a stacked structure prior to heating, chemical reaction and diffusion
hardly occurs, as shown in the TEM photograph, and neither does crystallization, as shown in the EDP photograph. For a stacked structure heated at 763°K, as shown in the corresponding TEM and EDP photographs, a small amount of chemical reaction, diffusion, and crystallization occur. For a stacked structure heated at 783°K, a fair amount of chemical reaction, diffusion, and crystallization occur, as shown in the corresponding TEM and EDP photographs. FIG. 2B is a graph showing the transparency (k) and magnetic hystereses (inset) of the TbFeCo intermediate layer versus temperature, which were measured using an optical microscope connected to a multi-channel photodetector. Apparently, until the temperature rise caused by a laser beam or electron beam irradiation reaches a predetermined level, neither chemical reaction nor diffusion occurs, so that transparency remains as small as it is prior to heating. However, the transparency of the TbFeCO intermediate layer increases gradually as a result of chemical reaction and diffusion from the predetermined temperature level, and sharply for a temperature range from 763°K to 783°K, but flattens out when the temperature of the TbFeCo intermediate layer irradiated by a laser beam or electron beam exceeds 783°K. The TbFeCo intermediate layer before laser beam or electron beam irradiation retains the original magnetic properties of TbFeCo, but its magnetic properties change when the temperature of heating by laser beam or electron beam irradiation is between 763°K and 783°K. Referring to FIG. 2C, which is a graph of the degree of diffusion in the TbFeCo intermediate layer, S, Si, O, and Co nearly do not diffuse before laser beam or electron beam irradiation but diffuse slightly when the temperature of heating by laser beam or electron beam irradiation reaches 763°K. The diffusion of S, Si, O, and Co is nearly saturated at 783°K. As is apparent from FIG. 2, the stacked structure according to the present invention can be used as a semiconductor when subjected to laser beam or electron beam irradiation for changing the properties of the stacked structure.
FIG. 3 is a graph of resistance versus voltage. As shown in FIG. 3, the resistance of the stacked structure according to the present invention varies with voltage, like a conductor, when the stacked structure is heated by a laser beam or electron beam irradiation at a temperature of 753°C, varies like a semiconductor at a heating temperature ranging from 763°C to 773°C, and varies like an insulator at a heating temperature of 783°C. These results indicate the possibility that a semiconductor can be manufactured from the stacked structure according to the present invention by heating with laser beam or electron beam irradiation to induce chemical reaction and diffusion in the dielectric layers and the intermediate layer. It will be appreciated that a compound semiconductor manufactured from the stacked structure according to the present invention can be used to construct electronic circuits.

FIG. 4 is a graph of change in resistance versus temperature. As shown in FIG. 4, the resistance of the stacked structure according to the present invention varies with temperature, like a conductor, when it is heated with a laser beam or electron beam irradiation at a temperature of 753°C, varies like a semiconductor at a heating temperature ranging from 763°C to 773°C, and varies like an insulator at a heating temperature of 783°C. These results indicate that a semiconductor can be manufactured from the stacked structure according to the present invention through chemical reaction and diffusion, as expected from the results of FIG. 3. In addition, a compound semiconductor manufactured from the stacked structure according to the present invention can be applied to construct electronic circuits.

FIG. 5 is a comparative graph of current versus voltage in a diode formed by connecting an n-type semiconductor according to the present invention and a conventional p-type silicon semiconductor. The n-type semiconductor according to the present invention was manufactured by heating the stacked structure described above with laser beam or
electron beam irradiation at 773°K to induce chemical reaction and diffusion therein.

As shown in FIG. 5, the diode shows typical voltage-current characteristics of diodes, indicating that the stacked structure according to the present invention can be used as a semiconductor with heating by laser beam or electron beam irradiation that is performed to induce chemical reaction and diffusion therein.

FIG. 6 is a graph of quantization efficiency versus light wavelength in a photocell manufactured using an n-type semiconductor according to the present invention and a p-type silicon semiconductor. The n-type semiconductor according to the present invention used for the results of FIG. 6 was manufactured by heating the stacked structure described above with laser beam or electron beam irradiation at 773°K to induce chemical reaction and diffusion therein.

As shown in FIG. 6, for light wavelengths ranging from 400 nm to 1000 nm, the photocell has a quantization efficiency of about 0.4. Although that quantization efficiency is slightly lower than conventional photocells, the photocell can be manufactured at low costs with more ease because the n-type compound semiconductor according to the present invention that is easy to manufacture is used therefor.

