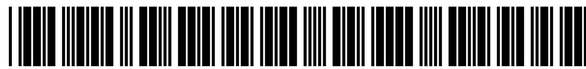

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Lee et al.

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(45) **Date of Patent: Sep. 16, 2014**

(54) **NANOPOROUS MEMBRANE AND MANUFACTURING METHOD THEREOF**

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(73) Assignee: **Korea Advanced Institute of Science and Technology**, Daejeon (KR)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 218 days.

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(51) **Int. Cl.**

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B82Y 30/00	(2011.01)
C23C 14/02	(2006.01)
C23C 14/06	(2006.01)
B82Y 40/00	(2011.01)
C23C 16/56	(2006.01)
C23F 1/02	(2006.01)

(52) **U.S. Cl.**

CPC ***C23C 14/06*** (2013.01); ***B82Y 30/00*** (2013.01); ***C23C 14/024*** (2013.01); ***B82Y 40/00*** (2013.01); ***C23C 16/56*** (2013.01); ***C23F 1/02*** (2013.01)

USPC **216/56**

(58) **Field of Classification Search**

None

See application file for complete search history.

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Primary Examiner — Shamim Ahmed

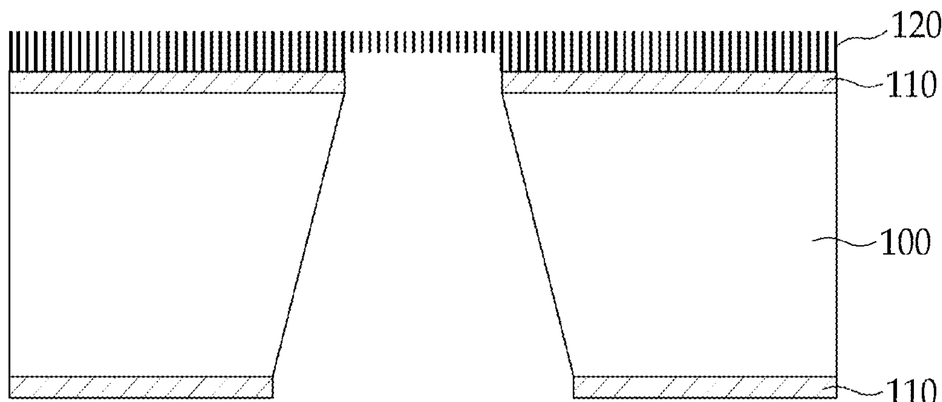
Assistant Examiner — Bradford Gates

(74) *Attorney, Agent, or Firm* — Volpe and Koenig, P.C.

(57) **ABSTRACT**

In the present invention, a nanoporous membrane having a columnar structure is manufactured through a deposition technology used in a semiconductor process, and the size of a nanopore is adjusted by etching the lower surface of the manufactured nanoporous membrane or using a seed layer and a nanobead layer so that scaling up is available at a lowered process temperature and the size of the nanopore can be easily adjusted when manufacturing the nanoporous membrane having a columnar structure.

