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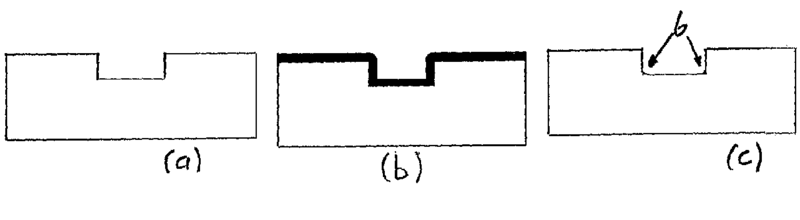
(54) Title: METHOD FOR MANUFACTURING A NANOSTRUCTURE



(57) Abstract: The invention relates to a method for fabricating a nanostructure, comprising the selection of a carrier for the material of the nanostructure during the formation of the same, wherein the carrier is provided with a shape that corresponds with the final shape of the nanostructure, and wherein the nanostructure material is applied on the carrier in a predetermined thickness and following the shape of the carrier. The material is removed substantially isotropically from the side facing away from the carrier, with the result that material that is not removed is left on a place or places determined by the shape of the carrier.

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Method for manufacturing a nanostructure

The invention relates to a method for fabricating a nanostructure, comprising the selection of a carrier for the material of the nanostructure during the formation of the same, wherein the carrier is provided with a shape that corresponds with the final shape of the nanostructure.

From WO 03/055793 a method is known for the fabrication of a nanostructure on at least one predetermined point of a carrier substrate. The known method comprises the selection of a suitable material for the substrate, applying on the substrate a template in a suitable shape that corresponds with the final shape of the nanostructure to be fabricated, after which a film of a nanostructure material having the desired dimensions is formed on the template. When this is done, the material of the applied film undergoes a recrystallisation with regard to a portion of the template, to form the desired nanostructure.

The known method has the drawback that the steps necessary for the fabrication of the desired nanostructure are relatively complex.

The aim of the present invention is to provide a very simple method for the fabrication of a nanostructure with which advantages can be realised that will be explained hereinbelow.

From the article by Tas N.R. et al., entitled "2D-confined nanochannels fabricated by conventional micromachining", NANO LETTERS, Sept. 2002, American Chemical Society USA, vol. 2, no. 9, pp. 1031-32 a method according to the preamble is known wherein the nanostructure material is applied on the carrier in a predetermined thickness and adhering to the shape of the carrier. Subsequently the nanostructure material is partly removed by means of a directional etching technique so as to leave material that is not etched away and that is to form the nanostructure.

The method for the fabrication of a nanostructure in accordance with the invention is characterized in that the material is removed substantially isotropically from the side facing away from the carrier, with the result that material that is not removed is left on a place or places determined by the shape of the carrier.

With this surprisingly simple method it has become possible to fabricate nanostructures in a very controlled manner, whose dimension or dimensions can be accurately controlled and which, in contrast with the known method mentioned in the above article, can produce nanostructures whose shape and dimensions are independent of the shape and dimensions of the carrier.

With this method according to the invention it has further become possible to realise nanostructures by using conventional photolithografical methods for the realisation of the desired shape of a substrate serving as carrier, such as to correspond with the final desired shape of the nanostructure. A further advantage of the proposed method is that it is not limited to specific types of materials. The only condition with regard to the application of the nanostructure material is that the same can at least partly be applied on the carrier in a substantially uniform thickness.

For example, a suitable embodiment of the method according to the invention is characterized in that the nanostructure material is applied on the carrier by means of atomic layer deposition or LPCVD. This assures that the applied layer will have a uniform thickness, without taking special measures.

A further important advantage of the invention is that the same allows nanostructures to be fabricated from a combination of different materials. Coupling the fabricated nanostructure to a microstructure while allowing precise positioning of the nanostructure in relation to the microstructure also falls within the scope of the invention. This is of interest with regard to, for example, scanning probe microscopy.

The nanostructures to be fabricated can be made in all kinds of shapes. A suitable shape may be selected from the group comprising cubes, tetrahedrons, pyramids, bars, points.

With respect to the removal of the material that is applied on the carrier, it is preferred that for this purpose an etching agent be used that affects the nanostructure material while affecting the carrier to a relatively lesser extent. This promotes the ability to control and repeat the fabrication of the nanostructures in the desired dimensions.

The method is preferably embodied such that the etching agent is a chemical etching that is effectively employed during a predetermined period of time, which is governed by the dimensions, this includes the shape, the nanostructure is to be given.

The inventors also draw attention to the fact that the method according to the present invention possesses a wide range of application, however, that a promising application lies in the fabrication of probes for scanning probe microscopy (SPM).

