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1 ETCHING SOLUTION FOR ETCHING POROUS SILICON, ETCHING
METHOD USING THE ETCHING SOLUTION AND METHOD OF
PREPARING SEMICONDUCTOR MEMBER USING THE ETCHING
SOLUTION

5

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to an etching solution for porous silicon, an etching method using the etching solution and a method of producing a semiconductor member using the etching solution. Particularly, this invention relates to a method of producing a semiconductor member which is suitable for separation of dielectric materials or electronic devices, integrated circuits prepared on a monocrystalline semiconductor layer on an insulating material.

Related Background Art

Formation of a monocrystalline Si semiconductor layer on an insulating material has been widely known as the silicon on insulator (SOI) technology, and since a large number of advantages which cannot be reached by bulk Si substrates for preparation of conventional Si integrated circuits are possessed by the device utilizing the SOI structure, so many researches have

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1 been done. More specifically, by utilizing the SOI
structure, the following advantages can be obtained:

1. Dielectric isolation can be easily done to
enable high degree of integration;

5 2. Radiation hardness is excellent;

3. Stray capacity is reduced to attain high speed;

4. Well formation step can be omitted;

5. Latch-up can be prevented;

6. Fully depleted field effect transistor can be
10 made by thin film formation.

In order to realize the many advantages in device
characteristics as mentioned above, studies have been
made about the method for forming the SOI structure for
these some 10 years. The contents are summarized in,
15 for example, the literature as mentioned below:

Special Issue: "Single-crystal silicon on non-
single-crystal insulators"; edited by G. W. Cullen,
Journal of Crystal Growth, Volume 63, No. 3, pp. 429 - 590
(1983).

20 Also, it has been known for a long time to form the
SOS (silicon on sapphire) structure by heteroepitaxy of
Si on a monocrystalline sapphire substrate by CVD
(chemical vapor deposition) method. This was
successful to some extent as the most mature SOI
25 technique, but for such reasons as a large amount of

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1 crystal defects because of lattice mismatching at the
interface between the Si layer and the sapphire
substrate, introduction of aluminum from the sapphire
substrate into the Si layer, and above all the high cost
5 of the substrate and delay in enlargement of the
substrate wafer size, it is obstructed from being widely
applied. Relatively in recent years, attempts to
realize the SOI structure without use of a sapphire
substrate have been done. Such attempts may be broadly
10 classified into the two shown below:

(1) After surface oxidation of an Si
monocrystalline substrate, a window is formed to have
the Si substrate partially exposed, and epitaxial growth
is proceeded in the lateral direction with that exposed
15 portion as the seed to form an Si monocrystalline layer
on SiO_2 . (In this case, deposition of Si layer on SiO_2
is accompanied).

(2) By use of an Si monocrystalline substrate
itself as an active layer, SiO_2 is formed therebeneath.
20 (This method is accompanied with no deposition of Si
layer).

As the means for realizing the above (1), there
have been known the method in which a monocrystalline Si
layer is formed directly to lateral epitaxial growth by
25 CVD, the method in which amorphous Si is deposited and

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1 subjected to solid phase lateral epitaxial growth by
heat treatment, the method in which an amorphous or
polycrystalline Si layer is irradiated convergently with
an energy beam such as electron beam, laser beam, etc.
5 and a monocrystalline layer is grown on SiO₂ by melting
and recrystallization, and the method in which a melting
region is scanned in a zone fashion by a rod-shaped
heater (Zone melting recrystallization). These methods
have both advantages and disadvantages, they still have
10 many problems with respect to controllability,
productivity, uniformity and quality, and none of them
have been industrially applied yet up to date. For
example, the CVD method requires sacrifice-oxidation in
flat thin film formation, while the crystallinity is
15 poor in the solid phase growth method. On the other
hand, in the beam annealing method, problems are
involved in controllability such as treatment time by
converged beam scanning, the manner of overlapping of
beams, focus adjustment, etc. Among these, the Zone
20 Melting Recrystallization method is the most mature, and
a relatively larger scale integrated circuit has been
trially made, but still a large number of crystal
defects such as point defects, line defects, plane
defects (sub-boundary), etc. remain, and no device
25 driven by minority carriers has been prepared.

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1 Concerning the method using no Si substrate as the
seed for epitaxial growth which is the above method (2),
for example, the following methods may be included.

1. An oxide film is formed on an Si monocrystalline
5 substrate with V-grooves as anisotropically etched on
the surface, a polycrystalline Si layer is deposited on
the oxide film thick to the extent as the Si substrate,
and thereafter by polishing from the back surface of the
Si substrate, Si monocrystalline regions dielectrically
10 separated by surrounding with the V-grooves on the thick
polycrystalline Si layer are formed. In this method,
although crystallinity is good, there are problems with
respect to controllability and productivity in the step
of depositing the polycrystalline Si thick as some
15 hundred microns and the step in which the
monocrystalline Si substrate is polished from the back
surface to leave only the Si active layer as separated.

2. This is the method called SIMOX (Separation by
ion-implanted oxygen) in which an SiO₂ layer is formed
20 by ion implantation of oxygen into an Si monocrystalline
substrate, which is one of the most mature methods
because of good matching with the Si-IC (Integrated
Circuit) process. However, for formation of the SiO₂
layer, 10¹⁸ ions/cm² or more of oxygen ions are required
25 to be implanted, and the implantation time is very long

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1 to be not high in productivity, and also the wafer cost
is high. Further, many crystal defects remain, and
from an industrial point of view, no sufficient level of
quality capable of preparing a device driven by minority
5 carriers have been attained.

3. This is the method to form an SOI structure by
dielectric isolation according to oxidation of porous
Si. This is a method in which an N-type Si layer is
formed on the surface of a P-type Si monocrystalline
10 substrate in shape of islands by way of proton ion
implantation (Imai et al., J. Crystal Growth, Vol. 63,
547 (1983)), or by epitaxial growth and patterning; only
the P-type Si substrate is made porous by anodization in
HF solution so as to surround the Si islands from the
15 surface; and then the N-type Si islands are
dielectrically isolated by accelerated oxidation. In
this method, the separated Si region is determined
before the device steps, whereby there is the problem
that the degree of freedom in drive and circuit design
20 may be limited in some cases.

A light-transmissive substrate is important for
forming a contact sensor serving as a light-receiving
device and a projection-type liquid crystal image
display. A high-quality driving device is required
25 for further increasing the density, resolution and

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1 definition of the pixels (picture element) of such a
sensor or display. It is consequently necessary to
produce a device to be provided on a light-
transmissive substrate by using a monocrystalline layer
5 having excellent crystallinity.

However, if an Si layer is deposited on a light-
transmissive substrate such as glass substrate, etc.,
the Si layer is generally an amorphous layer
or, at best, a polycrystalline layer because the Si
10 layer reflects the disorder of the crystal structure of
the substrate, and no high-quality device can thus be
formed by using the Si layer. This is because the
substrate has an amorphous crystal structure, and thus a
monocrystalline layer of high quality cannot be easily
15 obtained by simply depositing the Si layer. It is
therefore difficult to produce a driving device having
properties sufficient for the present demands or future
demands because the crystal structure of an amorphous Si
or polycrystalline Si has many defects.

20 Further, any one of the methods using an Si mono-
crystalline substrate is unsuitable for obtaining a good
monocrystalline film on a light-transmissive substrate.

Takao Yonehara, one of the inventors, previously
proposed a method of forming a semiconductor substrate

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1 which is capable of solving the above problems in Japanese
Patent Application No. 2-206548.

The method of forming a semiconductor substrate
disclosed in Patent Application No. 2-206548 comprises
5 forming a substrate having a non-porous semiconductor
monocrystalline layer and a porous semiconductor layer,
bonding another substrate having an insulating material
surface to the surface of the monocrystalline layer, and
removing the porous semiconductor layer by etching.

10 This invention has been achieved for improving the
invention disclosed in Patent Application No. 2-206548
previously proposed.

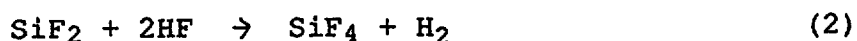
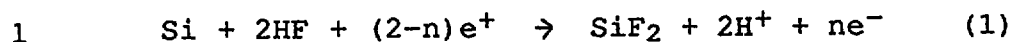
The method of forming a semiconductor substrate
disclosed in Patent Application No. 2-206548 comprises
15 the step of removing porous Si by selective etching.

Porous Si is described below.

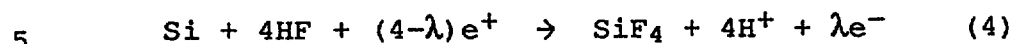
Porous Si was discovered in the course of research
on electrolytic polishing of a semiconductor which was
conducted by Uhler et al, in 1956 (A. Uhler, Bell Syst.
20 Tech. J., Vol. 35, pp 333 (1956)).

Unagami et al. investigated dissolving reaction of Si
during anodization and reported that the anodic reaction
of Si in a HF solution requires positive holes, and
that the reaction is expressed as follows (T. Unagami,
25 J. Electrochem. Soc., Vol. 127, pp 476 (1980)):





or



wherein e^+ and e^- respectively denote a positive hole and an
electron, and n and λ each denotes the number of positive holes
required for dissolving one silicon atom. Porous Si
10 can be formed when the condition, $n > 2$ or $\lambda > 4$, is
satisfied.

It is therefore found that positive holes are required for
forming porous Si, and that P-type Si can be more easily
made porous than N-type Si. However, it is also known
15 that N-type Si can be made porous if holes are implanted
thereto (R. P. Holmstrom and J. Y. Chi, Appl. Phys.
Lett., Vol. 42, 386 (1983)).

The density of the porous Si layer can be changed
to the range of 1.1 to 0.6 g/cm³ by changing the
20 concentration of the HF solution from 50 to 20%, as
compared with the density of 2.33 g/cm³ of
monocrystalline Si. The porous Si layer has pores
having an average size of about 600 Å which was measured
by observation by a transmission electron microscope.
25 Although the porous Si layer has a density which is half



1 or less than that of monocrystalline Si,
monocrystallinity is maintained, and a monocrystalline
Si layer can be formed on the porous layer by epitaxial
growth.

5 Although the volume of an Si monocrystal is
generally increased by 2.2 times by oxidation, the
increase in volume can be suppressed by controlling the
density of the porous Si so that the occurrence of
curvature of a substrate or the occurrence of a crack in
10 a monocrystalline layer remained on the surface
can be avoided during the oxidation process.

The volume ratio R of monocrystalline Si to porous Si
after oxidation can be expressed as follows:

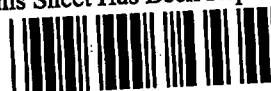
$$R = 2.2 \times (A/2.33) \quad (6)$$

15 wherein A denotes the density of porous Si. If $R = 1$,
i.e., there is no increase in volume after oxidation, A
 $= 1.06 \text{ (g/cm}^3\text{)}$. Namely, if the density of the porous
Si layer is 1.06, an increase in volume, which is caused
by oxidation, can be suppressed.

20 It can be said that at present, porous Si is subjected
as such directly to subsequent steps (epitaxial growth
and oxidation) after producting it, and the porous
Si itself is not processed. This is because the porous
Si cannot be easily processed or removed with good

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1 controllability. Namely, it has been not reported yet
that porous Si is etched with good controllability.

In addition, P generally shown by the
following equation is referred as porosity:

5
$$P = (2.33 - A)/2.33 \quad (7)$$

When the value of porosity is adjusted to 30 to 55%
during anodization, the properties of oxidized porous Si
can be equalized to those of a monocrystalline Si oxide
film. The porosity is expressed as follows:

10
$$P = (m1 - m2)/(m1 - m3) \quad (8)$$

or

$$P = (m1 - m2)/\rho A t \quad (9)$$

wherein m1: total weight before anodization

m2: total weight after anodization

15 m3: total weight after removal of porous Si

ρ : density of monocrystalline Si

A: area of porous region

t: thickness of porous Si

However, the area of the porous region cannot be
20 accurately calculated in many cases. In this case,
although the equation (8) is effective, the porous Si
must be etched for measuring the value of m3.

In addition, during epitaxial growth on the porous
Si, the porous Si is capable of relieving distortion
25 produced during heteroepitaxial growth and suppressing

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1 the occurrence of defects. However, in this case,
since it is clear that the porosity is a very
important parameter, measurement of the porosity is
necessary and indispensable.

5 Known methods of etching porous Si are the
following methods (1) and (2):

(1) The method of etching porous Si with an aqueous
NaOH solution (G. Bonchil, R. Herino, K. Barla, and J.
C. Pfister, J. Electrochem. Soc., Vol. 130, No. 7, 1611
10 (1983)).

(2) The method of etching porous Si with an etching
solution which is capable of etching non-porous Si.

In the above method (2), a fluoronitric acid-type
etching solution is generally used, and etching of Si
15 proceeds as follows:

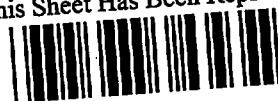


As shown by the above reaction formulas, Si is oxidized
to SiO_2 , and the SiO_2 produced is etched with
20 hydrofluoric acid.

Examples of etching solutions for non-porous Si
include the above fluoronitric acid-type etching solution
as well as ethylenediamine-type, KOH-type and hydrazine-
type etching solutions and the like.

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1 In this invention, it is necessary in selective
etching of porous Si to select an etching solution which is
capable of etching porous Si, other than the above
etching solutions for non-porous Si. The porous Si is
5 generally selectively etched by the above method (1)
which uses an aqueous NaOH solution as an etching
solution.

As described above, both porous and non-porous Si
are etched with the fluoronitric acid-type etching
10 solution.

On the other hand, in the conventional method of
selectively etching porous Si with an aqueous NaOH
solution, Na ions are inevitably adsorbed on the etched
surface. Since the Na ions cause impurity
15 contamination, are movable and have adverse effects such
as the formation of a interfacial states, the ions must not
be introduced into the semiconductor process.

SUMMARY OF THE INVENTION

20 An object of this invention is to provide an
etching solution which efficiently, uniformly,
selectively and chemically etches porous Si without
affecting the semiconductor process and
etching non-porous Si.

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1 Another object of this invention is to provide a
method of preparing a semiconductor member using an
etching solution for uniformly and selectively etching
porous Si.

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BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1A and 1B are schematic views explaining
an etching step using an etching solution of this
invention;

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Figs. 2A and 2B are schematic views explaining
an etching step using an etching solution of this
invention;

Figs. 3A to 3C are schematic views explaining an
etching step using an etching solution of this

15

invention;

Figs. 4A to 4C are schematic views explaining an
etching step using an etching solution of this
invention;

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Figs. 5A to 5D are schematic views explaining an
etching step using an etching solution of this
invention;

Figs. 6A to 6H are graphs showing the etching
properties of porous and non-porous Si when etching
solutions of this invention are respectively used;

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1 Figs. 7A to 7H are graphs showing the relations
between the etched thickness (etching depth) of porous Si
and etching time when etching solutions of this invention
are respectively used;

5 Figs. 8A to 8C are schematic views explaining a
process for preparing a semiconductor member of this
invention;

Figs. 9A to 9D are schematic views explaining a
process for preparing a semiconductor member of this
10 invention;

Figs. 10A to 10C are schematic views explaining
a process for preparing a semiconductor member of this
invention;

Figs. 11A to 11D are schematic views explaining
15 a process for preparing a semiconductor member of this
invention;

Figs. 12A to 12C are schematic views explaining
a process for preparing a semiconductor member of this
invention;

20 Figs. 13A to 13C are schematic views explaining
a process for preparing a semiconductor member of this
invention; and

Figs. 14A to 14D are schematic views explaining
a process for preparing a semiconductor member of this
25 invention.

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1 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

According to one aspect of this invention, this invention provides a chemical etching solution for etching porous silicon.

- 5 A first embodiment of the chemical etching solution of this invention is hydrofluoric acid.

A second embodiment of the chemical etching solution is a mixture containing hydrofluoric acid and an alcohol.

- 10 A third embodiment of the chemical etching solution is a mixture containing hydrofluoric acid and hydrogen peroxide.

A fourth embodiment of the chemical etching solution is a mixture containing hydrofluoric acid, an alcohol and hydrogen peroxide.

- 15 A fifth embodiment of the chemical etching solution is buffered hydrofluoric acid.

A sixth embodiment of the chemical etching solution is a mixture containing buffered hydrofluoric acid and an alcohol.

- 20 A seventh embodiment of the chemical etching solution is a mixture containing buffered hydrofluoric acid and hydrogen peroxide.

- A eighth embodiment of the chemical etching solution is a mixture of buffered hydrofluoric acid, an alcohol and
25 hydrogen peroxide.

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1 The etching method of this invention comprises
selectively etching porous silicon using the etching
solution of this invention.

 According to another aspect of this invention, this
5 invention provides a method of preparing a semiconductor
member.

 A first embodiment of the method of preparing a
semiconductor member of this invention comprises forming
a substrate having a non-porous monocrystalline silicon
10 layer and a porous silicon layer, bonding another
substrate having a surface made of insulating material to the
surface of the monocrystalline layer, and etching the
porous silicon layer by immersing it in hydrofluoric
acid.

15 A second embodiment of the method of preparing
a semiconductor member of this invention uses each of
the second to eighth forms of the etching solution of
this invention in place of hydrofluoric acid used as an
etching solution in the first form of the method of
20 preparing a semiconductor member of this invention.

 A third embodiment of the method of preparing a
semiconductor member of this invention comprises the
steps of making a silicon substrate porous, forming a
non-porous monocrystalline silicon layer on the silicon
25 substrate made porous, bonding a light-transmissive glass

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- 1 substrate to the surface of the non-porous
monocrystalline silicon layer, and selectively etching
porous silicon so as to remove porous silicon by
chemical etching using an etching
5 solution of this invention by immersing the
silicon substrate made porous therein.

A fourth embodiment of the method of preparing a
semiconductor member of this invention comprises the
steps of making a silicon substrate porous, forming a
10 non-porous monocrystalline silicon layer on the silicon
substrate made porous, bonding another silicon substrate
having an insulating layer on the surface thereof to the
surface of the non-porous monocrystalline silicon layer,
and selectively etching porous silicon so as to remove
15 porous silicon by chemical etching using
an etching solution of this invention by immersing the
silicon substrate made porous therein.

A fifth embodiment of the method of preparing a
semiconductor member of this invention comprises the
20 steps of making a silicon substrate porous, forming a
non-porous monocrystalline silicon layer on the silicon
substrate made porous, forming an oxide layer on the surface
of the non-porous monocrystalline silicon layer, bonding
a light-transmissive substrate to the surface of the

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1 oxide layer and selectively etching the silicon
substrate made porous to remove it by chemical
etching using an etching solution of this invention by
immersing the silicon substrate made porous therein.

5 A sixth embodiment of the method of preparing a
semiconductor member of this invention comprises the
steps of making a silicon substrate porous, forming a non-
porous monocrystalline silicon layer on the silicon
substrate made porous, forming an oxide layer on the surface
10 of the non-porous monocrystalline silicon layer, bonding
another silicon substrate having an insulating layer on
the surface thereof to the oxide layer formed on the non-
porous monocrystalline silicon layer, and selectively
etching the silicon substrate made porous to remove it
15 by chemical etching using an etching solution
of this invention by immersing the silicon substrate
made porous therein.

In each of the above embodiments according to the
method of preparing a semiconductor member of the present
20 invention, the etching step may be carried out with
coating the surfaces other than the surface of the silicon
layer made porous with a protecting material before
etching.

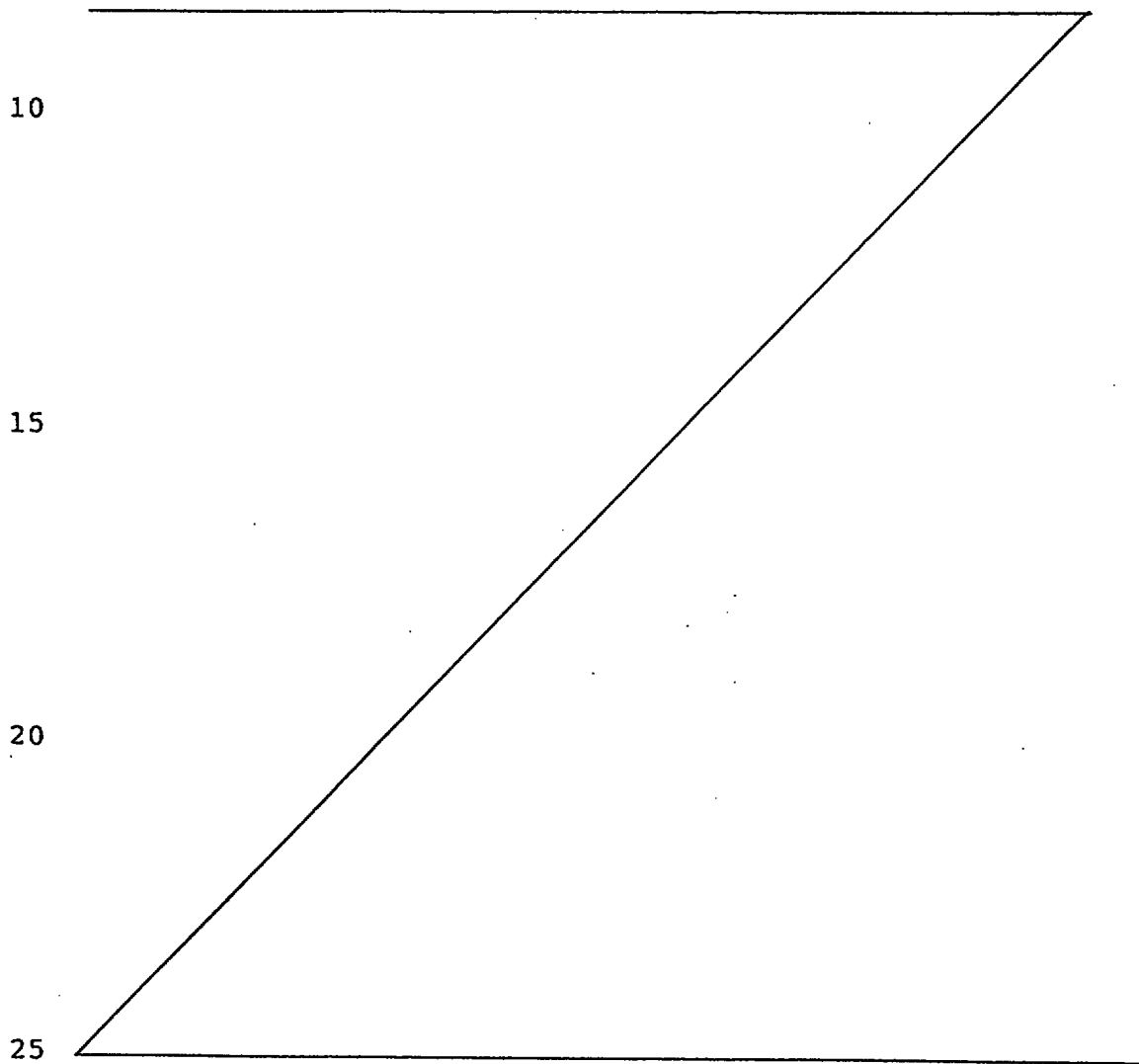
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1 The etching solution for porous Si of this invention is capable of uniformly and efficiently etching porous Si without the danger of contaminating the semiconductor process.

5 The etching method of this invention can be applied to usual semiconductor processes and is capable of selectively etching, with high accuracy, the porous Si



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1 provided on the same substrate provided non-porous
Si to remove the porous Si because a
chemical etching solution which does not etch
non-porous Si is used.

5 The method of preparing a semiconductor member of
this invention is excellent in productivity, uniformity,
controllability and economy for forming a crystalline Si
layer having excellent crystallinity equal to that of a
monocrystalline wafer on insulating substrates
10 such as light-transmissive insulating substrates
represented by a glass substrate.

The method of preparing a semiconductor member of
this invention is capable of realizing the advantages of
conventional SOI devices and can be applied to various
15 fields.

The method of preparing a semiconductor member of
this invention can also be used in place of the
expensive SOS or SIMOX used for producing a large-
scale integrated circuit having the SOI structure.

20 In addition, the method of preparing a
semiconductor member of this invention comprises the
steps of chemically removing the lower portion of a
monocrystalline Si substrate of high quality used as a
starting material, with leaving only a monocrystalline
25 layer on the surface thereof, and bonding the substrate



1 to an insulating layer, and thus enables many treatments
to be performed for a short time and has excellent
productivity and economy.

Further, the method of preparing a semiconductor
5 member of this invention can use a chemical etching
solution which has a bad effect on the
semiconductor process in etching of porous Si and
exhibits an etching selection ratio of a five digits
value or more of porous Si to non-porous Si and
10 excellent controllability and productivity.

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1 I. A description will now be given of the etching
solution in accordance with the present invention.

I-(1) A description will be made first as to the case
where hydrofluoric acid is used as the electroless wet
5 chemical etching solution for porous Si, with specific
reference to Fig. 7A.

Fig. 7A shows the etching time dependency of etched
thickness of porous Si when the latter is etched by being
immersed in hydrofluoric acid. The porous Si was formed by
10 anodizing a monocrystalline Si. The conditions of
anodization are shown below. It is to be noted, however,
that the starting material for producing porous Si by
anodization is not limited to monocrystalline Si and Si of
other crystalline structure may be used as the starting
15 material.

Voltage applied: 2.6 (V)
Current density: 30 ($\text{mA} \cdot \text{cm}^{-2}$)
Anodizing solution: $\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1 : 1 : 1$
20 Time: 2.4 hours
Thickness of porous Si: 300 (μm)
Porosity: 56 (%)

Test pieces of the porous Si thus prepared were
25 immersed in 49 % hydrofluoric acid solution (white circles)

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1 and 20 % hydrofluoric acid solution (black circles) both at
the room temperature, and the solutions were agitated. The
reduction in the thickness of these test pieces of the
porous Si were then measured. A large etching rate was
5 observed: namely, 90 μm in 40 minutes in case of the 49 %
hydro hydro acid solution and 72 μm in 40 minutes in case
of the 20 % hydrofluoric acid solution. After elapse of
80 minutes, the porous Si test pieces were etched by 205 μm
with a high degree of surface state in case of the 49 %
10 hydrofluoric acid solution, whereas, in case of the 20 %
hydrofluoric acid solution, the etching depth was 164 μm
after elapse of 80 minutes.

The etching rate has dependencies on the concentration of
the etching solution and the temperature. The etching
15 solution concentration and temperature are suitably determined in
practical ranges. Although solution concentration of 49 % and
20 % and the room temperature are mentioned above, these
are only illustrative and are not intended for limiting
purpose. Preferably, the concentration of the hydrofluoric acid
20 ranges between 5 % and 95 % and the temperature of the
solution is set to a level which is ordinarily adopted in
this field of technology.

The etched test pieces of porous Si were then rinsed
with water and the surfaces after the rinsing were examined



1 by microanalysis using secondary ions but no impurity was
detected.

A description will now be given with specific
reference to Fig. 6A of the etching characteristics of
5 porous Si and non-porous Si when hydrofluoric acid is used
as the etching solution, followed by a description of an
example of etching of a non-porous Si substrate whose one side
surface is completely porous Si, taken in conjunction with
Figs. 1A and 1B.

10 Fig. 6A is a graph showing the time dependency of
etching depth of porous Si and monocrystalline Si as
observed when they are immersed in hydrofluoric acid
solution. Porous Si was formed by anodizing
monocrystalline Si under the same conditions as those
15 mentioned above. In this case also, the use of monocrystalline
Si as the starting material for anodization is only
illustrative and Si of other crystalline structures may be
used as the starting material.

Test pieces of the porous Si thus prepared were
20 immersed in 49 % hydrofluoric acid solution (white circles)
at the room temperature, and the solutions were agitated.
The reduction in the thickness of these test pieces of
porous Si were then measured. A large etching rate was
observed: namely, 90 μm in 40 minutes in case of the 49 %
25 hydrofluoric acid solution and, after elapse of 80 minutes,

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1 the porous Si test pieces were etched by 205 μm with a high
degree of surface state. The etching rate has dependencies
on the concentration of the etching solution and the temperature.
The etching solution concentration and temperature are suitably
5 determined in practical ranges. Although solution density
of 49 % and the room temperature are mentioned above, these
are only illustrative and are not intended for limiting
purpose. Preferably, the concentration of the hydrofluoric acid
ranges between 5 % and 95 % and the temperature of the
10 solution is set to a level which is ordinarily adopted in
this field of technology.

A test piece of a non-porous Si of 500 μm thick was
immersed in a 49 % solution of hydrofluoric acid (black
circles), followed by an agitation of the solution. The
15 reduction in the thickness was then measured. In this
case, the test piece of non-porous Si was etched only by
100 Angstrom or less even after elapse of 120 minutes. The
etching rate showed almost no dependency on solution
concentration and temperature.

20 Both the porous and non-porous Si test pieces after
the etching were rinsed with water and the surface states
of these test pieces were examined by microanalysis with
secondary ions but no impurity was detected.