6 Claims, 10 Drawing Sheets



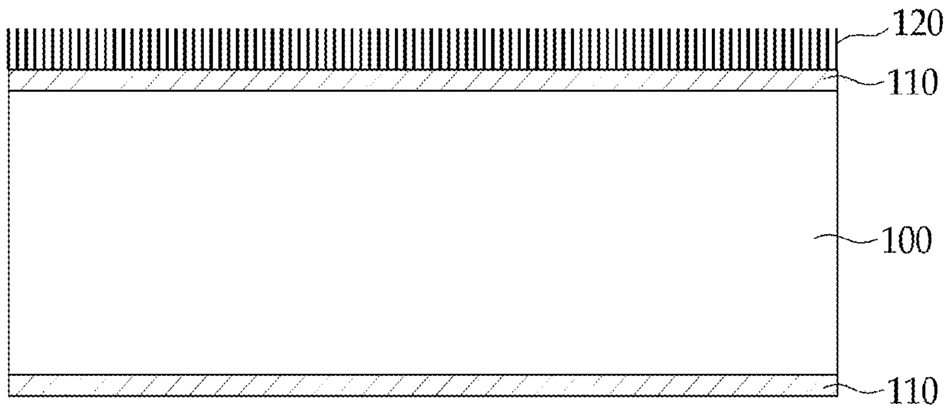


FIG. 1

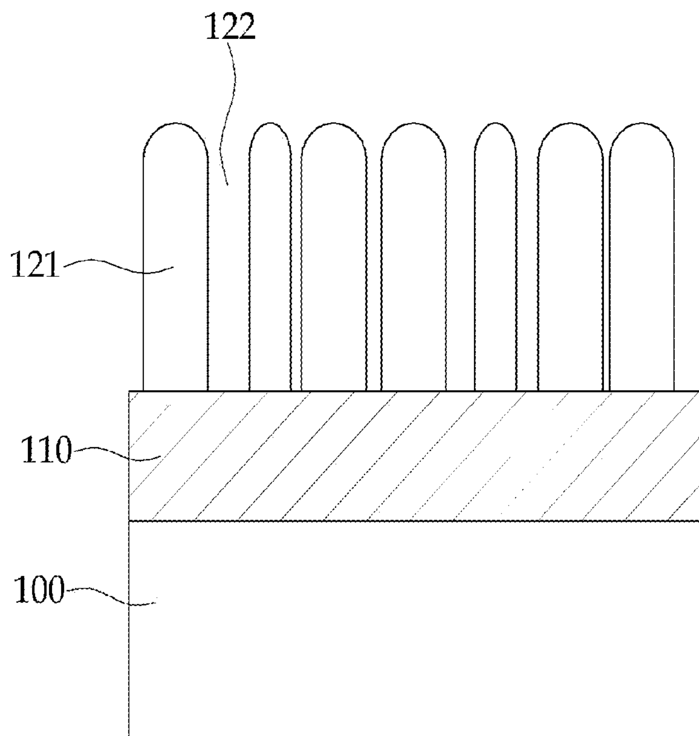


FIG. 2

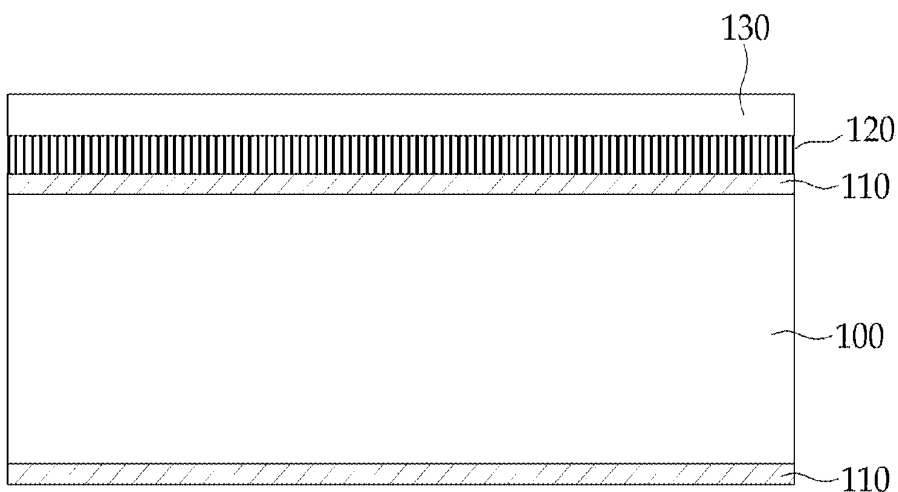


FIG. 3

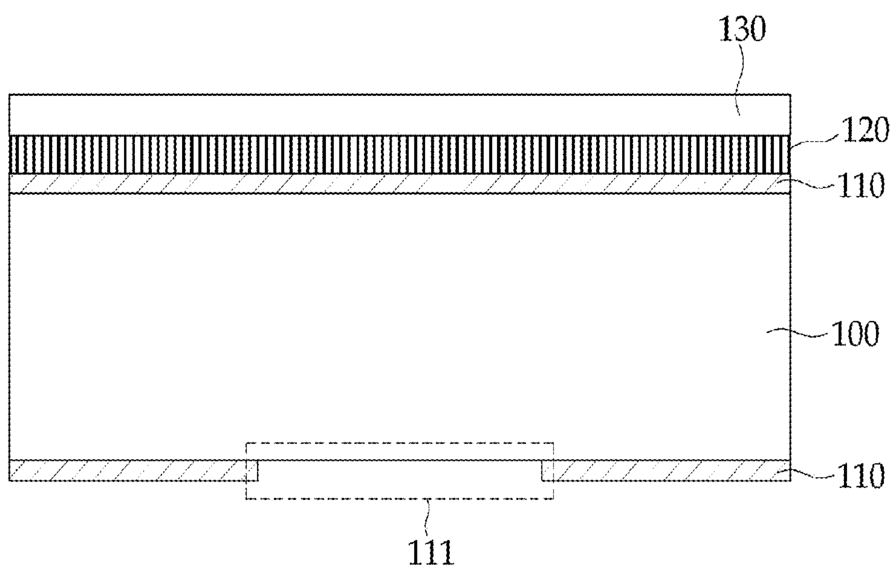


FIG. 4

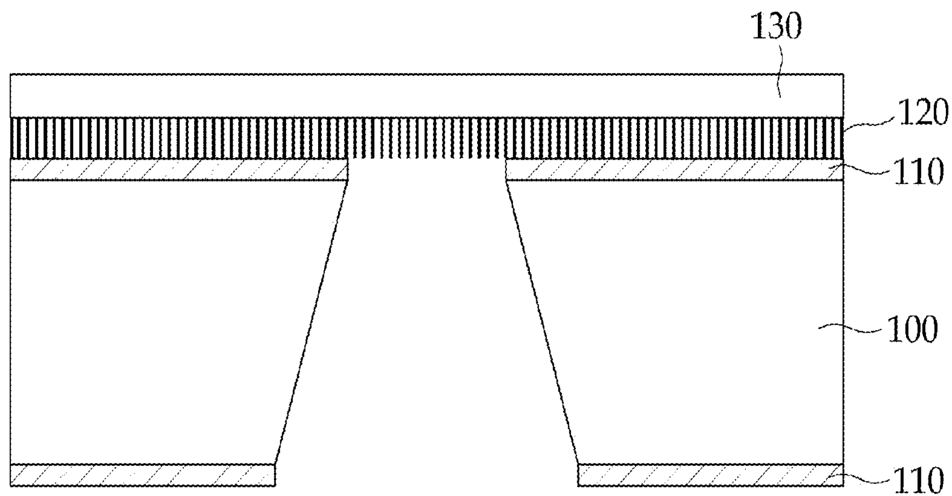


FIG. 5

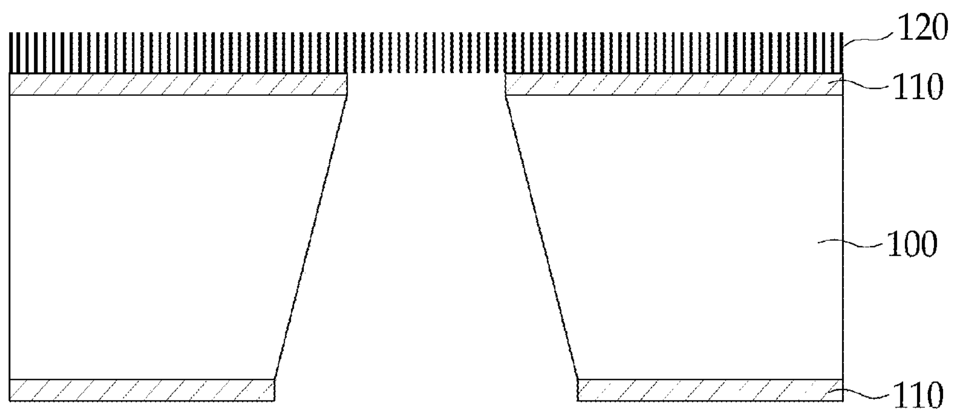


FIG. 6

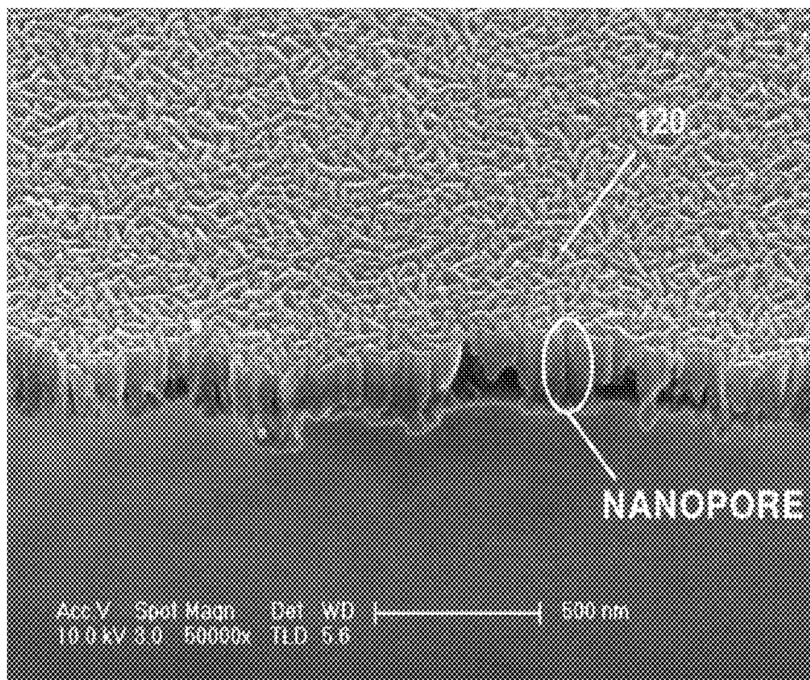


FIG. 7

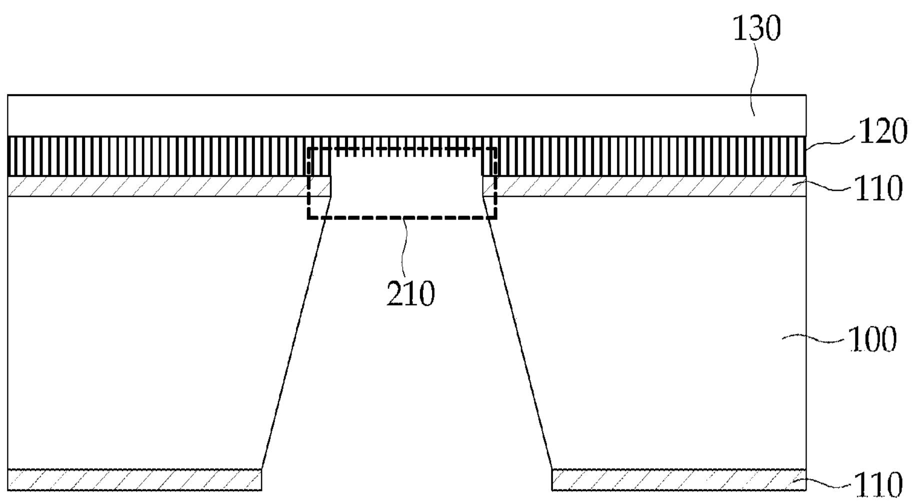


FIG. 8

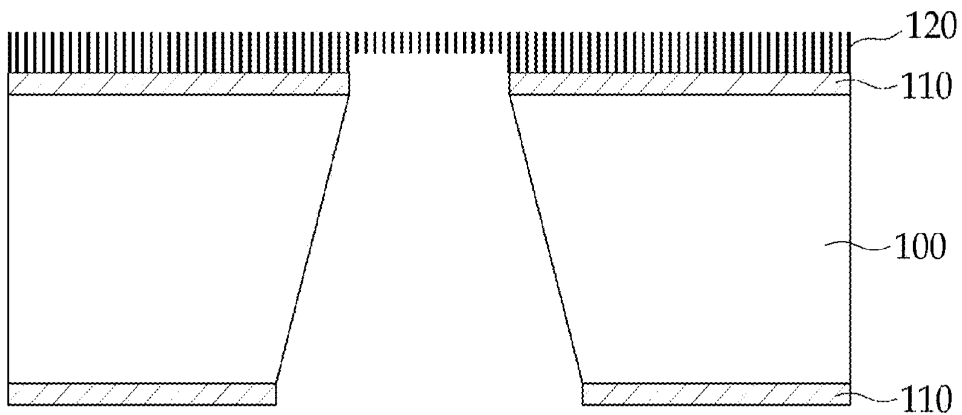


FIG. 9

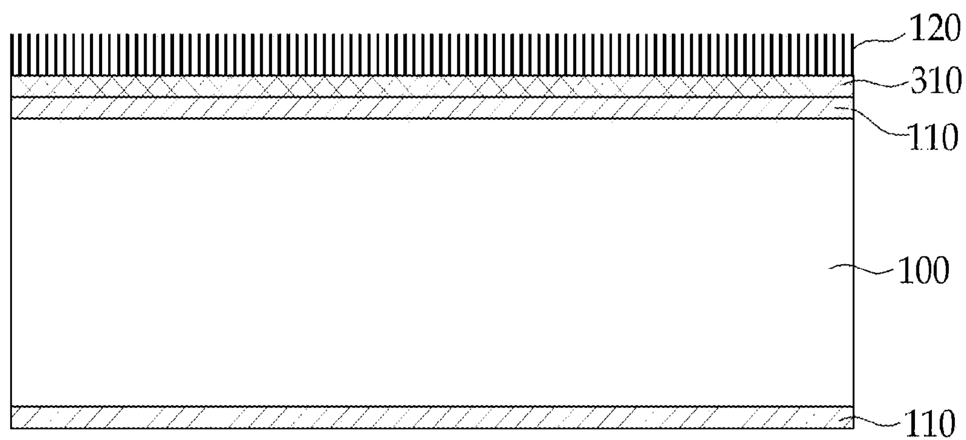


FIG. 10

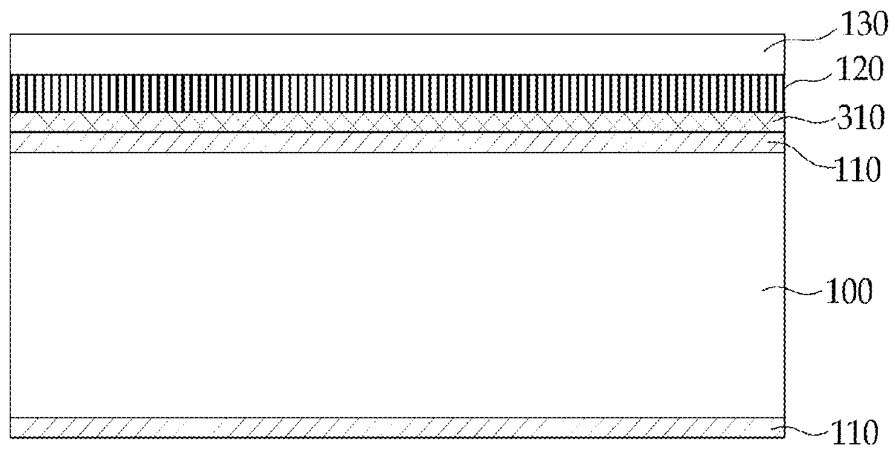


FIG. 11

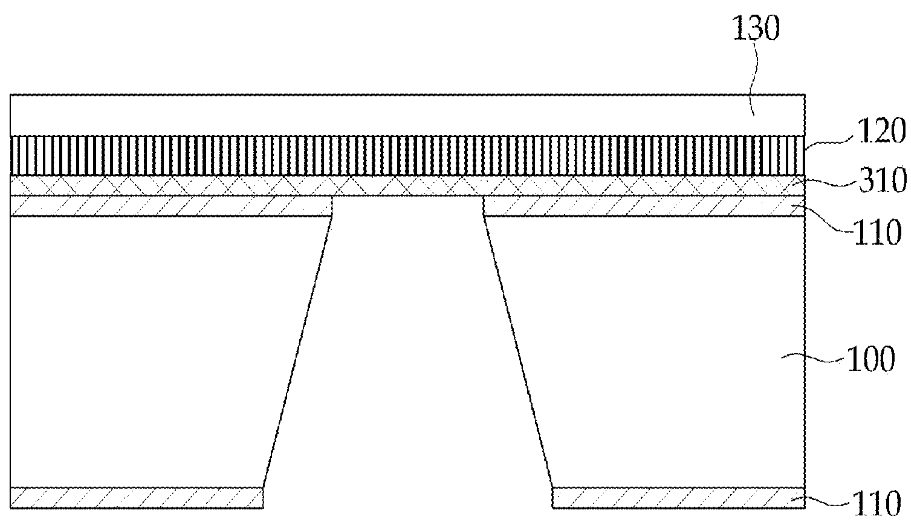


FIG. 12

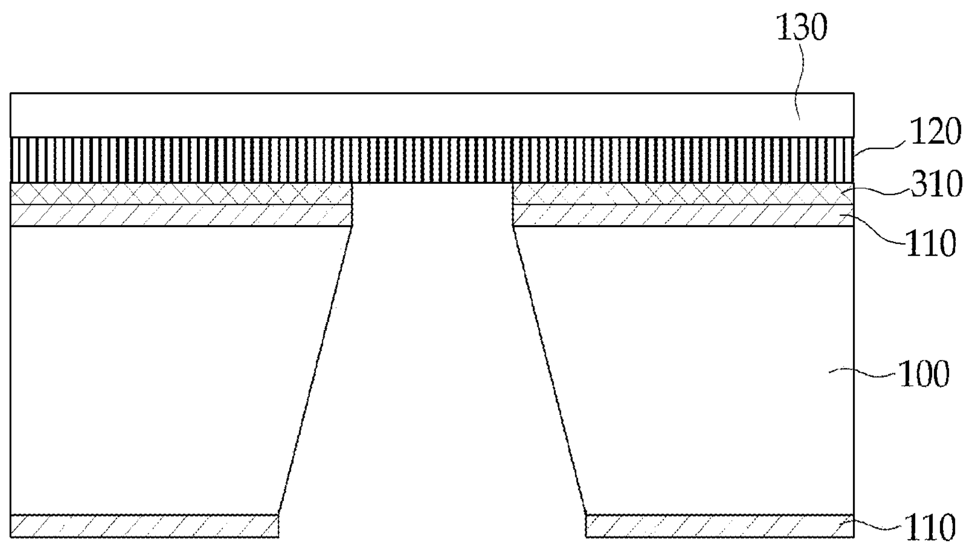


FIG. 13

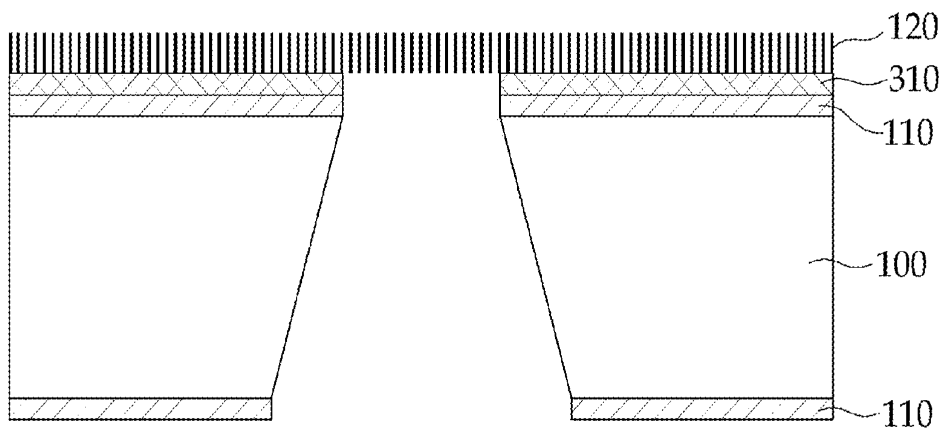


FIG. 14

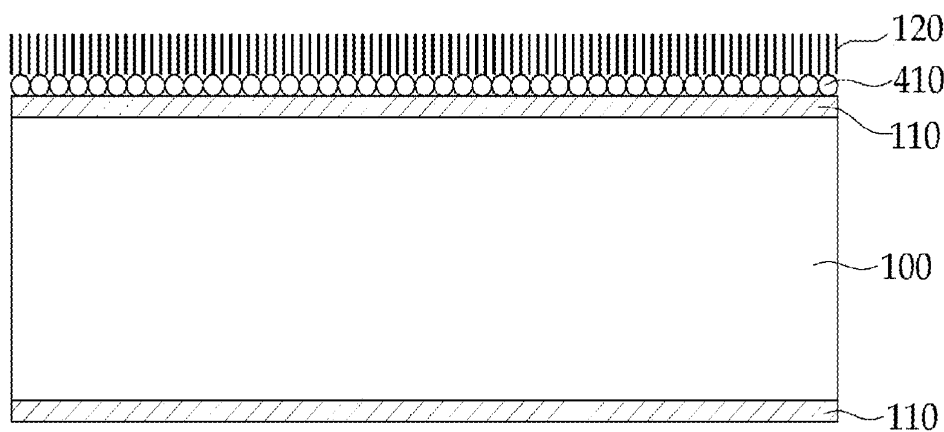


FIG. 15

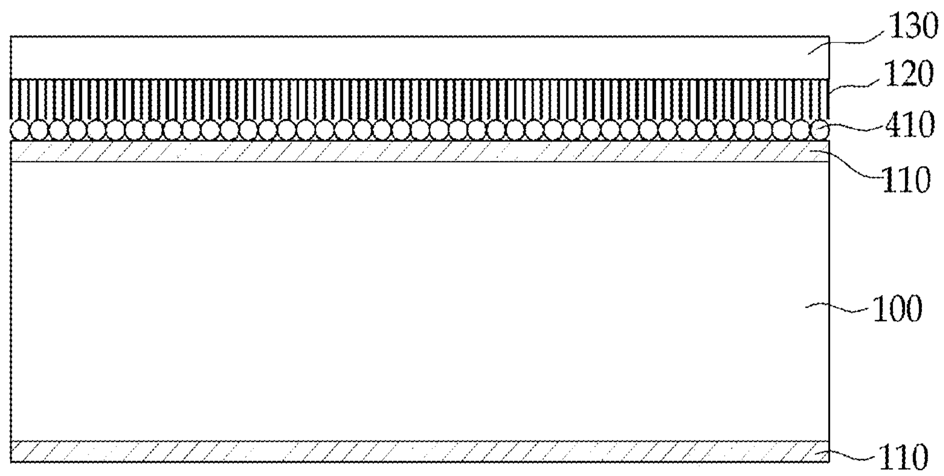


FIG. 16

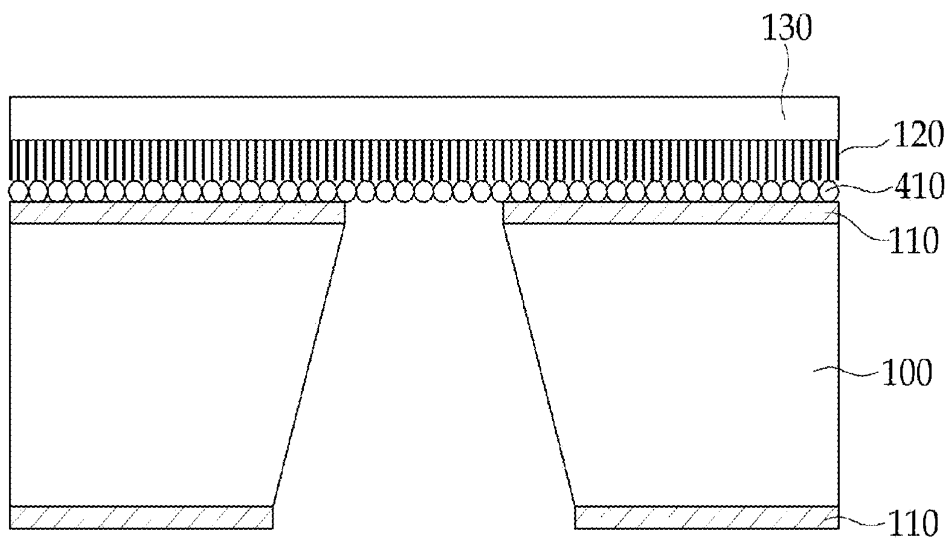


FIG. 17

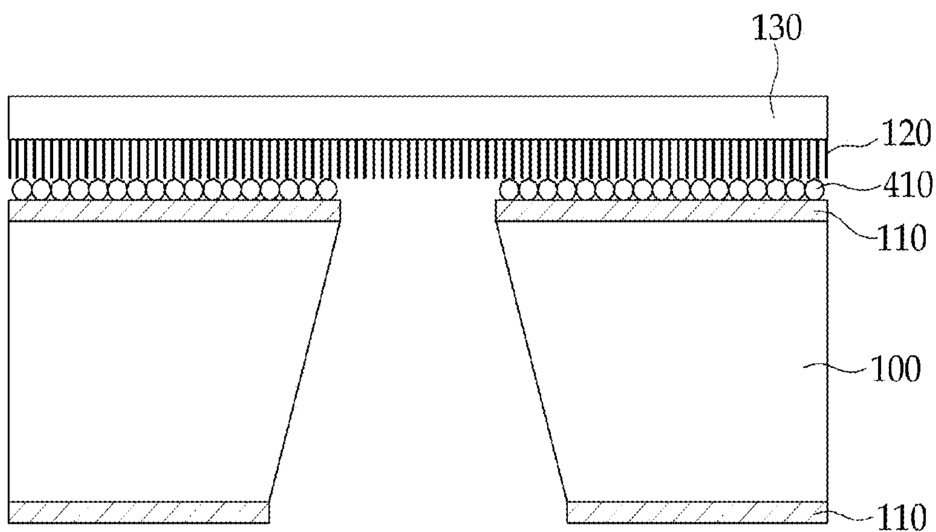


FIG. 18

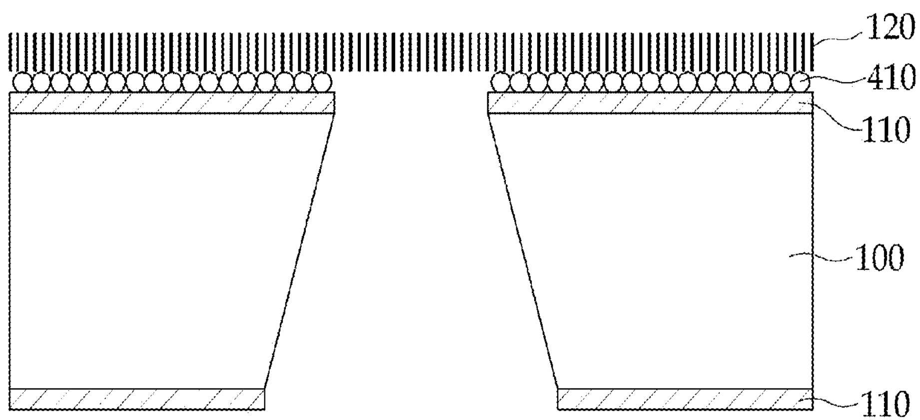


FIG. 19

NANOPOROUS MEMBRANE AND MANUFACTURING METHOD THEREOF

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is based on and claims priority from Korean Patent Application No. 10-2011-0049500, filed on May 25, 2011, with the Korean Intellectual Property Office, the disclosure of which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

The present invention relates to a nanoporous membrane and a method for manufacturing the same. More specifically, the present invention relates to a nanoporous membrane and a method for manufacturing the same, wherein the nanoporous membrane having a columnar structure is manufactured through a deposition technology used in a semiconductor process, and the size of a nanopore is adjusted by etching the lower surface of the manufactured nanoporous membrane or by using a seed layer and a nanobead layer so that scaling up is available at a lowered process temperature and the size of the nanopore can be easily adjusted when manufacturing the nanoporous membrane having a columnar structure.