It is believed, that the above given explanation is already so complete and clear that a person skilled in the art is able to reproduce the invention without any problems. Nonetheless, hereinbelow a non-limiting exemplary embodiment of the method according to the invention will be given. In view of the fact that the invention provides a generally usable method for the fabrication of nanostructures of very divers nature, this exemplary embodiment must expressly be understood as elucidation of the method according to the invention only, without in any way limiting the protective scope due the claims as formulated hereafter.

In the exemplary embodiment reference is made to the drawing, which:

- in Figure 1a shows a first substrate having a previously determined shape,

- in Figure 1b shows the substrate of Figure 1a to which is applied some nanostructure material in a substantially uniform thickness, and

- in Figure 1c shows the substrate according to Figure 1b after the nanostructure material in accordance with the prior art has been directionally removed, leaving material that is not removed and which is to form the nanostructure;

- in the Figures 2a, 2b and 2c shows a second substrate in several stages of the fabrication of a nanostructure in accordance with what is shown in the Figures 1a, 1b and 1c;

- in the Figures 3a, 3b and 3c, and 4a, 4b and 4c respectively, shows the first substrate and the second substrate, respectively, in various stages of fabrication of a nanostructure according to the invention corresponding with the stages shown in the Figures 1a, 1b, 1c and 2a, 2b and 2c, respectively;

- in Figure 5a shows a third substrate having a previously determined shape;

- in Figure 5b shows the substrate of Figure 5a on which some nanostructure material is applied in a substantially uniform thickness, and

- in Figure 5c shows the substrate according to Figure 5b after the nanostructure material according to the invention has been isotropically removed in accordance with the invention, leaving material that has not been removed on a place that is determined by the shape of the substrate.

Similar parts in the figures carry identical reference numerals.

In order to explain and clarify the invention, the fabrication of a nanostructure according to the prior art will be elucidated first with reference to the Figures 1 and 2.

To this end the Figures 1 and 2 show a first substrate and a second substrate, respectively, each having a different shape, see the Figures 1a and 2a.

In the Figures 1b and 2b the first substrate and second substrate referred to above are shown, upon which a layer of the material that forms the nanostructure is applied.

Figures 1c and 2c subsequently show that this material is subjected to a conventional directional etching technique whereby the material is partly removed so as to leave material 6' that is not removed and that is to form the final nanostructure.

The Figures 1c and 2c clearly show that after directional etching, the shape of this material 6' is to some extent determined by the shape and dimensions of the substrate on which the nanostructure material is applied.

The method according to the invention is distinguished from the known method in that isotropic etching is used instead of directional etching. The effect of this can be illustrated by way of the Figures 3 and 4.

Like Figures 1a and 2a, Figures 3a and 4a again show the first substrate and the second substrate.

Figures 3b and 4b subsequently show the first substrate and the second substrate on which the nanostructure material is applied in a predetermined thickness.

The structures shown in the Figures 3b and 4b are then subjected to an isotropic etching technique. This results in the nanostructures shown in the Figures 3c and 4c and indicated with reference numeral 6.

From this example it is clear that with regard to the shape and dimensions of the final nanostructure to be obtained in accordance with the invention, the shape and dimensions of the substrate are only of minor importance.

In the Figures 5a, 5b, and 5c, the method according to the invention will be further elucidated by way of a detailed illustration of a third substrate.

Reference numeral 1 indicates a cross-sectional view of a substrate of silicon serving as carrier. This substrate 1 has a base 2, which is provided with a column 3 having a height h of, for example, 100 nanometer. The angle α between the base 2 and the column 3 is, for example, 90°C but the angle α may conceivably also have other dimensions. The choice of this angle α partly determines the final dimensions of the nanostructure to be fabricated, as will become clear from the following.

The substrate 1 may consist of a material or materials of any suitable composition. For example, it is possible to use a silicon substrate, on which subsequently a thin silicon nitrate film 4 is applied by means of low pressure chemical vapour deposition (LPCVD), as shown in Figure 1b. This thin film 4 has a uniform thickness t of, for example, 17 nanometer.

After the application of the thin film 4 formed by the material of the desired nanostructure on the substrate 1, the same must be isotropically removed from the side 5 facing away from the substrate 1. To this end the material of the thin film 4 may suitably be chemically etched using 50% HF. In the example given, in which etching takes place on a thin film 4 of silicon nitride, the etching rate is 3.3 nanometer per minute. The etchability of the substrate 1 made of silicon is much poorer, i.e. 0.027 nanometer per minute.

