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METHOD FOR ORIENTING SINGLE CRYSTAL FILMS
ON POLYCRYSTALLINE SUBSTRATES
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3,370,980

SINGLE	A
SINGLE	B

FIG. 1

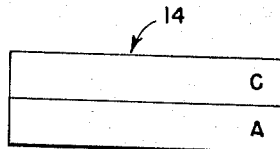


FIG. 3

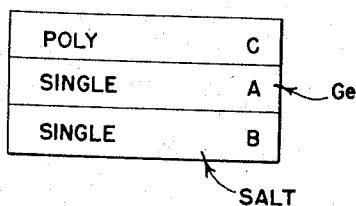


FIG. 2

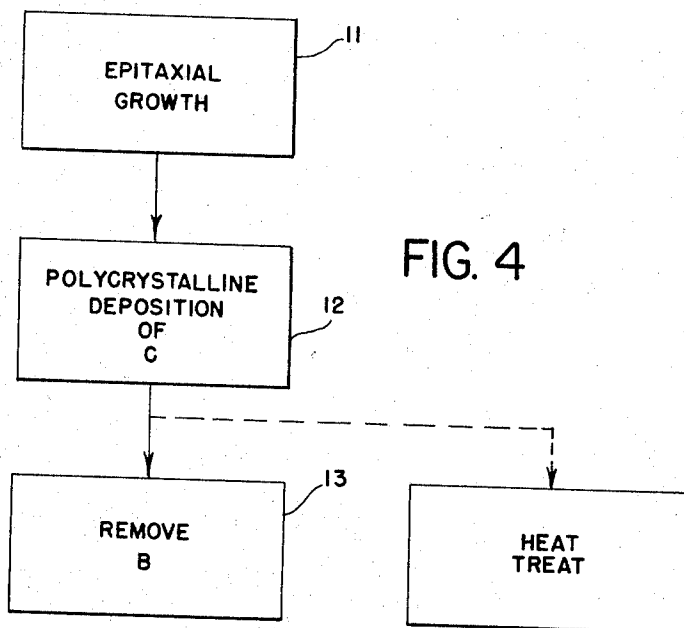


FIG. 4

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METHOD FOR ORIENTING SINGLE CRYSTAL FILMS ON POLYCRYSTALLINE SUBSTRATES

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15 Claims. (Cl. 117—227)

This invention relates to a method of producing layers of material having different crystallographic characteristics and more particularly to production of single crystal films on polycrystalline substrates.

In the semiconductor industry and similar industries, it is often desirable to produce a thin film of a material which has a single crystal structure. This thin film often must be placed on a backing material in order to provide structural rigidity and strength for the thin film of material. These thin films of a single crystalline material may be as thin as several atomic layers or they may be considerably thicker depending upon the application of the single crystalline layer. Such devices might be utilized in the semiconductor industry where germanium or other semiconductor material is used to product small electronic components such as transistors, diodes, and the like. Unfortunately, thin films with a single crystal structure on a substrate of a polycrystalline material have been difficult if not impossible to accomplish for the reason that material which is deposited on a polycrystalline substrate tends to form a polycrystalline structure which cannot be utilized.

It is, therefore, an object of the present invention to provide a new and improved method for producing a layer of a single crystalline material on a substrate of a polycrystalline material.

It is another object of the present invention to provide a new and improved method of producing a single crystalline layer on a polycrystalline layer by utilizing epitaxial growth of the single crystalline layer on a single crystalline substrate.

It is a further object of the present invention to provide a method for producing a single crystal film of a semiconductor, metal or insulator on a polycrystalline substrate composed of a semiconductor, metal or insulating material.

It is a further object of the present invention to provide a single crystalline film on a polycrystalline substrate by first depositing the single crystalline film on a destructible single crystalline layer which is removed from the deposited film after a polycrystalline layer has been placed on the film.

It is yet another object of the present invention to provide a single crystalline film on a polycrystalline substrate wherein the single crystalline film is heat treated to improve the single crystalline characteristics of the film.

Other objects and advantages of the invention will become apparent by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIGURES 1, 2 and 3 illustrate the various configurations which the layers of material take as the method is carried out, and

FIGURE 4 is a process diagram illustrating the steps of the process.