BACKGROUND

As a nanoporous membrane can separate nano-sized particles by size using a nano-sized pore, it is a future critical element that can be used in various fields such as a medical appliance, food and environment.

Most of the conventional nanoporous membranes were manufactured using polymer substances. The conventional nanoporous membranes had a highly complex structure and were greatly thick, which resulted in low selectivity and low permeability. Recently, in order to resolve these problems, efforts to manufacture a nanoporous membrane, which has a straight nanochannel and is thin, are actively being made using a micro machining technology.

The conventional methods for manufacturing a nanoporous membrane using the micro machining technology can be classified into: a method of forming a nano-sized pore by a specific type of chemical etching method, such as anodizing or ion-track etching, on a thin film formed on a substrate; a method of forming a nano-sized pore using a carbon nanotube as a mold; and a method of forming a nano-sized pore using an ion beam of high energy.

However, the above methods of forming a nanopore cannot be commonly used. Thus, they are difficult to be reproduced. Moreover, scaling up is difficult because those methods were prepared by using equipment generally designed and manufactured at laboratory level. Additionally, the method of using an ion beam of high energy is labor intensive in process, which requires high process costs.

SUMMARY

The present invention was devised to solve the aforesaid problems. The objective of the present invention is to provide a nanoporous membrane and a method for manufacturing the same, wherein the nanoporous membrane having a columnar structure is manufactured through a deposition technology used in a semiconductor process, and the size of a nanopore is adjusted by etching the lower surface of the manufactured nanoporous membrane or by using a seed layer and a nanobead layer so that scaling up is available at a lowered process temperature and the size of the nano pore can be easily adjusted when manufacturing the nanoporous membrane having a columnar structure.