FIG. 7 shows the variation of carrier to noise ratio (CNR) with mark lengths in stacked structures according to the present invention when irradiated with a 630-nm red laser beam to induce chemical reaction and diffusion therein.

In FIG. 7, (a) shows various mark lengths of semiconductors manufactured according to the present invention, in which dot regions in the left photograph correspond to laser-irradiated regions where chemical reaction and diffusion occurred, rendering the stacked structure semi-conductive, and the other black region corresponds to a non-irradiated region having conductive properties. In (a) of FIG. 7, marks as small as 100 nm can be seen as distinct in the semiconductors.
In the right photograph of (a) of FIG. 7, a relatively thick white line, corresponds to a semiconductor region, a relatively thin white line corresponds to an insulator region, and the remaining black line corresponds to a conductor region.

In FIG. 7, (b) is a graph of CNR versus mark length in semiconductors manufactured according to the present invention, indirectly showing how precisely marks can be formed in a semiconductor and an insulator according to the present invention. For the measurement of (b), semiconductors were manufactured with irradiation at 7.0 mW through a lens having a numerical aperture (NA) of 0.65 with a 405-nm blue laser beam, and a laser beam of 2.5 mW was radiated onto each of the semiconductors to measure how small the marks are from the reflection of the laser beam. Referring to (b) of FIG. 7, for mark lengths of 150 nm or larger, the CNR is greater than 40 dB, indicating the formation of distinct semi-conducting marks resulting from the chemical reaction and diffusion induced by laser beam irradiation. The CNR is about 20 dB for a mark length of 100 nm, indicating the possibility of the practical application of a structure with such a small mark length as a semiconductor. Although a blue laser beam was used to form the semiconductors in the above embodiment, super-micro semiconductors of about one tenth of those manufactured using a blue laser can be manufactured by irradiation of an electron beam. Therefore, according to the present invention, nano-sized semiconductors or memory chips with a higher integration density can be manufactured.

FIG. 8 shows a flash memory according to the present invention and a laser beam irradiation temperature profile applied to manufacture the flash memory, in which (a) is a top view of a flash memory according to the present invention, and (b) is a laser beam irradiation temperature profile applied to form the flash memory of (a). Referring to (a) of FIG. 8, semiconductor regions 235 and 260 were formed with a laser beam irradiation of a stacked structure according to the present invention at
773°K, and insulator regions 210 and 250 were formed with a laser beam irradiation at 803°K. However, conductor regions 220, 230, and 240 were not irradiated with a laser beam. The semiconductor region 235 is to form a channel connecting a source 230 and a drain 240. When electric current is applied to a gate 220, an electric field is generated due to a hole effect, and the electric field is retained in the semiconductor region 260 acting as a floating gate, as in a flash memory. Accordingly, by irradiating the stacked structure according to the present invention with a laser beam or electron beam, having such a simple temperature profile as shown in FIG. 8(b), flash memories can be easily manufactured at low costs.

Alternatively, the semiconductor region 260 of the flash memory of FIG. 8(a) may be formed as an insulator region. In this case, the insulator region retains an electric field while a current is applied to the gate 220, and the retained electric field of the insulator region consumes while the supply of current to the gate 220 is suspended. Accordingly, by making both the insulator region 250 and the semiconductor region 260 as insulator in the memory structure of FIG. 8(a), DRAMs can be manufactured at low costs with more ease.

Alternatively, the insulator region 250 and the semiconductor region 260 in the memory configuration of FIG. 8(a) may be replaced by a power source. In this case, when electric current is applied to the gate 220, the semiconductor 235 becomes a channel between the source 230 and the drain 240, thereby producing a electric current thereacross. Accordingly, such a transistor can be manufactured at low costs with more ease.

In manufacturing such an electronic circuit, photocell, flash memory, DRAM, and transistor according to the present invention, a lead wire may be formed by first forming a metal oxide insulating layer and thermally decomposing the metal oxide to make it conductive. AgOx can be used as a metal oxide for the lead wire. A sulfurized metal
instead of a metal oxide can be used for the lead wire.