As shown in Fig. 1A, a monocrystalline Si substrate 22
25 was anodized only at its one side so as to have a porous Si

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1 structure only at its one side as denoted by 21. Then, the
substrate having the porous Si/monocrystalline Si structure
was immersed in a hydrofluoric acid. As a consequence,
only the porous Si portion was removed by the etching while
5 the monocrystalline Si substrate 22 alone remained
unetched. It is thus possible to selectively etch porous
Si by using monocrystalline Si as the etch
stopper.

A description will now be given of a case where both
10 porous Si portion and monocrystalline Si portion are
provided on one side of the substrate.

As shown in Fig. 2A, a portion of one side of a
monocrystalline Si substrate 32 was anodized to become
porous Si structure 31. Since the current and voltage
15 necessary for the anodization vary depending on the carrier
concentration, it is possible to selectively form porous Si
structure by locally varying the carrier concentration in the
monocrystalline Si surface layer through implantation of
proton or impurities. The substrate having the porous
20 Si/monocrystalline Si structure was then immersed in
hydrofluoric acid. As a result, only the porous Si portion
was removed while the monocrystalline Si substrate 32
remained unetched. It is thus possible to selectively etch
porous Si.

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1 A description will be made as to the case where a
porous Si structure and a polycrystalline structure are
formed in layers on one side of the substrate.

As shown in Fig. 3A, a polycrystalline Si layer 41 was
5 formed by deposition on a single-crystalline Si substrate
42, and the surface layer of this polycrystalline Si
was changed into a porous Si layer 43 by anodization, as
shown in Fig. 3B. The substrate having the porous
Si/polycrystalline Si/monocrystalline Si structure was
10 immersed in a solution of hydrofluoric acid, whereby the
porous Si structure alone was removed by etching while the
monocrystalline Si substrate 42 and the polycrystalline Si
layer 41 remained unetched. It was thus possible to
selectively etch the porous Si by using
15 polycrystalline Si as the etching stopper.

A description will now be given of a case where porous
Si portion is formed in the surface of a polycrystalline Si
layer which is formed on one side of the substrate.

As shown in Fig. 4A, a polycrystalline Si layer 51 was
20 formed by deposition in a monocrystalline Si substrate 52
and a portion of this polycrystalline Si layer was changed
into porous Si layer 53 by anodization. Then, the
substrate having the porous
Si/polycrystalline Si/monocrystalline Si structure was
25 immersed in a solution of hydrofluoric acid, so that the

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1 porous Si alone was removed while the monocrystalline Si
substrate 52 and the polycrystalline Si layer 51 remained
unetched. It was thus possible to selectively etch the
porous Si

5 I-(2)

A description will now be given of the case where a
mixture of hydrofluoric acid and an alcohol is used as the
electroless wet chemical etching solution for porous Si,
with reference to Fig. 7B.

10 Fig. 7B shows the time dependency of etching thickness
of porous Si as observed when the porous Si is immersed in
a mixture liquid of hydrofluoric acid and ethyl alcohol
without agitation of the liquid. The porous Si was formed
by anodizing monocrystalline Si under the conditions shown
15 below. The use of the monocrystalline Si as the starting
material for forming the porous Si structure through
anodization is only illustrative and Si of other
crystalline structures can be used as the starting
material.

20

Voltage applied:	2.6 (V)
Current density:	30 (mA·cm ⁻²)
Anodizing solution:	HF:H ₂ O:C ₂ H ₅ OH = 1 : 1 : 1
Time:	2.4 (hours)
25 Thickness of porous Si:	300 (μm)

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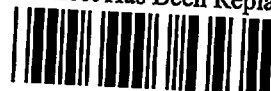


1 Porosity: 56 (%)

Test pieces of the porous Si prepared as described above were immersed, without agitation, in a mixture solution of 49 % hydrofluoric acid and ethyl alcohol (10 : 1) (white circles) and in a mixture solution of 20 % hydrofluoric acid and ethyl alcohol (10 : 1) (black circles). The reductions in the thicknesses of the porous Si test pieces were then measured. Large rates of etching of the porous Si were observed: namely, in the case of the mixture solution of 49 % hydrofluoric acid and ethyl alcohol (10 : 1), the porous Si was etched by 85 μm and, in case of the mixture solution of 20 % hydrofluoric acid and ethyl alcohol (10 : 1), the porous Si was etched by 68 μm , in about 40 minutes. After elapse of 80 minutes, the porous Si was etched by a thickness as large as 195 μm in the case of the mixture solution of 49 % hydrofluoric acid and ethyl alcohol (10 : 1) and 156 μm even in the case of the mixture solution of 20 % hydrofluoric acid and ethyl alcohol (10 : 1), with high degrees of states of the etched surfaces.

The etching rate has dependencies on the concentration of the hydrofluoric acid solution, as well as on the temperature. The addition of alcohol serves to remove bubbles of reaction product gases generated as a

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1 result of the etching without delay from the surface being
etched, without necessitating agitation, thus ensuring a
high efficiency and uniformity of the etching.

The solution concentration and the temperature are
5 determined such that a practical etching speed is obtained in
preparation process and the effect of addition of alcohol is
appreciable. Although the mixture solutions of 49 %
hydrofluoric acid and ethyl alcohol (10 : 1) and 20 %
hydrofluoric acid and ethyl alcohol (10 : 1), as well as
10 the room temperature as the solution temperature, are
mentioned, these solution densities and temperature are
only illustrative and are not intended to restrict the
scope of the invention. The HF concentration with respect
to the etching solution preferably ranges between 1 and 95
15 %, more preferably between 5 and 90 % and most preferably
between 5 and 80 %. The concentration of alcohol with
respect to the etching solution is preferably 80 % or less,
more preferably 60 % or less and most preferably 40 % or
less, and is determined so as to provide an appreciable
20 effect of addition of the alcohol. The temperature is
selected to range preferably 0 to 100°C, more preferably 5
to 80°C and most preferably 5 to 60°C.

Although ethyl alcohol has been mentioned
specifically, the invention does not exclude the use of
25 other alcohol such as isopropyl alcohol which does not

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1 cause any inconvenience in the production process and which
can provide an appreciable effect of addition of such
alcohol.

The porous Si after the etching was rinsed with water
5 and the rinsed surface was examined by microanalysis by
using secondary ions but no impurity was detected.

A description will now be given of the etching
characteristic of porous Si and non-porous Si when they are
etched by a mixture solution of hydrofluoric acid and
10 ethyl alcohol, with specific reference to Fig. 6B.

Fig. 6B shows time dependencies of etched thicknesses of
porous Si and monocrystalline Si as observed when the porous
Si and the monocrystalline Si are immersed in a mixture
solution of hydrofluoric acid and ethyl alcohol without
15 agitation. The porous Si was formed by anodization of
monocrystalline Si conducted under the same conditions as
those shown before. The use of monocrystalline Si as the
starting material for forming porous Si through anodization
is only illustrative and Si of other crystalline structures
20 can be used as the starting material.

A test piece of porous Si prepared as described above
was immersed, without agitation, in a mixture solution of
49 % hydrofluoric acid and ethyl alcohol(10 : 1) (while
circles), and reduction in the thickness of the porous Si
25 was measured. The porous Si was rapidly etched: namely, by

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1 a thickness of 85 μm in 40 minutes and 195 μm in 80
minutes, with high degrees of surface quality and
uniformity.

5 The etching rate depends on the concentration and the
temperature of the hydrofluoric acid solution.

The addition of alcohol serves to remove bubbles of
reaction product gases generated as a result of the etching
without delay from the surface being etched, without
necessitating agitation, thus ensuring a high efficiency
10 and uniformity of the etching.

A test piece of a non-porous Si of 500 μm thick was
immersed in a mixture solution of 49 % hydrofluoric acid
and ethyl alcohol (10 : 1) (black circles), without
agitation of the solution. The reduction in the thickness
15 was then measured. In this case, the test piece of non-
porous Si was etched only by 100 Angstrom or less even
after elapse of 120 minutes. The etching rate showed
almost no dependency on the solution concentration and
temperature.

20 Both the porous and non-porous Si test pieces after
the etching were rinsed with water and the surface states
of these test pieces were examined by microanalysis with
secondary ions but no impurity was detected.

Naturally, various etching methods explained in
25 connection with I by making reference to Figs. 1A and 1B,

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1 Figs. 2A and 2B, Figs. 3A to 3C and Figs. 4A to 4C can be
realized also in the case where the mixture solution of
hydrofluoric acid and an alcohol is used as the etchant
for porous Si.

5 I-(3)

A description will now be given of the case where a
mixture of hydrofluoric acid and aqueous hydrogen peroxide
(hereinafter also referred to as "hydrogen peroxide") is
used as the electroless wet chemical etching solution for
10 porous Si, with reference to Fig. 7C.

Fig. 7C shows the time dependency of etched thickness
of porous Si as observed when the porous Si is immersed in
a mixture liquid of hydrofluoric acid and hydrogen peroxide
under agitation of the liquid. The porous Si was formed by
15 anodizing monocrystalline Si under the conditions shown
below. The use of the monocrystalline Si as the starting
material for forming the porous Si structure through
anodization is only illustrative and Si of other
crystalline structures can be used as the starting
20 material.

Voltage applied:	2.6 (V)
Current density:	30 (mA·cm ⁻²)
Anodizing solution:	HF:H ₂ O:C ₂ H ₅ OH = 1 : 1 : 1
25 Time:	2.4 (hours)
Thickness of porous Si:	300 (μm)

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1 Porosity: 56 (%)

Test pieces of the porous Si prepared as described above were immersed, without agitation, in a mixture
5 solution of 49 % hydrofluoric acid and hydrogen peroxide (1 : 5) (white circles) and in a mixture solution of 49 % hydrofluoric acid and hydrogen peroxide (1 : 1) (black circles). The reductions in the thicknesses of the porous Si test pieces were then measured. Large rates of etching
10 of the porous Si were observed: namely, in the case of the 1 : 5 solution, the porous Si was etched by 112 μm and, in case of the 1 : 1 solution, the porous Si was etched by 135 μm , in about 40 minutes. After elapse of 80 minutes, the porous Si was etched by a thickness as large as 256 μm in
15 the case of the 1 : 5 solution and 307 μm in the case of the 1 : 1 solution, with high degrees of states of the etched surfaces. The concentration of hydrogen peroxide was 30 % in this case but the hydrogen peroxide concentration may be determined in a range which provides
20 an appreciable effect of addition of hydrogen peroxide and which does not cause any practical problem in the production process.

The etching rate has dependencies on the density of the hydrofluoric acid solution, as well as on the
25 temperature of the same. The addition of alcohol serves to

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1 accelerate oxidation of silicon, thus enhancing the
reaction speed as compared to the case where hydrogen
peroxide is not used. It is also possible to control the
reaction speed by suitably selecting the content of
5 hydrogen peroxide.

The solution concentration and the solution temperature
are determined such that a practical etching speed is obtained
in preparation process and the effect of hydrofluoric acid
and hydrogen peroxide is appreciable. Although the mixture
10 solutions of 49 % hydrofluoric acid and hydrogen peroxide
(1 : 5) and 49 % hydrofluoric acid and hydrogen peroxide (1
: 1), as well as the room temperature as the solution
temperature, are mentioned, these solution concentrations and
temperature are only illustrative and are not intended to
15 restrict the scope of the invention.

The HF concentration with respect to the etching
solution preferably ranges between 1 and 95 %, more
preferably between 5 and 90 % and most preferably between 5
and 80 %. The concentration of H_2O_2 with respect to the
20 etching solution is preferably selected to range between 1
and 95 %, more preferably between 5 and 90% and most
preferably between 10 and 80%, and is determined so as to
provide an appreciable effect of addition of the hydrogen
peroxide. The temperature is selected to range preferably

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1 0 to 100°C, more preferably 5 to 80°C and most preferably 5
to 60°C.

The porous Si after the etching was rinsed with water
and the rinsed surface was examined by microanalysis by
5 using secondary ions but no impurity was detected.

A description will now be given of the etching
characteristics of porous Si and non-porous Si as observed
when they are etched by a mixture solution of hydrofluoric
acid and aqueous hydrogen peroxide, with specific reference
10 to Fig. 6C. Fig. 6C shows the time dependencies of etched
depth of porous Si and monocrystalline Si as observed when the
porous Si and the monocrystalline Si are immersed in a
mixture solution of hydrofluoric acid and aqueous hydrogen
peroxide. The porous Si was formed by anodization of
15 monocrystalline Si conducted under the same conditions as
those shown before. The use of monocrystalline Si as the
starting material for forming porous Si through anodization
is only illustrative and Si of other crystalline structures
can be used as the starting material.

20 A test piece of porous Si prepared as described above
was immersed, followed by agitation, in a mixture solution
of 49 % hydrofluoric acid and aqueous hydrogen peroxide (white
circles), and reduction in the thickness of the porous Si
was measured. The porous Si was rapidly etched: namely, by
25 a thickness of 112 μm in 40 minutes and 256 μm in 80

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1 minutes, with high degrees of surface quality and
uniformity. Although the concentration of aqueous hydrogen
peroxide was 30 % in this case, the concentration of hydrogen
5 does not impair the effect of addition of hydrogen peroxide
and which does not cause any practical inconvenience in the
production.

The etching rate depends on the concentration and the tem-
perature of the hydrofluoric acid and aqueous hydrogen peroxide

10 The addition of hydrogen peroxide serves to
accelerate oxidation of silicon, thus enhancing the
reaction speed as compared to the case where hydrogen
peroxide is not added. Furthermore, the reaction speed
can be controlled by suitably selecting the content of the
15 hydrogen peroxide.

A test piece of a non-porous Si of 500 μm thick was
immersed in a mixture solution of 49 % hydrofluoric acid
and aqueous hydrogen peroxide (1 : 5) (Black circles), followed
by agitation of the solution. The reduction in the thickness
20 of the porous Si was then measured. In this case, the test
piece of nonporous Si was etched only by 100 Angstrom or less
even after elapse of 120 minutes. The etching rate showed
almost no dependency on the solution concentration and
temperature.

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1 Both the porous and non-porous Si test pieces after
the etching were rinsed with water and the surface states
of these test pieces were examined by microanalysis with
secondary ions but no impurity was detected.

5 Naturally, various embodiments explained in
connection with I by making reference to Figs. 1A and 1B,
Figs. 2A and 2B, Figs. 3A to 3C and Figs. 4A to 4C can be
realized also in the case where the mixture solution of
hydrofluoric acid and aqueous hydrogen peroxide is used as
10 the etching solution.

I-(4)

A description will now be given of the case where a
mixture of hydrofluoric acid, an alcohol and aqueous hydrogen
peroxide is used as the electroless wet chemical etching
15 solution for porous Si, with reference to Fig. 7D.

Fig. 7D shows the time dependency of etched thickness of
porous Si as observed when the porous Si is immersed in a
mixture liquid of hydrofluoric acid, ethyl alcohol and aqueous
hydrogen peroxide without agitation of the liquid. The
20 porous Si was formed by anodizing monocrystalline Si under
the conditions shown below. The use of the monocrystalline
Si as the starting material for forming the porous Si
structure through anodization is only illustrative and Si
of other crystalline structures can be used as the starting
25 material.

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Voltage applied: 2.6 (V)
Current density: 30 ($\text{mA} \cdot \text{cm}^{-2}$)
Anodizing solution: $\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1 : 1 : 1$

5

Time: 2.4 (hours)
Thickness of porous Si: 300 (μm)
Porosity: 56 (%)

Test pieces of the porous Si prepared as described
10 above were immersed, without agitation, in a mixture
solution of 49 % hydrofluoric acid, ethyl alcohol and aqueous
hydrogen peroxide (10 : 6 : 50) (white circles) and in a
mixture solution of 49 % hydrofluoric acid, ethyl alcohol
and hydrogen peroxide (10 : 2 : 10) (black circles). The
15 reductions in the thicknesses of the porous Si test pieces
were then measured. Large rates of etching of the porous
Si were observed: namely, in the case of the 10 : 6 : 50
solution, the porous Si was etched by 107 μm and, in case
of the 10 : 2 : 10 solution, the porous Si was etched by
20 128 μm , in about 40 minutes. After elapse of 80 minutes,
the porous Si was etched by a thickness as large as 244 μm
in the case of the 10 : 6 : 50 solution and 292 μm in the
case of the 10 : 2 : 10 solution, with high degrees of
states of the etched surfaces. The concentration of aqueous
25 hydrogen peroxide was 30 % in this case but the hydrogen



1 peroxide concentration may be determined in a range which
provides an appreciable effect of addition of hydrogen
peroxide and which does not cause any practical problem in
the production process.

5 The etching rate has dependencies on the density of
the hydrofluoric acid solution, as well as on the
temperature of the same. The addition of alcohol serves to
accelerate oxidation of silicon, thus enhancing the
reaction speed as compared to the case where hydrogen
10 peroxide is not used. It is also possible to control the
reaction speed by suitably selecting the content of
hydrogen peroxide. On the other hand, the addition of
alcohol serves to remove, without delay, bubbles of
reaction gases generated as a result of the etching from
15 the etched surface, without requiring agitation of the
solution, thus offering high degrees of efficiency and
uniformity of etching of the porous Si.

The solution density and the solution temperature are
determined such that a practical etching speed is obtained
20 and such that the effect of the use of hydrofluoric acid,
alcohol and hydrogen peroxide is appreciable. Although the
mixture solutions of 49 % hydrofluoric acid, ethyl alcohol
and hydrogen peroxide (10 : 6 : 50) and 49 % hydrofluoric
acid, ethyl alcohol and hydrogen peroxide (10 : 2 : 10), as
25 well as the room temperature as the solution temperature,

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1 are mentioned, these solution densities and temperature are only illustrative and are not intended to restrict the scope of the invention.

5 The HF concentration with respect to the etching solution preferably ranges between 1 and 95 %, more preferably between 5 and 90 % and most preferably between 5 and 80 %. The concentration of H_2O_2 with respect to the etching solution is preferably selected to range between 1 and 95 %, more preferably between 5 and 90% and most
10 preferably between 10 and 80%, and is determined so as to provide an appreciable effect of addition of the hydrogen peroxide. The concentration of the alcohol with respect to the etching solution is preferably determined to be 80 % or less, more preferably 60 % or less and most preferably 40 %
15 or less, and is selected so as to provide an appreciable effect of addition of the alcohol. The temperature is selected to range preferably 0 to 100°C, more preferably 5 to 80°C and most preferably 5 to 60°C.

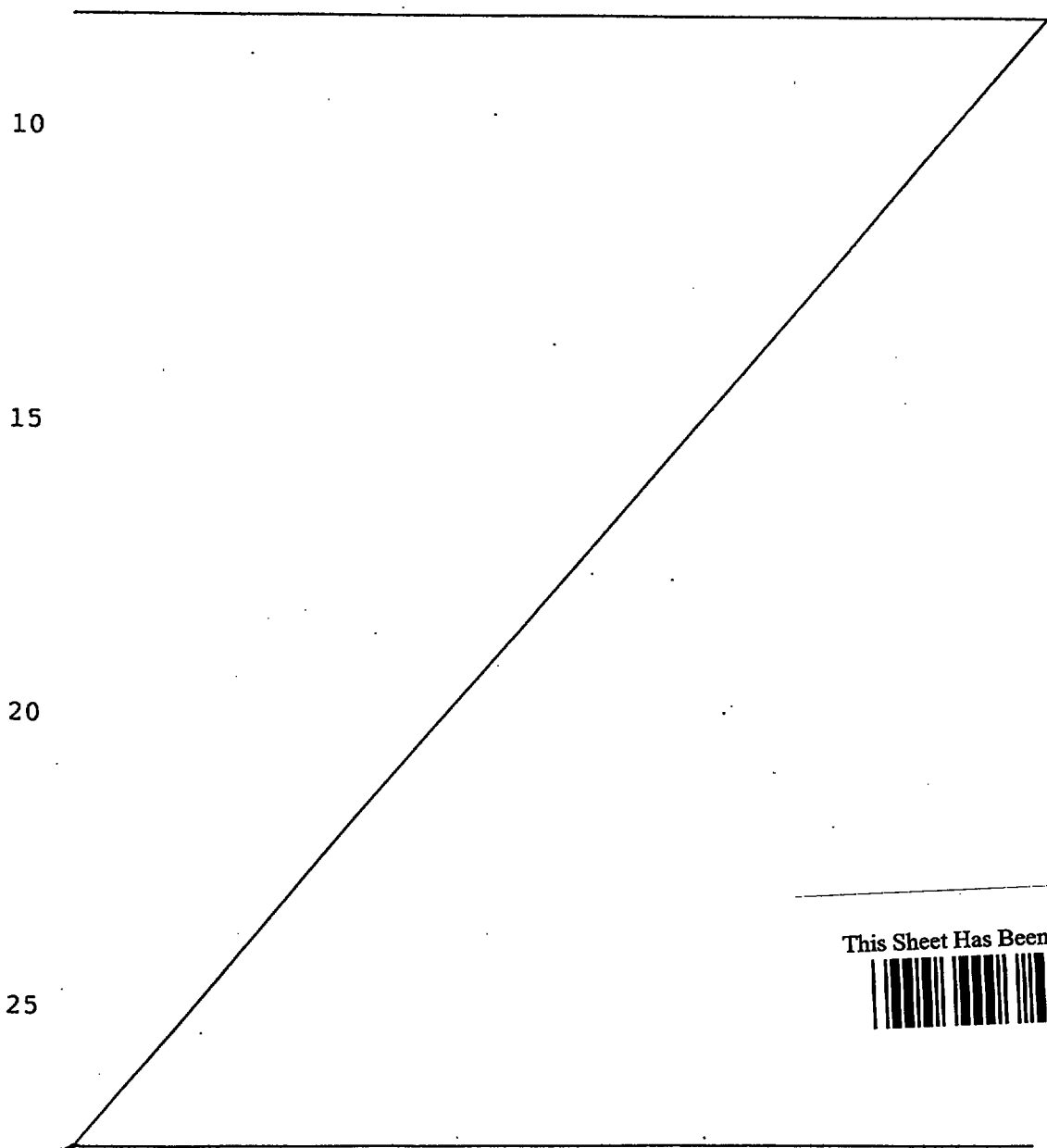
20 Alcohol to be used in the present invention is not limited to ethyl alcohol and includes those alcohols such as isopropyl alcohol which can practically be used in preparation process and accomplish the effect of the addition of alcohol as mentioned above.

25



- 1 The porous Si after the etching was rinsed with water and the rinsed surface was examined by microanalysis by using secondary ions but no impurity was detected.

This type of etching solution is advantageous in that
5 bubbles of reaction product gases generated as a result of the etching can be removed without delay from the surface being etched, without requiring agitation, so that the



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1 surface is etched with high degrees of smoothness and
uniformity even to the bottoms of minute recesses which may
exist in the etched surface.

A description will now be given of the etching
5 characteristics of porous Si and non-porous Si as observed
when they are etched by a mixture solution of hydrofluoric
acid, ethyl alcohol and aqueous hydrogen peroxide, with
specific reference to Fig. 6D.

Fig. 6D shows the time dependencies of etched
10 thickness of porous Si and monocrystalline Si as observed
when the porous Si and the monocrystalline Si are immersed
in a mixture solution of hydrofluoric acid, ethyl alcohol
and aqueous hydrogen peroxide, without agitation. The
porous Si was formed by anodization of monocrystalline Si
15 conducted under the same conditions as those shown before.
The use of monocrystalline Si as the starting material for
forming porous Si through anodization is only
illustrative and Si of other crystalline structures can be
used as the starting material.

20 A test piece of porous Si prepared as described
above was immersed, without agitation, in a mixture
solution of 49 % hydrofluoric acid, ethyl alcohol and
aqueous hydrogen peroxide (10 : 6 : 50) (v/v/v) at
the room temperature, and reduction in the thickness of
25 the porous Si was measured. The porous Si was rapidly
etched: namely, by a thickness of 107 μm in 40 minutes
and 244 μm in 80 minutes, with high degrees of



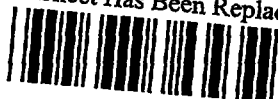
1 surface quality and uniformity. Although the
concentration of the aqueous hydrogen peroxide was 30 % in
this case, the content of hydrogen peroxide may be
suitably determined within a range which does not impair
5 the effect of addition of hydrogen peroxide and which does
not cause any practical inconvenience in the production.

The etching rate depends on the concentration and
the temperature of the hydrofluoric acid and aqueous
hydrogen peroxide.

10 The addition of hydrogen peroxide serves to accelerate
oxidation of silicon, thus enhancing the reaction speed as
compared to the case where hydrogen peroxide is not added.
Furthermore, the reaction speed can be controlled by
suitably selecting the content of the hydrogen peroxide.
15 In addition, alcohol serves to remove, without delay,
bubbles of the reaction product gases generated as a result
of the etching without requiring agitation, thus ensuring
high degrees of uniformity and etching of the porous Si.

A test piece of a non-porous Si of 500 μm thick was
20 immersed in a mixture solution of 49 % hydrofluoric acid,
ethyl alcohol and aqueous hydrogen peroxide (10 : 6 : 50)
(black circles) at the room temperature, without agitation
of the solution. The reduction in the thickness was then
measured. In this case, the test piece of non-porous Si
25 was etched only by 100 Angstrom or less even after elapse

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1 of 120 minutes. The etching rate showed almost no
dependency on the solution concentration and temperature.

Both the porous and non-porous Si test pieces after
the etching were rinsed with water and the surface states
5 of these test pieces were examined by microanalysis with
secondary ions but no impurity was detected.

Naturally, the various embodiments explained in
connection with I by making reference to Figs. 1A and 1B,
Figs. 2A and 2B, Figs. 3A to 3C and Figs. 4A to 4C can be
10 realized also in the case where the mixture solution of
hydrofluoric acid, alcohol and aqueous hydrogen peroxide is
used as the etchant for porous Si.

I-(5)

A description will now be given of the case where a
15 buffered hydrofluoric acid is used as the electroless wet
chemical etching solution for porous Si, with reference to
Fig. 7E. For instance, an aqueous solution containing 36.2
% of ammonium fluoride (NH_4F) and 4.5 % of hydrogen
fluoride (HF) is used as the buffered hydrofluoric acid.

20 Fig. 7E shows the time dependency of etching thickness
of porous Si as observed when the porous Si is immersed in
the buffered hydrofluoric acid followed by agitation. The
porous Si was formed by anodizing monocrystalline Si under
the conditions shown below. The use of the monocrystalline
25 Si as the starting material for forming the porous Si



1 structure through anodization is only illustrative and Si
of other crystalline structures can be used as the starting
material.

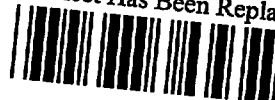
5 Voltage applied: 2.6 (V)
Current density: 30 (mA·cm⁻²)
Anodizing solution: HF:H₂O:C₂H₅OH = 1 : 1 : 1
Time: 2.4 (hours)
Thickness of porous Si: 300 (μm)
10 Porosity: 56 (%)

Test pieces of the porous Si prepared as described
above were immersed, followed by agitation, in the buffered
hydrofluoric acid (white circles) and in a 20 % diluted
15 buffered hydrofluoric acid (black circles). The reductions
in the thicknesses of the porous Si test pieces were then
measured. Large rates of etching of the porous Si were
observed: namely, in the case of buffered hydrofluoric
acid, the porous Si was etched by 70 μm and, in case of the
20 20 % diluted buffered hydrofluoric acid, the porous Si was
etched by 56 μm, in about 40 minutes. After elapse of 120
minutes, the porous Si was etched by a thickness as large
as 118 μm in the case of the buffered hydrofluoric acid and
94 μm in the case of the 20 % diluted buffered hydrofluoric
25 acid, with high degrees of states of the etched surfaces.



1 The etching rate has dependencies on the density of
the hydrofluoric acid solution, as well as on the
temperature of the same. The density of the solution and
the temperature of the same are determined to fall within
5 the ranges which would not cause any practical
inconvenience. Although the buffered hydrofluoric acid
which is an aqueous solution containing 36.2 % of ammonium
fluoride (NH_4F) and 4.5 % of hydrogen fluoride (HF) and the
20 % diluted buffered hydrofluoric acid, as well as the
10 room temperature as the solution temperature, are
mentioned, these solution densities and temperature are
only illustrative and are not intended to restrict the
scope of the invention.

The HF concentration in the buffered hydrofluoric acid
15 with respect to the etching solution preferably ranges
between 1 and 95 %, more preferably between 1 and 85 % and
most preferably between 1 and 70 %. The concentration of
 NH_4 in the buffered hydrofluoric acid with respect to the
etching solution is preferably selected to range between 1
20 and 95 %, more preferably between 5 and 90% and most
preferably between 5 and 80%. The temperature is selected
to range preferably 0 to 100°C, more preferably 5 to 80°C
and most preferably 5 to 60°C.



1 The porous Si after the etching was rinsed with water
and the rinsed surface was examined by microanalysis by
using secondary ions but no impurity was detected.