One aspect of this invention includes a nanoporous membrane characterized by comprising a first protective layer formed on both surfaces of a substrate and a nanoporous thin film with a columnar structure formed on the first protective layer, which is formed in the upper surface of the substrate, through a physical vapor deposition (PVD) process or a chemical vapor deposition (CVD) process, and patterning a part of the first protective layer formed in the lower surface of the substrate so that the substrate and a part of the first protective layer are etched.

The method according to the second aspect of this invention is characterized by comprising: forming a first protective layer on the both surfaces of a substrate; forming a nanoporous thin film having a columnar structure by depositing one of the metallic materials, oxides, nitrides and fluorides on the first protective layer formed in the upper surface of the substrate through the PVD process or the CVD process; forming a second protective layer in the thin film; patterning the first protective layer formed in the lower surface of the substrate to expose a part of the lower surface of the substrate; etching the exposed part of the substrate until a part of the first protection layer underneath the nanoporous thin film is exposed; etching the exposed part of the first protective layer to expose the nanoporous thin film having a columnar structure; and removing the second protective layer.

The method according to the third aspect of this invention is characterized by comprising: forming a first protective layer on both surfaces of a substrate; forming a nanoporous thin film having a columnar structure by depositing one of the metallic materials, oxides, nitrides and fluorides on the first protective layer formed in the upper surface of the substrate through a physical vapor deposition method or a chemical vapor deposition method; forming a second protective layer in the thin film; patterning the first protective layer formed in the lower surface of the substrate to expose a part of the lower surface of the substrate; etching the exposed part of the substrate until a part of the first protection layer underneath the nanoporous thin film is exposed; etching the exposed part of the first protective layer underneath the nanoporous thin film to expose the nanoporous thin film having a columnar structure; adjusting the size of the nanopores by etching the exposed part of the nanoporous thin film partially; and etching the second protective layer to remove the second protective layer.

The method according to the fourth aspect of this invention is characterized by comprising: forming a first protective layer on both surfaces of a substrate; forming a seed layer in the upper surface of the substrate; forming a nanoporous thin film having a columnar structure by depositing one of the metallic materials, oxides, nitrides and fluorides on a seed layer formed in the upper surface of the substrate through a physical vapor deposition method or a chemical vapor deposition method; forming a second protective layer in the thin film; patterning the first protective layer formed in the lower surface of the substrate to expose a part of the lower surface of the substrate; etching the exposed part of the substrate until a part of the first protection layer underneath the seed layer is exposed; etching the exposed part of the first protective layer underneath the seed layer to expose the seed layer; etching the exposed part of the seed layer to expose the nanoporous thin film having columnar structure; and etching the second protective layer to remove the second protective layer.