After etching has taken place for a previously determined length of time in order to substantially remove the thin film 4, in this case for example 5 minutes and 9 seconds, the nanostructure as shown in Figure 1c and indicated with reference numeral 6 remains, having the shape of a bar with a substantially triangular cross section. Some of the dimensions of this nanostructure, which are determined by the above-elucidated method of fabrication, are in the figure indicated with 'r' and 'l' and are in the example discussed above both 17 nanometer.

Although, as already mentioned above, the explanation of the invention just given concerns a very specific example, it nevertheless aptly elucidates the general idea of the invention as expressed in the appended claims. The method according to the invention is expressly not limited to this exemplary embodiment.

CLAIMS

1. A method for fabricating a nanostructure, comprising the selection of a carrier for the material of the nanostructure during the formation of the same, wherein the carrier is provided with a shape that corresponds with the final shape of the nanostructure, and wherein the nanostructure material is applied on the carrier in a predetermined thickness and following the shape of the carrier, **characterised** in that the material is removed substantially isotropically from the side facing away from the carrier, with the result that material that is not removed is left on a place or places determined by the shape of the carrier.

2. A method according to claim 1, **characterised** in that the nanostructure material is applied on the carrier by means of atomic layer deposition or LPCVD.

3. A method according to claim 1 or 2, **characterised** in that for the isotropic removal of the nanostructure material that is applied on the carrier an etching agent is used that affects said material while affecting the carrier to a relatively lesser extent.

4. A method according to claim 3, **characterised** in that the etching agent is a chemical etchant that is effectively employed during a previously determined period of time, which is governed by the dimensions the nanostructure is to be given.

5. A method according to one of the preceding claims, **characterised** in that the shape of the nanostructure is selected from the group comprising cubes, tetrahedrons, pyramids, bars, points.

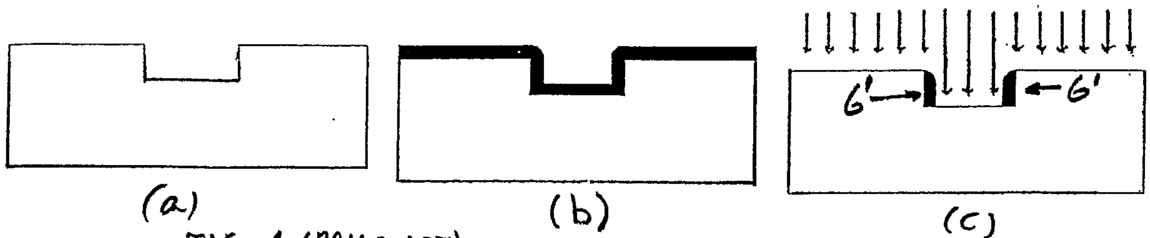

FIG. 1 (PRIOR ART)

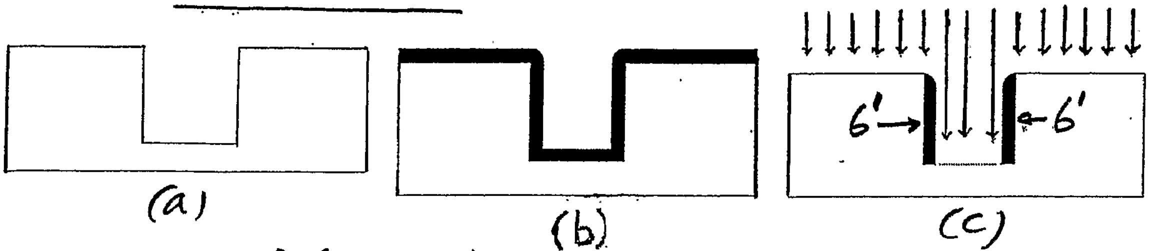

FIG. 2 (PRIOR ART)