 A description will now be given of the etching
5 characteristics of porous Si and non-porous Si as observed
when they are etched by the buffered hydrofluoric acid,
with specific reference to Fig. 6E. Fig. 6E shows the time
dependencies of etching of porous Si and monocrystalline Si
as observed when the porous Si and the monocrystalline Si
10 are immersed in the buffered hydrofluoric acid. The porous
Si was formed by anodization of monocrystalline Si
conducted under the same conditions as those shown before.
The use of monocrystalline Si as the starting material for
forming porous Si through anodization is only illustrative
15 and Si of other crystalline structures can be used as the
starting material.

 A test piece of porous Si prepared as described above
was immersed, followed by agitation, in the buffered
hydrofluoric acid (white circles) at the room temperature,
20 and reduction in the thickness of the porous Si was
measured. The porous Si was rapidly etched: namely, by a
thickness of 70 μm in 40 minutes and 118 μm in 120 minutes,
with high degrees of surface quality and uniformity.

 The etching rate has dependencies on the density of
25 the hydrofluoric acid solution, as well as on the

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1 temperature of the same. The density of the solution and
the temperature of the same are determined to fall within
the ranges which would not cause any practical
inconvenience. Although the buffered hydrofluoric acid
5 which is an aqueous solution containing 36.2 % of ammonium
fluoride (NH_4F) and 4.5 % of hydrogen
fluoride (HF) as well as the
room temperature as the solution temperature, are
mentioned, these solution densities and temperature are
10 only illustrative and are not intended to restrict the
scope of the invention.

A test piece of a non-porous Si of 500 μm thickness was
immersed in the buffered hydrofluoric acid(black circles)
at the room temperature, followed by agitation of the
15 solution. The reduction in the thickness was then
measured. In this case, the test piece of non-porous Si
was etched only by 100 Angstroms or less even after elapse
of 120 minutes. The etching rate showed almost no
dependency on the solution density and temperature.

20 Both the porous and non-porous Si test pieces after
the etching were rinsed with water and the surface states
of these test pieces were examined by microanalysis with
secondary ions but no impurity was detected.

Obviously, various etching methods explained in
25 connection with (1) by making reference to Figs. 1A and 1B,

1 Figs. 2A and 2B, Figs. 3A to 3C and Figs. 4A to 4C can be realized also in the case where the buffered hydrofluoric acid is used as the etching solution.

I-(6)

5 A description will now be given of the case where a mixture liquid of a buffered hydrofluoric acid and an alcohol is used as the electroless wet chemical etching solution for porous Si, with reference to Fig. 7F. For instance, an aqueous solution containing 36.2 % of ammonium
10 fluoride (NH_4F) and 4.5 % of hydrogen fluoride (HF) is used as the buffered hydrofluoric acid.

Fig. 7F shows the time dependency of etching thickness of porous Si as observed when the porous Si is immersed in the mixed solution of the buffered hydrofluoric acid and
15 ethyl alcohol, without agitation. The porous Si was formed by anodizing monocrystalline Si under the conditions shown below. The use of the monocrystalline Si as the starting material for forming the porous Si structure through anodization is only illustrative and Si of other
20 crystalline structures can be used as the starting material.

	Voltage applied:	2.6 (V)
	Current density:	30 ($\text{mA} \cdot \text{cm}^{-2}$)
25	Anodizing solution:	$\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1 : 1 : 1$

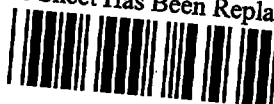
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1 Time: 2.4 (hours)
 Thickness of porous Si: 300 (μm)
 Porosity: 56 (%)

5 Test pieces of the porous Si prepared as described
above were immersed, without agitation, in a mixture
solution of the buffered hydrofluoric acid and ethyl
alcohol (10 : 1) (white circles) and in a mixture solution
of 20 % diluted buffered hydrofluoric acid and ethyl
10 alcohol (10 : 1) (black circles). The reductions in the
thicknesses of the porous Si test pieces were then
measured. Large rates of etching of the porous Si were
observed: namely, in the case of the mixture solution of
the buffered hydrofluoric acid and ethyl alcohol (10 : 1),
15 the porous Si was etched by 67 μm and, in case of the
mixture solution of the 20 % diluted buffered hydrofluoric
acid and ethyl alcohol (10 : 1), the porous Si was etched
by 54 μm , in about 40 minutes. After elapse of 120
minutes, the porous Si was etched by a thickness as large
20 as 112 μm in the case of the mixture solution of the
buffered hydrofluoric acid and ethyl alcohol (10 : 1) and
90 μm in the case of the mixture solution of 20 % diluted
buffered hydrofluoric acid and ethyl alcohol (10 : 1), with
high degrees of states of the etched surfaces. The
25 etching rate has dependencies on the density of the

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1 hydrofluoric acid solution, as well as on the temperature
of the same. The addition of alcohol serves to remove,
without delay, bubbles of reaction product gases generated
as a result of the etching from the surface being etched,
5 without requiring agitation, thus enabling etching of the
porous Si with high degrees of uniformity and efficiency.

The density of the solution and the temperature of the
same are determined to fall within the ranges which would
not cause any practical inconvenience. Although the
10 mixture solution of the buffered hydrofluoric acid and
ethyl alcohol (10 : 1) and the mixture solution of the 20 %
diluted buffered hydrofluoric acid and ethyl alcohol (10 :
1), as well as the room temperature as the solution
temperature, are mentioned, these solution densities and
15 temperature are only illustrative and are not intended to
restrict the scope of the invention.

The HF concentration in the buffered hydrofluoric acid
with respect to the etching solution preferably ranges
between 1 and 95 %, more preferably between 1 and 85 % and
20 most preferably between 1 and 70 %. The concentration of
NH₄ in the buffered hydrofluoric acid with respect to the
etching solution is preferably selected to range between 1
and 95 %, more preferably between 5 and 90% and most
preferably between 5 and 80%. The concentration of the
25 alcohol with respect to the etching solution is preferably

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- 1 80 % or less, more preferably 60 % or less and most preferably 40 % or less, and is determined to make the effect of addition of the alcohol appreciable. The temperature is selected to range preferably 0 to 100°C, 5 more preferably 5 to 80°C and most preferably 5 to 60°C.

Although ethyl alcohol has been specifically mentioned, other alcohols such as isopropyl alcohol, which does not cause any inconvenience in the commercial production and which can provide an appreciable effect of 10 addition of such alcohol, may be used as the alcohol used in this type of etching solution.

The porous Si after the etching was rinsed with water and the rinsed surface was examined by microanalysis by using secondary ions but no impurity was detected.

- 15 In this etching solution, bubbles of reaction product gases generated as a result of the etching can be removed without delay and without requiring agitation of the solution, by virtue of the addition of the alcohol, so that the bottoms of minute recesses can be formed with high 20 degrees of smoothness and uniformity.

A description will now be given of the etching characteristics of porous Si and non-porous Si as observed when they are etched by the mixture solution of the buffered hydrofluoric acid and the ethyl alcohol, with

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1 specific reference to Fig. 6F. Fig. 6F shows the time
dependencies of etching thickness of porous Si and mono-
crystalline Si as observed when the porous Si and the monocrys-
talline Si are immersed in the mixture solution of the buffered
5 hydrofluoric acid and ethyl alcohol. The porous Si was
formed by anodization of monocrystalline Si conducted under
the same conditions as those shown before. The use of
monocrystalline Si as the starting material for forming
porous Si through anodization is only illustrative and Si
10 of other crystalline structures can be used as the starting
material.

A test piece of porous Si prepared as described above
was immersed, without agitation, in the mixture solution of
the buffered hydrofluoric acid and ethyl alcohol (10 : 1)
15 (white circles) at the room temperature, and reduction in
the thickness of the porous Si was measured. The porous Si
was rapidly etched: namely, by a thickness of 67 μm in 40
minutes and 112 μm in 120 minutes, with high degrees of
surface quality and uniformity.

20 A test piece of a non-porous Si of 500 μm thickness
was immersed in the mixture solution of the buffered
hydrofluoric acid and ethyl alcohol (10 : 1) (black
circles) at the room temperature, without agitation of the
solution. The reduction in the thickness of the non-porous
25 Si was then measured. In this case, the test piece of

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1 non-porous Si was etched only by 100 Angstroms or less even
after elapse of 120 minutes. The etching rate showed
almost no dependency on the solution density and
temperature.

5 Both the porous and non-porous Si test pieces after
the etching were rinsed with water and the surface states
of these test pieces were examined by microanalysis with
secondary ions but no impurity was detected.

Obviously, various etching methods explained in
10 connection with (1) by making reference to Figs. 1A and 1B,
Figs. 2A and 2B, Figs. 3A to 3C and Figs. 4A to 4C can be
realized also in the case where the mixture solution of the
buffered hydrofluoric acid and alcohol is used as the
etching solution.

15 I-(7)

A description will now be given of the case where a
mixture solution of a buffered hydrofluoric acid and
hydrogen peroxide is used as the electroless wet chemical
etching solution for porous Si, with reference to Fig. 7G.
20 For instance, an aqueous solution containing 36.2 % of
ammonium fluoride (NH_4F) and 4.5 % of hydrogen fluoride
(HF) is used as the buffered hydrofluoric acid.

Fig. 7G shows the time dependency of etching thickness
of porous Si as observed when the porous Si is immersed in
25 the mixed solution of the buffered hydrofluoric acid and



1 hydrogen peroxide followed by agitation. The porous Si was
formed by anodizing monocrystalline Si under the conditions
shown below. The use of the monocrystalline Si as the
starting material for forming the porous Si structure
5 through anodization is only illustrative and Si of other
crystalline structures can be used as the starting
material.

	Voltage applied:	2.6 (V)
10	Current density:	30 (mA·cm ⁻²)
	Anodizing solution:	HF:H ₂ O:C ₂ H ₅ OH = 1 : 1 : 1
	Time:	2.4 (hours)
	Thickness of porous Si:	300 (μm)
	Porosity:	56 (%)

15

Test pieces of the porous Si prepared as described
above were immersed, followed by agitation, in a mixture
solution of the buffered hydrofluoric acid and hydrogen
peroxide (1 : 5) (white circles) and in a mixture solution
20 of the buffered hydrofluoric acid and hydrogen peroxide (5
: 1) (black circles). The reductions in the thicknesses of
the porous Si test pieces were then measured. Large rates
of etching of the porous Si were observed: namely, in the
case of the 1 : 5 mixture solution, the porous Si was
25 etched by 88 μm and, in case of the 5 : 1 mixture solution,



1 the porous Si was etched by 105 μm , in about 40 minutes.

After elapse of 120 minutes, the porous Si was etched by a thickness as large as 147 μm in the case of the 1 : 5 mixture and 177 μm in the case of the 5 : 1 mixture

5 solution, with high degrees of states of the etched surfaces. In this case, the concentration of hydrogen peroxide was 30 %. This, however, is only illustrative and the concentration of hydrogen peroxide is suitably selected within a range which does not impair the effect of addition
10 of hydrogen peroxide. The etching rate has dependencies on the solution densities of the buffered hydrofluoric acid and hydrogen peroxide, as well as on the temperature of the same. The addition of hydrogen peroxide accelerates the oxidation of silicon, thus
15 attaining a higher reaction speed as compared to the case where hydrogen peroxide is not added. In addition, the reaction speed can be controlled by suitably determining the content of hydrogen peroxide.

The density of the solution and the temperature of the
20 same are determined to fall within the ranges which would not cause any practical inconvenience in commercial production. Although the mixture solution of the buffered hydrofluoric acid and hydrogen peroxide (1 : 5) and the mixture solution of the buffered hydrofluoric acid and
25 hydrogen peroxide (5 : 1), as well as the room temperature as the solution temperature, are mentioned, these solution

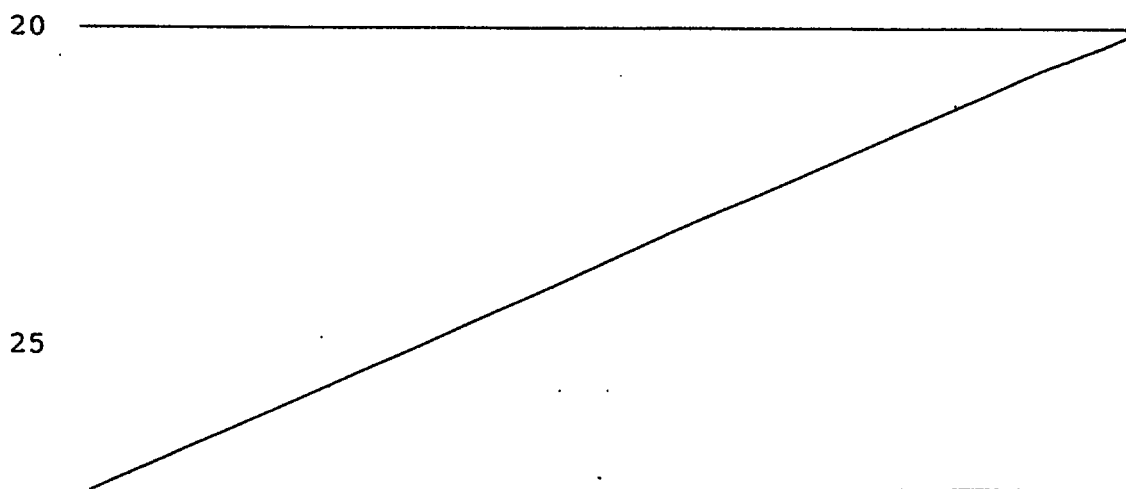
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1 densities and temperature are only illustrative and are not intended to restrict the scope of the invention.

The HF concentration in the buffered hydrofluoric acid with respect to the etching solution preferably ranges
5 between 1 and 95 %, more preferably between 1 and 85 % and most preferably between 1 and 70 %. The concentration of NH_4 in the buffered hydrofluoric acid with respect to the etching solution is preferably selected to range between 1 and 95 %, more preferably between 5 and 90% and most
10 preferably between 5 and 80%. The concentration of H_2O_2 with respect to the etching solution is preferably 1 to 95 %, more preferably 5 to 90 % and most preferably 10 to 80 %, and is determined to make the effect of addition of the hydrogen peroxide. The temperature is selected to range
15 preferably 0 to 100°C, more preferably 5 to 80°C and most preferably 5 to 60°C.

The porous Si after the etching was rinsed with water and the rinsed surface was examined by microanalysis by using secondary ions but no impurity was detected.



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1 A description will now be given of the etching
characteristics of porous Si and non-porous Si as observed
when they are etched by the mixture solution of the
buffered hydrofluoric acid and hydrogen peroxide, with
5 specific reference to Fig. 6G. Fig. 6G shows the time
dependencies of etching thickness of porous Si and monocrys-
talline Si as observed when the porous Si and the monocrys-
talline Si are immersed in the mixture solution of the buffered
hydrofluoric acid hydrogen peroxide. The porous Si was
10 formed by anodization of monocrystalline Si conducted under
the same conditions as those shown before. The use of
monocrystalline Si as the starting material for forming
porous Si through anodization is only illustrative and Si
of other crystalline structures can be used as the starting
15 material.

A test piece of porous Si prepared as described above
was immersed, followed by agitation, in the mixture
solution of the buffered hydrofluoric acid and hydrogen
peroxide (1 : 5) (white circles) at the room temperature,
20 and reduction in the thickness of the porous Si was
measured. The porous Si was rapidly etched: namely, by a
thickness of 88 μm in 40 minutes and 147 μm in 120 minutes,
with high degrees of surface quality and uniformity.
Although in this case the concentration of hydrogen
25 peroxide was 30 %, this is only illustrative and the

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1 content of hydrogen peroxide is suitably selected within a
range which does not cause any practical inconvenience and
which does not impair the effect produced by the addition
of hydrogen peroxide.

5 Both the porous and non-porous Si test pieces after
the etching were rinsed with water and the surface states
of these test pieces were examined by microanalysis with
secondary ions but no impurity was detected.

Obviously, various etching methods explained in
10 connection with (1) by making reference to Figs. 1A and 1B,
Figs. 2A and 2B, Figs. 3A to 3C and Figs. 4A to 4C can be
realized also in the case where the mixture solution of the
buffered hydrofluoric acid and alcohol is used as the
etching solution.

15 I-(8)

The following will now be given of the case where a
mixture solution of a buffered hydrofluoric acid, an
alcohol and hydrogen peroxide is used as the electroless
wet chemical etching solution for porous Si, with reference
20 to Fig. 7H. For instance, an aqueous solution containing
36.2 % of ammonium fluoride (NH_4F) and 4.5 % of hydrogen
fluoride (HF) is used as the buffered hydrofluoric acid.

Fig. 7H shows the time dependency of etching thickness
of porous Si as observed when the porous Si is immersed in
25 the mixed solution of the buffered hydrofluoric acid, ethyl



1 alcohol and hydrogen peroxide without agitation. The
porous Si was formed by anodizing monocrystalline Si under
the conditions shown below. The use of the monocrystalline
Si as the starting material for forming the porous Si
5 structure through anodization is only illustrative and Si
of other crystalline structures can be used as the starting
material.

	Voltage applied:	2.6 (V)
10	Current density:	30 (mA·cm ⁻²)
	Anodizing solution:	HF:H ₂ O:C ₂ H ₅ OH = 1 : 1 : 1
	Time:	2.4 (hours)
	Thickness of porous Si:	300 (μm)
	Porosity:	56 (%)

15

Test pieces of the porous Si prepared as described
above were immersed, without agitation, in a mixture
solution of the buffered hydrofluoric acid, ethyl alcohol
and hydrogen peroxide (10 : 6 : 50) (white circles) and in
20 a mixture solution of the buffered hydrofluoric acid, ethyl
alcohol and hydrogen peroxide (50 : 6 : 10) (black
circles). The reductions in the thicknesses of the porous
Si test pieces were then measured. Large rates of etching
of the porous Si were observed: namely, in the case of the
25 10 : 6 : 50 mixture solution, the porous Si was etched by

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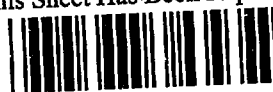
1 83 μm and, in case of the 50 : 6 : 10 mixture solution, the
porous Si was etched by 100 μm , in about 40 minutes. After
elapse of 120 minutes, the porous Si was etched by a
thickness as large as 140 μm in the case of the 10 : 6 : 50
5 mixture and 168 μm in the case of the 50 : 6 : 10 mixture
solution, with high degrees of states of the etched
surfaces. In this case, the concentration of hydrogen
peroxide was 30 %. This, however, is only illustrative and
the concentration of hydrogen peroxide is suitably selected
10 within a range which does not impair the effect of addition
of hydrogen peroxide. The etching rate has dependencies on
the concentrations of the buffered hydrofluoric acid and
hydrogen peroxide, as well as on the temperature of the
same. The addition of hydrogen peroxide accelerates the
15 oxidation of silicon, thus attaining a higher reaction
speed as compared to the case where hydrogen peroxide is
not added. In addition, the reaction speed can be
controlled by suitably determining the ratio of hydrogen
peroxide. The addition of alcohol enables bubbles of
20 reaction products gases generated as a result of the
etching to be removed from the surface being etched,
without delay and without agitation, thus making it
possible to etch the porous Si uniformly and with high
efficiency.



1 The concentrations of the solution and
the temperature of the solution are determined to fall
within the ranges which provide the above effects of the
use of the buffered hydrofluoric acid, hydrogen peroxide
5 and the alcohol and which would not cause any practical
inconvenience in commercial production. Although the
mixture solution of the buffered hydrofluoric acid, ethyl
alcohol and hydrogen peroxide (10 : 6 : 50) and the mixture
solution of the buffered hydrofluoric acid, ethyl alcohol
10 and hydrogen peroxide (50 : 6 : 10), as well as the room
temperature as the solution temperature, are mentioned,
these solution ratio and temperature are only
illustrative and are not intended to restrict the scope of
the invention.

15 The HF concentration in the buffered hydrofluoric acid
with respect to the etching solution preferably ranges
between 1 and 95 %, more preferably between 1 and 85 % and
most preferably between 1 and 70 %. The concentration of
NH₄F in the buffered hydrofluoric acid with respect to the
20 etching solution is preferably selected to range between 1
and 95 %, more preferably between 5 and 90% and most
preferably between 5 and 80%. The concentration of H₂O₂
with respect to the etching solution is preferably 1 to 95
%, more preferably 5 to 90 % and most preferably 10 to 80
25 %, and is determined to make the effect of addition of the

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1 alcohol appreciable. The concentration of the alcohol
with respect to the etching solution is preferably 80 % or
less, more preferably 60 % or less and most preferably 40 %
or less, and is determined to make the effect of addition
5 of the alcohol appreciable. The temperature is selected to
range preferably 0 to 100°C, more preferably 5 to 80°C and
most preferably 5 to 60°C.

Although ethyl alcohol has been specifically
mentioned, other alcohols such as isopropyl alcohol, which
10 does not cause any inconvenience in the commercial
production and which can provide an appreciable effect of
addition of such alcohol, may be used as the alcohol used
in this type of etching solution.

The porous Si after the etching was rinsed with water
15 and the rinsed surface was examined by microanalysis by
using secondary ions but no impurity was detected.

This etching solution enables bubbles of reaction
product gases generated by the etching to be removed from
the surface being etched, without delay and without
20 requiring agitation, so that the etching can be performed
with high degrees of smoothness and uniformity at the
bottoms of minute recesses of the surface to be
etched.

Clearly, embodiments explained in the
25 above (1) by making reference to Figs. 1A and 1B,



1 Figs. 2A and 2B, Figs. 3A to 3C and Figs. 4A to 4C can be
realized also in the case where the mixture solution of the
buffered hydrofluoric acid, alcohol and hydrogen peroxide
is used as the etching solution.

5

II. The following will now be given of a process of the
invention for producing a semiconductor member.

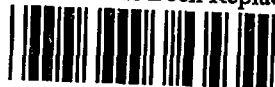
As explained before, the first embodiment of the process
for producing the semiconductor member in accordance with
10 the present invention has the following features.

Namely, the first embodiment of the process of the
invention for producing a semiconductor member comprises
the steps of: forming a member having a non-porous silicon
monocrystalline layer and a porous silicon layer; bonding
15 to the monocrystalline layer a member having an insulating
material surface; and removing by etching the porous
silicon layer by immersing it in hydrofluoric acid.

As explained before, the second embodiment of the process
of the invention for producing a semiconductor member uses
20 the same steps as those in the method of the first
embodiment, except that, in place of the hydrofluoric acid
used in the first embodiment, one of the second to eighth
embodiments of the etching solutions mentioned before.

The third to sixth embodiments of the process of the
25 invention for producing a semiconductor member, which also

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1 were explained before, are more practical embodiments of the
first and the second embodiments of the process of the inven-
tion. The process of the present invention for producing a
semiconductor member will be described hereinafter with
5 reference to the third to sixth embodiments.

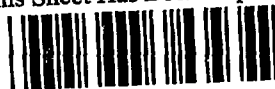
II-(1) The third embodiment of the process of the invention
for producing a semiconductor member will be described with
reference to the drawings.

10 Embodiment 1

The following will be first given of a method in which
the whole member is changed into porous structure and then
a monocrystalline layer is formed on the porous structure
by epitaxial growth method. Figs. 8A to 8C are schematic
15 sectional views of the semiconductor member illustrating
each of steps of the process.

Referring to Fig. 8A, as the first step, an Si
monocrystalline semiconductor member 11 is prepared
and is wholly changed into porous structure and, then, an
20 epitaxial growth method is applied to one surface of the
porous member, thereby forming a thin film of monocrystalline
Si layer 12. The porous structure of Si member is
formed by, for example, an anodization employing an HF
solution. The initial monocrystalline Si having the
25 density of 2.33 g/cm^3 can be changed into a porous Si member

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1 the density of which can be varied within the range between
1.1 and 0.6 g/cm³ by varying the HF concentration of the
etching solution between 50 % and 20 %.

Referring now to Fig. 8B, a light-transmissive
5 substrate 13, which is typically a glass sheet, is prepared
and bonded on the surface of the monocrystalline Si layer
12 on the porous Si member. Subsequently, an Si₃N₄ layer
14 is formed by deposition as an anti-etching film to cover
the entire member composed of the layer 12 and the
10 substrate 13 and the Si₃N₄ layer on the porous Si
member 11 is removed. Although Si₃N₄ layer is suitably
used as the anti-etching layer, it is possible to use other
materials such as Apiezon wax as the material of the anti-
etching layer. The porous Si member 11 is then immersed in
15 the etching solution of the present invention and the
solution is agitated so that only the porous Si is etched
by electroless chemical etching, whereby a thinned non-
porous monocrystalline silicon layer 12 is left on the
light-transmissive substrate 13.

20 Fig. 8C shows the semiconductor member obtained by the
present process. It will be said that, as a result of the
removal of the anti-etching Si₃N₄ layer 14 in the step
shown in Fig. 8B, a monocrystalline Si layer 12 having a
crystallinity equivalent to that of a silicon wafer is
25 formed on the light-transmissive substrate 13 with high

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1 degrees of smoothness and uniformity and with a small
thickness, over a wide area covering the whole surface of
the wafer.

The semiconductor member thus obtained is advantageous
5 from the view point of production of an insulation-isolated
electronic device.

Embodiment 2

The following will now be given of a process in which
an N-type layer is formed before changing the initial
10 member into porous structure and, subsequently to the
formation of the P-type layer, a selective anodization is
effected to change only the P-type substrate into porous
structure.

Referring to Fig. 9A, as the first step, a layer 32 of
15 a low impurity concentration is formed on the surface of a
P-type Si monocrystalline substrate 31, by an epitaxial
growth. Alternatively, an N-type monocrystalline layer 32
may be formed on the surface of the P-type Si
monocrystalline substrate 31 by ion-implantation of proton.

20 Then, as shown in Fig. 9B, the P-type Si
monocrystalline substrate 31 is changed into a porous Si
substrate 33 by effecting, on the reverse side of the P-
type Si monocrystalline substrate 31, an anodization using,
for example, an HF solution. The initial monocrystalline
25 Si having the density of 2.33 g/cm^3 can be changed into a



1 porous member the density of which can be varied within the
range between 1.1 and 0.6 g/cm³ by varying the HF
concentration of the etching solution between 50 % and 20
%.

5 Referring now to Fig. 9C, a light-transmissive
substrate 34, which is typically a glass sheet, is prepared
and bonded on the surface of the monocrystalline Si layer
32 on the porous Si member. Subsequently, an Si₃N₄ layer
35 is formed by deposition as an anti-etching film to cover
10 the entire member composed of the layer 32 and the
substrate 34 and the Si₃N₄ layer on the porous Si
member 33 is removed. Although Si₃N₄ layer is suitably
used as the anti-etching layer, it is possible to use other
materials such as Apiezon wax as the material of the anti-
15 etching layer. The porous Si substrate 33 is then immersed
in the etching solution of the present invention and the
solution is agitated so that only the porous Si is etched
by electroless chemical etching, whereby a thinned non-
porous monocrystalline silicon layer 32 is left on the
20 light-transmissive substrate 34.

Fig. 9D shows the semiconductor member obtained by the
present process. That is, as a result of the
removal of the anti-etching Si₃N₄ layer in the step
shown in Fig. 9D, a monocrystalline Si layer 32 having a
25 crystallinity equivalent to that of a silicon wafer is

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1 formed on the light-transmissive substrate 34 with high
degrees of smoothness and uniformity and with a small
thickness, over a wide area covering the whole surface of
the wafer.

5 The semiconductor member thus obtained is advantageous
from the view point of production of an insulation-isolated
electronic device.

According to the result of an observation by a
transmission electron microscope, micro-pores of an average
10 diameter of about 600 Angstrom are formed in the porous Si
layer, so that the density of the layer has been
reduced half or below that of the monocrystalline Si.

Nevertheless, the monocrystallinity is still
maintained, so that it is possible to form a
15 monocrystalline Si layer on the porous layer by epitaxial
growth. When the temperature exceeds 1000°C,
rearrangement of internal pores occurs, which impedes the
acceleration of the etching. For this reason, the
epitaxial growth of the Si layer is preferably effected by
20 a low-temperature growth method such as, for example, a
molecule-ray epitaxial growth method, a CVD method such as
plasma CVD method, low-pressure CVD method or photo-CVD
method, a bias sputter method or a liquid-phase growth
method.

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1 The fourth embodiment of the process of the invention of
producing a semiconductor member will be described with
reference to the drawings.

Embodiment 1

5 The following will be first given of a form in which
the whole P- or high-density N-type substrate is changed
into porous structure and then a monocrystalline layer is
formed on the porous structure by epitaxial growth method.
Figs. 10A to 10C are schematic sectional views of the
10 semiconductor member illustrating each of steps of the
process.

Referring to Fig. 10A, as the first step, an Si
monocrystalline semiconductor member 11 of P-type (or high-
density N-type) is prepared
15 and is wholly changed into porous structure and, then, an
epitaxial growth is effected by a suitable method on the
surface of the porous member, thereby forming a thin film
of monocrystalline Si layer 12. The porous structure is
formed by, for example, an anodization employing an HF
20 solution. The initial monocrystalline Si having the
density of 2.33 g/cm^3 can be changed into a porous member
the density of which can be varied within the range between
1.1 and 0.6 g/cm^3 by varying the HF concentration of the
etching solution between 50 % and 20 %.