Refer to FIGURES 1, 2 and 3 of the drawings. As a starting point for the process, a layer of a single crystalline growth substrate B is first prepared. This growth substrate may be prepared by selecting a naturally occurring single crystalline material or as in the case with a semiconductor, the substrate B may be grown by conventional methods. Such a method is illustrated with the case where a layer of a silicon or germanium semiconductive mate-

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rial is grown by conventional methods to product a wafer or layer of single crystalline semiconductor material. The single crystal growth substrate may, however, be composed of a metal, semiconductor, or insulating material as long as it can be readily prepared in a single crystalline form. Further, since this growth substrate B is to be removed from the final product, the substrate must be capable of being readily removed from the subsequent deposited material. By way of example, such material which has been successfully used are alkali halides which include such materials as NaCl and LiF.

Next, a material is selected for epitaxial deposition on the single crystalline growth substrate B. This material may likewise be either a metal, a semiconductor material, or an insulating material. The selection of the material depends primarily on the ultimate application of the single crystal film. The epitaxial process of growing a crystal, for instance of a solid semiconductor, involves the deposition of the material on a growth substrate of a single crystal in order that the deposited material will take on the characteristics of the single crystalline substrate. The resulting layer or film of single crystalline material A will also be a single crystal and may be a material which is the same or which is different from the growth substrate B. For instance, silicon layers have been epitaxially grown on silicon substrates, and germanium layers or films on germanium substrates. However, it is possible to epitaxially grow dissimilar material. For instance, gallium arsenide films can be grown on germanium substrates. It is also possible to epitaxially produce single crystal films of metals, semi-conductors, or insulators on any combination of metals, insulators, or semiconductors forming the single crystalline growth substrate. In order to attain efficient epitaxial growth on the growth substrate B, there may be some need to match the properties of the single crystalline layer A and the properties of the single crystalline layer B. However, in general, the three classes of material may be deposited on single crystalline substrates of any of the other classes. Example of materials which may be epitaxially deposited on substrate B include Ni, Fe, Ni-Fe alloys, Ni-Co alloys, Ge, Ag, Au, Al, Pd, Cu, and Sn.

The epitaxial growth may be accomplished by several conventional methods. For instance, the epitaxial growth may be accomplished by sputtering techniques, evaporation techniques, or vapor deposition techniques to name several. Sputtering of metals of semiconductors is well known in the art and means and methods for sputtering of insulators is explained in copending application Serial No. 134,458, filed August 28, 1961 by Gerald S. Anderson and Roger M. Moseson, now abandoned.

After the single crystalline film has been deposited epitaxially on the growth substrate B, a layer of a polycrystalline material is next deposited on the single crystalline layer A. As with the previous layers, the polycrystalline material C may be either a metal, a semiconductor or an insulating material. Each of these types of materials can be deposited on the other type of material. It may also be a wax, adhesive material or a cured epoxy resin. The resin may be any one of a number of commonly used epoxy resins prepared by known methods. The polycrystalline material provides a backing for the single crystalline layer A to provide physical strength and rigidity for the thin single crystalline film A or to provide a means for attaching the film A to another material. The polycrystalline material may be deposited on the single crystalline material A by simply violating the conditions for epitaxial growth. This will result in a polycrystalline development of the material being deposited on the single crystalline layer A. The polycrystalline material may also be deposited by a number of conventional methods which includes, for example, evaporation, sputtering, and

similar methods of deposition. The selection of the deposition method may in some cases depend upon the nature of the material which is being deposited. For example, a different method might be utilized for depositing an insulator on single crystalline layer A than might be utilized if, for example, a semiconductor layer C is deposited on the single crystalline layer A. After this step represented by box 12 of FIGURE 4 has been accomplished, the resulting product appears in FIGURE 2. First a single crystalline layer or growth substrate B is formed by conventional methods. Next, the single crystalline film A is epitaxially grown, see box 11 of FIGURE 4, on the growth substrate B. Finally, the polycrystalline layer C established on the single crystalline layer A, box 12.