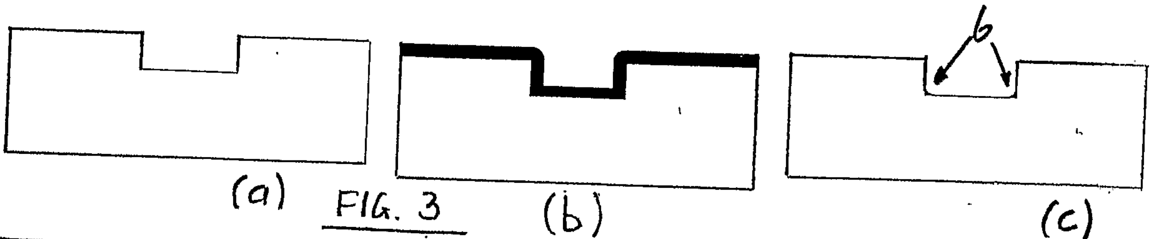

FIG. 3

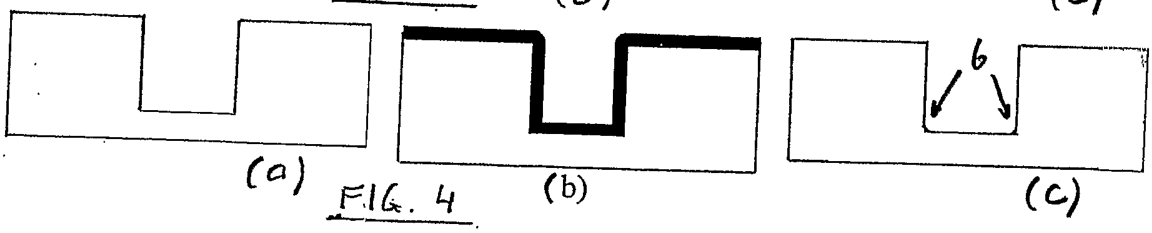

FIG. 4

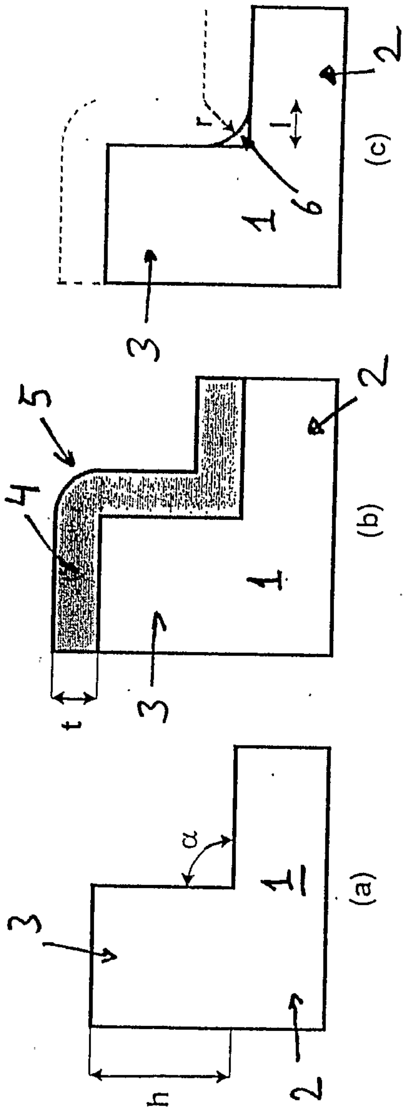

FIG. 5

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A. CLASSEMENT DE L'OBJET DE LA DEMANDE
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Selon la classification internationale des brevets (CIB) ou à la fois selon la classification nationale et la CIB

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C. DOCUMENTS CONSIDERES COMME PERTINENTS

Catégorie °	Identification des documents cités, avec, le cas échéant, l'indication des passages pertinents	no. des revendications visées
X	TAS N R ET AL: "2D-confined nanochannels fabricated by conventional micromachining" NANO LETTERS, SEPT. 2002, AMERICAN CHEM. SOC, USA, vol. 2, no. 9, 1 septembre 2002 (2002-09-01), pages 1031-1032, XP002283203 ISSN: 1530-6984 cité dans la demande figure 1A page 1031, colonne 1, ligne 21 - colonne 2, ligne 11	1-5
A	US 4 358 340 A (FU HORNG-SEN) 9 novembre 1982 (1982-11-09) figures 1-4 colonne 2, ligne 56 - colonne 3, ligne 30	1-5

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[X] Voir la suite du cadre C pour la fin de la liste des documents

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C.(suite) DOCUMENTS CONSIDERES COMME PERTINENTS		
Catégorie °	Identification des documents cités, avec, le cas échéant, l'indication des passages pertinents	no. des revendications visées
A	GUI C ET AL: "NANOMECHANICAL OPTICAL DEVICES FABRICATED WITH ALIGNED WAFER BONDING" MEMS 98. PROCEEDINGS IEEE OF THE 11TH ANNUAL INTERNATIONAL WORKSHOP ON MICRO ELECTRO MECHANICAL SYSTEMS. AN INVESTIGATION OF MICRO STRUCTURES, SENSORS, ACTUATORS, MACHINES AND SYSTEMS. HEIDELBERG, JAN. 25 - 29, 1998, IEEE WORKSHOP ON MICRO ELECTRO ME, 25 janvier 1998 (1998-01-25), pages 482-487, XP000829209 ISBN: 0-7803-4413-8 figure 4 alinéa '03.1! -----	1-5

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Document brevet cité au rapport de recherche		Date de publication	Membre(s) de la famille de brevet(s)		Date de publication
US 4358340	A	09-11-1982	JP	57083063 A	24-05-1982