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1 Referring now to Fig. 10B, another Si substrate 13 is
prepared and an insulating layer (silicon oxide layer) 14
is formed on the surface of this Si substrate 13.
Subsequently, the surface of the insulating layer 14 of the
5 Si substrate 13 is bonded to the surface of the
monocrystalline layer 12 on the porous Si substrate. The
whole structure 11-14 composed of the substrates and layers to
14 is then immersed in the etching solution of the present
invention and the solution is agitated so that only the
10 porous Si is etched by electroless wet chemical etching,
whereby a thinned non-porous monocrystalline silicon layer
12 is left on the insulating layer 14.

Fig. 10C shows the semiconductor member obtained by
the present process. That is, the
15 monocrystalline Si layer 12 having a crystallinity
equivalent to that of a silicon wafer is formed on the
insulating layer 14 on the Si substrate 13 with high degrees of
smoothness and uniformity and with a small thickness, over a
wide area covering the whole surface of the wafer.

20 The semiconductor member thus obtained is advantageous
from the view point of production of an insulation-isolated
electronic device.

Embodiment 2

The following will now be given of a process in which
25 an N-type layer is formed before changing the initial

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1 member into porous structure and, subsequently to the
formation of the N-type layer, a selective anodization is
effected to change only the P-type substrate or the high-
density N-type substrate into porous structure. Figs. 11A
5 to 11D show, in schematic sectional views, the
semiconductor member in different steps of the production
process.

Referring to Fig. 11A, as the first step, a layer 22
of a low impurity concentration is formed on the surface of
10 a P-type (or high-density N-type) Si monocrystalline
substrate 21, by an epitaxial growth performed by a
suitable method. Alternatively, an N-type monocrystalline
layer 22 may be formed on the surface of the P-type Si
monocrystalline substrate 21 by ion-implantation of proton.

15 Then, as shown in Fig. 11B, the P-type Si
monocrystalline substrate 21 is changed into a porous Si
substrate 23 by effecting, on the reverse side of the P-
type monocrystalline substrate 21, an anodization using,
for example, an HF solution. The initial monocrystalline
20 Si having the density of 2.33 g/cm^3 can be changed into a
porous member the density of which can be varied within the
range between 1.1 and 0.6 g/cm^3 by varying the HF
concentration of the etching solution between 50 % and 20
%.

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1 Referring now to Fig. 11C, another Si substrate 24 is
prepared and an insulating layer 25 (silicon oxide layer)
is formed on the surface of the Si substrate 24. Then, the
insulating layer 25 on the Si substrate 24 is bonded to the
5 surface of the monocrystalline Si layer 22 on the porous
substrate. Subsequently, the whole structure composed of
the substrates and layers 22 to 25 is immersed in the
etching solution of the present invention and the solution
is agitated so that only the porous Si is etched by
10 electroless chemical etching, whereby a thinned non-porous
monocrystalline silicon layer 22 is left on the insulating
layer 25.

Fig. 11D shows the semiconductor member obtained by
the present process. That is, a
15 monocrystalline Si layer 22 having a crystallinity
equivalent to that of a silicon wafer is formed on the
insulating layer 25 with high degrees of smoothness and
uniformity and with a small thickness, over a wide area
covering the whole surface of the wafer.

20 The semiconductor member thus obtained is advantageous
from the view point of production of an insulation-isolated
electronic device.

II-(3)

The fifth embodiment of the process of the invention will
25 be described with reference to the drawings. A description



1 will be first given of a form in which the whole Si substrate is
changed into porous structure and then a monocrystalline
layer is formed on the porous structure by epitaxial growth
method.

5 Referring to Fig. 12A, as the first step, an Si
monocrystalline substrate 11 is prepared
and is wholly changed into porous structure and, then, an
epitaxial growth is effected by a suitable method on the
surface of the porous substrate, thereby forming a thin film
10 monocrystalline layer 12. The porous structure is
formed by, for example, an anodization employing an HF
solution. The initial monocrystalline Si having the
density of 2.33 g/cm^3 can be changed into a porous Si layer
the density of which can be varied within the range between
15 1.1 and 0.6 g/cm^3 by varying the HF concentration of the
etching solution between 50 % and 20 %. The porous layer is
tended to form in a P type Si substrate. A transmission
electromicroscopic observation showed that the porous Si layer
thus formed has micropores of a mean diameter of about 600
20 Angstroms.

Referring now to Fig. 12B, a light-transmissive
substrate 13, which is typically a glass sheet, is
prepared. Then, the surface of the monocrystalline Si
layer on the porous Si substrate is oxidized to form an
25 oxide layer 14. The above-mentioned light-transmissive
substrate 13 is then bonded on the surface of the oxide

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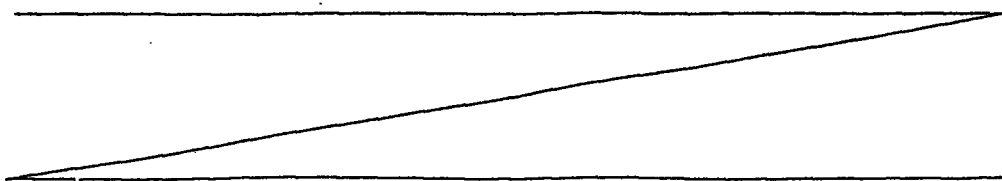


1 layer 14. This oxide layer plays an important role
formation of device. Namely, with such an oxide layer,
the interface level generated at the interface under
the Si active layer can be made lower as compared
5 with the glass interface, so that the characteristics
of the electronic device can be remarkably improved.

Referring further to Fig. 12B, and Si_3N_4 layer 15 is
deposited as an anti-etching film(protective material) to
cover the entire member composed of the two substrates
10 bonded together, and the Si_3N_4 layer on the surface of
porous Si substrate is removed. Although Si_3N_4 layer is
suitably used as the anti-etching layer, it is possible to
use other materials such as Apiezon wax as the material
of the anti-etching layer. The porous Si substrate 11
15 is then immersed in the etching solution of the present
invention with agitating so that only the porous Si is
etched by electroless chemical etching, whereby a thinned
monocrystalline silicon layer is left on the light-
transmissive substrate 13.

20 Fig. 12C shows the semiconductor member obtained by
the described process. It will be seen that, as a result
of the removal of the anti-etching Si_3N_4 layer 15 in the
step shown in Fig. 12B, a monocrystalline Si layer 12
having a crystallinity equivalent to that of a silicon

25



1 wafer is formed on the light-transmissive substrate 13 with
high degree of smoothness and uniformity and with a small
thickness, over a wide area covering the whole surface of
the wafer.

5 The semiconductor member thus obtained is advantageous
from the view point of production of an insulation-isolated
electronic device.

II-(4)

The sixth embodiment of the process of the invention for
10 producing a semiconductor member will now be described.

Embodiment 1

A description will be first given of a form in which
the whole Si substrate is changed into porous structure and
then a monocrystalline layer is formed by epitaxial
15 growth method.

Figs. 13A to 13C illustrate successive steps of the
first embodiment in accordance with the
invention.

Referring to Fig. 13A, as the first step, an Si
20 monocrystalline substrate is prepared
and is wholly changed into porous structure (11). Then, an
epitaxial growth is effected by a suitable method on the
surface of the porous substrate, thereby forming a thin
film of monocrystalline layer 12. The porous structure is
25 formed by, for example, an anodization employing an HF



1 solution. The initial monocrystalline Si having the
density of 2.33 g/cm^3 can be changed into a porous Si layer
the density of which can be varied within the range between
1.1 and 0.6 g/cm^3 by varying the HF concentration of the
5 etching solution between 50 % and 20 %. A transmission
electromicroscopic observation showed that the porous Si
layer thus formed has micropores of a mean diameter of
about 600 Angstroms.

Referring now to Fig. 13B, another Si substrate 13 is
10 prepared and an insulating material 14 is formed on the
surface. Then the Si substrate having the
insulating material 14 is bonded to the surface of an oxide
layer 15 which is formed on the monocrystalline Si layer
carried by the porous Si substrate. The insulating
15 material 14 may be a deposited silicon oxide, nitride,
nitrided oxide, or tantalum, not to mention the insulating
layer of Si. The bonding step may be conducted by adhering
closely the rinsed surfaces, and heating both substrate in an
oxygen atmosphere or a nitrogen atmosphere. The oxide layer 15
20 is formed for the purpose of reducing the interface level
of the monocrystalline layer 12 which is the final active
layer.

Then, as shown in Fig. 13C, the porous Si substrate 11
is immersed in the etching solution of the present



1 invention and the solution is agitated, so that only the
porous Si is etched by electroless wet chemical etching so
as to leave a thinned monocrystalline Si layer on the
insulating material. Fig. 13C shows the semiconductor
5 substrate obtained according to the present invention. As
a result, a monocrystalline Si layer 12 having crystallinity
equivalent to that of a silicon wafer is formed on the
insulated substrate 13 through the intermediary of the
insulating material 14 and the oxide layer 15, with high
10 degrees of smoothness and uniformity and with a small
thickness over a wide area covering the whole surface of
the wafer.

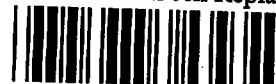
The semiconductor member thus obtained is advantageous
from the view point of production of an insulation-isolated
15 electronic device.

Embodiment 2

A second embodiment will be described with reference
to the drawings.

Figs. 14A to 14D show, in schematic sectional views,
20 the second embodiment according to the present invention.

Referring to Fig. 14A, as the first step, a layer 32
of a low impurity concentration is formed on the surface of
a P-type Si monocrystalline substrate 31, by an epitaxial
growth performed by a suitable method. Alternatively, an
25 N-type monocrystalline layer 32 may be formed on the
surface of the P-type Si monocrystalline substrate 21 by
implantation of proton.



1 Then, as shown in Fig. 14B, the P-type Si
monocrystalline substrate 31 is changed into a porous Si
substrate 33 by effecting, on the reverse side of the P-
type Si monocrystalline substrate 31 by anodization using,
5 for example, an HF solution. The initial monocrystalline
Si having the density of 2.33 g/cm^3 can be changed into a
porous member the density of which can be varied within the
range between 1.1 and 0.6 g/cm^3 by varying the HF
concentration of the etching solution between 50 % and 20
10 %. As explained before, this porous layer is formed in the
P-type substrate.

Referring now to Fig. 14C, another Si substrate 34 is
prepared and an insulating layer 35 is formed on the
surface of the Si substrate 34. Then, the Si
15 substrate 34 having the insulating layer 35 is bonded to
the surface of the oxide layer 36 formed on the monocrystalline
Si layer on the porous Si substrate. Then, the porous
Si substrate is immersed in the etching solution of the
present invention and the solution is agitated so that only
20 the porous Si is etched by electroless chemical etching,
whereby a thinned non-porous monocrystalline silicon layer
is left on the insulating layer.

Fig. 14D shows the semiconductor substrate obtained by
the described process. It will be seen that a
25 monocrystalline Si layer 32 having a crystallinity



1 equivalent to that of a silicon wafer is formed on the
insulated substrate 34 through the intermediary of the
oxide layer 36 and the insulation layer 35, with high
degrees of smoothness and uniformity and with a small
5 thickness, over a wide area covering the whole surface of
the wafer.

The semiconductor member thus obtained is advantageous
from the view point of production of an insulation-isolated
electronic device.

10 The processes described above are the type in
which the N-type layer is formed prior to changing into
porous structure and then only the P-type substrate
is selectively changed into porous structure by anodization.

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1 III. The present invention will be described below in
detail by way of examples. However, the invention is not
limited to these examples except as defined in the appended
claims.

5 Example 1

A porous Si layer 21 was formed to a thickness of 50 μm
($t_2 = 50 \mu\text{m}$) on the entirety of one of the major surfaces of
a monocrystalline Si substrate 22 by anodization (Fig. 1A).

10 Anodization was performed under the following
conditions:

Applied voltage:	2.6 (V)
Current density:	30 ($\text{mA}\cdot\text{cm}^{-2}$)
Anodizing solution:	$\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1:1:1$
15 Time:	0.4 (hour)
Thickness of porous Si:	50 (μm)
Porosity:	56 (%)

20 Thereafter, the porous Si/monocrystalline Si substrate
was subjected to selective etching using a 49% HF solution.
In thirty-three minutes, the porous Si was selectively
etched with the monocrystalline Si acting as an etch
stopper, only the monocrystalline Si being left behind, as
shown in Fig. 1B.

25 Example 2

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1 Prior to anodization, boron ions were implanted in one
 of the surfaces of a monocrystalline Si substrate 32 at an
 average concentration of $1.0 \times 10^{19} \text{ cm}^{-3}$ in stripes spaced
 apart from each other by a distance of $100 \mu\text{m}$. As shown in
 5 Fig. 2A, porous Si 31 was formed by anodization in stripes
 spaced apart from each other by a distance ($b_3 = 100 \mu\text{m}$) of
 $100 \mu\text{m}$, each stripe having a width ($a_3 = 100 \mu\text{m}$) of $100 \mu\text{m}$ and
 a thickness ($t_3 = 1 \mu\text{m}$) of $1 \mu\text{m}$.

Anodization was performed under the following
 10 conditions:

Applied voltage:	2.6 (V)
Current density:	30 ($\text{mA} \cdot \text{cm}^{-2}$)
Anodizing solution:	$\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1:1:1$
15 Thickness of porous Si:	1 (μm)
Porosity:	56 (%)

Thereafter, the porous Si/monocrystalline Si substrate
 20 was subjected to selective etching using a 49% HF solution.
 In two minutes, the porous Si was selectively etched, only
 the monocrystalline Si being left behind, as shown in Fig.
 2B.

Example 3

25 A $3 \mu\text{m}$ ($u_4 = 3 \mu\text{m}$) thick polycrystalline Si layer 41 was

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1 formed on a monocrystalline Si substrate 42 by CVD (Fig.
3A). As shown in Fig. 3B, a surface layer of 2 μm ($t_4 = 2$
3 μm) of the polycrystalline Si layer 41 was made porous by
anodization to form a porous Si layer 43.

5 Anodization was performed under the following
conditions:

	Applied voltage:	2.6 (V)
	Current density:	30 ($\text{mA}\cdot\text{cm}^{-2}$)
10	Anodizing solution:	$\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1:1:1$
	Thickness of porous Si:	2 (μm)
	Porosity:	56 (%)

15 Thereafter, the porous Si/polycrystalline
Si/monocrystalline Si substrate was subjected to selective
etching using a 49% HF solution. In four minutes, the
porous Si was selectively etched with the polycrystalline
Si acting as an etch stopper, only the polycrystalline Si
20 and monocrystalline Si being left behind, as shown in Fig.
3C.

Example 4

A 3 μm ($u_5 = 3 \mu\text{m}$) thick polycrystalline Si layer 51 was
formed on a monocrystalline Si substrate 52 by CVD. Prior
25 to anodization, boron ions were implanted into the surface

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1 of the polycrystalline Si layer 51 at $1.0 \times 10^{19} \text{ cm}^{-3}$ in
 stripes spaced apart from each other by a distance of $20 \text{ }\mu\text{m}$.
 As shown in Fig. 4A, porous Si 53 was formed by anodization
 in stripes spaced apart from each other by a distance ($b_5 =$
 5 $20 \text{ }\mu\text{m}$) of $20 \text{ }\mu\text{m}$, each stripe having a width ($a_5 = 20 \text{ }\mu\text{m}$) of
 $20 \text{ }\mu\text{m}$ and a thickness ($t_5 = 1 \text{ }\mu\text{m}$) of $1 \text{ }\mu\text{m}$.

Anodization was performed under the following
 conditions:

10	Applied voltage:	2.6 (V)
	Current density:	30 ($\text{mA} \cdot \text{cm}^{-2}$)
	Anodizing solution:	HF:H ₂ O:C ₂ H ₅ OH = 1:1:1
	Thickness of porous Si:	1 (μm)
	Porosity:	56 (%)

15

Thereafter, the porous Si/polycrystalline
 Si/monocrystalline Si substrate was subjected to selective
 etching using a 49% HF solution. In two minutes, the porous
 20 Si was selectively etched, only the polycrystalline Si and
 monocrystalline Si being left behind, as shown in Fig. 4B.

Example 5

A porous Si layer 61 was formed to a thickness of $50 \text{ }\mu\text{m}$
 ($t_6 = 50 \text{ }\mu\text{m}$) on the entirety of one of the major surfaces of
 25 a monocrystalline Si substrate 62 by anodization (Fig. 5A).



1 Anodization was performed under the following
conditions:

Applied voltage:	2.6 (V)
5 Current density:	30 ($\text{mA}\cdot\text{cm}^{-2}$)
Anodizing solution:	$\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1:1:1$
Time:	0.4 (hour)
Thickness of porous Si:	50 (μm)
Porosity:	56 (%)

10 As shown in Fig. 5B, a resist 63 was patterned in
stripes spaced apart from each other by a distance ($b_6 = 100$
 μm) of $100 \mu\text{m}$, each stripe having a width ($a_6 = 100 \mu\text{m}$) of
 $100 \mu\text{m}$.

15 Thereafter, the porous Si/monocrystalline Si substrate
was subjected to selective etching using a 49% HF solution.
In thirty-three minutes, the porous Si was selectively
removed, only the monocrystalline Si being left behind, as
shown in Fig. 5C. Finally, the resist was removed (Fig.
20 5D).

Example 6

Etching was performed in the same manner as that of
Example 1 with the exception that a mixture solution (10:1)
of 49% hydrofluoric acid and ethyl alcohol was used as an
25 etchant. In twenty-nine minutes after initialization of

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1 etching, the porous Si was selectively removed with the
monocrystalline Si acting as an etch stopper.

Example 7

Etching was performed in the same manner as that of
5 Example 2 with the exception that a mixture solution (10:1)
of 49% hydrofluoric acid and ethyl alcohol was used as an
etchant. In one point seven minutes after initialization of
etching, the porous Si was selectively removed, only the
monocrystalline Si being left behind.

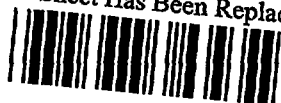
10 Example 8

Etching was performed in the same manner as that of
Example 3 with the exception that a mixture solution (10:1)
of 49% hydrofluoric acid and ethyl alcohol was used as an
etchant. In three point four minutes after initialization
15 of etching, the porous Si was selectively removed with the
polycrystalline Si acting as an etch stopper, only the
polycrystalline Si and the monocrystalline Si being left
behind, as shown in Fig. 3C.

Example 9

20 Etching was performed in the same manner as that of
Example 4 with the exception that a mixture solution (10:1)
of 49% hydrofluoric acid and ethyl alcohol was used as an
etchant. In one point seven minutes after initialization of
etching, the porous Si was selectively removed, only the
25 polycrystalline Si and monocrystalline Si being left behind,

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1 as shown in Fig. 4B.

Example 10

Etching was performed in the same manner as that of
Example 5 with the exception that a mixture solution (10:1)
5 of 49% hydrofluoric acid and ethyl alcohol was used as an
etchant. In twenty-nine minutes after initialization of
etching, the porous Si was selectively removed, only the
monocrystalline Si being left behind, as shown in Fig. 5C.
Finally, the resist was removed (Fig. 5D).

10 Example 11

Etching was performed in the same manner as that of
Example 1 with the exception that a mixture solution (1:5)
of 49% hydrofluoric acid and hydrogen peroxide was used as
an etchant. In twenty-one minutes after initialization of
15 etching, the porous Si was selectively removed with the
monocrystalline Si acting as an etch stopper, only the mono-
crystalline Si being left behind, as shown in Fig. 1B.

Example 12

Etching was performed in the same manner as that of
20 Example 2 with the exception that a mixture solution (1:5)
of 49% hydrofluoric acid and hydrogen peroxide was used as
an etchant. In one point three minutes after initialization
of etching, the porous Si was selectively removed, only the
monocrystalline Si being left behind, as shown in Fig. 2B.

25 Example 13

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1 Etching was performed in the same manner as that of
Example 3 with the exception that a mixture solution (1:5)
of 49% hydrofluoric acid and hydrogen peroxide was used as
an etchant. In two point six minutes after initialization
5 of etching, the porous Si was selectively removed with the
polycrystalline Si acting as an etch stopper, only the
polycrystalline Si and the monocrystalline Si being left
behind, as shown in Fig. 3C.

Example 14

10 Etching was performed in the same manner as that of
Example 4 with the exception that a mixture solution (1:5)
of 49% hydrofluoric acid and hydrogen peroxide was used as
an etchant. In one point three minutes after initialization
of etching, only the porous Si was selectively removed, only
15 the polycrystalline Si and monocrystalline Si being left
behind, as shown in Fig. 4B.

Example 15

Etching was performed in the same manner as that of
Example 5 with the exception that a mixture solution (1:5)
20 of 49% hydrofluoric acid and hydrogen peroxide was used as
an etchant. In this etching, only the porous Si was
selectively removed, leaving the monocrystalline Si behind,
as shown in Fig. 5C. Finally, the resist was removed (Fig.
5D).

25 Example 16

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1 Etching was performed in the same manner as that of
Example 1 with the exception that a mixture solution
(10:6:50) of 49% hydrofluoric acid, ethyl alcohol and
hydrogen peroxide was used as an etchant. In twenty-six
5 minutes after initialization of etching, the porous Si was
selectively removed with the remaining monocrystalline Si
acting as an etch stopper, as shown in Fig. 1B.

Example 17

Etching was performed in the same manner as that of
10 Example 2 with the exception that a mixture solution
(10:6:50) of 49% hydrofluoric acid, ethyl alcohol and
hydrogen peroxide was used as an etchant. In one point four
minutes after initialization of etching, the porous Si was
selectively removed, only the monocrystalline Si being left
15 behind, as shown in Fig. 2B.

Example 18

Etching was performed in the same manner as that of
Example 3 with the exception that a mixture solution
(10:6:50) of 49% hydrofluoric acid, ethyl alcohol and
20 hydrogen peroxide was used as an etchant. In two point
eight minutes after initialization of etching, the porous Si
was selectively removed with the polycrystalline Si acting
as an etch stopper, only the polycrystalline Si and the
monocrystalline Si being left behind, as shown in Fig. 3C.

25 Example 19



1 Etching was performed in the same manner as that of
Example 4 with the exception that a mixture solution
(10:6:50) of 49% hydrofluoric acid, ethyl alcohol and
hydrogen peroxide was used as an etchant. In one point four
5 minutes after initialization of etching, the porous Si was
selectively removed, only the polycrystalline Si and
monocrystalline Si being left behind, as shown in Fig. 4B.

Example 20

Etching was performed in the same manner as that of
10 Example 5 with the exception that a mixture solution
(10:6:50) of 49% hydrofluoric acid, ethyl alcohol and
hydrogen peroxide was used as an etchant. In twenty-eight
minutes after initialization of etching, the porous Si was
selectively removed, only the monocrystalline Si being left
15 behind, as shown in Fig. 5C. Finally, the resist was
removed (Fig. 5D).

Example 21

Etching was performed in the same manner as that of
Example 1 with the exception that a buffered hydrofluoric
20 acid (NH_4F : 36.2%, HF : 4.5%) was used as an etchant. In
nineteen minutes after initialization of etching, the porous
Si was selectively removed with the monocrystalline Si
acting as an etch stopper, as shown in Fig. 1B.

Example 22

25 Etching was performed in the same manner as that of

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1 Example 2 with the exception that a buffered hydrofluoric
acid (NH_4F : 36.2%, HF : 4.5%) was used as an etchant. In
seven seconds after initialization of etching, only the
porous Si was selectively removed, leaving the
5 monocrystalline Si behind, as shown in Fig. 2B.

Example 23

Etching was performed in the same manner as that of
Example 3 with the exception that a buffered hydrofluoric
acid (NH_4F : 36.2%, HF : 4.5%) was used as an etchant. In
10 fourteen seconds after initialization of etching, the porous
Si was selectively removed with the polycrystalline Si
acting as an etch stopper, only the polycrystalline Si and
the monocrystalline Si being left behind, as shown in Fig.
3C.

15 Example 24

Etching was performed in the same manner as that of
Example 4 with the exception that a buffered hydrofluoric
acid (NH_4F : 36.2%, HF : 4.5%) was used as an etchant. In
seven seconds after initialization of etching, only the
20 porous Si was selectively removed, leaving the
polycrystalline Si and monocrystalline Si behind, as shown
in Fig. 4B.

Example 25

Etching was performed in the same manner as that of
25 Example 5 with the exception that a buffered hydrofluoric

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1 acid (NH_4F : 36.2%, HF : 4.5%) was used as an etchant. In
nineteen minutes after initialization of etching, the porous
Si was selectively removed, only the monocrystalline Si
being left behind, as shown in Fig. 5C. Finally, the resist
5 was removed (Fig. 5D).

Example 26

Etching was performed in the same manner as that of
Example 1 with the exception that a mixture solution (10:1)
of buffered hydrofluoric acid and ethyl alcohol was used as
10 an etchant. In twenty-one minutes after initialization of
etching, the porous Si was selectively removed with the
monocrystalline Si acting as an etch stopper, only the
monocrystalline Si being left behind, as shown in Fig. 1B.

Example 27

15 Etching was performed in the same manner as that of
Example 2 with the exception that a mixture solution (10:1)
of buffered hydrofluoric acid and ethyl alcohol was used as
an etchant. In seven seconds after initialization of
etching, only the porous Si was selectively removed, leaving
20 the monocrystalline Si behind, as shown in Fig. 2B.

Example 28

Etching was performed in the same manner as that of
Example 3 with the exception that a mixture solution (10:1)
of buffered hydrofluoric acid and ethyl alcohol was used as
25 an etchant. In fourteen seconds after initialization of



1 etching, the porous Si was selectively removed with the
polycrystalline Si acting as an etch stopper, only the
polycrystalline Si and the monocrystalline Si being left
behind, as shown in Fig. 3C.

5 Example 29

Etching was performed in the same manner as that of
Example 4 with the exception that a mixture solution (10:1)
of buffered hydrofluoric acid and ethyl alcohol was used as
an etchant. In seven seconds after initialization of
10 etching, only the porous Si was selectively removed, leaving
the polycrystalline Si and monocrystalline Si behind, as
shown in Fig. 4B.

Example 30

Etching was performed in the same manner as that of
15 Example 5 with the exception that a mixture solution (10:1)
of buffered hydrofluoric acid and ethyl alcohol was used as
an etchant. In twenty-one minutes after initialization of
etching, the porous Si was selectively removed, only the
monocrystalline Si being left behind, as shown in Fig. 5C.
20 Finally, the resist was removed (Fig. 5D).

Example 31

Etching was performed in the same manner as that of
Example 1 with the exception that a mixture solution (1:5)
of buffered hydrofluoric acid and hydrogen peroxide was used
25 as an etchant. In nine minutes after initialization of



1 etching, the porous Si was selectively removed with the
monocrystalline Si acting as an etch stopper, only the mono-
crystalline Si being left behind, as shown in Fig. 1B.

Example 32

5 Etching was performed in the same manner as that of
Example 2 with the exception that a mixture solution (1:5)
of buffered hydrofluoric acid and hydrogen peroxide was used
as an etchant. In five seconds after initialization of
etching, only the porous Si was selectively removed, leaving
10 the monocrystalline Si behind, as shown in Fig. 2B.

Example 33

Etching was performed in the same manner as that of
Example 3 with the exception that a mixture solution (1:5)
of buffered hydrofluoric acid and hydrogen peroxide was used
15 as an etchant. In ten seconds after initialization of
etching, the porous Si was selectively removed with the
polycrystalline Si acting as an etch stopper, only the
polycrystalline Si and the monocrystalline Si being left
behind, as shown in Fig. 3C.

20 Example 34

Etching was performed in the same manner as that of
Example 4 with the exception that a mixture solution (1:5)
of buffered hydrofluoric acid and hydrogen peroxide was used
as an etchant. In five seconds after initialization of
25 etching, only the porous Si was selectively removed, leaving



1 the polycrystalline Si and monocrystalline Si behind, as
shown in Fig. 4B.

Example 35

Etching was performed in the same manner as that of
5 Example 5 with the exception that a mixture solution (1:5)
of buffered hydrofluoric acid and hydrogen peroxide was used
as an etchant. In nine minutes, the porous Si was
selectively removed, only the monocrystalline Si being left
behind, as shown in Fig. 5C. Finally, the resist was
10 removed (Fig. 5D).

Example 36

Etching was performed in the same manner as that of
Example 1 with the exception that a mixture solution
(10:6:50) of buffered hydrofluoric acid (NH_4F : 36.2%, HF :
15 4.5%), ethyl alcohol and hydrogen peroxide was used as an
etchant. In ten minutes after initialization of etching,
the porous Si was selectively removed with the
monocrystalline Si acting as an etch stopper, only the mono-
crystalline Si being left, as shown in Fig. 1B.