The method according to the fifth aspect of this invention is characterized by comprising: forming a first protective layer on both surfaces of a substrate; forming a nanobead layer in the upper surface of the substrate; forming a nanoporous thin film having a columnar structure by depositing one of the metallic materials, oxides, nitrides and fluorides on the nanobead layer formed in the upper surface of the substrate through a physical vapor deposition method or a chemical vapor deposition method; forming a second protective layer in the thin film; patterning the first protective layer formed in the lower surface of the substrate to expose a part of the lower surface of the substrate; etching the exposed part of the substrate until a part of the first protection layer underneath the nanobead layer is exposed; etching the exposed part of the first protective layer underneath the nanobead layer to expose the nanobead layer; etching the exposed part of the nanobead layer to expose the nanoporous thin film having the columnar structure; and etching the second protective layer to remove the second protective layer.

The said thin film is characterized by comprising one of SiO2, Si3N4 and silicon carbide.

In the step of forming the thin film, the PVD process is characterized by including a sputtering deposition method or a thermal evaporation method.

In the step of forming the thin film, the CVD process is characterized by including atmospheric pressure chemical vapor deposition (APCVD), low-pressure chemical vapor deposition (LPCVD) or plasma enhanced chemical vapor deposition (PECVD).

In the step of forming the thin film, the metallic materials are characterized by including at least one from Ni, Cr, Co, Fe, Ti, Pt and Al; the oxides are characterized by including at least one from indium tin oxide (ITO), ZnO, SiO and TiO2; the nitrides are characterized by including at least one from TiN, CrN and NbN; and the fluorides are characterized by including CaF2 and MgF2.

In the step of forming the second protective layer, the second protective layer is characterized by including at least one from SiO2, Si3N4, silicon carbide and electroplated Au, Cu and Ni.

In accordance with the present invention, a nanoporous membrane having a columnar structure is manufactured through a deposition technology used in a semiconductor process, and the size of a nanopore is adjusted by etching the lower surface of the manufactured nanoporous membrane or by using a seed layer and a nanobead layer so that scaling up is available at a lowered process temperature and the size of the nanopore can be easily adjusted when manufacturing the nanoporous membrane having a columnar structure.

In accordance with the present invention, a thin film having a columnar structure is formed through the PVD process or the CVD process without including a specific etching step or an additional process to form a nano-sized pore, and thus is used as a nanoporous membrane. Accordingly, reproducibility of elements can be enhanced in terms of process, and the process costs can be reduced with mass production.

Further, the present invention allows a low temperature process, because it does not require a heat treatment process. Accordingly, micro fluid channels and electronic devices can be easily integrated.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1** to **6** show a process flow of a method for manufacturing a nanoporous membrane in accordance with an example of the present invention.

FIG. **7** shows an example of electron microscope photograph of a nanoporous membrane manufactured according to the process flow illustrated in FIGS. **1** to **6**.

FIGS. **8** and **9** show a process flow of a method for adjusting the size of a nanopore in the nanoporous membrane in accordance with Example 1 of the present invention.

FIGS. **10** to **14** show a process flow of a method for controlling the size of a nanopore in the nanoporous membrane in accordance with Example 2 of the present invention.

FIGS. **15** to **19** show a process flow of a method for controlling the size of a nanopore in the nanoporous membrane in accordance with Example 3 of the present invention.

DETAILED DESCRIPTION

In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. The illustrative embodiments described in the detailed description, drawing, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented here. Also, prior to describe particularly the present disclosure, it is to be understood that like numerals represent like constitutional elements throughout the accompanying drawings, and the detailed description relating to the known technical constitution will be omitted in order to unnecessarily obscure the gist of the present disclosure.

The present invention relates to a nanoporous membrane having a columnar structure and a method for manufacturing the same, as set out below.

A nanoporous membrane in accordance with the present invention is characterized by comprising a first protective layer formed on both surfaces of a substrate and a nanoporous thin film with a columnar structure formed on the first protective layer, which is formed in the upper surface of the substrate, through the PVD process or the CVD process, and patterning a part of the first protective layer formed in the lower surface of the surface so that the substrate and a part of the first protective layer are etched.

A method for manufacturing the nanoporous membrane in accordance with the present invention is characterized by forming a nanoporous membrane, which comprises: forming a first protective layer in a substrate for etch stop; forming a thin film having a columnar structure through the PVD process or the CVD process; forming a second protective layer in the thin film; removing the first protective layer to remove the substrate of the lower nanoporous thin film and the first protective layer; adjusting the size of the pore by etching a part of the lower nanoporous thin film; and removing the second protective layer.

It is desirable that the first protective layer select a material having excellent etching selectivity with respect to the substrate.

In the process of forming the thin film, it is desirable that the PVD process include a sputtering deposition method or a thermal evaporation method.

In the process of forming the thin film, it is desirable that the CVD process include APCVD, LPCVD or PECVD.

In the process of forming the thin film, it is desirable that the metallic materials include at least one from Ni, Cr, Co, Fe, Ti, Pt and Al.

In the process of forming the thin film, it is desirable that the oxides include ITO, ZnO, SiO and TiO2.

In the process of forming the thin film, it is desirable that the nitrides include TiN, CrN and NbN.

In the process of forming the thin film, it is desirable that the fluorides include at least one from CaF2 and MgF2.

In the process of forming the second protective layer, it is desirable that the second protective layer be formed of a material having high etching selectivity with respect to the nanoporous thin film formed in the process of forming the thin film and high mechanical and chemical strength.

It is desirable that the method of etching the lower surface in the process of adjusting the size of the pore include a sputtering deposition method and an ion-milling method.

Referring to FIGS. **1** to **6**, an example of the method for manufacturing the nanoporous membrane having a columnar structure in accordance with the present invention is set out below.

FIGS. **1** to **6** show a process flow of the method for manufacturing the nanoporous membrane in accordance with the present invention.

FIG. **1** shows a process of forming a first protective layer **110** and a nanoporous thin film **120**. As shown in FIG. **1**, the first protective layer **110** is formed on both surfaces of a substrate **100**. The substrate **100** includes a silicon substrate, a glass substrate or a plastic substrate. The first protective layer **110** can be formed through LPCVD, PECVD or APCVD.

A thin film **120** having a nano-sized pore is formed in one surface of the first protective layer **110** due to the columnar structure.

FIG. **2** shows an enlarged figure of a thin film **120** having a columnar structure.

As shown in FIG. **2**, a nanopore **122** is formed to be vertical to the substrate **100** between columnar grains **121**.

It is desirable that the thin film **120** be formed to have a columnar structure through the PVD process.

The thin film **120** can include metallic materials, oxides or nitrides. Here, the metallic materials for forming the thin film **120** include Ni, Cr, Co, Fe, Ti, Pt and Al. Further, the oxides include ITO, ZnO, SiO and TiO2. The nitrides include TiN, CrN and NbN. Further, CaF2 and MgF2 can be used as the materials to form the thin film **120**. The PVD process for forming the thin film **120** includes a sputtering deposition method or a thermal evaporation method. Meanwhile, when the specific materials are deposited by increasing a deposition temperature through the CVD process, a preferred orientation in the z-axis direction allows the nanopore to form naturally a vertical columnar structure. The CVD process includes APCVD, LPCVD or PECVD.