As described above, according to the present invention, a compound semiconductor and a compound insulator can be manufactured through simple processes by heating a stacked structure according to the present invention, including a rare earth transition metal intermediate layer that is highly reactive to oxygen and/or sulfur between oxygen and/or sulfur containing dielectric layers, with laser irradiation to induce chemical reaction and diffusion in the dielectric layers and the intermediate layer. In addition, photocells, electronic circuits, transistors, DRAMs, and flash memories including such a compound semiconductor or a compound insulator can be manufactured at low costs.
What is claimed is:

1. A method for manufacturing a compound semiconductor, the method comprising:
   forming a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

2. A method for manufacturing a compound semiconductor, the method comprising:
   forming a stacked structure including an intermediate layer comprising alloys of rare earth metal and transition metal, both of which are highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

3. A method for manufacturing a compound semiconductor, the method comprising:
   forming a stacked structure including a rare earth metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

4. A method for manufacturing a compound semiconductor, the method comprising:
   forming a stacked structure including a transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and
heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

5. The method of any one of claims 1 through 4, wherein the heating is performed by laser beam irradiation.

6. The method of any one of claims 1 through 4, wherein the heating is performed by electron beam irradiation.

7. The method of any one of claims 1 through 6, wherein the heating is performed at a temperature ranging from 753°K to 783°K.

8. The method of any one of claims 1 through 7, wherein the dielectric layers and the intermediate layer are simultaneously formed as a single mixed layer.

9. A compound semiconductor formed from a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

10. A compound semiconductor formed from a stacked structure including an intermediate layer comprising alloys of rare earth metal and transition metal, both of which are highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

11. A compound semiconductor formed from a stacked
structure including a rare earth metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

12. A compound semiconductor formed from a stacked structure including a transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

13. The compound semiconductor of any one of claims 9 through 12, wherein the heating is performed by laser beam irradiation.

14. The compound semiconductor of any one of claims 9 through 12, wherein the heating is performed by electron beam irradiation.

15. The compound semiconductor of any one of claims 9 through 14, wherein the heating is performed at a temperature ranging from 753°C to 783°C.

16. The compound semiconductor of any one of claims 9 through 15, wherein the dielectric layers and the intermediate layer are simultaneously formed as a single mixed layer.

17. A method for manufacturing a compound insulator, the method comprising:

forming a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and
heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

18. A method for manufacturing a compound insulator, the method comprising:

forming a stacked structure including an intermediate layer comprising alloys of rare earth metal and transition metal, both of which are highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and

heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

19. A method for manufacturing a compound insulator, the method comprising:

forming a stacked structure including a rare earth metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and

heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

20. A method for manufacturing a compound insulator, the method comprising:

forming a stacked structure including a transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and

heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

21. The method of any one of claims 17 through 20, wherein the heating is performed by laser beam irradiation.
22. The method of any one of claims 17 through 20, wherein the heating is performed by electron beam irradiation.

23. The method of any one of claims 17 through 22, wherein the heating is performed above 783°K.

24. The method of any one of claims 17 through 23, wherein the dielectric layers and the intermediate layer are simultaneously formed as a single mixed layer.

25. A compound insulator formed from a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

26. A compound insulator formed from a stacked structure including an intermediate layer comprising alloys of rare earth metal and transition metal, both of which are highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

27. A compound insulator formed from a stacked structure including a rare earth metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

28. A compound insulator formed from a stacked structure including a transition metal intermediate layer, which is highly reactive to
oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

29. The compound insulator of any one of claims 25 through 28, wherein the heating is performed by laser beam irradiation.

30. The compound insulator of any one of claims 25 through 28, wherein the heating is performed by electron beam irradiation.

31. The compound insulator of any one of claims 25 through 30, wherein the heating is performed above 783°K.

32. The compound insulator of any one of claims 25 through 31, wherein the dielectric layers and the intermediate layer are simultaneously formed as a single mixed layer.

33. A photocell comprising a compound semiconductor formed from a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

34. A photocell comprising a compound semiconductor formed from a stacked structure including an intermediate layer comprising alloys of rare earth metal and transition metal, both of which are highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.
35. A photocell comprising a compound semiconductor formed from a stacked structure including a rare earth metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

36. A photocell comprising a compound semiconductor formed from a stacked structure including a transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

37. The photocell of any one of claims 33 through 36, wherein the heating is performed by laser beam irradiation.

38. The photocell of any one of claims 33 through 36, wherein the heating is performed by electron beam irradiation.

39. The photocell of any one of claims 33 through 38, wherein the heating is performed at a temperature ranging from 753°K to 783°K.