20 Example 37

Etching was performed in the same manner as that of
Example 2 with the exception that a mixture solution
(10:6:50) of buffered hydrofluoric acid (NH_4F : 36.2%, HF :
4.5%), ethyl alcohol and hydrogen peroxide was used as an
25 etchant. In six seconds after initialization of etching,

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1 only the porous Si was selectively removed, leaving the
monocrystalline Si behind, as shown in Fig. 2B.

Example 38

Etching was performed in the same manner as that of
5 Example 3 with the exception that a mixture solution
(10:6:50) of buffered hydrofluoric acid (NH_4F : 36.2%, HF :
4.5%), ethyl alcohol and hydrogen peroxide was used as an
etchant. In twelve seconds after initialization of etching,
the porous Si was selectively removed with the
10 polycrystalline Si acting as an etch stopper, only the
polycrystalline Si and the monocrystalline Si being left
behind, as shown in Fig. 3C.

Example 39

Etching was performed in the same manner as that of
15 Example 4 with the exception that a mixture solution
(10:6:50) of buffered hydrofluoric acid (NH_4F : 36.2%, HF :
4.5%), ethyl alcohol and hydrogen peroxide was used as an
etchant. In six seconds after initialization of etching,
only the porous Si was selectively removed, leaving the
20 polycrystalline Si and monocrystalline Si behind, as shown
in Fig. 4B.

Example 40

Etching was performed in the same manner as that of
Example 5 with the exception that a mixture solution
25 (10:6:50) of buffered hydrofluoric acid (NH_4F : 36.2%, HF :

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- 1 4.5%), ethyl alcohol and hydrogen peroxide was used as an etchant. In ten minutes after initialization of etching, the porous Si was selectively removed, only the monocrystalline Si being left behind, as shown in Fig. 5C.
- 5 Finally, the resist was removed (Fig. 5D).

Example 41

Anodization was conducted on a P-type (100) monocrystalline Si substrate having a thickness of 200 μm in a 50% HF solution at a current density of 100 mA/cm^2 . The porous structure formation rate was 8.4 $\mu\text{m}/\text{min}$ and hence it took twenty four minutes for the 200 μm -thick P-type (100) Si substrate to be made entirely porous.

A Si epitaxial layer with a thickness of 0.5 μm was grown on the P-type (100) porous Si substrate at a low temperature by molecular beam epitaxy (MBE). Deposition was conducted under the following conditions:

Temperature:	700°C
Pressure:	1×10^{-9} Torr
Growth rate:	0.1 nm/sec.

Next, an optically polished fused silica glass substrate was placed on the surface of the epitaxial layer. The whole structure was then heated at 800°C in an oxygen atmosphere for 0.5 hours to firmly join the two substrates

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1 to each other.

Si₃N₄ was deposited to a thickness of 0.1 μm by plasma CVD method to cover the bonded substrates, and then only the nitride film on the porous substrate was removed by reactive
5 ion etching. Thereafter, selective etching was conducted on the bonded substrates in a 49% hydrofluoric acid solution while the solution was being stirred. In seventy eight minutes, the porous Si substrate was completely etched with the monocrystalline Si layer acting as an etch stopper, only
10 the monocrystalline Si layer being left behind.

The etching rate of the non-porous monocrystalline Si was so low that only a maximum of 50 Å of non-porous monocrystalline Si was removed in seventy eight minutes. Since the ratio of the etching rate of the non-porous
15 monocrystalline Si to that of the porous layer is 1 : 10⁵ or more, the amount of non-porous layer which is etched (several tens angstroms) can be ignored in a practical operation. That is, the 200 μm-thick porous Si substrate was removed, and subsequently the Si₃N₄ layer was removed with a result that
20 the 0.5 μm-thick monocrystalline Si layer formed on the glass substrate remained.

The cross-section of the monocrystalline Si layer was observed with a transmission type electron microscope. It was found that no crystal defect was newly introduced in the
25 Si layer and hence the Si layer had excellent crystalline

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1 structure.

Example 42

Anodization was conducted on a P type (100) monocrystalline Si substrate having a thickness of 200 μm in
5 a 50% HF solution at a current density of 100 mA/cm^2 . The porous structure formation rate was 8.4 $\mu\text{m}/\text{min}$ and hence it took twenty four minutes for the 200 μm -thick P type (100) Si substrate to be made entirely porous. A Si epitaxial layer with a thickness of 5.0 μm was grown on the P type
10 (100) porous Si substrate at a low temperature by plasma CVD. Deposition was conducted under the following conditions:

	Gas:	SiH_4
15	High-frequency power:	100 W
	Temperature:	800°C
	Pressure:	1×10^{-2} Torr
	Growth rate:	2.5 nm/sec.

20 Next, an optically polished glass substrate having a softening point of about 500 °C was placed on the surface of the epitaxial layer. The whole structure was heated at 450°C in an oxygen atmosphere for 0.5 hours to firmly join the two substrates to each other.

25 Si_3N_4 was deposited to a thickness of 0.1 μm by plasma

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1 CVD to cover the two bonded substrates, and then only the
nitride film on the porous substrate was removed by reactive
ion etching.

Thereafter, selective etching was conducted on the
5 bonded substrates in a 49% hydrofluoric acid solution while
the solution was being stirred. In seventy eight minutes,
the porous Si substrate was completely etched with the
monocrystalline Si layer acting as an etch stopper, only the
monocrystalline Si layer being left behind.

10 The etching rate of the non-porous monocrystalline Si
was so low that only a maximum of 50 Å of non-porous
monocrystalline Si was removed in seventy eight minutes.
Since the ratio of the etching rate of the non-porous
monocrystalline Si to that of the porous layer is $1 : 10^5$ or
15 more, the amount of non-porous layer which is etched (several
tens angstroms) can be ignored in a practical operation. That
is, the 200 µm-thick porous Si substrate was removed, and
subsequently the Si₃N₄ layer was removed with a result that
the 5.0 µm-thick monocrystalline Si layer formed on the
20 glass substrate having a low softening point remained.

Example 43

Anodization was conducted on a P type (100)
monocrystalline Si substrate having a thickness of 200 µm in
a 50% HF solution at a current density of 100 mA/cm². The
25 porous structure formation rate was 8.4 µm/min and hence it

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1 took twenty four minutes for the 200 μm -thick P type (100)
Si substrate to be made entirely porous. A Si epitaxial
layer with a thickness of 1.0 μm was grown on the P type
(100) porous Si substrate at a low temperature by bias
5 sputtering. Deposition was conducted under the following
conditions:

	RF frequency:	100 MHz
	High-frequency power:	600 W
10	Temperature:	300°C
	Ar gas pressure:	8×10^{-3} Torr
	Growth rate:	120 minutes
	Target d.c. bias:	-200 V
	Substrate d.c. bias:	+5 V

15

Next, an optically polished glass substrate having a
softening point of about 500 °C was placed on the surface of
the epitaxial layer. The whole structure was heated at
450°C in an oxygen atmosphere for 0.5 hours to firmly join
20 the two substrates to each other.

Si_3N_4 was deposited to a thickness of 0.1 μm by plasma
CVD to cover the two bonded substrates, and then only the
nitride film on the porous substrate was removed by reactive
ion etching.

25

Thereafter, selective etching was conducted on the
bonded substrates in a 49% hydrofluoric acid solution while
the solution was being stirred. In seventy eight minutes,



1 the porous Si substrate was completely etched with the
monocrystalline Si layer acting as an etch stopper, only the
monocrystalline Si layer being left behind.

The etching rate of the non-porous monocrystalline Si
5 was so low that only a maximum of 50 Å of non-porous
monocrystalline Si was removed in seventy eight minutes.
Since the ratio of the etching rate of the non-porous
monocrystalline Si to that of the porous layer is 1 : 10⁵ or
more, the amount of non-porous layer which is etched (several
10 tens angstroms) can be ignored in a practical operation. That
is, the 200 µm-thick porous Si substrate was removed, and
subsequently the Si₃N₄ layer was removed with a result that
the 1.0 µm-thick monocrystalline Si layer on the glass
substrate having a low softening point remained.

15 In case of coating of Apixen Wax or Electron Wax in
place of the Si₃N₄ layer, the same effect was obtained and
only the Si substrate made porous was completely removed.

Example 44

Anodization was conducted on a N type (100)
20 monocrystalline Si substrate having a thickness of 200 µm in
a 50% HF solution at a current density of 100 mA/cm². The
porous structure formation rate was 8.4 µm/min and hence it
took twenty four minutes for the 200 µm-thick N type (100)
Si substrate to be made entirely porous. A Si epitaxial
25 layer with a thickness of 10 µm was grown on the N type
(100) porous Si substrate at a low temperature by liquid



1 phase growth method under the following conditions:

	Solvent:	Sn, Solute:	Si
	Growth temperature:	900°C	
5	Growth atmosphere:	H ₂	
	Growth time:	20 minutes	

Next, an optically polished glass substrate having a softening point of about 800 °C was placed on the surface of the epitaxial layer. The whole structure was heated at 750°C in an oxygen atmosphere for 0.5 hours to firmly join the two substrates to each other.

Si₃N₄ was deposited to a thickness of 0.1 μm by plasma CVD to cover the two bonded substrates, and then only the nitride film on the porous substrate was removed by reactive ion etching.

Thereafter, selective etching was conducted on the bonded substrates in a 49% hydrofluoric acid solution while the solution was being stirred. In seventy eight minutes, the porous Si substrate was completely etched with the monocrystalline Si layer acting as an etch stopper, only the monocrystalline Si layer being left behind.

The etching rate of the non-porous monocrystalline Si was so low that only a maximum of 50 Å of non-porous monocrystalline Si was removed in seventy eight minutes.

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1 Since the ratio of the etching rate of the non-porous
monocrystalline Si to that of the porous layer is $1 : 10^5$ or
more, the amount of non-porous layer which is etched (several
tens angstroms) can be ignored in a practical operation. That
5 is, the 200 μm -thick porous Si substrate was removed, and
subsequently the Si_3N_4 layer was removed with a result that
the 10 μm -thick monocrystalline Si layer on the glass
substrate remained.

Coating of Apiezon Wax in place of the Si_3N_4 layer was
10 also effective and assured complete removal of only the
porous Si substrate.

Example 45

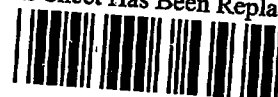
Anodization was conducted on a P type (100)
monocrystalline Si substrate having a thickness of 200 μm in
15 a 50% HF solution at a current density of 100 mA/cm^2 .

The porous structure formation rate was $8.4 \mu\text{m/min}$ and
hence it took twenty four minutes for the 200 μm -thick P
type (100) Si substrate to be made entirely porous. A Si
epitaxial layer with a thickness of 1.0 μm was grown on the
20 P type (100) porous Si substrate at a low temperature by
low-pressure CVD. Deposition was conducted under the
following conditions:

Source gas: SiH_4 800 SCCM

25 Carrier gas: H_2 150 liter/min

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1 Temperature: 850°C
 Pressure: 1 x 10⁻² Torr
 Growth rate: 3.3 nm/sec

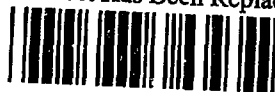
5 Next, an optically polished fused silica glass
substrate was placed on the surface of the epitaxial layer.
The whole structure was heated at 800°C in an oxygen
atmosphere for 0.5 hours to firmly join the two substrates
to each other.

10 Si₃N₄ was deposited to a thickness of 0.1 μm by plasma
CVD to cover the two bonded substrates, and then only the
nitride film on the porous substrate was removed by reactive
ion etching.

 Thereafter, selective etching was conducted on the
15 bonded substrates in a 49% hydrofluoric acid solution while
the solution was being stirred. In seventy eight minutes,
the porous Si substrate was completely etched with the
monocrystalline Si layer acting as an etch stopper, the
monocrystalline Si layer being left behind.

20 The etching rate of the non-porous monocrystalline Si
was so low that only a maximum of 50 Å of non-porous
monocrystalline Si was removed in seventy eight minutes.
Since the ratio of the etching rate of the non-porous
monocrystalline Si to that of the porous layer is 1 : 10⁵ or
25 more, the amount of non-porous layer which is etched (several

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1 tens angstroms) can be ignored in a practical operation. That
is, the 200 μm -thick porous Si substrate was removed, and
subsequently the Si_3N_4 layer was removed with a result that
the 1.0- μm -thick monocrystalline Si layer on the silica
5 glass substrate remained.

When SiH_2Cl_2 was used as the source gas, the growth
temperature had to be higher by several tens of degrees.
However, high-speed etching characteristics to the porous
substrate did not deteriorate.

10 Example 46

A Si epitaxial layer with a thickness of 1.0 μm was
grown on a P type (100) Si substrate having a thickness of
200 μm by CVD. Deposition was conducted under the following
conditions:

15 Reactive gas flow rate: SiH_4 1000 SCCM
 H_2 230 liter/min.
 Temperature: 1080°C
 Pressure: 760 Torr
20 Time: 2 min

" Anodization was conducted on the substrate in a 50% HF
solution at a current density of 100 mA/cm^2 . The porous
structure formation rate was 8.4 $\mu\text{m}/\text{min}$ and hence it took
25 twenty four minutes for the 200 μm -thick P type (100) Si

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1 substrate to be made entirely porous. At that time, there
was no change in the Si epitaxial layer.

Next, an optically polished fused silica glass
substrate was placed on the surface of the epitaxial layer.
5 The whole structure was heated at 800°C in an oxygen
atmosphere for 0.5 hours to firmly join the two substrates
to each other.

Si_3N_4 was deposited to a thickness of 0.1 μm by plasma
CVD to cover the two bonded substrates, and then only the
10 nitride film on the porous substrate was removed by reactive
ion etching.

Thereafter, selective etching was conducted on the
bonded substrates in a 49% hydrofluoric acid solution while
the solution was being stirred. In seventy eight minutes,
15 the porous Si substrate was completely removed with the
monocrystalline Si layer acting as an etch stopper, only the
monocrystalline Si layer being left behind.

The etching rate of the non-porous monocrystalline Si
was so low that only a maximum of 50 Å of non-porous
20 monocrystalline Si was removed in seventy eight minutes.
Since the ratio of the etching rate of the non-porous
monocrystalline Si to that of the porous layer is 1 : 10^5 ,
the amount of non-porous layer which is etched (several tens
angstroms) can be ignored in a practical operation. That
25 is, the 200 μm -thick porous Si substrate was removed, and



1 subsequently the Si_3N_4 layer was removed with a result that
the 1.0 μm monocrystalline Si layer on the silica glass
substrate remained.

5 The cross-section of the monocrystalline Si layer was
observed with a transmission type electron microscope. It
was found that no crystal defect was newly introduced in the
Si layer and hence the Si layer had excellent crystalline
structure.

Example 47

10 A Si epitaxial layer with a thickness of 0.5 μm was
grown on a P type (100) Si substrate having a thickness of
200 μm by CVD. Deposition was conducted under the following
conditions:

15 Reactive gas flow rate: SiH_2Cl_2 1000 SCCM

H_2 230 liter/min

Temperature: 1080°C

Pressure: 80 Torr

Time: 1 min

20 Anodization was conducted on the substrate in a 50% HF
solution at a current density of 100 mA/cm^2 . The porous
structure formation rate was 8.4 $\mu\text{m}/\text{min}$ and hence it took
twenty four minutes for the 200 μm -thick P type (100) Si
25 substrate to be made entirely porous. As mentioned above,



1 anodization made only the P type (100) Si substrate porous,
and there was no change in the Si epitaxial layer.

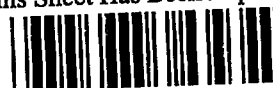
Next, an optically polished fused silica glass
substrate was placed on the surface of the epitaxial layer.
5 The whole structure was heated at 800°C in an oxygen
atmosphere for 0.5 hours to firmly join the two substrates
to each other.

Si_3N_4 was deposited to a thickness of 0.1 μm by plasma
CVD to cover the two bonded substrates, and then only the
10 nitride film on the porous substrate was removed by reactive
ion etching.

Thereafter, selective etching was conducted on the
bonded substrates in a 49% hydrofluoric acid solution while
the solution was being stirred. In seventy eight minutes,
15 the porous Si substrate was completely etched with the
monocrystalline Si layer acting as an etch stopper, only the
monocrystalline Si layer being left behind.

The etching rate of the non-porous monocrystalline Si
was so low that only a maximum of 50 Å of non-porous
20 monocrystalline Si was removed in seventy eight minutes.
Since the ratio of the etching rate of the non-porous
monocrystalline Si to that of the porous layer is 1 : 10^5 ,
the amount of non-porous layer which is etched (several tens
angstroms) can be ignored in a practical operation. That
25 is, the 200 μm -thick porous Si substrate was removed, and

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1 subsequently the Si_3N_4 layer was removed with a result that
the 0.5 μm -thick monocrystalline Si layer on the silica
glass substrate remained.

5 The cross-section of the monocrystalline Si layer was
observed by a transmission type electron microscope. It
was found that no crystal defect was newly introduced in the
Si layer and hence the Si layer had excellent crystalline
structure.

Example 48

10 A N type Si layer with a thickness of 1 μm was formed
on a P type (100) Si substrate having a thickness of 200 μm
by proton implantation. Implantation rate of H^+ was $5 \times$
 10^{15} (ions/ cm^2).

15 Anodization was conducted on the substrate in a 50% HF
solution at a current density of 100 mA/cm^2 . The porous
structure formation rate was 8.4 $\mu\text{m}/\text{min}$ and hence it took
twenty four minutes for the 200 μm -thick P type (100) Si
substrate to be made entirely porous. As mentioned above,
anodization made only the P type (100) Si substrate porous,
20 and there was no change in the N type Si layer.

Next, an optically polished fused silica glass
substrate was placed on the surface of the N type Si layer.
The whole structure was heated at 800°C in an oxygen
atmosphere for 0.5 hours to firmly join the two substrates
25 to each other.

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1 Si_3N_4 was deposited to a thickness of $0.1\text{ }\mu\text{m}$ by plasma CVD to cover the two bonded substrates, and then only the nitride film on the porous substrate was removed by reactive ion etching.

5 Thereafter, selective etching was conducted on the bonded substrates in a 49% hydrofluoric acid solution while the solution was being stirred. In seventy eight minutes, the porous Si substrate was completely etched with the monocrystalline Si layer acting as an etch stopper, only the
10 monocrystalline Si layer being left behind.

 The etching rate of the non-porous monocrystalline Si was so low that only a maximum of $50\text{ }\text{\AA}$ of non-porous monocrystalline Si was removed in seventy eight minutes. Since the ratio of the etching rate of the non-porous
15 monocrystalline Si to that of the porous layer is $1 : 10^5$, the amount of non-porous layer which is etched (several tens angstroms) can be ignored in a practical operation. That is, the $200\text{ }\mu\text{m}$ -thick porous Si substrate was removed, and subsequently the Si_3N_4 layer was removed with a result that
20 the $1\text{ }\mu\text{m}$ -thick monocrystalline Si layer on the silica glass substrate remained.

 The cross-section of the monocrystalline Si layer was observed by a transmission type electron microscope. It was found that no crystal defect was newly introduced in the
25 Si layer and hence the Si layer had excellent crystalline



1 structure.

Example 49

Anodization was conducted on a P type (100)
monocrystalline Si substrate having a thickness of 200 μm in
5 a HF solution under the following conditions:

Applied voltage:	2.6 (V)
Current density:	30 ($\text{mA}\cdot\text{cm}^{-2}$)
Anodizing solution:	HF:H ₂ O:C ₂ H ₅ OH = 1:1:1
10 Time:	1.6 (hour)
Thickness of porous Si:	200 (μm)
Porosity:	56 (%)

A Si epitaxial layer with a thickness of 0.5 μm was
15 grown on the P type (100) porous Si substrate at a low
temperature by molecular beam epitaxy (MBE). Deposition was
conducted under the following conditions:

Temperature:	700°C
20 Pressure:	1×10^{-9} Torr
Growth rate:	0.1 nm/sec.

Next, a second Si substrate with a 5000 Å thick
oxidized layer formed on the surface thereof was placed on
25 the surface of the epitaxial layer. The whole structure was

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1 heated at 800°C in an oxygen atmosphere for 0.5 hours to
firmly join the two substrates to each other.

Thereafter, selective etching was conducted on the
bonded substrates in a 49% hydrofluoric acid solution while
5 the solution was being stirred. In sixty two minutes, the
porous Si substrate was completely etched with the
monocrystalline Si layer acting as an etch stopper, only the
monocrystalline Si layer being left behind.

The etching rate of the non-porous monocrystalline Si
10 was so low that only a maximum of 50 Å of non-porous
monocrystalline Si was removed in sixty-two minutes. Since
the ratio of the etching rate of the non-porous
monocrystalline Si to that of the porous layer is 1 : 10⁵,
the amount of non-porous layer which is etched (several tens
15 angstroms) can be ignored in a practical operation. That
is, the 200 µm-thick porous Si substrate was removed with a
result that the 0.5 µm-thick monocrystalline Si layer formed
on the SiO₂ layer remained.

The cross-section of the monocrystalline Si layer was
20 observed by a transmission type electron microscope. It
was found that no crystal defect was newly introduced in the
Si layer and hence the Si layer had excellent crystalline
structure.

Example 50

25 Anodization was conducted on a P type (100)



1 monocrystalline Si substrate having a thickness of 200 μm in
a HF solution in the same manner as that of Example 49.

A Si epitaxial layer with a thickness of 0.5 μm was
grown on the P type (100) porous Si substrate at a low
5 temperature by plasma CVD. Deposition was conducted under
the following conditions:

Gas:	SiH_4
High-frequency power:	100 W
10 Temperature:	800°C
Pressure:	1×10^{-2} Torr
Growth rate:	2.5 nm/sec.

Next, a second Si substrate with a 5000 Å thick
15 oxidized layer formed on the surface thereof was placed on
the surface of the epitaxial layer. The whole structure was
heated at 800°C in an oxygen atmosphere for 0.5 hours to
firmly join the two substrates to each other.

Thereafter, selective etching was conducted on the
20 bonded substrates in a 49% hydrofluoric acid solution while
the solution was being stirred. In sixty two minutes, the
porous Si substrate was completely etched with the
monocrystalline Si layer acting as an etch stopper, only the
monocrystalline Si layer being left behind.

25 The etching rate of the non-porous monocrystalline Si

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1 was so low that only a maximum of 50 Å of non-porous
monocrystalline Si was removed in sixty-two minutes. Since
the ratio of the etching rate of the non-porous
monocrystalline Si to that of the porous layer is 1 : 10⁵,
5 the amount of non-porous layer which is etched (several tens
angstroms) can be ignored in a practical operation. That
is, the 200 µm-thick porous Si substrate was removed with a
result that the 0.5 µm thick monocrystalline Si layer on the
SiO₂ layer remained.

10 Example 51

Anodization was conducted on a P type (100)
monocrystalline Si substrate having a thickness of 200 µm in
a HF solution in the same manner as that of Example 49.

15 A Si epitaxial layer with a thickness of 0.5 µm was
grown on the P type (100) porous Si substrate at a low
temperature by bias sputtering. Deposition was conducted
under the following conditions:

RF frequency:	100 MHz
20 High-frequency power:	600 W
Temperature:	300°C
Ar gas pressure:	8 x 10 ⁻³ Torr
Growth time:	60 minutes
Target d.c. bias:	-200 V
25 Substrate d.c. bias:	+5 V

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1 Next, a second Si substrate with a 5000 Å thick
oxidized layer formed on the surface thereof was placed on
the surface of the epitaxial layer. The whole structure was
heated at 800°C in an oxygen atmosphere for 0.5 hours to
5 firmly join the two substrates to each other.

Thereafter, selective etching was conducted on the
bonded substrates in a 49% hydrofluoric acid solution while
the solution was being stirred. In sixty two minutes, the
porous Si substrate was completely etched with the
10 monocrystalline Si layer acting as an etch stopper, the
monocrystalline Si layer being left behind.

The etching rate of the non-porous monocrystalline Si
was so low that only a maximum of 50 Å of non-porous
monocrystalline Si was removed in sixty-two minutes. Since
15 the ratio of the etching rate of the non-porous
monocrystalline Si to that of the porous layer is 1 : 10⁵,
the amount of non-porous layer which is etched (several tens
angstroms) can be ignored in a practical operation. That
is, the 200 μm-thick porous Si substrate was removed with a
20 result that the 0.5 μm thick monocrystalline Si layer on the
SiO₂ layer remained.

Example 52

Anodization was conducted on a N type (100)
monocrystalline Si substrate having a thickness of 200 μm in



1 a HF solution in the same manner as that of Example 49.

A Si epitaxial layer with a thickness of 5 μm was grown on the N type (100) porous Si substrate at a low temperature by liquid phase growth under the following conditions:

5

Solvent:	Sn,	Solute:	Si
Growth temperature:	900°C		
Growth atmosphere:	H ₂		
Growth rate:	10 minutes		

10

Next, a second Si substrate with a 5000 Å thick oxidized layer formed on the surface thereof was placed on the surface of the epitaxial layer. The whole structure was heated at 800°C in an oxygen atmosphere for 0.5 hours to firmly join the two substrates to each other.

15

Thereafter, selective etching was conducted on the bonded substrates in a 49% hydrofluoric acid solution while the solution was being stirred. In sixty two minutes, the porous Si substrate was completely etched with the monocrystalline Si layer acting as an etch stopper, the monocrystalline Si layer being left behind.

20

The etching rate of the non-porous monocrystalline Si was so low that only a maximum of 50 Å of non-porous monocrystalline Si was removed in sixty-two minutes. Since the ratio of the etching rate of the non-porous

25

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monocrystalline Si to that of the porous layer is $1 : 10^5$, the amount of non-porous layer which is etched (several tens angstroms) can be ignored in a practical operation. That is, the 200 μm -thick porous Si substrate was removed with a result that the 5 μm thick monocrystalline Si layer on the SiO_2 layer remained.

Example 53

Anodization was conducted on a P type (100) monocrystalline Si substrate having a thickness of 200 μm in a HF solution in the same manner as that of Example 49.

A Si epitaxial layer with a thickness of 1.0 μm was grown on the P type (100) porous Si substrate at a low temperature by low-pressure CVD. Deposition was conducted under the following conditions:

Source gas:	SiH_4
Carrier gas:	H_2
Temperature:	850°C
Pressure:	1×10^{-2} Torr
Growth rate:	3.3 nm/sec

Next, a second Si substrate with a 5000 $\text{\AA}$ thick oxidized layer formed on the surface thereof was placed on the surface of the epitaxial layer. The whole structure was heated at 800°C in an oxygen atmosphere for 0.5 hours to



1 firmly join the two substrates to each other.

Thereafter, selective etching was conducted on the bonded substrates in a 49% hydrofluoric acid solution while the solution was being stirred. In sixty two minutes, the porous Si substrate was completely etched with the monocrystalline Si layer acting as an etch stopper, the monocrystalline Si layer being left behind.

The etching rate of the non-porous monocrystalline Si was so low that only a maximum of 50 Å of non-porous monocrystalline Si was removed in sixty-two minutes. Since the ratio of the etching rate of the non-porous monocrystalline Si to that of the porous layer is 1 : 10⁵, the amount of non-porous layer which is etched (several tens angstroms) can be ignored in a practical operation. That is, the 200 µm-thick porous Si substrate was removed with a result that the 1.0 µm thick monocrystalline Si layer on the SiO₂ layer remained.

When SiH₂Cl₂ was used as the source gas, the growth temperature had to be higher by several tens of degrees. However, high-speed etching characteristics to the porous substrate did not deteriorate.

Example 54

A Si epitaxial layer with a thickness of 1 µm was grown on a P type (100) Si substrate having a thickness of 200 µm by low-pressure CVD. Deposition was conducted under the

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1 following conditions:

Reactive gas flow rate: SiH_2Cl_2 1000 SCCM

H_2 230 liter/min

5 Temperature: 1080°C

Pressure: 80 Torr

Time: 2 min

10 Anodization was conducted on the substrate in a 50% HF solution at a current density of 100 mA/cm². The porous structure formation rate was 8.4 $\mu\text{m}/\text{min}$ and hence it took twenty four minutes for the 200 μm -thick P type (100) Si substrate to be made entirely porous. As mentioned above, anodization made only the P type (100) Si substrate porous, 15 and did not affect the Si epitaxial layer at all.

Next, a second Si substrate with a 5000 Å-thick oxidized layer formed on the surface thereof was placed on the surface of the epitaxial layer. The whole structure was heated at 800°C in an oxygen atmosphere for 0.5 hours to 20 firmly join the two substrates to each other.

Thereafter, selective etching was conducted on the bonded substrates in a 49% hydrofluoric acid solution while the solution was being stirred. In sixty two minutes, the porous Si substrate was completely etched with the 25 monocrystalline Si layer acting as an etch stopper, while

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1 the monocrystalline Si layer remained.

The etching rate of the non-porous monocrystalline Si was so low that only a maximum of 50 Å of non-porous monocrystalline Si was removed in sixty two minutes. Since
5 the ratio of the etching rate of the non-porous monocrystalline Si to that of the porous layer is $1 : 10^5$, the amount of non-porous layer which is etched (several tens angstroms) can be ignored in a practical operation. That is, the 200 µm-thick porous Si substrate was removed with a
10 result that the 1.0 µm thick monocrystalline Si layer on the SiO₂ layer remained.