A nano-sized pore **122** having a columnar structure can be produced when a deposition material for forming the thin film **120** reaches the substrate **100** and when a surface diffusion does not occur. That is, when the deposition material reaches the substrate **100** and the temperature of the substrate **100** is low (e.g., a normal temperature), the deposition material is not stabilized and immediately grows to have a columnar structure. Therefore, in the case where the deposition material is deposited by use of a sputtering deposition method, a thermal evaporation method or an electron beam evaporation method, the nanopore **122** are formed to have a columnar structure by depositing the material at a normal temperature or cooling the substrate **100** instead of heating the substrate **100**.

Meanwhile, in the nanopore, it is possible to adjust the size of the pore **122** due to the atomic shadowing effect according to an incident flux angle at which the deposition material is deposited.

Referring to FIG. **3**, below is a process of forming a second protective layer **130**.

As shown in FIG. **3**, the second protective layer **130** is formed in the nanoporous thin film **120**. A process of forming the second protective layer is a subsequent process to the process of forming the thin film **120**. Thus, the second protective layer **130** is required to be formed of a material having an excellent mechanical strength. Further, it is desirable that the second protective layer **130** be formed of a material having etching selectivity with respect to the substrate **100**, the first protective layer **110** and the nanoporous thin film **120**.

Accordingly, it is desirable that the second protective layer **130** be formed of a material having an excellent mechanical strength, such as Si02, Si3N4. Further, it is desirable that the second protective layer **130** be formed of a metal that is relatively thick, such as electroplated Au, Cu and Ni.

Referring to FIGS. **4** and **5**, below is a process of etching the substrate **100** and the first protective layer **110**.

As shown in FIG. **4**, a part **111** of the first protective layer **110** is patterned in order to be used as a mask for etching the substrate **100**. It is desirable to pattern the first protective layer **110** by using a dry etching method or a wet etching method.

Thereafter, as shown in FIG. **5**, the first protective layer **110** etches the substrate **100** through the patterned part **111**. Here, it is desirable that the substrate **100** is dry-etched or wet-etched towards the depth direction of the substrate **100** having anisotropy. The first protective layer **110** has high etching selectivity with respect to the substrate **100**, and thus is no more etched when the etchant or the etching gas encounters with the first protective layer **110**. Generally, it is difficult to uniformly etch the substrate **100**, because the substrate is relatively thick. If etching the substrate is not stopped by the first protective layer **110**, the nanoporous thin film **120** may be physically or chemically damaged by the etching gas or etchant for etching the substrate **100**. Accordingly, as stated above, it is desirable that the first protective layer **110** be formed of a material having excellent etching selectivity with respect to the substrate **100**.

As shown in FIG. **5**, it is desirable that the first protective layer **110** placed in the region, in which the substrate **100** is removed, be etched after etching the substrate **100** is completed. Here, it is desirable to use a dry etching method or a wet etching method in order to remove the first protective layer **110**.

Referring to FIG. **6**, below is a process of removing the second protective layer **130**.

As shown in FIG. **6**, a membrane having a nanopore caused by a columnar is formed structure by removing the second protective layer **130**. Here, a wet etching method or a dry etching method can be employed in order to remove the second protective layer **130**. Once the second protective layer **130** is removed, a nanoporous membrane having a columnar structure that is in the air.

Meanwhile, FIG. **7** shows an example of an electron microscope photograph of the nanoporous membrane manufactured in accordance with the process flow as shown in FIGS. **1** to **6**.

The electron microscope photograph as shown in FIG. **7** shows a nanoporous thin film **120**.

Meanwhile, as stated above, a shadowing effect generated by roughness of the surface is one of the causes of forming a columnar structure. Accordingly, the size of the nanopore can be adjusted by adjusting roughness of the surface deposited.

Further, the size of the nanopore varies depending on the increase of the thickness of the thin film having a columnar structure.

Accordingly, the size of the nanopore can be adjusted by using the above two features.

Referring the FIGS. **8** to **19**, Examples 1 to 3 for the method of adjusting the size of the nanopore in the nanoporous membrane having a nanopore with a columnar structure is set out below.

FIGS. **8** and **9** show a process flow of Example 1 for the method of adjusting the size of the nanopore in the nanoporous membrane in accordance with the present invention.

Referring to FIGS. **8** and **9**, a method for adjusting the size of the nanopore by using the etching of the lower surface in accordance with Example 1 of the present invention.

First, forming the first protective layer **110**, forming the thin film **120** having a columnar structure and etching the substrate **100** are conducted as shown in FIGS. **1** to **4**.

As shown in FIG. **8**, it is desirable to etch a part **210** of the thin film **120** having a columnar structure in order to adjust the size of the nanopore. Here, it is desirable to employ a dry etching method, which has a constant etching rate towards the front of the substrate **100**.

As shown in FIG. **9**, once the second protective layer **130** is removed, a nanoporous membrane, in which the size of the nanopore is adjusted, is formed.

FIGS. **10** to **14** are a process flow of Example 2 for the method for adjusting the size of the nanopore in the nanoporous membrane in accordance with the present invention.

Referring to FIGS. **10** to **14**, below is a review of the method for adjusting the size of the nanopore by using a seed layer in accordance with Example 2 of the present invention.

As shown in FIG. **10**, the protective layer **110** is formed on both surfaces of the substrate **100**. Here, the materials of the substrate **100** and the first protective layer **110** and the forming method thereof are the same as the example explained through FIG. **1**.

A seed layer **310** is formed on the first protective layer **110**. It is desirable that the seed layer **310** have high etching selectivity with respect to the nanoporous thin film **120**.

The seed layer **310** can be formed by using PVD, LPCVD, PECVD or APCVD. Here, it is desirable that the seed layer **310** include a subsequent process in order to have high surface roughness. Further, it is desirable to employ a sputtering deposition method or an ion milling method as a subsequent process.

Thereafter, the thin film **120** having a nano-sized pore is formed in the seed layer **310** due to a columnar structure. It is desirable that the thin film **120** be formed by using the aforementioned materials and methods.

As shown in FIG. **11**, the second protective layer **130** is formed in the thin film **120** having a nano-sized pore. It is desirable that the second protective layer **130** have etching selectivity with respect to the substrate **100**, the first protective layer **110**, the seed layer **310** and the thin film **120**.

Accordingly, it is desirable that the second protective layer be formed of a material having an excellent mechanical strength, such as SiO2, Si3N4 and a silicon carbide. It is also desirable that the second protective layer **130** be formed of metals that are relatively thick, such as electroplated Cu and Ni.

After forming the second protective layer **130**, the substrate **100** is etched and the first protective layer **110** is patterned, as shown in FIG. **12**. It is desirable to pattern the substrate **100** and the first protective layer **110** in the same way as the above example explained through FIG. **5**.

As shown in FIG. **13**, the seed layer **310** is etched after patterning the substrate **100** and the first protective layer **110**. It is desirable to etch the seed layer **310** in the limited region in which the substrate **100** is removed. It is desirable that the seed layer **310** be dry-etched or wet-etched.

As shown in FIG. **14**, a membrane having a nanopore caused by a columnar structure is formed by removing the second protective layer **130**. Here, a wet etching method or a dry etching method can be employed in order to remove the second protective layer **130**. Once the second protective layer is removed, a nanoporous membrane having a columnar structure, which is in the air, is formed.

FIGS. **15** to **19** show a process flow of Example 13 for the method for adjusting the size of the nanopore in the nanoporous membrane in accordance with the present invention.