Since the single crystalline growth substrate B is no longer necessary, it is now removed from the other layer. It is at this removal stage, box 13 of FIGURE 4, that the selection of the single crystalline material which forms the growth substrate B becomes important. The growth substrate B must be a material which can be easily removed from the layer A without damage to the layer A. Preferably, the single crystalline layer B is an expendable material which may be disposed of in an economical fashion. An example of such a combination of materials is the utilization of rock-salt as the single crystalline substrate B. Germanium is then epitaxially deposited on the growth substrate layer B. After the polycrystalline layer C is established, the rock-salt may be easily removed from the germanium layer A by simply exposing the growth substrate layer B to water which quickly dissolves the rock-salt layer B. This leaves the single crystalline film A with the polycrystalline layer C intact as shown in FIGURE 3 of the drawings.

After the cell or unit 14 is completed or before the polycrystalline layer C is deposited, an additional step might be utilized in order to improve the crystalline characteristics of the single crystalline layer A. Heat treatment of the layer A at a temperature, depending upon the characteristics of the material utilized for the layers A and C if it is present, results in an improvement of the single crystalline characteristics of the layer A. It is believed that these improvements in the single crystalline lattice structure are accomplished due to a relief of stresses which may have developed in the single crystalline layer A during the epitaxial growth of the layer A on the growth substrate B.

It is to be understood that the above described arrangements are simply illustrative of the application of the principles of the invention. Numerous variations may be readily devised by those skilled in the art which will embody the principles of the invention and fall within the spirit and scope thereof.

Now, therefore, I claim:

1. A method for producing a single crystal film of a desired material on a polycrystalline substrate, which comprises the steps of:

providing a single crystal substrate,
epitaxially depositing said desired material on said single crystal substrate to form said single crystal film,
depositing a polycrystalline film on said single crystal film to form said polycrystalline substrate, and
removing said single crystal substrate from said single crystal film.

2. A method in accordance with claim 1 in which said polycrystalline film is formed by the deposition of a material taken from the group consisting of adhesives, waxes and cured epoxy resins.

3. A method in accordance with claim 1 in which said desired material is a metallic material and in which said polycrystalline substrate is formed from a metallic material.

4. A method in accordance with claim 1 in which said desired material is a metallic material and in which said

polycrystalline substrate is formed from a semiconductor material.

5. A method in accordance with claim 1 in which said desired material is a metallic material and in which said polycrystalline substrate is formed from an insulating material.

6. A method in accordance with claim 1 in which said desired material is a semiconductor material and in which said polycrystalline substrate is formed from a metallic material.

7. A method in accordance with claim 1 in which said desired material is a semiconductor material and in which said polycrystalline substrate is formed from a semiconductor material.

8. A method in accordance with claim 1 in which said desired material is a semiconductor material and in which said polycrystalline substrate is formed from an insulating material.

9. A method in accordance with claim 1 in which said desired material is an insulating material and in which said polycrystalline substrate is formed from a metallic material.

10. A method in accordance with claim 1 in which said desired material is an insulating material and in which said polycrystalline substrate is formed from a semiconductor material.

11. A method in accordance with claim 1 in which said desired material is an insulating material and in which said polycrystalline substrate is formed from an insulating material.

12. A method in accordance with claim 1 in which said single crystal substrate is water soluble.

13. A method in accordance with claim 12 in which said water soluble substrate is rock-salt and in which said desired material is germanium.

14. A method for producing a single crystal film of a desired material on a polycrystalline substrate, which comprises the steps of:

providing a single crystal substrate;
epitaxially depositing said desired material onto said single crystal substrate to form said single crystal film, said film having an exposed surface;
depositing a polycrystalline film on said exposed surface of said single crystal film to form said polycrystalline substrate; and
removing said single crystal substrate from said single crystal film.

15. A method for producing a single crystal film of a selected material on a polycrystalline substrate of a given material, which comprises the steps of:

providing a single crystal substrate having a surface area for receiving said selected material;
epitaxially depositing said desired material onto said surface area of said single crystal substrate to form said single crystal film, said single crystal film having an exposed surface;
depositing a polycrystalline film of said given material on said exposed surface to form said polycrystalline substrate; and
removing said single crystal substrate from said single crystal film.

References Cited

UNITED STATES PATENTS

2,692,839	10/1954	Christensen et al. ..	117—106 X
2,974,388	3/1961	Ault	264—313
3,186,880	6/1965	Skaggs et al.	148—1.6

FOREIGN PATENTS

1,029,941	5/1958	Germany.
1,063,870	8/1959	Germany.
692,598	6/1940	Germany.
1,088,779	9/1960	Germany.

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