The cross-section of the monocrystalline Si layer was observed by a transmission type electron microscope. It was found that no crystal defect was newly introduced in the
15 Si layer and hence the Si layer had excellent crystalline structure.

Example 55

A Si epitaxial layer with a thickness of 5 µm was grown on a P type (100) Si substrate having a thickness of 200 µm
20 by atmospheric CVD. Deposition was conducted under the following conditions:

Reactive gas flow rate: SiH₂Cl₂ 1000 SCCM

H₂ 230 liter/min

25 Temperature: 1080°C

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1 Pressure: 760 Torr
 Time: 1 min

5 Anodization was conducted on the substrate in a HF
 solution in the same manner as that of Example 49. As
 mentioned above, anodization made only the P type (100) Si
 substrate porous, and did not affect the Si epitaxial layer
 at all.

10 Next, a second Si substrate with a 5000 Å-thick
 oxidized layer formed on the surface thereof was placed on
 the surface of the epitaxial layer. The whole structure was
 heated at 800°C in an oxygen atmosphere for 0.5 hours to
 firmly join the two substrates to each other.

15 Thereafter, selective etching was conducted on the
 bonded substrates in a 49% hydrofluoric acid solution while
 the solution was being stirred. In sixty two minutes, the
 porous Si substrate was completely etched with the
 monocrystalline Si layer acting as an etch stopper, the
 monocrystalline Si layer being left behind.

20 The etching rate of the non-porous monocrystalline Si
 was so low that only a maximum of 50 Å of non-porous
 monocrystalline Si was removed in sixty two minutes. Since
 the ratio of the etching rate of the non-porous
 monocrystalline Si to that of the porous layer is 1 : 10⁵,
25 the amount of non-porous layer which is etched (several tens



1 angstroms) can be ignored in a practical operation. That
is, the 200 μm -thick porous Si substrate was removed with a
result that the 5.0 μm thick monocrystalline Si layer on the
SiO₂ layer remained.

5 The cross-section of the monocrystalline Si layer was
observed by a transmission type electron microscope. It
was found that no crystal defect was newly introduced in the
Si layer and hence the Si layer had excellent crystalline
structure.

10 Example 56

A N type Si layer with a thickness of 1 μm was formed
on a P type (100) Si substrate having a thickness of 200 μm
by proton implantation. Implantation rate of H⁺ was 5 x
10¹⁵ (ions/cm²).

15 Anodization was conducted on the substrate in a 50% HF
solution at a current density of 100 mA/cm². The porous
structure formation rate was 8.4 $\mu\text{m}/\text{min}$ and hence it took
twenty four minutes for the 200 μm -thick P type (100) Si
substrate to be made entirely porous. As mentioned above,
20 anodization made only the P type (100) Si substrate porous,
and did not change the N type Si layer.

Next, a second Si substrate with a 5000 Å-thick
oxidized layer formed on the surface thereof was placed on
the surface of the N type Si layer. The whole structure was
25 heated at 800°C in an oxygen atmosphere for 0.5 hours to



1 firmly join the two substrates to each other.

Thereafter, selective etching was conducted on the bonded substrates in a 49% hydrofluoric acid solution while the solution was being stirred. In sixty two minutes, the porous Si substrate was completely etched with the monocrystalline Si layer acting as an etch stopper, the monocrystalline Si layer being left behind.

The etching rate of the non-porous monocrystalline Si was so low that only a maximum of 50 Å of non-porous monocrystalline Si was removed in sixty two minutes. Since the ratio of the etching rate of the non-porous monocrystalline Si to that of the porous layer is 1 : 10^5 , the amount of non-porous layer which is etched (several tens angstroms) can be ignored in a practical operation. That is, the 200 μm-thick porous Si substrate was removed with a result that the 1.0 μm thick monocrystalline Si layer on the SiO₂ layer remained.

The cross-section of the monocrystalline Si layer was observed by a transmission type electron microscope. It was found that no crystal defect was newly introduced in the Si layer and hence the Si layer had excellent crystalline structure.

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1 Example 57

 A P-type (100) single-crystals (monocrystal)
Si substrate of a thickness of 200 μ was anodized in
50 % HF solution. The current density then was 100
5 mA/cm². The porous structure formation rate then was
about 8.4 μ m/min., and the P-type (100) Si substrate
of a thickness of 200 μ was rendered porous in its
entirety for 24 minutes.

 According to MBE (molecular beam epitaxy) method,
10 an Si epitaxial layer of 0.5 μ was grown at a lower
temperature on the P-type (100) porous Si substrate.
The conditions for deposition are as follows;

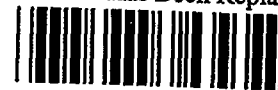
temperature:	700 °C
pressure:	1×10^{-9} Torr
15 growth rate:	0.1 nm/sec.

 Subsequently, the surface of the epitaxial
layer was thermally oxidized in a depth of 50 nm.
A substrate of fused silica glass processed with
optical polishing was bonded onto the thermally oxidized
20 membrane (i.e., film), and both of the substrates were
strongly bonded together by heating at 800 °C for 0.5
hour in oxygen atmosphere.

 According to low pressure CVD, Si₃N₄ was
deposited to 0.1 μ m, thereby coating the bonded two
25 substrates. Thereafter, only the nitride membrane
(film) on the porous substrate was removed by reactive
ion etching.

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1 Then, the bonded substrates were selectively
etched with 49 % hydrofluoric acid. In 78 minutes,
only the single-crystal Si layer remained without
etching, while the porous Si substrate was
5 selectively etched with the single-crystal Si as a
material for etching stopper and then completely
removed.

 The etching rate of the non-porous Si single-
crystal (monocrystal) with the etching solution was
10 extremely low, such as 50 angstroms or less even 78
minutes later, so that the selective ratio of the
etching rate of the porous layer to that of the non-
porous Si single-crystal was as large as 10^5 or more.
The etched amount in the non-porous layer (several
15 tens angstroms) is a practically negligible decrease
in membrane thickness. That is, the Si substrate of
a thickness of 200 μ , rendered porous, was removed,
and after the removal of the Si_3N_4 layer, a single-
crystal Si layer of a thickness of 0.5 μm was formed
20 on the substrate of the silica glass.

 As a result of observation of the section
under a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced
in the Si layer and that excellent crystallinity was
25 maintained.

Example 58

A P-type (100) single-crystal Si substrate of



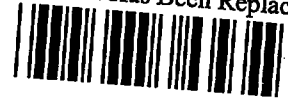
1 a thickness of 200 μ was anodized in 50 % HF solution.
The current density then was 100 mA/cm². The porous
structure formation rate then was about 8.4 μ m/min.,
and the P-type (100) Si substrate of a thickness of
5 200 μ was rendered porous in its entirety for 24
minutes. According to plasma CVD method, an Si
epitaxial layer of 5 μ was grown at a lower temperature
on the P-type (100) porous Si substrate. The conditions
for deposition are as follows;

10 gas: SiH₄
high-frequency power: 100 W
temperature 800 °C
pressure: 1 x 10⁻² Torr
growth rate: 2.5 nm/sec.

15 Subsequently, the surface of the epitaxial
layer was thermally oxidized in a depth of 50 nm.
A glass substrate, having being processed with
optical polishing and having a softening point
around 500 °C, was bonded onto the thermally oxidized
20 membrane, and both of the substrates were strongly
bonded together by heating at 450 °C for 0.5 hour in
oxygen atmosphere.

According to plasma CVD method, Si₃N₄ was
deposited to 0.1 μ m, thereby coating the bonded two
25 substrates. Thereafter, only the nitride membrane on the
porous substrate was removed by reactive ion etching.

Then, the bonded substrates were selectively



1 etched with 49 % hydrofluoric acid. In 78 minutes,
only the single-crystal Si layer remained without
etching, while the porous Si substrate was selectively
etched with the single-crystal Si as a material for
5 etching stopper and then completely removed.

The etching rate of the non-porous Si single-crystal with the etching solution was extremely low, such as 50 angstroms or less even 78 minutes later, so that the selective ratio of the etching rate of the
10 porous layer to that of the non-porous Si single-crystal was as large as 10^5 or more. The etched amount in the non-porous layer (several tens angstroms) is a practically negligible decrease in membrane thickness. That is, the Si substrate of a thickness
15 of 200 μ , rendered porous, was removed, and after the removal of the Si_3N_4 layer, a single-crystal Si layer of a thickness of 5 μ was formed on the glass substrate of a lower softening point.

Example 59

20 A P-type (100) single-crystal Si substrate of a thickness of 200 μ was anodized in 50 % HF solution. The current density then was 100 mA/cm^2 . The porous structure formation rate then was about 8.4 $\mu\text{m}/\text{min.}$, and the P-type (100) Si substrate of a thickness of
25 200 μ was rendered porous in its entirety for 24 minutes. According to thermal CVD method, an Si epitaxial layer of 5 μ was grown at a lower temperature

1 on the P-type (100) porous Si substrate. The
conditions for deposition are as follows;

gas: SiH_4 (0.6 l/min), H_2 (100 l/min)
temperature: 850 °C
5 pressure: 50 Torr
growth rate: 0.1 $\mu\text{m}/\text{min}$.

Subsequently, the surface of the epitaxial layer
was thermally oxidized in a depth of 50 nm. A glass
substrate, having being processed with optical
10 polishing and having a softening point around 500 °C,
was bonded onto the thermally oxidized membrane, and
both of the substrates were strongly bonded together
by heating at 450 °C for 0.5 hour in oxygen atmosphere.

According to plasma CVD method, Si_3N_4 was
15 deposited to 0.1 μm , thereby coating the bonded two
substrates. Thereafter, only the nitride membrane on
the porous substrate was removed by reactive ion etching.

Then, the bonded substrates were selectively
etched with 49 % hydrofluoric acid. In 78 minutes,
20 only the single-crystal Si layer remained without
etching, while the porous Si substrate was selectively
etched with the single-crystal Si as a material for
etching stopper and then completely removed.

The etching rate of the non-porous Si single-
25 crystal with the etching solution was extremely low,
such as 50 angstroms or less even 78 minutes later,
so that the selective ratio of the etching rate of



1 the porous layer to that of the non-porous Si single-
crystal was as large as 10^5 or more. The etched
amount in the non-porous layer (several tens angstroms)
is a practically negligible decrease in membrane
5 thickness. That is, the Si substrate of a thickness
of 200 μ , rendered porous, was removed, and after the
removal of the Si_3N_4 layer, a single-crystal Si layer
of a thickness of 5 μ was formed on the glass substrate
of a lower softening point.

10 A similar effect could be obtained by using
Apiezon wax or electron wax, instead of Si_3N_4 , so that
only the Si substrate rendered porous could be removed
completely.

Example 60

15 A P-type (100) single-crystal Si substrate of
a thickness of 200 μ was anodized in 50 % HF solution.
The current density then was 100 mA/cm^2 . The porous
structure formation rate then was about 8.4 $\mu\text{m}/\text{min.}$,
and the P-type (100) Si substrate of a thickness of
20 200 μ was rendered porous in its entirety for 24
minutes. According to bias sputter method, an Si
epitaxial layer of 1.0 μ was grown at a lower
temperature on the P-type (100) porous Si substrate.
The conditions for deposition are as follows;

25 RF frequency: 100 MHz
high-frequency power: 600 W
temperature: 300 °C

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- 1 Ar gas pressure: 8×10^{-3} Torr
growth time: 120 minutes
target direct current bias: -200 V
substrate direct current bias: +5 V.

- 5 Subsequently, the surface of the epitaxial layer was thermally oxidized in a depth of 50 nm. A glass substrate, having being processed with optical polishing and having a softening point around 500 °C, was bonded onto the thermally oxidized membrane, and
10 both of the substrate were strongly bonded together by heating at 450 °C for 0.5 hour in oxygen atmosphere.

- According to plasma CVD method, Si_3N_4 was deposited to 0.1 μm , thereby coating the bonded two substrates. Thereafter, only the nitride membrane on
15 the porous substrate was removed by reactive ion etching.

- Then, the bonded substrates were selectively etched with 49 % hydrofluoric acid. In 78 minutes, only the single-crystal Si layer remained without
20 etching, while the porous Si substrate was selectively etched with the single-crystal Si as a material for etching stopper and then completely removed.

- The etching rate of the non-porous Si single-crystal with the etching solution was extremely low,
25 such as 50 angstroms or less even 78 minutes later, so that the selective ratio of the etching rate of the porous layer to that of the non-porous Si



1 single-crystal was as large as 10^5 or more. The etched
 amount in the non-porous layer (several tens angstroms)
 is a practically negligible decrease in membrane
 thickness. That is, the Si substrate of thickness
 5 of 200 μ , rendered porous, was removed, and after
 the removal of the Si_3N_4 layer, a single-crystal Si
 layer of a thickness of 1.0 μm was formed on the
 glass substrate of a lower melting point.

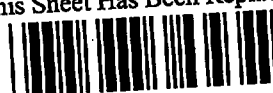
A similar effect could be obtained by using
 10 Apiezon wax or electron wax, instead of Si_3N_4 , so that
 only the Si substrate rendered porous could be removed
 completely.

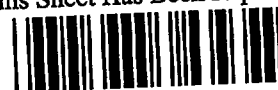
Example 61

A N-type (100 single-crystal Si substrate of
 15 a thickness of 200 μ was anodized in 50 % HF
 solution. The current density then was 100 mA/cm^2 .
 The porous structure formation rate then was about
 8.4 $\mu\text{m}/\text{min.}$, and the N-type (100) Si substrate of a
 thickness of 200 μ was rendered porous in its
 20 entirety for 24 minutes. According to liquid phase
 growth method, an Si epitaxial layer of 10 μ was grown
 at a lower temperature on the N-type (100) porous Si
 substrate. The conditions for deposition are as
 follows;

25 solvent:	Sn,	Solute:	Si
growth temperature:	900 °C		
growth atmosphere:	H_2		

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1 growth time: 20 minutes.

Subsequently, the surface of the epitaxial layer was thermally oxidized in a depth of 50 nm. A glass substrate, having being processed with optical polishing and having a softening point
5 around 800 °C, was bonded onto the thermally oxidized membrane, and both of the substrates were strongly bonded together by heating at 750 °C for 0.5 hour in oxygen atmosphere.

10 According to low pressure CVD method, Si_3N_4 was deposited to 0.1 μm , thereby coating the bonded two substrates. Thereafter, only the nitride membrane on the porous substrate was removed by reactive ion etching.

15 Then, the bonded substrates were selectively etched with 49 % hydrofluoric acid. In 78 minutes, only the single-crystal Si layer remained without etching in 78 minutes, while the porous Si substrate was selectively etched with the single-crystal Si as
20 a material for etching stopper and then completely removed.

The etching rate of the non-porous Si-single crystal with the etching solution was extremely low, such as 50 angstroms or less even 78 minutes later,
25 so that the selective ratio of the etching rate of the porous layer to that of the non-porous Si single-crystal was as large as 10^5 or more. The etched

1 amount in the non-porous layer (several tens angstroms)
 is a practically negligible decrease in membrane
 thickness. That is, the Si substrate, rendered porous,
 of a thickness of 200 μ was removed, and after the
 5 removal of the Si_3N_4 layer, a single-crystal Si layer
 of a thickness of 10 μm was formed on the glass
 substrate of a lower softening point.

A similar effect could be obtained by using
 Apiezon wax or electron wax, instead of Si_3N_4 , so that
 10 only the Si substrate rendered porous could be
 removed completely.

Example 62

According to CVD method, an Si epitaxial layer
 of 0.5 μ was grown at a lower temperature on a P-type
 15 (100) Si substrate of a thickness of 200 μ . The
 conditions for deposition are as follows;

reactive gas flow rate:	SiH_2Cl_2	1000 SCCM
	H_2	230 l/min.
temperature:	1080 $^{\circ}\text{C}$	
20 pressure:	80 Torr	
time:	1 minute.	

The present substrate was anodized in 50 % HF
 solution. The current density then was 100 mA/cm^2 .
 The porous structure formation rate then was about
 25 8.4 $\mu\text{m}/\text{min.}$, and the P-type (100) Si substrate of a
 thickness of 200 μ was rendered porous in its entirety
 for 24 minutes. As has been described above, the



1 present anodization rendered only the P-type (100) Si
substrate porous, but no change was observed in the Si
epitaxial layer.

Subsequently, the surface of the epitaxial
5 layer was thermally oxidized in a depth of 50 nm. A
substrate of fused silica glass, processed with optical
polishing, was bonded onto the thermally oxidized
membrane, and both of the substrates were strongly
bonded together by heating at 800 °C for 0.5 hour in
10 oxygen atmosphere.

According to low pressure CVD method, Si_3N_4
was deposited to 0.1 μm , thereby coating the bonded
two substrates. Thereafter, only the nitride
membrane on the porous substrate was removed by
15 reactive ion etching.

Then, the bonded substrates were selectively
etched with 49 % hydrofluoric acid. In 78 minutes,
only the single-crystal Si layer remained without
etching, while the porous Si substrate was
20 selectively etched with the single-crystal Si as a
material for etching stopper and then completely
removed.

The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
25 such as 50 angstroms or less even 78 minutes later,
so that the selective ratio of the etching rate of
the porous layer to that of the non-porous Si



1 single-crystal was as large as 10^5 or more. The
etched amount in the non-porous layer (several tens
angstroms) is a practically negligible decrease in
membrane thickness. That is, the Si substrate of a
5 thickness of 200 μ , rendered porous, was removed,
and after the removal of the Si_3N_4 layer, a single-
crystal Si layer of a thickness of 0.5 μm was formed
on the glass substrate.

A similar effect could be obtained by using
10 Apiezon wax or electron wax, instead of Si_3N_4 , so that
only the Si substrate rendered porous could be
removed completely.

As a result of observation of the section
under a transmission-type electron microscope, it
15 was confirmed that no new crystal defect was
introduced in the Si layer and that excellent
crystallinity was maintained.

Example 63

A N-type Si layer 1 μ was formed on the
20 surface of a P-type (100) Si substrate of a
thickness of 200 μ , by ion implantation of proton.
The implanted amount of H^+ was 5×10^{15} ions/ cm^2 .
The substrate was anodized in 50 % HF solution.
The current density then was 100 mA/cm^2 . The porous
25 structure formation rate then was about 8.4 $\mu\text{m}/\text{min.}$,
and the P-type (100) Si substrate of a thickness of
200 μ was rendered porous in its entirety for 24



1 minutes. According to the present anodization as has
been described above, only the P-type (100) Si
substrate was rendered porous, but no change was
observed in the N-type Si layer. Subsequently, the
5 surface of the N-type single-crystal layer was
thermally oxidized in a depth of 50 nm. A substrate
of fused silica glass processed with optical
polishing was bonded onto the thermally oxidized
membrane, and both of the substrates were strongly
10 bonded together by heating at 800 °C for 0.5 hour in
oxygen atmosphere.

According to low pressure CVD method, Si_3N_4
was deposited to 0.1 μm , thereby coating the bonded
two substrates. Thereafter, only the nitride
15 membrane on the porous substrate was removed by
reactive ion etching. Then, the bonded substrates
were selectively etched with 49 % hydrofluoric acid.
In 78 minutes, only the single-crystal Si layer
remained without etching, while the porous Si
20 substrate was selectively etched with the single-
crystal Si as a material for etching stopper and then
completely removed.

The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
25 such as 50 angstroms or less even 78 minutes later,
so that the selective ratio of the etching rate of
the porous layer to that of the non-porous Si



1 single-crystal was as large as 10^5 or more. The etched
 amount in non-porous layer (several tens angstroms) is
 a practically negligible decrease in membrane
 thickness. That is, the Si substrate of a thickness
 5 of 200 μ , rendered porous, was removed, and after the
 removal of the Si_3N_4 layer, a single-crystal Si layer
 of a thickness of 1.0 μm was formed on the glass
 substrate.

A similar effect could be obtained by using
 10 Apiezon wax or electron wax, instead of Si_3N_4 , so
 that only the Si substrate rendered porous could be
 removed completely.

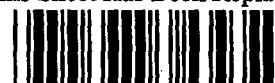
As a result of observation of the section
 under a transmission-type electron microscope, it was
 15 confirmed that no new crystal defect was introduced
 in the Si layer and that excellent crystallinity was
 maintained.

Example 64

A P-type (100) single-crystal Si substrate of
 20 a thickness of 200 μ was anodized in 50 % HF solution.

The conditions for deposition are as follows;

applied voltage:	2.6 V
current density:	30 $\text{mA}\cdot\text{cm}^{-2}$
solution for anodization:	$\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1:1:1$
25 time:	1.6 hours
thickness of porous Si:	200 μm
porosity:	56 %.



1 According to MBE method, an Si epitaxial layer
of 0.5 μ was grown at a lower temperature on the P-
type (100) porous Si substrate. The conditions for
deposition are as follows;

5 temperature: 700 °C
pressure: 1×10^{-9}
growth rate: 0.1 nm/sec.

Subsequently, an oxidized layer of 1000
angstroms was formed on the surface of the epitaxial
10 layer, and another Si substrate on the surface of
which was formed an oxidized layer of 5000 angstroms,
was bonded to the oxidized surface. By heating in
oxygen atmosphere at 800 °C for 0.5 hour, both of the
Si substrates were strongly bonded together.

15 Then, the bonded substrates were selectively
etched with 49 % hydrofluoric acid while under
stirring. In 78 minutes, only the single-crystal Si
layer remained without etching, while the porous Si
substrate was selectively etched with the single-
20 crystal Si as a material for etching stopper and then
completely removed.

The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
such as 50 angstroms or less even 78 minutes later,
25 so that the selective ratio of the etching rate of the
porous layer to that of the non-porous Si single-
crystal was as large as 10^5 or more. The etched



1 amount in the non-porous layer (several tens angstroms)
 is a practically negligible decrease in membrane
 thickness. That is, the Si substrate of a thickness
 of 200 μ , rendered porous, was removed, and after the
 5 removal of the Si_3N_4 layer, a single-crystal Si layer
 of a thickness of 0.5 μm was formed on the SiO_2 . As
 a result of observation of the section under a
 transmission-type electron microscope, it was confirmed
 that no new crystal defect was introduced in the Si
 10 layer and that excellent crystallinity was maintained.

Example 65

A P-type (100) single-crystal Si substrate of
 a thickness of 200 μ was anodized in HF solution.

The conditions for anodization are as follows;

15	applied voltage:	2.6 V
	current density:	30 $\text{mA}\cdot\text{cm}^{-2}$
	solution for anodization:	$\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1:1:1$
	time:	1.6 hours
	thickness of porous Si:	200 μm
20	porosity:	56 %.

According to plasma CVD method, and Si
 epitaxial layer of 0.5 μ was grown at a lower
 temperature on the P-type (100) porous Si substrate.
 The conditions for deposition are as follows;

25	gas:	SiH_4
	high-frequency power:	100 W
	temperature:	800 $^{\circ}\text{C}$

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1 pressure: 1×10^{-2} Torr
 growth rate: 2.5 nm/sec.

 Subsequently, an oxidized layer of 1000
angstroms was formed on the surface of the epitaxial
5 layer, and another Si substrate on the surface of
 which was formed as oxidized layer of 5000 angstroms
 was bonded to the oxidized surface. By heating in
 oxygen atmosphere at 800 °C for 0.5 hour, both of
 the Si substrates were strongly bonded together.

10 Then, the bonded substrates were selectively
 etched with 49 % hydrofluoric acid while under
 stirring. In 78 minutes, only the single-crystal Si
 layer remained without etching, while the porous Si
 substrate was selectively etched with the single-
15 crystal Si as a material for etching stopper and then
 completely removed.

 The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
such as 50 angstroms or less even 78 minutes later,
20 so that the selective ratio of the etching rate of the
 porous layer to that of the non-porous Si single-
 crystal was as large as 10^5 or more. The etched
 amount in the non-porous layer (several tens
 angstroms) is a practically negligible decrease in
25 membrane thickness. That is, the Si substrate of a
 thickness of 200 μ , rendered porous, was removed,
 and a single-crystal Si layer of a thickness of 0.5 μ m

1 was formed on the SiO_2 .

Example 66

A P-type (100) single-crystal Si substrate of a thickness of 200 μ was anodized in HF solution.

5 The conditions for anodization are as follows;

applied voltage: 2.6 V

current density: 30 $\text{mA}\cdot\text{cm}^{-2}$

solution for anodization: $\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1:1:1$

time: 1.6 hours

10 thickness of porous Si: 200 μm

porosity: 56 %.

According to bias sputter method, an Si epitaxial layer of 0.5 μ was grown at a lower temperature on the P-type (100) porous Si substrate.

15 The conditions for deposition are as follows;

RF frequency: 100 MHz

high-frequency power: 600 W

temperature: 300 $^{\circ}\text{C}$

Ar gas pressure: 8×10^{-3} Torr

20 growth time: 60 minutes

target direct current bias: -200 V

substrate direct current bias: +5 V.

Subsequently, an oxidized layer of 1000 angstroms was formed on the surface of the epitaxial
25 layer, and another Si substrate on the surface of which was formed an oxidized layer of 5000 angstroms was bonded to the oxidized surface. By heating in

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1 oxygen atmosphere at 800 °C for 0.5 hour, both of the
Si substrates were strongly bonded together.

Then, the bonded substrates were selectively
etched with 49 % hydrofluoric acid while under
5 stirring. In 78 minutes, only the single-crystal Si
layer remained without etching, while the porous Si
substrate was selectively etched with the single-
crystal Si as a material for etching stopper and then
completely removed. The etching rate of the non-
10 porous Si single-crystal with the etching solution
was extremely low, such as 50 angstroms or less
even 78 minutes later, so that the selective ratio
of the etching rate of the porous layer to that of
the non-porous Si single-crystal was as large as 10^5
15 or more. The etched amount in the non-porous layer
(several tens angstroms) is a practically negligible
decrease in membrane thickness. That is, the Si
substrate of a thickness of 200 μ , rendered porous,
was removed, and a single-crystal Si layer of a
20 thickness of 0.5 μ m was formed on the SiO₂.

Example 67

A N-type (100) single-crystal Si substrate
of a thickness of 200 μ was anodized in HF solution.

The conditions for anodization are as follows;

25 applied voltage: 2.6 V
current density: 30 mA·cm⁻²
solution for anodization: HF:H₂O:C₂H₅OH = 1:1:1



1 time: 1.6 hours
 thickness of porous Si: 200 μm
 porosity: 56 %.

 According to liquid phase growth method, an
5 Si epitaxial layer of 5 μ was grown at a lower
 temperature on the N-type (100) porous Si substrate.
 The conditions for growth are as follows;

 solvent: Sn, Solute: Si
 growth temperature: 900 $^{\circ}\text{C}$
10 growth atmosphere: H_2
 growth period: 10 minutes

 Subsequently, an oxidized layer of 1000
 angstroms was formed on the surface of the epitaxial
 layer, and another Si substrate on the surface of
15 which was formed an oxidized layer of 5000 angstroms
 was bonded to the oxidized surface. By heating in
 oxygen atmosphere at 800 $^{\circ}\text{C}$ for 0.5 hour, both of the
 Si substrates were strongly bonded together.

 Then, the bonded substrates were selectively
20 etched with 49 % hydrofluoric acid while under stirring.
 Only the single-crystal Si layer remained without
 etching in 78 minutes, while the porous Si substrate
 was selectively etched with the single-crystal Si
 as a material for etching stopper and then completely
25 removed.

 The etching rate of the non-porous Si single-
 crystal with the etching solution was extremely low,



1 such as 50 angstroms or less even 78 minutes layer, so
 that the selective ratio of the etching rate of the
 porous layer to that of the non-porous Si single-
 crystal was as large as 10^5 or more. The etched
 5 amount in the non-porous layer (several tens
 angstroms) is a practically negligible decrease in
 membrane thickness. That is, the Si substrate of a
 thickness of 200 μ , rendered porous, was removed, and
 a single-crystal Si layer of a thickness of 0.5 μ m was
 10 formed on the SiO_2 .

Example 68

A P-type (100) single-crystal Si substrate of
 a thickness of 200 μ was anodized in HF solution.

The conditions for anodization are as follows;

15 applied voltage: 2.6 V
 current density: 30 $\text{mA}\cdot\text{cm}^{-2}$
 solution for anodization: $\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1:1:1$
 time: 1.6 hours
 thickness of porous Si: 200 μm
 20 porosity: 56 %.

According to low pressure CVD method, an Si
 epitaxial layer of 1.0 μ was grown at a lower temperature
 on the P-type (100) porous Si substrate. The
 conditions for deposition are as follows;

25 source gas: SiH_4
 carrier gas: H_2
 temperature: 850 $^{\circ}\text{C}$



1 pressure: 1×10^{-2} Torr
growth rate: 3.3 nm/sec.