Referring to FIGS. **15** to **19**, below is a review of the method for adjusting the size of the nanopore by using the nanobead layer in accordance with Example 3 of the present invention. The method shown in FIGS. **15** to **19** is a method for adjusting the size of the nanopore by using the nanobead method instead of the method of using the seed layer as explained in FIGS. **10** to **14**.

First, as shown in FIG. **15**, the first protective layer **110** is formed on both surfaces of the substrate **100**. Here, the materials of the substrate **100** and the first protective layer **110** and the forming methods thereof are the same as the example as explained through FIG. **1**.

A nanobead layer **410** is formed on the first protective layer **110**. It is desirable that the nanobead layer **410** have high etching selectivity with respect to the nanoporous thin film **120**. It is desirable to form the nanobead layer **410** by using a spin coating method. Here, it is desirable to use a nanobead layer **410** equally dispersed in a solvent. After the spin coating, it is desirable that the solvent evaporate and only the nanobead layer **410** be left. Here, the size of the nanopore can be adjusted depending on the size of the nanobead.

Thereafter, a thin film **120** having a nano-sized pore caused by a columnar structure is formed on the nanobead layer **410**. It is desirable to form the thin film **120** by using the materials and methods in the example as explained through FIG. **1**.

As shown in FIG. **16**, the second protective layer **130** is formed on the substrate **120** have a nano-sized pore. It is desirable that the second protective layer **130** have etching selectivity with respect to the substrate **100**, the first protective layer **110**, the seed layer **310** and the thin film **120**.

Accordingly, it is desirable that the second protective layer **130** be formed of a material having an excellent mechanical strength, such as SiO2, Si3N4 and a silicon carbide. It is also desirable that the second protective layer **130** be formed of metals that are relatively thick, such as electroplated Cu and Ni.

After forming the second protective layer **130**, the substrate **100** is etched and the first protective layer **110** is patterned, as shown in FIG. **17**. It is desirable to pattern the substrate **100** and the first protective layer **110** in the same way as the above example explained through FIG. **5**.

As shown in FIG. **18**, the nanobead layer **410** is etched after patterning the substrate **100** and the first protective layer **110**. It is desirable to etch the nanobead layer **410** in the limited region in which the substrate **100** is removed. It is desirable to etch the seed layer **310** by using a dry etching method or a wet etching method.

As shown in FIG. **19**, a membrane having a nanopore caused by a columnar structure is formed by removing the second protective layer **130**. Here, a wet etching method or a dry etching method can be employed in order to remove the second protective layer **130**. Once the second protective layer **130** is removed, a nanoporous membrane having a columnar structure is formed through the nanobead layer **410**.

The above description merely exemplifies the present invention, and can be variously modified by a person having an ordinary skill in the art to which the claimed invention pertains within the scope of the subject matter of the claimed invention. Accordingly, the present invention is not limited by the examples disclosed in the specification of the subject application. The scope of the present invention should be

interpreted based on the claims, and to include all techniques that are within the equivalent scope.

From the foregoing, it will be appreciated that various embodiments of the present disclosure have been described herein for purposes of illustration, and that various modifications may be made without departing from the scope and spirit of the present disclosure. Accordingly, the various embodiments disclosed herein are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

What is claimed is:

1. A method for manufacturing a nanoporous membrane, the method comprising:

forming a first protective layer on both surfaces of a substrate;

forming a nanoporous thin film having a columnar grain structure by depositing one of metallic materials, oxides, nitrides and fluorides on the first protective layer formed in the upper surface of the substrate through a physical vapor deposition method or a chemical vapor deposition method at a normal temperature or cooling the substrate;

forming a second protective layer in the thin film;

patterning the first protective layer formed in the lower surface of the substrate to expose a part of the lower surface of the substrate;

etching the exposed part of the substrate until a part of the first protection layer underneath the nanoporous thin film is exposed;

etching the exposed part of the first protective layer underneath the nanoporous thin film to expose the nanoporous thin film having the columnar grain structure;

adjusting the size of the nanopores by etching the exposed lower part of the nanoporous thin film partially in order to remove an amorphous layer formed in the deposition at the normal temperature or cooling the substrate; and

etching the second protective layer to remove the second protective layer,

wherein the nanopores are formed to be vertical to the substrate between columnar grains, wherein the size of the nanopores varies depending on an increase of a thickness of the nanoporous thin film having the columnar grain structure,

wherein the first protective layer is formed of a material having etching selectivity with respect to the substrate and wherein the second protective layer is formed of a material having etching selectivity with respect to the substrate, the first protective layer and the nanoporous thin film.

2. The method of claim **1**, wherein the size of the nanopores is adjusted due to the atomic shadowing effect according to an incident flux angle at which the deposition material is deposited.

3. A method for manufacturing a nanoporous membrane, the method comprising:

forming a first protective layer on both surfaces of a substrate;

forming a seed layer having surface roughness in the upper surface of the substrate;

forming a nanoporous thin film having a columnar grain structure by depositing one of metallic materials, oxides, nitrides and fluorides on a seed layer formed in the upper surface of the substrate through a physical vapor deposition method or a chemical vapor deposition method;

forming a second protective layer in the thin film;

patterning the first protective layer formed in the lower surface of the substrate to expose a part of the lower surface of the substrate;

etching the exposed part of the substrate until a part of the first protection layer underneath the seed layer is exposed;

etching the exposed part of the first protective layer underneath the seed layer to expose the seed layer;

etching the exposed part of the seed layer to expose the nanoporous thin film having columnar grain structure; and

etching the second protective layer to remove the second protective layer,

wherein the size of the nanopores is adjusted by adjusting roughness of the surface deposited,

wherein the first protective layer is formed of a material having etching selectivity with respect to the substrate and wherein the second protective layer is formed of a material having etching selectivity with respect to the substrate, the first protective layer and the nanoporous thin film.

4. The method of claim **3**, wherein the size of the nanopores is adjusted due to the atomic shadowing effect according to an incident flux angle at which the deposition material is deposited.

5. A method for manufacturing a nanoporous membrane, the method comprising:

forming a first protective layer on both surfaces of a substrate;

forming a nanobead layer in the upper surface of the substrate;

forming a nanoporous thin film having a columnar grain structure by depositing one of metallic materials, oxides, nitrides and fluorides on the nanobead layer formed in the upper surface of the substrate through a physical vapor deposition method or a chemical vapor deposition method;

forming a second protective layer in the thin film;

patterning the first protective layer formed in the lower surface of the substrate to expose a part of the lower surface of the substrate;

etching the exposed part of the substrate until a part of the first protection layer underneath the nanobead layer is exposed;

etching the exposed part of the first protective layer underneath the nanobead layer to expose the nanobead layer;

etching the exposed part of the nanobead layer to expose the nanoporous thin film having the columnar grain structure; and

etching the second protective layer to remove the second protective layer,

wherein the size of the nanopores is adjusted by diameter of columnar grain depending on the size of the nanobead,

wherein the first protective layer is formed of a material having etching selectivity with respect to the substrate and wherein the second protective layer is formed of a material having etching selectivity with respect to the substrate, the first protective layer and the nanoporous thin film.

6. The method of claim **5**, wherein the size of the nanopores is adjusted due to the atomic shadowing effect according to an incident flux angle at which the deposition material is deposited.

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