The Director of the United States Patent and Trademark Office

Has received an application for a patent for a new and useful invention. The title and description of the invention are enclosed. The requirements of law have been complied with, and it has been determined that a patent on the invention shall be granted under the law.

Therefore, this

United States Patent

Grants to the person(s) having title to this patent the right to exclude others from making, using, offering for sale, or selling the invention throughout the United States of America or importing the invention into the United States of America for the term set forth below, subject to the payment of maintenance fees as provided by law.

If this application was filed prior to June 8, 1995, the term of this patent is the longer of seventeen years from the date of grant of this patent or twenty years from the earliest effective U.S. filing date of the application, subject to any statutory extension.

If this application was filed on or after June 8, 1995, the term of this patent is twenty years from the U.S. filing date, subject to any statutory extension. If the application contains a specific reference to an earlier filed application or applications under 35 U.S.C. 120, 121 or 365(c), the term of the patent is twenty years from the date on which the earliest application was filed, subject to any statutory extensions.

[Signature]
Director of the United States Patent and Trademark Office

[Signature]
The present invention discloses the doping of rare earth elements into porous silicon, resulting in enhancement of luminescence. The doping process involves a well-defined solution of electrolytes that controls the conductivity of the solution, and set values of constant voltages that selectively allow the desired rare earth elements being doped into porous silicon.

20 Claims, 1 Drawing Sheet
1

RARE EARTH DOPING OF POROUS SILICON

FIELD OF THE INVENTION

The present invention concerns the doping process of rare earth (RE) elements into porous silicon using a constant voltage electro-chemical method.

BACKGROUND OF THE INVENTION

Porous silicon is a light emitting material that can emit visible light. In its natural state, it is highly resistive, i.e., insulative, and its open structure allows doping of foreign element(s) into porous silicon. Although it has a strong luminescence, its spectrum is broad and therefore not suitable for potential light emitting device application. Doping can change the optical property of porous silicon, producing a narrower bandwidth luminescence spectrum and better color tuning over the visible band. There are several doping methods that can be used: co-deposition, ion-implantation, and electro-chemical deposition. The first method is difficult to achieve due to the incompatibility between the fabrication solution and the doping solution.

The second method (ion-implantation) can only be applied to a small area and implantation time is a function of doping depth. In fact, implantation time can be as long as 3 hours or more.

The third method, however, can be used to apply a large area in a shorter time and compatible existing semiconductor chip processing. With appropriate lithographic masking, light emitting or optoelectronic integrated devices can be produced on a wafer.

SUMMARY OF THE INVENTION

The present invention discloses the doping of rare earth elements into porous silicon, resulting in enhancement of luminescence. The doping is an electro-chemical process using constant voltage bias across the two electrodes in which the anode is porous silicon and the cathode is platinum. In the present invention, the doping process involves a well-defined solution of electrolytes that controls the conductivity of the solution, and sets values of constant voltages that selectively allow the desired rare earth being doped into porous silicon. There are two doping conditions and the end results are:

i) An enhancement of visible luminescence by at least on order of magnitude is obtained.

ii) IR emission at RE intra-transition wavelength is obtained.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic representation of the doping setup.

DETAILED DESCRIPTION OF THE INVENTION

Referring to FIG. 1, the source material for the doping process 1 is porous silicon 2 that can be fabricated by various methods. The porous silicon 2 can be prepared from both h-type and p-type silicon. The preferred method of preparation is anodization. Using this method the silicon serves as the cathode 3 and the preferred anode 4 is platinum. The cathode 3 and the anode 4 are each attached to connecting electrodes 5 and 6. An etching solution is preferably a mixture of hydrofluoric acid which is used undiluted or mixed with de-ionized water, and ethanol.
preparing said porous silicon by use of an etching solution;
preparing an electrolytic solution comprising nitrates of
the rare earth elements;
placing two electrodes in said electrolytic solution;
and passing a constant voltage potential between said two
electrodes in said electrolytic solution, wherein one of
said two electrodes is a cathode comprising the porous
silicon, and another of said two electrodes is an anode
comprising platinum.
13. The method for doping rare earth elements into porous
silicon according to claim 12, further comprising preparing
said porous silicon from the group selected from h-type
silicon and p-type silicon.
14. The method for doping rare earth elements into porous
silicon according to claim 12, wherein said etching solution
is hydrofluoric acid.
15. The method for doping rare earth elements into porous
silicon according to claim 12, wherein the concentration of
nitrates of rare earth in said electrolyte solution is 0.1—0.2
mol/L.
16. The method for doping rare earth elements into porous
silicon according to claim 15, wherein said electrolytic
solution further comprises acetonitrile.
17. The method for doping rare earth elements into porous
silicon according to claim 15, wherein said electrolytic
solution further comprises a basic electrolyte.
18. The method for doping rare earth elements into porous
silicon according to claim 12, further comprising passing a
constant voltage in the range of about 4 to about 5 volts
between the electrodes in the solution of electrolytes.
19. The method for doping rare earth elements into porous
silicon according to claim 18, further comprising having a
doping time of from about 10 minutes to about 60 minutes
for enhanced visible luminescence.
20. The method for doping rare earth elements into porous
silicon according to claim 19, further comprising having a
doping time of from about 30 minutes to about 120 minutes
for infrared emission.

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

Column 1,
Line 40, change "the anode is" to -- the cathode is --, and change "and the cathode is" to -- and the anode is --;
Line 47, change "on" to -- one --;
Line 61, change "h-type" to -- n-type --;
Line 63, change "as the cathode" to -- as the anode --, and change "the preferred anode" to -- the preferred cathode --.

Column 2,
Line 9, change "and for and about" to -- and four about --;
Line 24, change "h-type" to -- n-type --;

Column 3,
Line 14, change "h-type" to -- n-type --.

Signed and Sealed this
Seventh Day of May, 2002

Attest:

JAMES E. ROGAN
Director of the United States Patent and Trademark Office
It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Title Page, item [76]. Inventors.
Change “Kok Wei Cheah” to --Kok Wai Cheah--;
Change “Zhoongshan” to --Zhongshan--
Change “Wan Han Zheng” to --Wan Hua Zheng--

Title Page, item [57]. Abstract.
Amend the Abstract as follows:
The present invention discloses the doping of rare earth elements into porous silicon, resulting in enhancement of luminescence. The doping is an electro-chemical process using constant voltage bias across the two electrodes in which the [anode] cathode is porous silicon and the [cathode] anode is platinum. The doping process, involves a well-defined solution of electrolytes that controls the conductivity of the solution, and set values of constant voltages that selectively allow the desired rare earth elements being doped into porous silicon.

Column 1,
Line 40, change “the anode is” to -- the cathode is --, and change “and the cathode is” to -- and the anode is --;
Line 47, change “On” to -- one --;
Line 61, change “h-type” to -- n-type --;
Line 63, change “as the cathode” to -- as the anode --, and change “the preferred anode” to -- the preferred cathode --.

Column 2,
Line 9, change “and for and about” to-- and four about --;
Line 24, change “h-type” to -- n-type --;
UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,056,868
APPLICATION NO. : 09/083124
DATED : May 2, 2000
INVENTOR(S) : Kok Wai Cheah et al.

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

Column 3,
Line 14, change “h-type” to -- n-type --.

This certificate supersedes Certificate of Correction issued May 7, 2002.

Signed and Sealed this
Fourth Day of September, 2007

JON W. DUDAS
Director of the United States Patent and Trademark Office