Subsequently, an oxidized layer of 1000 angstroms was formed on the surface of the epitaxial layer, and another Si substrate on the surface of which was formed an oxidized layer of 5000 angstroms was bonded to the oxidized surface. By heating in oxygen atmosphere at 800 °C for 0.5 hour, both of the Si substrates were strongly bonded together.

10 Then, the bonded substrates were selectively etched with 49 % hydrofluoric acid while under stirring. In 78 minutes, only the single-crystal Si layer remained without etching in 78 minutes, while the porous Si substrate was selectively etched with the single-crystal Si as a material for etching stopper and then completely removed.

The etching rate of the non-porous Si single-crystal with the etching solution was extremely low, such as 50 angstroms or less even 78 minutes later, so that the selective ratio of the etching rate of the porous layer to that of the non-porous Si single-crystal was as large as 10^5 or more. The etched amount in the non-porous layer (several tens angstroms) is a practically negligible decrease in membrane thickness. That is, the Si substrate, rendered porous, of a thickness of 200 μ was removed, and a single-crystal Si layer of a thickness of 1.0 μ m



1 was formed on the SiO_2 . When SiH_2Cl_2 was used as a
source gas, it was required to raise the growth
temperature by several tens of degrees. Nevertheless,
the accelerating etching characteristics to porous
5 substrates was maintained.

Example 69

According to low pressure CVD method, an Si
epitaxial layer of $1\ \mu$ was grown at a lower temperature
on a P-type (100) porous Si substrate. The conditions
10 for deposition are as follows;

reactive gas flow rate:	SiH_2Cl_2	1000 SCCM
	H_2	230 l/min
temperature:		1080 °C
pressure:		80 Torr
15 time:		2 min.

The substrate was anodized in 50 % HF solution.
The current density then was $100\ \text{mA}/\text{cm}^2$. The porous
structure formation rate then was $8.4\ \mu\text{m}/\text{min.}$, and
the P-type (100) Si substrate of a thickness of $200\ \mu$
20 was rendered porous in its entirety for 24 minutes.
According to the present anodization, as has been
described above, only the P-type (100) Si substrate
was rendered porous, but no change was observed in the
Si epitaxial layer.

25 Subsequently, an oxidized layer of 1000
angstroms was formed on the surface of the epitaxial
layer, and another Si substrate on the surface of



1 which was formed an oxidized layer of 5000 angstroms
was bonded to the oxidized surface. By heating in
oxygen atmosphere at 800 °C for 0.5 hour, both of the
Si substrates were strongly bonded together.

5 Then, the bonded substrates were selectively
etched with 49 % hydrofluoric acid while under
stirring. In 78 minutes, only the single-crystal Si
layer remained without etching, while the porous Si
substrate was selectively etched with the single-
10 crystal Si as a material for etching stopper and then
completely removed.

The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
such as 50 angstroms or less even 78 minutes later, so
15 that the selective ratio of the etching rate of the
porous layer to that of the non-porous Si single-
crystal was as large as 10^5 or more. The etched
amount in the non-porous layer (several tens angstroms)
is a practically negligible decrease in membrane
20 thickness. That is, the Si substrate of a thickness
of 200 μ , rendered porous, was removed, and a single-
crystal Si layer of a thickness of 1.0 μ m was formed
on the SiO₂.

As a result of observation of the section under
25 a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced
in the Si layer and that excellent crystallinity was
maintained.



1 Example 70

According to atmospheric pressure CVD method,
 an Si epitaxial layer of 5 μ was grown at a lower
 temperature on a P-type (100) Si substrate. The
 5 conditions for deposition are as follows;

reactive gas flow rate: SiH_2Cl_2 1000 SCCM
 H_2 230 l/min
 temperature: 1080 $^{\circ}\text{C}$
 pressure: 760 Torr
 10 time: 1 min.

The Si substrate was anodized in HF solution.

The conditions for anodization are as follows;

applied voltage: 2.6 V
 current density: 30 $\text{mA}\cdot\text{cm}^{-2}$
 15 solution for anodization: $\text{HF}:\text{H}_2\text{O}:\text{C}_2\text{H}_5\text{OH} = 1:1:1$
 time: 1.6 hours
 thickness of porous Si: 200 μm
 porosity: 56 %.

According to the present anodization as has
 20 been described above, only the P-type (100) Si
 substrate was rendered porous, but no change was
 observed in the Si epitaxial layer.

Subsequently, an oxidized layer of 1000
 angstroms was formed on the surface of the epitaxial
 25 layer, and another Si substrate on the surface of
 which was formed an oxidized layer of 5000 angstroms
 was bonded to the oxidized surface. By heating in



1 oxygen atmosphere at 800 °C for 0.5 hour, both of the
Si substrates were strongly bonded together.

Then, the bonded substrates were selectively
etched with 49 % hydrofluoric acid while under
5 stirring. In 78 minutes, only the single-crystal Si
layer remained without etching, while the porous Si
substrate was selectively etched with the single-
crystal Si as a material for etching stopper and then
completely removed.

10 The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
such as 50 angstroms or less even 78 minutes later,
so that the selective ratio of the etching rate of the
porous layer to that of the non-porous Si single-
15 crystal was as large as 10^5 or more. The etched
amount in the non-porous layer (several tens
angstroms) is a practically negligible decrease in
membrane thickness. That is, the Si substrate,
rendered porous, of a thickness of 200 μ was removed,
20 and a single-crystal Si layer of a thickness of 5 μ m
was formed on the SiO_2 . As a result of observation
of the section under a transmission-type electron
microscope, it was confirmed that no new crystal
defect was introduced in the Si layer and that
25 excellent crystallinity was maintained.

Example 71

A N-type Si layer of 1 μ was formed on the



1 surface of a P-type (100) Si substrate of a thickness
of 200 μ , by ion implantation of proton. The implanted
amount of H^+ was 5×10^{15} ions/cm². The substrate was
anodized in 50 % HF solution. The current density
5 then was 100 mA/cm². The porous structure formation
rate then was 8.4 μ m/min., and the P-type (100) Si
substrate of a thickness of 200 μ was rendered porous
in its entirety for 24 minutes. According to the
present anodization as has been described above, only
10 the P-type (100) Si substrate was rendered porous,
but no change was observed in the N-type Si layer.

Subsequently, an oxidized layer of 1000
angstroms was formed on the surface of the N-type Si
layer, and another Si substrate on the surface of
15 which was formed an oxidized layer of 5000 angstroms
was bonded to the oxidized surface. By heating in
oxygen atmosphere at 800 °C for 0.5 hour, both of the
Si substrates were strongly bonded together.

Then, the bonded substrates were selectively
20 etched with 49 % hydrofluoric acid with stirring.
In 78 minutes, only the single-crystal Si layer
remained without etching, while the porous Si
substrate was selectively etched with the single-
crystal Si as a material for etching stopper and then
25 completely removed.

The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,



1 such as 50 angstroms or less even 78 minutes later,
so that the selective ratio of the etching rate of
the porous layer to that of the non-porous Si single-
crystal was as large as 10^5 or more. The etched
5 amount in the non-porous layer (several tens angstroms)
is a practically negligible decrease in membrane
thickness. That is, the Si substrate, rendered porous,
of a thickness of $200\ \mu$ was removed, and a single-
crystal Si layer of a thickness of $1.0\ \mu\text{m}$ was formed
10 on SiO_2 .

As a result of observation of the section under
a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced
in the Si layer and that excellent crystallinity was
15 maintained.

Example 72

A P-type (100) single-crystal Si substrate of
a thickness of $200\ \mu$ was anodized in 50 % HF solution.
The current density then was $100\ \text{mA}/\text{cm}^2$. The porous
20 structure formation rate then was about $8.4\ \mu\text{m}/\text{min.}$,
and the P-type (100) Si substrate of a thickness of
 $200\ \mu$ was rendered porous in its entirety for 24
minutes.

According to MBE (monocular beam epitaxy)
25 method, an Si epitaxial layer was grown at a lower
temperature on the P-type (100) porous Si substrate.
The conditions for deposition are as follows;



1 temperature: 700 °C
 pressure: 1 x 10⁻⁹ Torr
 growth rate: 0.1 nm/sec.

 Subsequently, a substrate of fused silica glass
5 processed with optical polishing was bonded onto the
 the surface of the epitaxial layer, and both of the
 substrates were strongly bonded together by heating
 at 800 °C for 0.5 hour in oxygen atmosphere.

 According to plasma CVD method, Si₃N₄ was
10 deposited to 0.1 μm, thereby coating the bonded two
 substrates. Thereafter, only the nitride membrane on
 the porous substrate was removed by reactive ion
 etching. Then, the bonded substrates were selectively
 etching with a mixed solution of 49 % hydrofluoric
15 acid and alcohol (10:1), without stirring. In 82
 minutes, only the single-crystal Si layer remained
 without etching, while the porous Si substrate was
 selectively etched with the single-crystal Si as a
 material for etching stopper, and completely removed.

20 The etching rate of the non-porous Si single-
 crystal with the etching solution was extremely
 low, such as 50 angstroms or less even 82 minutes
 later, so that the selective ratio of the etching
 rate of the porous layer to that of the non-porous Si
25 single-crystal was as large as 10⁵ or more. The
 etched amount in the non-porous layer (several tens
 angstroms) is a practically negligible decrease in





1 membrane thickness. That is, the Si substrate of a
thickness of 200 μ , rendered porous, was removed,
and after the removal of the Si_3N_4 layer, a single-
crystal Si layer of a thickness of 0.5 μm was formed
5 on the substrate of the glass.

As a result of observation of the section under
a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced
in the Si layer and that excellent crystallinity was
10 maintained.

Examples 73 to 86

The same procedure as in Examples 42 to 55 was
effected, replacing the etching solution used in
Examples 42 to 55 with that in Example 72. In any
15 of the present Examples, consequently, a single-
crystal Si layer was formed with extremely less
crystal defect on insulating materials.

Example 87

A N-type Si layer of 1 μ was formed on the
20 surface of a P-type (100) Si substrate of a thickness
of 200 μ , by ion implantation of proton. The implanted
amount of H^+ was 5×10^{15} ions/ cm^2 .

The substrate was anodized in 50 % HF
solution. The current density then was 100 mA/cm^2 .
25 The porous structure formation rate then was 8.4 $\mu\text{m}/\text{min.}$,
and the P-type (100) Si substrate of a thickness of
200 μ was rendered porous in its entirety for 24



1 minutes. According to the present anodization as
has been described above, only the P-type (100) Si
substrate was rendered porous, but no change was
observed in the N-type Si layer.

5 Subsequently, a second Si substrate on the
surface of which was formed an oxidized layer of 5000
angstroms, was bonded to the surface of the N-type
Si layer. By heating in oxygen atmosphere at 800 °C
for 0.5 hour, both of the Si substrates were strongly
10 bonded together.

Then, the bonded substrates were selectively
etched with a mixed solution of 49 % hydrofluoric
acid and alcohol (10:1) without stirring. In 82
minutes, only the single-crystal Si layer remained
15 without etching, while the porous Si substrate was
selectively etched with the single-crystal Si as a
material for etching stopper and then completely
removed.

The etching rate of the non-porous Si single-
20 crystal with the etching solution was extremely low,
such as 50 angstroms or less even 82 minutes later,
so that the selective ratio of the etching rate of the
porous layer to that of the non-porous Si single-
crystal was as large as 10^5 or more. The etched
25 amount in the non-porous layer (several tens
angstroms) is a practically negligible decrease in
membrane thickness. That is, the Si substrate of

1 a thickness of 200 μ , rendered porous, was removed,
and a single-crystal Si layer of a thickness of 1.0 μ m
was formed on the SiO₂ layer.

As a result of observation of the section
5 under a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced
in the Si layer and that excellent crystallinity was
maintained.

Examples 88 to 102

10 The same procedure as in Examples 57 to 71 was
effected, replacing the etching solution in Examples
57 to 71 with that in Example 72. In any of the
present Examples, consequently, a single-crystal Si
layer was formed with extremely less crystal defect
15 on insulating materials.

Example 103

A P-type (100) single-crystal Si substrate of
a thickness of 200 μ was anodized in 50 % HF solution.
The current density then was 100 mA/cm². The porous
20 structure formation rate then was about 8.4 μ m/min.,
and the P-type (100) Si substrate of a thickness of
200 μ was rendered porous in its entirety for 24
minutes.

According to MBE (molecular beam epitaxy)
25 method, an Si epitaxial layer of 0.5 μ was grown at a
lower temperature on the P-type (100) porous Si
substrate. The conditions for deposition are as





1 follows;

temperature: 700 °C
pressure: 1×10^{-9} Torr
growth rate: 0.1 nm/sec.

5 Subsequently, a substrate of fused silica glass processed with optical polishing was bonded onto the surface of the epitaxial layer, and both of the substrates were strongly bonded together by heating at 800 °C for 0.5 hour in oxygen atmosphere.

10 According to plasma CVD method, Si_3N_4 was deposited at 0.1 μm , thereby coating the bonded two substrates. Thereafter, only the nitride membrane on the porous substrate was removed by reactive ion etching. Then, the bonded substrates were selectively
15 etched with a mixed solution of 49 % hydrofluoric acid and aqueous hydrogen peroxide solution (1:5), while under stirring. In 62 minutes, only the single-crystal Si layer remained without etching, while the porous Si substrate was selectively etched with the
20 single-crystal Si as a material for etching stopper and completely removed.

The etching rate of the non-porous Si single-crystal with the etching solution was extremely low, such as 50 angstroms or less even 62 minutes later,
25 so that the selective ratio of the etching rate of the porous layer to that of the non-porous Si single-crystal was as large as 10^5 or more. The etched

1 amount in the non-porous layer (several tens angstroms)
is a practically negligible decrease in membrane
thickness. That is, the Si substrate of a thickness
of 200 μ , rendered porous, was removed, and after the
5 removal of the Si_3N_4 layer, a single-crystal Si layer
of a thickness of 0.5 μm was formed on the substrate of
the glass.

As a result of observation of the section under
a transmission-type electron microscope, it was
10 confirmed that no new crystal defect was introduced
in the Si layer and that excellent crystallinity was
maintained.

Examples 104 to 118

The same procedure as in Examples 42 to 56
15 was effected, replacing the etching solution in
Examples 42 to 56 with that in Example 103. In any
of the present Examples, consequently, a single-crystal
Si layer was formed with extremely less crystal defect
on insulating materials.

20 Example 119

A P-type (100) single-crystal Si substrate of
a thickness of 200 μ was anodized in 50 % HF solution.
The current density then was 100 mA/cm^2 . The porous
structure formation rate then was about 8.4 $\mu\text{m}/\text{min.}$,
25 and the P-type (100) Si substrate of a thickness of
200 μ was rendered porous in its entirety for 24
minutes.



1 According to MBE (molecular beam epitaxy)
method, an Si epitaxial layer of 0.5 μ was grown at a
lower temperature on the P-type (100) porous Si
substrate. The conditions for deposition are as
5 follows;

temperature: 700 °C
pressure: 1×10^{-9} Torr
growth rate: 0.1 nm/sec.

Subsequently, the surface of the epitaxial
10 layer was thermally oxidized in a depth of 50 nm. A
substrate of fused silica glass processed with optical
polishing was bonded onto the thermally oxidized
membrane, and both of the substrates were strongly
bonded together by heating at 800 °C for 0.5 hour in
15 oxygen atmosphere.

According to low pressure CVD method, Si_3N_4
was deposited to 0.1 μm , thereby coating the bonded
two substrates. Thereafter, only the nitride membrane
on the porous substrate was removed by reactive ion
20 etching.

Then, the bonded substrates were selectively
etched with a mixed solution of 49 % hydrofluoric
acid and aqueous hydrogen peroxide solution (1:5).
In 62 minutes, only the single-crystal Si layer
25 remained without etching, while the porous Si
substrate was selectively etched with the single-
crystal Si as a material for etching stopper and



1 completely removed.

The etching rate of the non-porous Si single-crystal with the etching solution was extremely low, such as 50 angstroms or less even 62 minutes later, so that the selective ratio of the etching rate of the porous layer to that of the non-porous Si single-crystal was as large as 10^5 or more. The etched amount in the non-porous layer (several tens angstroms) is a practically negligible decrease in membrane thickness. That is, the Si substrate of a thickness of 200 μ , rendered porous, was removed, and after the removal of the Si_3N_4 layer, a single-crystal Si layer of a thickness of 0.5 μm was formed on the substrate of the silica glass.

15 As a result of observation of the section under a transmission-type electron microscope, it was confirmed that no new crystal defect was introduced in the Si layer and that excellent crystallinity was maintained.

20 Examples 120 to 133

The same procedure as in Examples 58 to 71 was effected, replacing the etching solution in Examples 58 to 71 with that in Example 103. In any of the present Examples, consequently, a single-crystal Si layer was formed with extremely less crystal defect on insulating materials.



1 Example 134

 A P-type (100) single-crystal Si substrate of
a thickness of 200 μ was anodized in 50 % HF solution.
The current density then was 100 mA/cm². The porous
5 structure formation rate then was 8.4 μ m/min., and
the P-type (100) Si substrate of a thickness of 200 μ
was rendered porous in its entirety for 24 minutes.

 According to MBE (molecular beam epitaxy)
method, an Si epitaxial layer of 0.5 μ was grown at a
10 lower temperature on the P-type[?] (100) porous Si
substrate. The conditions for deposition are as
follows;

temperature:	700 °C
pressure:	1×10^{-9} Torr
15 growth rate:	0.1 nm/sec.

 Subsequently, a substrate of fused silica
glass processed with optical polishing was bonded
onto the surface of the epitaxial layer, and both of
the substrates were strongly bonded together by
20 heating at 800 °C for 0.5 hour in oxygen atmosphere.

 According to plasma CVD method, Si₃N₄ was
deposited to 0.1 μ m, thereby coating the bonded two
substrates. Thereafter, only the nitride membrane
on the porous substrate was removed by reactive ion
25 etching. Then, the bonded substrates were selectively
etched with a mixed solution of 49 % hydrofluoric acid,
alcohol and aqueous hydrogen peroxide solution





1 (10:6:50), without stirring. In 65 minutes, only the
single-crystal Si layer remained without etching,
while the porous Si substrate was selectively etched
with the single-crystal Si as a material for etching
5 stopper and completely removed.

The etching rate of the non-porous Si single
crystal with the etching solution was extremely low,
such as approximately slightly less than 40 angstroms
even 65 minutes later, so that the selective ratio of
10 the etching rate of the porous layer to that of the
non-porous Si single-crystal was as large as 10^5 or
more. The etched amount in the non-porous layer
(several tens angstroms) is a practically negligible
decrease in membrane thickness. That is, the Si
15 substrate of a thickness of 200 μ , rendered porous,
was removed, and after the removal of the Si_3N_4 layer,
a single-crystal Si layer of a thickness of 0.5 μm was
formed on the substrate of the silica glass.

As a result of observation of the section
20 under a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced in
the Si layer and that excellent crystallinity was
maintained.

Examples 135 to 148

25 The same procedure as in Examples 42 to 55
was effected, replacing the etching solution in Examples
42 to 55 with that in Example 134. In any of the

- 1 present Examples, consequently, a single-crystal Si
layer was formed with extremely less crystal defect
on insulating materials.

Example 149

- 5 A N-type Si layer of 1 μ was formed on the
surface of a P-type (100) Si substrate of a thickness
of 200 μ , by ion implantation of proton. The
implanted amount of H^+ was 5×10^{15} ions/cm².

- The substrate was anodized in 50 % HF solution.
10 The current density then was 100 mA/cm². The porous
structure formation rate then was 8.4 μ m/min., and the
P-type (100) Si substrate of a thickness of 200 μ was
rendered porous in its entirety for 24 minutes.
According to the present anodization as has been
15 described above, only the P-type (100) Si substrate
was rendered porous, but no change was observed in
the N-type Si layer.

- Subsequently, a second Si substrate on the
surface of which was formed an oxidized layer of
20 5000 angstroms was bonded to the surface of the N-
type Si layer. By heating in oxygen atmosphere at
800 °C for 0.5 hour, both of the substrates were
strongly bonded together.

- Then, the bonded substrates were selectively
25 etched with a mixed solution of 49 % hydrofluoric
acid, alcohol and aqueous 30 % hydrogen peroxide
solution (10:6:50) without stirring. In 65 minutes,





1 only the single-crystal Si layer remained without
etching, while the porous Si substrate was selectively
etched with the single-crystal Si as a material for
etching stopper, and then completely removed.

5 The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
such as 50 angstroms or less even 65 minutes later, so
that the selective ratio of the etching rate of the
porous layer to that of the non-porous Si single-
10 crystal was as large as 10^5 or more. The etched
amount in the non-porous layer (several tens angstroms)
is a practically negligible decrease in membrane
thickness. That is, the Si substrate of a thickness
of 200 μ , rendered porous, was removed, and a single-
15 crystal Si layer of a thickness of 1.0 μm was formed
on the SiO_2 layer.

As a result of observation of the section
under a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced
20 in the Si layer and that excellent crystallinity was
maintained.

Examples 150 to 164

The same procedure as in Examples 57 to 71 was
effected, replacing the etching solution in Examples
25 57 to 71 with that in Example 134. In any of the
present Examples, consequently, a single-crystal Si
layer was formed with extremely less crystal defect



1 on insulating materials.

Example 165

A P-type (100) single-crystal Si substrate of a thickness of 200 μ was anodized in 50 % HF solution.

5 The current density then was 100 mA/cm². The porous structure formation rate then was 8.4 μ m/min., and the P-type (100) Si substrate of a thickness of 200 μ was rendered porous in its entirety for 24 minutes.

According to MBE (molecular beam epitaxy) method,
10 an Si epitaxial layer of 0.5 μ was grown at a lower temperature on the P-type (100) porous Si substrate. The conditions for deposition are as follows;

temperature:	700 °C
pressure:	1×10^{-9} Torr
15 growth rate:	0.1 nm/sec.

Subsequently, a substrate of fused silica glass processed with optical polishing was bonded onto the surface of the epitaxial layer, and both of the substrates were strongly bonded together by heating
20 at 800 °C for 0.5 hour in oxygen atmosphere.

According to plasma CVD method, Si₃N₄ was deposited to 0.1 μ m, thereby coating the bonded two substrates. Thereafter, only the nitride membrane on the porous substrate was removed by reactive ion etching.
25 Then, the bonded substrates were selectively etched, under stirring, with buffered hydrofluoric acid. In 258 minutes, only the single-crystal Si layer remained

1 without etching, while the porous Si substrate was
selectively etched with the single-crystal Si as a
material for etching stopper and then completely
removed.

5 The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
such as 100 angstroms or less even 258 minutes later,
so that the selective ratio of the etching rate of the
porous layer to that of the non-porous Si single-
10 crystal was as large as 10^5 or more. The etched
amount in the non-porous layer (several tens angstroms)
is a practically negligible decrease in membrane
thickness. That is, the Si substrate of a thickness
of 200 μ , rendered porous, was removed, and after the
15 removal of the Si_3N_4 layer, a single-crystal Si layer
of a thickness of 0.5 μm was formed on the substrate of
the glass.

As a result of observation of the section
under a transmission-type electron microscope, it was
20 confirmed that no new crystal defect was introduced in
the Si layer and that excellent crystallinity was
maintained.

Examples 166 to 180

The same procedure as in Examples 42 to 56
25 was effected, replacing the etching solution in
Examples 42 to 56 with that in Example 165. In any
of the present Examples, consequently, a single-crystal





- 1 Si layer was formed with extremely less crystal
defect on insulating materials.

Example 181

- 5 A P-type (100) single-crystal Si substrate of
a thickness of 200 μ was anodized in 50 % HF solution.
The current density then was 100 mA/cm². The porous
structure formation rate then was about 8.4 μ m/min.,
and the P-type (100) Si substrate of a thickness of
200 μ was rendered porous in its entirety for 24
10 minutes.

- According to MBE (molecular beam epitaxy)
method, an Si epitaxial layer of 0.5 μ was grown at a
lower temperature on the P-type (100) porous Si
substrate. The conditions for deposition are as
15 follows;

temperature:	700 °C
pressure:	1×10^{-9} Torr
growth rate:	0.1 nm/sec.

- Subsequently, the surface of the epitaxial
20 layer was thermally oxidized in a depth of 50 nm.
A substrate of fused silica glass processed with
optical polishing was bonded onto the thermally
oxidized membrane, and both of the substrates were
strongly bonded together by heating at 800 °C for 0.5
25 hour in oxygen atmosphere.

According to low pressure CVD method, Si₃N₄ was
deposited to 0.1 μ m, thereby coating the bonded two

1 substrates. Thereafter, only the nitride membrane on
the porous substrate was removed by reactive ion etching.

Then, the bonded substrates were immersed in
buffered hydrofluoric acid, and stirred. In 258
5 minutes, only the single-crystal Si layer remained
without etching, while the porous Si substrates was
selectively etched with the single-crystal Si as a
material for etching stopper and then completely removed.

The etching rate of the non-porous Si single-
10 crystal with the etching solution was extremely low,
such as 100 angstroms or less even 258 minutes later,
so that the selective ratio of the etching rate of the
porous layer to that of the non-porous Si single-
crystal was as large as 10^5 or more. The etched amount
15 in the non-porous layer (several tens angstroms) is a
practically negligible decrease in membrane thickness.
That is, the Si substrate of a thickness of 200 μ ,
rendered porous, was removed, and after the removal of
the Si_3N_4 layer, a single-crystal Si layer of a
20 thickness of 0.5 μm on the substrate of the silica
glass was formed.

As a result of observation of the section under
a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced
25 in the Si layer and that excellent crystallinity was
maintained.



1 Examples 182 to 195

The same procedure as in Examples 58 to 71 was effected, replacing the etching solution in Examples 58 to 71 with that in Example 165. In any of the present Examples, consequently, a single-crystal Si layer was formed with extremely less crystal defect on insulating materials.

Example 196

A P-type (100) single-crystal Si substrate of a thickness of 200 μ was anodized in 50 % HF solution. The current density then was 100 mA/cm². The porous structure formation rate then was 8.4 μ m/min., and the P-type (100) Si substrate of a thickness of 200 μ was rendered porous in its entirety for 24 minutes.

15 According to MBE (molecular beam epitaxy) method, an Si epitaxial layer of 0.5 μ was grown at a lower temperature on the P-type (100) porous Si substrate. The conditions for deposition are as follows;

temperature:	700 °C
20 pressure:	1×10^{-9} Torr
growth rate:	0.1 nm/sec.

Subsequently, a substrate of fused silica glass processed with optical polishing was bonded onto the surface of the epitaxial layer, and both of the substrates were strongly bonded together by heating at 800 °C for 0.5 hour in oxygen atmosphere.

According to plasma CVD method, Si₃N₄ was



1 deposited to 0.1 μm , thereby coating the bonded two
substrates. Thereafter, only the nitride membrane on
the porous substrate was removed by reactive ion
etching. Then, the bonded substrates were selectively
5 etched in a mixed solution of buffered hydrofluoric
acid and alcohol (10:1) without stirring. In 275
minutes, only the single-crystal Si layer remained
without etching, while the porous Si substrate was
selectively etched with the single-crystal Si as a
10 material for etching stopper and completely removed.

The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
such as 100 angstroms or less even 275 minutes later,
so that the selective ratio of the etching rate of the
15 porous layer to that of the non-porous Si single-
crystal was as large as 10^5 or more. The etched
amount in the non-porous layer (several tens angstroms)
is a practically negligible decrease in membrane
thickness. That is, the Si substrate of a thickness
20 of 200 μ , rendered porous, was removed, and after the
removal of the Si_3N_4 layer, a single-crystal Si layer
of a thickness of 0.5 μm was formed on the substrate
of the glass.

As a result of observation of the section under
25 a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced
in the Si layer and that excellent crystallinity was
maintained.

1 Examples 197 to 210

 The same procedure as in Examples 42 to 55 was effected, replacing the etching solution in Examples 42 to 55 with that in Example 196. In any of the present Examples, consequently, a single-crystal Si layer was formed with extremely less crystal defect on insulating materials.

Example 211

 A N-type Si layer of thickness of 1 μ was formed on the surface of a P-type Si layer of 200 μ in thickness, by ion implantation of proton. The implanted amount of H^+ was 5×10^{15} ions/cm².

 The substrate was anodized in 50 % HF solution. The current density then was 100 mA/cm². The porous structure formation rate then was 8.4 μ m/min., and the N-type (100) Si substrate of a thickness of 200 μ was rendered porous in its entirety for 24 minutes. According to the present anodization as has been described above, only the P-type (100) Si substrate was rendered porous, but no change was observed in the N-type Si layer.

 Subsequently, a second Si substrate on the surface of which was formed an oxidized layer of 5000 angstroms was bonded to the surface of the N-type Si layer. By heating in oxygen atmosphere at 800 °C for 0.5 hour, both of the substrates were strongly bonded together.



1 Then, the bonded substrates were selectively
etched with a mixed solution of buffered hydrofluoric
acid (HF:4.46 %, NH_4F :36.2 %) and ethyl alcohol
(10:1), without stirring. In 275 minutes, only the
5 single-crystal Si layer remained without etching,
while the porous Si substrate was selectively etched
with the single-crystal Si as a material for etching
stopper and then completely removed.