40. The photocell of any one of claims 33 through 39, wherein the dielectric layers and the intermediate layer are simultaneously formed as a single mixed layer.

41. A method for manufacturing an electronic circuit comprising at least one of a conductor, a semiconductor, and an insulator, the method comprising:

forming a stacked structure including a rare earth transition metal
intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and

heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the heating is performed at less than 753°C to form the conductor, at a temperature ranging from 753°C to 783°C to form the semiconductor, and above 783°C to form the insulator.

42. A method for manufacturing an electronic circuit comprising at least one of a conductor, a semiconductor, and an insulator, the method comprising:

forming a stacked structure including an intermediate layer comprising alloys of rare earth metal and transition metal, both of which are highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and

heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and intermediate layer, wherein the heating is performed at less than 753°C to form the conductor, at a temperature ranging from 753°C to 783°C to form the semiconductor, and above 783°C to form the insulator.

43. A method for manufacturing an electronic circuit comprising at least one of a conductor, a semiconductor, and an insulator, the method comprising:

forming a stacked structure including a rare earth metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and

heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the heating is performed at less than 753°C to form the
conductor, at a temperature ranging from 753°C to 783°C to form the semiconductor, and above 783°C to form the insulator.

44. A method for manufacturing an electronic circuit comprising at least one of a conductor, a semiconductor, and an insulator, the method comprising:

forming a stacked structure including a transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur; and

heating the stacked structure to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the heating is performed at less than 753°C to form the conductor, at a temperature ranging from 753°C to 783°C to form the semiconductor, and above 783°C to form the insulator.

45. The method of any one of claims 41 through 44, wherein the heating is performed by laser beam irradiation.

46. The method of any one of claims 41 through 44, wherein the heating is performed by electron beam irradiation.

47. The method of any one of claims 41 through 46, wherein the dielectric layers and the intermediate layer are simultaneously formed as a single mixed layer.

48. The method of any one of claims 41 through 47, further comprising:

forming a metal oxide insulating layer in the electronic circuit; and

heating the insulating layer to decompose the metal oxide, thereby forming a conductive lead wire.
49. The method of claim 48, wherein the metal oxide is $\text{AgO}_x$.

50. An electronic circuit comprising at least one of a conductor, a semiconductor, and an insulator and formed from a stacked structure including a rare earth transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the heating is performed at less than 753°K to form the conductor, at a temperature ranging from 753°K to 783°K to form the semiconductor, and above 783°K to form the insulator.

51. An electronic circuit comprising at least one of a conductor, a semiconductor, and an insulator and formed from a stacked structure including an intermediate layer comprising alloys of rare earth metal and transition metal, both of which are highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layers, wherein the heating is performed at less than 753°K to form the conductor, at a temperature ranging from 753°K to 783°K to form the semiconductor, and above 783°K to form the insulator.

52. An electronic circuit comprising at least one of a conductor, a semiconductor, and an insulator and formed from a stacked structure including a rare earth metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the heating is performed at less than 753°K to form the conductor, at a temperature ranging from 753°K to 783°K to form the semiconductor,
and above 783°K to form the insulator.

53. An electronic circuit comprising at least one of a conductor, a semiconductor, and an insulator and formed from a stacked structure including a transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the heating is performed at less than 753°K to form the conductor, at a temperature ranging from 753°K to 783°K to form the semiconductor, and above 783°K to form the insulator.

54. The electronic circuit any one of claims 50 through 53, wherein the heating is performed by laser beam irradiation.

55. The electronic circuit of any one of claims 50 through 53, wherein the heating is performed by electron beam irradiation.

56. The electronic circuit of any one of claims 50 through 55, wherein the dielectric layers and the intermediate layer of the stacked structure are simultaneously formed as a single mixed layer.

57. The electronic circuit of any one of claims 50 through 56, further comprising a conductive lead wire formed by depositing a metal oxide insulating layer and heating to decompose the metal oxide insulating layer.