 The etching rate of the non-porous Si single-
10 crystal with the etching solution was extremely low,
such as approximately slightly less than 40 angstroms
even 275 minutes later, so that the selective ratio of
the etching rate of the porous layer to that of the
non-porous Si single-crystal was as large as 10^5 or
15 more. The etched amount in the non-porous layer
(several tens angstroms) is a practically negligible
decrease in membrane thickness. That is, the Si
substrate of a thickness of 200 μ , rendered porous,
was removed, and a single-crystal Si layer of a
20 thickness of 1.0 μm was formed on the SiO_2 layer.

 As a result of observation of the section
under a transmission-type electron microscope, it was
confirmed that no new crystal defect was introduced
in the Si layer and that excellent crystallinity was
25 maintained.



1 Examples 212 to 226

The same procedure as in Examples 57 to 71 was effected, replacing the etching solution in Examples 57 to 71 with that in Example 196. In any of the present Examples, consequently, a single-crystal Si layer was formed with extremely less crystal defect on insulating materials.

5 Example 227

A P-type (100) single-crystal Si substrate of a thickness of 200 μ was anodized in 50% HF solution. The current density then was 100 mA/cm². The porous structure formation rate then was 8.4 μ m/min., and the P-type (100) Si substrate of a thickness of 200 μ was rendered porous in its entirety for 24 minutes.

15 According to MBE (molecular beam epitaxy) method, an Si epitaxial layer of 0.5 μ was grown at a lower temperature on the P-type (100) porous Si substrate. The conditions for deposition are as follows;

20 temperature: 700 °C
pressure: 1 x 10⁻⁹ Torr
growth rate: 0.1 nm/sec.

Subsequently, a substrate of fused silica glass processed with optical polishing was bonded onto the surface of the epitaxial layer, and both of the substrates were strongly bonded together by heating at 800 °C for 0.5 hour in oxygen atmosphere.

1 According to plasma CVD method, Si_3N_4 was
deposited to $0.1\text{ }\mu\text{m}$, thereby coating the bonded two
substrates. Thereafter, only the nitride membrane on
the porous substrate was removed by reactive ion
5 etching. Then, the bonded substrates were selectively
etched in a mixed solution of buffered hydrofluoric
acid and aqueous hydrogen peroxide solution (1:5) with
stirring. In 190 minutes, only the single-crystal Si
layer remained without etching, while the porous Si
10 substrate was selectively etched with the single-
crystal Si as a material for etching stopper, and
completely removed.

The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
15 such as 50 angstroms or less even 190 minutes later,
so that the selective ratio of the etching rate of
the porous layer to that of the non-porous Si single-
crystal was as large as 10^5 or more. The etched amount
in the non-porous layer (several tens angstroms) is
20 a practically negligible decrease in membrane thickness.

That is, the Si substrate of a thickness of $200\text{ }\mu$,
rendered porous, was removed, and after the removal
of the Si_3N_4 layer, a single-crystal Si layer of a
thickness of $0.5\text{ }\mu\text{m}$ was formed on the substrate of the
25 silica glass.

As a result of observation of the section under
a transmission-type electron microscope, it was confirmed



- 1 that no new crystal defect was introduced in the Si
layer and that excellent crystallinity was maintained.

Examples 228 to 242

- The same procedure as in Examples 42 to 56 was
5 effected, replacing the etching solution in Examples
42 to 56 with that in Example 227. In any of the
present Examples, consequently, a single-crystal Si
layer was formed with extremely less crystal defect
on insulating materials.

10 Example 243

- A P-type (100) single-crystal Si substrate
of a thickness of 200 μ was anodized in 50% HF solution.
The current density then was 100 mA/cm². The porous
structure formation rate then was about 8.4 μ m/min.,
15 and the P-type (100) Si substrate of a thickness of
200 μ was rendered porous in its entirety for 24
minutes.

- According to MBE (molecular beam epitaxy)
method, an Si epitaxial layer of 0.5 μ was grown at
20 a lower temperature on the P-type (100) porous Si
substrate. The conditions for deposition are as follows;
temperature: 700 °C
pressure: 1 x 10⁻⁹ Torr
growth rate: 0.1 nm/sec.

- 25 subsequently, the surface of the epitaxial
layer was thermally oxidized in a depth of 50 nm. A
substrate of fused silica glass processed with optical



1 polishing was bonded onto the thermally oxidized
membrane, and both of the substrates were strongly
bonded together by heating at 800 °C for 0.5 hour in
oxygen atmosphere.

5 According to low pressure CVD method, Si_3N_4
was deposited to 0.1 μm , thereby coating the bonded
two substrates. Thereafter, only the nitride membrane
on the porous substrate was removed by reactive ion
etching.

10 Then, the bonded substrates were immersed in
a mixed solution of buffered hydrofluoric acid and
aqueous hydrogen peroxide solution (1:5), and stirred.
In 190 minutes, only the single-crystal Si layer
remained without etching, while the porous Si
15 substrate was selectively etched with the single-
crystal Si as a material for etching stopper and then
completely removed.

 The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
20 such as 70 angstroms or less even 190 minutes later,
so that the selective ratio of the etching rate of
the porous layer to that of the non-porous Si single-
crystal was as large as 10^5 or more. The etched amount
in the non-porous layer (several tens angstroms) is a
25 practically negligible decrease in membrane thickness.
That is, the Si substrate of a thickness of 200 μ ,
rendered porous, was removed, and after the removal of



- 1 the Si_3N_4 layer, a single-crystal Si layer of a
thickness of $0.5 \mu\text{m}$ was formed on the substrate of
the silica glass.

- As a result of observation of the section under
5 a transmission-type electron microscope, it was confirmed
that no new crystal defect was introduced in the Si
layer and that excellent crystallinity was maintained.

Examples 244 to 257

- The same procedure as in Examples 58 to 71
10 was effected, replacing the etching solution in
Examples 58 to 71 with that in Example 243. In any
of the present Examples, consequently, a single-
crystal Si layer was formed with extremely less
crystal defect on insulating materials.

15 Example 258

- A P-type (100) single-crystal Si substrate of
a thickness of 200μ was anodized in 50 % HF solution.
The current density then was 100 mA/cm^2 . The porous
structure formation rate then was $8.4 \mu\text{m/min.}$, and the
20 P-type (100) Si substrate of a thickness of 200μ was
rendered porous in its entirety for 24 minutes.

- According to MBE (molecular beam epitaxy)
method, an Si epitaxial layer of 0.5μ was grown at a
lower temperature on the P-type (100) porous Si substrate.
25 The conditions for deposition are as follows;

temperature: 700 °C
pressure: 1×10^{-9} Torr

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1 growth rate: 0.1 nm/sec.

Subsequently, a substrate of fused silica glass processed with optical polishing was bonded onto the surface of the epitaxial layer, and both of the
5 substrates were strongly bonded together by heating at 800 °C for 0.5 hour in oxygen atmosphere.

According to plasma CVD method, Si_3N_4 was deposited to 0.1 μm , thereby coating the bonded two substrates. Thereafter, only the nitride membrane
10 on the porous substrate was removed by reactive ion etching. Then, the bonded substrates were selectively etched in a mixed solution of buffered hydrofluoric acid, alcohol and aqueous hydrogen peroxide solution (10:6:50) without stirring. In 205 minutes, only
15 the single-crystal Si layer remained without etching, while the porous Si substrate was selectively etched with the single-crystal Si as a material for etching stopper and then completely removed.

The etching rate of the non-porous Si single-crystal with the etching solution was extremely low,
20 such as approximately slightly less than 40 angstroms even 205 minutes later, so that the selective ratio of the etching rate of the porous layer to that of the non-porous Si single-crystal was as large as 10^5
25 or more. The etched amount in the non-porous layer (several tens angstroms) is a practically negligible decrease in membrane thickness. That is, the Si



1 substrate of a thickness of 200 μ , rendered porous, was removed, and after the removal of the Si_3N_4 layer, a single-crystal Si layer of a thickness of 0.5 μm was formed on the substrate of the silica glass.

5 As a result of observation of the section under a transmission-type electron microscope, it was confirmed that no new crystal defect was introduced in the Si layer and that excellent crystallinity was maintained.

Examples 259 to 272

10 The same procedure as in Examples 42 to 55 was effected, replacing the etching solution in Examples 42 to 55 with that in Example 258. In any of the present Examples, consequently, a single-crystal Si layer was formed with extremely less crystal defect
15 on insulating materials.

Example 273

A N-type Si layer of thickness of 1 μ was formed on the surface of a P-type (100) Si substrate of thickness of 200 μ , by ion implantation of proton. The implanted
20 amount of H^+ was 5×10^{15} ions/ cm^2 .

The substrate was anodized in 50 % HF solution. The current density then was 100 mA/cm^2 . The porous structure formation rate then was 8.4 $\mu\text{m}/\text{min.}$, and the P-type (100) Si substrate of a thickness of 200 μ
25 was rendered porous in its entirety for 24 minutes. According to the present anodization as has been described above, only the P-type (100) Si substrate

1 was rendered porous, but no change was observed in the
N-type Si layer.

Subsequently, a second Si substrate on the
surface of which was formed an oxidized layer of 5000
5 angstroms was bonded to the surface of the N-type Si
layer. By heating in oxygen atmosphere at 800 °C for
0.5 hour, both of the substrates were strongly bonded
together.

Then, the bonded substrates were selectively
10 etched with a mixed solution of buffered hydrofluoric
acid (HF:4.46 %, NH_4F :36.2%), ethyl alcohol and 30%
aqueous hydrogen peroxide solution (10:6:50), without
stirring. In 180 minutes, only the single-crystal Si
layer remained without etching, while the porous Si
15 substrate was selectively etched with the single-
crystal Si as a material for etching stopper and then
completely removed.

The etching rate of the non-porous Si single-
crystal with the etching solution was extremely low,
20 such as approximately slightly less than 40 angstroms
even 180 minutes later, so that the selective ratio of
the etching rate of the porous layer to that of the
non-porous Si single-crystal was as large as 10^5 or
more. The etched amount in the non-porous layer
25 (several tens angstroms) is a practically negligible
decrease in membrane thickness. That is, the Si
substrate of a thickness of 200 μ , rendered porous, was



1 removed, and a single-crystal Si layer of a thickness
of 1.0 μm was formed on the SiO_2 layer.

As a result of observation of the section under
a transmission-type electron microscope, it was
5 confirmed that no new crystal defect was introduced
in the Si layer and that excellent crystallinity was
maintained.

Examples 274 to 288

The same procedure as in Examples 57 to 71
10 was effected, replacing the etching solution in
Examples 57 to 71 with that in Example 273. In any
of the present Examples, consequently, a single-crystal
Si layer was formed with extremely less crystal defect
on insulating materials.

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1 WHAT IS CLAIMED IS:

1. A chemical etching solution for porous Si comprising hydrofluoric acid as etchant.

5

2. A chemical etching solution for porous Si comprising a mixture of hydrofluoric acid and an alcohol as etchant.

10

3. A chemical etching solution for porous Si comprising a mixture of hydrofluoric acid and hydrogen peroxide as etchant.

15

4. A chemical etching solution for porous Si comprising a mixture of hydrofluoric acid, an alcohol and hydrogen peroxide as etchant.

20

5. A chemical etching solution for porous Si comprising buffered hydrofluoric acid as etchant.

25

6. A chemical etching solution for porous Si comprising a mixture of buffered hydrofluoric acid and an alcohol as etchant.

7. A chemical etching solution for porous Si comprising a mixture of buffered hydrofluoric acid and





1 hydrogen peroxide as etchant.

8. A chemical etching solution for porous Si
comprising a mixture of buffered hydrofluoric acid, an
5 alcohol and hydrogen peroxide as etchant.

9. A chemical etching method for porous Si,
which comprises using hydrofluoric acid as etchant.

10 10. A chemical etching method for porous Si,
which comprises using a mixture of hydrofluoric acid
and an alcohol as etchant.

11. A chemical etching method for porous Si,
15 which comprises using a mixture of hydrofluoric acid
and hydrogen peroxide as etchant.

12. A chemical etching method for porous Si,
which comprises using a mixture of hydrofluoric acid,
20 an alcohol and hydrogen peroxide as etchant.

13. A chemical etching method for porous Si,
which comprises using buffered hydrofluoric acid as
etchant.

25

14. A chemical etching method for porous Si,





1 which comprises using a mixture of buffered
hydrofluoric acid and an alcohol as etchant.

15. A chemical etching method for porous Si,
5 which comprises using a mixture of buffered
hydrofluoric acid and hydrogen peroxide as etchant.

16. A chemical etching method for porous Si,
which comprises using a mixture of buffered
10 hydrofluoric acid, an alcohol and hydrogen peroxide as
etchant.

17. A method for preparing a semiconductor
member, which comprises:

15 forming a substrate having a non-porous
silicon monocrystalline layer and a porous silicon
layer;

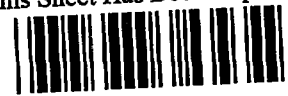
bonding another substrate having a surface
made of an insulating material to the surface of said
20 monocrystalline layer; and

etching to remove said porous silicon layer by
immersing in hydrofluoric acid.

18. A method for preparing a semiconductor
25 member, which comprises:

forming a substrate having a non-porous





1 silicon monocrystalline layer and a porous silicon layer;

bonding another substrate having a surface made of an insulating material to the surface of said

5 monocrystalline layer; and

etching to remove said porous silicon layer by immersing in a mixture of hydrofluoric acid and an alcohol.

10 19. A method for preparing a semiconductor member, which comprises:

forming a substrate having a non-porous silicon monocrystalline layer and a porous silicon layer;

15 bonding another substrate having a surface of an insulating material to the surface of said monocrystalline layer; and

etching to remove said porous silicon layer by immersing in a mixture of hydrofluoric acid and
20 hydrogen peroxide.

20. A method for preparing a semiconductor member, which comprises:

forming a substrate having a non-porous
25 silicon monocrystalline layer and a porous silicon layer;





- 1 bonding another substrate having a surface
made of an insulating material to the surface of said
monocrystalline layer; and
- etching to remove said porous silicon layer by
- 5 immersing in a mixture of hydrofluoric acid, an
alcohol and hydrogen peroxide.

21. A method for preparing a semiconductor
member, which comprises:

- 10 forming a substrate having a non-porous
silicon monocrystalline layer and a porous silicon
layer;

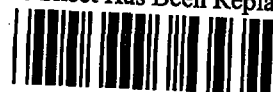
- bonding another substrate having a surface
made of an insulating material to the surface of said
- 15 monocrystalline layer; and
- etching to remove said porous silicon layer by
immersing in buffered hydrofluoric acid.

22. A method for preparing a semiconductor
20 member, which comprises:

- forming a substrate having a non-porous
silicon monocrystalline layer and a porous silicon
layer;

- bonding another substrate having a surface
- 25 made of an insulating material to the surface of said
monocrystalline layer; and





1 etching to remove said porous silicon layer by
immersing in a mixture of buffered hydrofluoric acid
and an alcohol.

5 23. A method for preparing a semiconductor
member, which comprises:

forming a substrate having a non-porous
silicon monocrystalline layer and a porous silicon
layer;

10 bonding another substrate having a surface
made of an insulating material to the surface of said
monocrystalline layer; and

etching to remove said porous silicon layer by
immersing in a mixture of buffered hydrofluoric acid
15 and hydrogen peroxide.

24. A method for preparing a semiconductor
member, which comprises:

forming a substrate having a non-porous
20 silicon monocrystalline layer and a porous silicon
layer;

bonding another substrate having a surface
made of an insulating material to the surface of said
monocrystalline layer; and

25 etching to remove said porous silicon layer by
immersing in a mixture of buffered hydrofluoric acid,





1 an alcohol and hydrogen peroxide.

25. A method for preparing a semiconductor member, which comprises the steps of:

5 making a silicon substrate porous;

forming a non-porous silicon monocrystalline layer on said silicon substrate made porous;

bonding a light-transmissive glass substrate to the surface of said non-porous silicon monocrystalline layer; and

10 selectively etching porous silicon by chemically etching to remove porous silicon by immersing said silicon substrate made porous in hydrofluoric acid.

15

26. A method for preparing a semiconductor member, which comprises the steps of:

making a silicon substrate porous;

forming a non-porous silicon monocrystalline layer on the silicon substrate made porous;

20 bonding another silicon substrate having an insulating layer on the surface thereof to the surface of said non-porous silicon monocrystalline layer; and

selectively etching porous silicon by chemically etching to remove porous silicon by immersing said silicon substrate made porous in





1 hydrofluoric acid.

27. A method for preparing a semiconductor member, which comprises the steps of:

5 making a silicon substrate porous;

forming a non-porous silicon monocrystalline layer on said silicon substrate made porous;

forming an oxide layer on the surface of said non-porous silicon monocrystalline layer;

10 bonding a light-transmissive substrate to the surface of said oxide layer; and

chemically etching to remove said silicon substrate made porous by immersing in hydrofluoric acid after coating the surfaces other than the surface of said silicon substrate made porous with a
15 protecting material.

28. A method for preparing a semiconductor member, which comprises the steps of:

20 making a silicon substrate porous;

forming a non-porous silicon monocrystalline layer on said silicon substrate made porous;

forming an oxide layer on the surface of said non-porous silicon monocrystalline layer;

25 bonding another silicon substrate having an insulating material on the surface thereof to the





1 surface of said oxide layer on said non-porous silicon
monocrystalline layer; and

chemically etching to remove said silicon
substrate made porous by immersing in hydrofluoric
5 acid.

29. A method for preparing a semiconductor
member, which comprises the steps of:

making a silicon substrate porous;
10 forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;

bonding a light-transmissive glass substrate
to the surface of said non-porous silicon
monocrystalline layer; and

15 selectively etching porous silicon by
chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
mixture of hydrofluoric acid and an alcohol.

20 30. A method for preparing a semiconductor
member, which comprises the steps of:

making a silicon substrate porous;
forming a non-porous silicon monocrystalline
layer on the silicon substrate made porous;

25 bonding another silicon substrate having an
insulating layer on the surface thereof to the surface





1 of said non-porous silicon monocrystalline layer; and
selectively etching porous silicon by
chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
5 mixture of hydrofluoric acid and an alcohol.

31. A method for preparing a semiconductor member, which comprises the steps of:
making a silicon substrate porous;
10 forming a non-porous silicon monocrystalline layer on said silicon substrate made porous;
forming an oxide layer on the surface of said non-porous silicon monocrystalline layer;
bonding a light-transmissive substrate to the
15 surface of said oxide layer; and
chemically etching to remove said silicon substrate made porous by immersing in a mixture of hydrofluoric acid and an alcohol after coating the surfaces other than the surface of said silicon
20 substrate made porous with a protecting material.

32. A method for preparing a semiconductor member, which comprises the steps of:
making a silicon substrate porous;
25 forming a non-porous silicon monocrystalline layer on said silicon substrate made porous;





1 forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
 bonding another silicon substrate having an
insulating material on the surface thereof to the
5 surface of said oxide layer on said non-porous silicon
monocrystalline layer; and
 chemically etching to remove said silicon
substrate made porous by immersing in a mixture of
hydrofluoric acid and an alcohol.

10

33. A method for preparing a semiconductor
member, which comprises the steps of:
 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
15 layer on said silicon substrate made porous;
 bonding a light-transmissive glass substrate
to the surface of said non-porous silicon
monocrystalline layer; and
 selectively etching porous silicon by
20 chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
mixture of hydrofluoric acid and hydrogen peroxide.

34. A method for preparing a semiconductor
25 member, which comprises the steps of:
 making a silicon substrate porous;





1 forming a non-porous silicon monocrystalline
layer on the silicon substrate made porous;
bonding another silicon substrate having an
insulating layer on the surface thereof to the surface
5 of said non-porous silicon monocrystalline layer; and
selectively etching porous silicon by
chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
mixture of hydrofluoric acid and hydrogen peroxide.

10

35. A method for preparing a semiconductor
member, which comprises the steps of:
making a silicon substrate porous;
forming a non-porous silicon monocrystalline
15 layer on said silicon substrate made porous;
forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
bonding a light-transmissive substrate to the
surface of said oxide layer; and
20 chemically etching to remove said silicon
substrate made porous by immersing in a mixture
comprising of hydrofluoric acid and hydrogen peroxide
after coating the surfaces other than the surface of
said silicon substrate made porous with a protecting
25 material.





1 36. A method for preparing a semiconductor
member, which comprises the steps of:
 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
5 layer on said silicon substrate made porous;
 forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
 bonding another silicon substrate having an
insulating material on the surface thereof to the
10 surface of said oxide layer on said non-porous silicon
monocrystalline layer; and
 chemically etching to remove said silicon
substrate made porous by immersing in a mixture of
hydrofluoric acid and hydrogen peroxide.

15

 37. A method for preparing a semiconductor
member, which comprises the steps of:
 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
20 layer on said silicon substrate made porous;
 bonding a light-transmissive glass substrate
to the surface of said non-porous silicon
monocrystalline layer; and
 selectively etching porous silicon by
25 chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a





1 mixture of hydrofluoric acid, an alcohol and hydrogen
peroxide.

38. A method for preparing a semiconductor
5 member, which comprises the steps of:
making a silicon substrate porous;
forming a non-porous silicon monocrystalline
layer on the silicon substrate made porous;
bonding another silicon substrate having an
10 insulating layer on the surface thereof to the surface
of said non-porous silicon monocrystalline layer; and
selectively etching porous silicon by
chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
15 mixture of hydrofluoric acid, an alcohol and hydrogen
peroxide.

39. A method for preparing a semiconductor
member, which comprises the steps of:
20 making a silicon substrate porous;
forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;
forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
25 bonding a light-transmissive substrate to the
surface of said oxide layer; and





1 chemically etching to remove said silicon
substrate made porous by immersing in a mixture of
hydrofluoric acid, an alcohol and hydrogen peroxide
after coating the surfaces other than the surface of
5 said silicon substrate made porous with a protecting
material.

40. A method for preparing a semiconductor
member, which comprises the steps of:

10 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;
 forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
15 bonding another silicon substrate having an
insulating material on the surface thereof to the
surface of said oxide layer on said non-porous silicon
monocrystalline layer; and
 chemically etching to remove said silicon
20 substrate made porous by immersing in a mixture of
hydrofluoric acid, an alcohol and hydrogen peroxide.

41. A method for preparing a semiconductor
member, which comprises the steps of:

25 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline

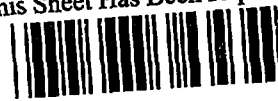




- 1 layer on said silicon substrate made porous;
bonding a light-transmissive glass substrate
to the surface of said non-porous silicon
monocrystalline layer; and
- 5 selectively etching porous silicon by
chemically etching to remove porous silicon by
immersing said silicon substrate made porous in
buffered hydrofluoric acid.
- 10 42. A method for preparing a semiconductor
member, which comprises the steps of:
making a silicon substrate porous;
forming a non-porous silicon monocrystalline
layer on the silicon substrate made porous;
- 15 bonding another silicon substrate having an
insulating layer on the surface thereof to the surface
of said non-porous silicon monocrystalline layer; and
selectively etching porous silicon by
chemically etching to remove porous silicon by
- 20 immersing said silicon substrate made porous in
buffered hydrofluoric acid.

43. A method for preparing a semiconductor
member, which comprises the steps of:
- 25 making a silicon substrate porous;
forming a non-porous silicon monocrystalline





1 layer on said silicon substrate made porous;
forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
bonding a light-transmissive substrate to the
5 surface of said oxide layer; and
chemically etching to remove said silicon
substrate made porous by immersing in buffered
hydrofluoric acid after coating the surfaces other
than the surface of said silicon substrate made porous
10 with a protecting material.

44. A method for preparing a semiconductor
member, which comprises the steps of:
making a silicon substrate porous;
15 forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;
forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
bonding another silicon substrate having an
20 insulating material on the surface thereof to the
surface of said oxide layer on said non-porous silicon
monocrystalline layer; and
chemically etching to remove said silicon
substrate made porous by immersing in buffered
25 hydrofluoric acid.





1 45. A method for preparing a semiconductor
member, which comprises the steps of:
 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
5 layer on said silicon substrate made porous;
 bonding a light-transmissive glass substrate
to the surface of said non-porous silicon
monocrystalline layer; and
 selectively etching porous silicon by
10 chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
mixture of buffered hydrofluoric acid and an alcohol.

 46. A method for preparing a semiconductor
15 member, which comprises the steps of:
 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
layer on the silicon substrate made porous;
 bonding another silicon substrate having an
20 insulating layer on the surface thereof to the surface
of said non-porous silicon monocrystalline layer; and
 selectively etching porous silicon by
chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
25 mixture of buffered hydrofluoric acid and an alcohol.





1 47. A method for preparing a semiconductor
member, which comprises the steps of:
 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
5 layer on said silicon substrate made porous;
 forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
 bonding a light-transmissive substrate to the
surface of said oxide layer; and
10 chemically etching to remove said silicon
substrate made porous by immersing in a mixture of
buffered hydrofluoric acid and an alcohol after
coating the surfaces other than the surface of said
silicon substrate made porous with a protecting
15 material.

 48. A method for preparing a semiconductor
member, which comprises the steps of:
 making a silicon substrate porous;
20 forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;
 forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
 bonding another silicon substrate having an
25 insulating material on the surface thereof to the
surface of said oxide layer on said non-porous silicon





1 monocrystalline layer; and

chemically etching to remove said silicon substrate made porous by immersing in a mixture of buffered hydrofluoric acid and an alcohol.

5

49. A method for preparing a semiconductor member, which comprises the steps of:

making a silicon substrate porous;

forming a non-porous silicon monocrystalline layer on said silicon substrate made porous;

10 bonding a light-transmissive glass substrate to the surface of said non-porous silicon monocrystalline layer; and

selectively etching porous silicon by
15 chemically etching to remove porous silicon by immersing said silicon substrate made porous in a mixture of buffered hydrofluoric acid and hydrogen peroxide.

20 50. A method for preparing a semiconductor member, which comprises the steps of:

making a silicon substrate porous;

forming a non-porous silicon monocrystalline layer on the silicon substrate made porous;

25 bonding another silicon substrate having an insulating layer on the surface thereof to the surface





1 of said non-porous silicon monocrystalline layer; and
selectively etching porous silicon by
chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
5 mixture of buffered hydrofluoric acid and hydrogen
peroxide.

51. A method for preparing a semiconductor
member, which comprises the steps of:

10 making a silicon substrate porous;
forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;
forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
15 bonding a light-transmissive substrate to the
surface of said oxide layer; and
chemically etching to remove said silicon
substrate made porous by immersing in a mixture
comprising buffered hydrofluoric acid and hydrogen
20 peroxide after coating the surfaces other than the
surface of said silicon substrate made porous with a
protecting material.

52. A method for preparing a semiconductor
25 member, which comprises the steps of:
making a silicon substrate porous;





- 1 forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;
 forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
- 5 bonding another silicon substrate having an
insulating material on the surface thereof to the
surface of said oxide layer on said non-porous silicon
monocrystalline layer; and
 chemically etching to remove said silicon
10 substrate made porous by immersing in a mixture of
buffered hydrofluoric acid and hydrogen peroxide.

53. A method for preparing a semiconductor
member, which comprises the steps of:
- 15 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;
 bonding a light-transmissive glass substrate
to the surface of said non-porous silicon
20 monocrystalline layer; and
 selectively etching porous silicon by
chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
mixture of buffered hydrofluoric acid, an alcohol and
25 hydrogen peroxide.





1 54. A method for preparing a semiconductor
member, which comprises the steps of:
 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
5 layer on the silicon substrate made porous;
 bonding another silicon substrate having an
insulating layer on the surface thereof to the surface
of said non-porous silicon monocrystalline layer; and
 selectively etching porous silicon by
10 chemically etching to remove porous silicon by
immersing said silicon substrate made porous in a
mixture of buffered hydrofluoric acid, an alcohol and
hydrogen peroxide.

15 55. A method for preparing a semiconductor
member, which comprises the steps of:
 making a silicon substrate porous;
 forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;
20 forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;
 bonding a light-transmissive substrate to the
surface of said oxide layer; and
 chemically etching to remove said silicon
25 substrate made porous by immersing in a mixture of
buffered hydrofluoric acid, an alcohol and hydrogen



1 peroxide after coating the surfaces other than the
surface of said silicon substrate made porous with a
protecting material.

5 56. A method for preparing a semiconductor
member, which comprises the steps of:

making a silicon substrate porous;

forming a non-porous silicon monocrystalline
layer on said silicon substrate made porous;

10 forming an oxide layer on the surface of said
non-porous silicon monocrystalline layer;

bonding another silicon substrate having an
insulating material on the surface thereof to the
surface of said oxide layer on said non-porous silicon
15 monocrystalline layer; and

chemically etching to remove said silicon
substrate made porous by immersing in a mixture
comprising buffered hydrofluoric acid, an alcohol and
hydrogen peroxide.

20

This Sheet Has Been Replaced



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