58. The electronic circuit of claim 57, wherein the metal oxide insulating layer is formed of AgOx.

59. A transistor comprising a conductor having a source, a
A transistor comprising a conductor having a source, a drain, and a gate, and a semiconductor forming a channel between the source and the drain when electric current is applied to the gate, wherein the conductor is formed from a stacked structure including an intermediate layer comprising alloys of rare earth metal and transition metal, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating at less than 753°C to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the semiconductor is formed from the stacked structure by heating at a temperature ranging from 753°C to 783°C to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.
heating at less than 753°K to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the semiconductor is formed from the stacked structure by heating at a temperature ranging from 753°K to 783°K to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

62. A transistor comprising a conductor having a source, a drain, and a gate, and a semiconductor forming a channel between the source and the drain when electric current is applied to the gate, wherein the conductor is formed from a stacked structure including a transition metal intermediate layer, which is highly reactive to oxygen and/or sulfur, interposed between dielectric layers containing oxygen and/or sulfur by heating at less than 753°K to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer, wherein the semiconductor is formed from the stacked structure by heating at a temperature ranging from 753°K to 783°K to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer.

63. The transistor of any one of claims 59 through 62, wherein the heating is performed by laser beam irradiation.

64. The transistor of any one of claims 52 through 62, wherein the heating is performed by electron beam irradiation.

65. The transistor of any one of claims 59 through 64, wherein the dielectric layers and the intermediate layer of the stacked structure are simultaneously formed as a single mixed layer.

66. The transistor of any one of claims 59 through 65, further comprising a conductive lead wire formed by depositing a metal oxide
insulating layer and heating to decompose the metal oxide insulating layer.

67. The transistor of claim 66, wherein the metal oxide insulating layer is formed of AgOx.

68. A memory comprising an insulator formed by heating the stacked structure described in any one of claims 59 through 67 above 783°C to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer in order to form a capacitor in the stacked structure between the source and the drain of the transistor according to any one of claims 59 through 67.

69. A flash memory comprising a floating gate forming semiconductor formed by heating the stacked structure described in any one of claims 59 through 67 at a temperature ranging from 753°C to 783°C to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer in order to form the floating gate in the stacked structure between the source and the drain of the transistor according to claims 59 through 67; and an insulator formed by heating the stacked structure at a temperature above 783°C to induce chemical reaction and diffusion between the dielectric layers and the intermediate layer in order to insulate the region between the floating gate forming semiconductor and the source and the region between the floating gate forming semiconductor and the drain.
FIG. 1

LASER BEAM OR ELECTRON BEAM

<table>
<thead>
<tr>
<th>LAYER</th>
<th>Thickness</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIELECTRIC</td>
<td>140</td>
<td>Si-Zn-TbFeCo-O-S COMPOUND</td>
</tr>
<tr>
<td>INTERMEDIATE</td>
<td>120</td>
<td>ZnS-SiO₂</td>
</tr>
<tr>
<td>DIELECTRIC</td>
<td>130</td>
<td>TbFeCo</td>
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FIG. 2A

(a) DEGREE OF DIFFUSION AT DIFFERENT TEMPERATURES
FIG. 2B

(b) TRANSPARENCY AND MAGNETIC HYSTERESIS VS. TEMPERATURE CURVES

FIG. 2C

(c) DEGREE OF DIFFUSION IN TbFeCo LAYER AT DIFFERENT TEMPERATURES
FIG. 7

(a) MARK LENGTHS OF SEMICONDUCTORS

(b) CNR AT DIFFERENT MARK LENGTHS OF SEMICONDUCTORS
FIG. 8

(a) FLASH MEMORY

(b) LASER BEAM IRRADIATION TEMPERATURE PROFILE
### INTERNATIONAL SEARCH REPORT

**A. CLASSIFICATION OF SUBJECT MATTER**

**IPC7** H01L 21/324

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

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

IPC7 H01SB 33/14, H05B 33/10, H01L 27/04, H01L 21/363

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

Korean Patent Documentations published since 1972

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

USPAT, FPD, PAJ

### C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>JP, A 6412498 (NEC CO LTD) 17 January 1989 see page 2, lower right paragraph line 8 - line 20 figure 1</td>
<td>1-4</td>
</tr>
<tr>
<td>A</td>
<td>JP, A 0498791 (SHARP CORP) 31 March 1992 see page 3, lower left, upper right paragraphs</td>
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<td>A</td>
<td>JP, A 07249837 (NIPPON STEEL CORP) 26 September 1995 see the whole document</td>
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<td>A</td>
<td>JP, A 2002184946 (MURATA MFG CO LTD) 28 June 2002 see the whole document</td>
<td>1-4</td>
</tr>
</tbody>
</table>

* Further documents are listed in the continuation of Box C.

See patent family annex.

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