

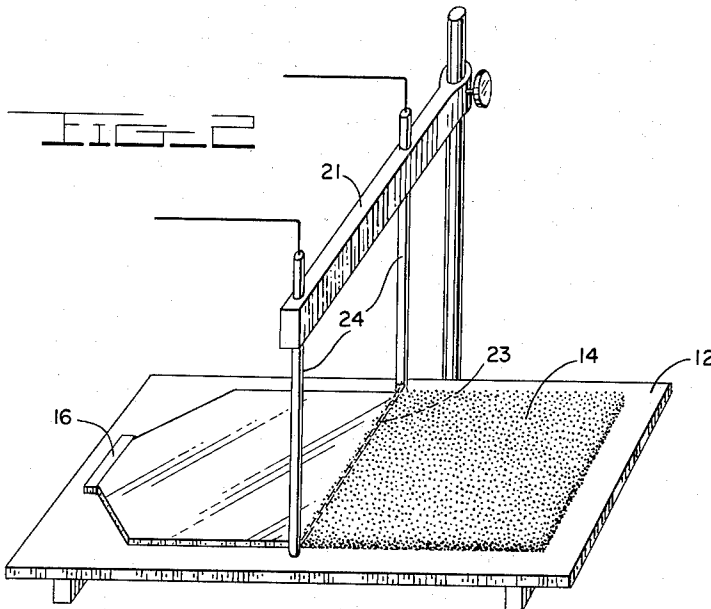
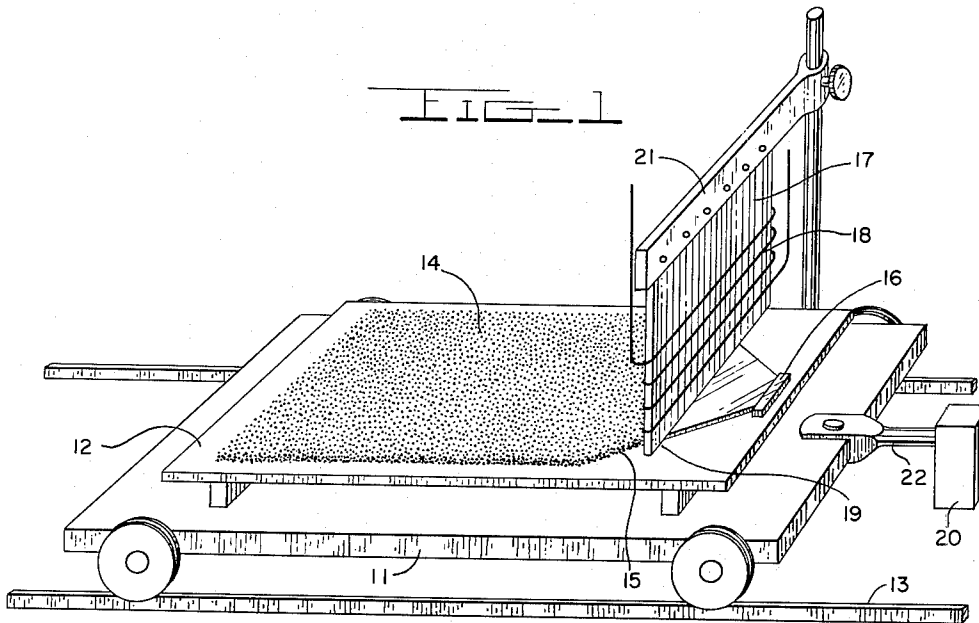
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APPARATUS FOR GROWING THIN CRYSTALS

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APPARATUS FOR GROWING THIN CRYSTALS

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The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.

This invention relates to a device for growing crystals, and more particularly to a method and apparatus for growing relatively thin sheet crystals of germanium, silicon, etc.

It has long been known that single crystals of elements and of compounds may be produced synthetically by growing the crystal from a seed which is in contact with a cooling liquid. While several methods have been utilized to grow single crystals from the fused state in molds, crucibles, hollow blocks and the like, the resultant solids are essentially massive crystal formations. These crystals assume the shape and size of the containers in which they are crystallized, the growth being extensive in all three crystal axes. Heretofore, a method and apparatus for growing relatively thin sheet crystals of such materials as germanium or silicon have not been disclosed and practiced successfully.

It is accordingly an object of the present invention to provide a satisfactory method for growing single crystals.

Another object of the invention is to provide a device of simple construction for growing relatively thin sheet crystals.

Still another object of the invention is to provide an apparatus useful for the production of crystals that are suitable for transistors and other electrical devices.

Other objects and the attendant advantages of this invention will become apparent from the following description with reference to the accompanying drawings, in which:

FIG. 1 illustrates a crystal growing apparatus according to this invention; and

FIG. 2 illustrates a modification of the crystal growing apparatus of FIG. 1.

Broadly stated the method and apparatus of the present invention involve the production of single crystals in thin slabs or sheets from the powdered form of a substance by melting small portions of the powder progressively on a flat surface or substrate. The substrate progresses slowly past a stationary heated sheet which contacts the powder layer and melts a portion of the powder. An orienting crystal or seed of the same substance influences the growth of the crystal slab by contacting the seed crystal with the molten portion, and when the melt has cooled sufficiently, it crystallizes integrally into a single crystal.

Referring now to the drawings, there is shown in FIG. 1, a movable carriage 11, on which substrate 12 is mounted, the carriage has freedom of travel on tracks or guides 13. Powdered germanium 14 is spread evenly on the substrate in the form of a thin layer which tapers at one end, as shown at 15, to contact with one side of a seed crystal 16. A heating element consisting of a broad sheet 17 is inductively heated by wire turns 18 and mounted so that the lower edge 19 of the sheet 17 is parallel to the top surface of the substrate and set partly within the powdered material. An adjustment clamp 21 permits a height adjustment of the heating element depending on the depth of the germanium powder that is to be crystallized. The heating element is adjusted initially so that it will melt a small section of germanium powder on both sides of the heated sheet and across the width and depth of the germanium layer. The carriage is propelled

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by any convenient means 20 (shown in block diagram for simplification) by arm 22 in the desired direction at a controlled speed. The germanium powder spread on the substrate melts on each side of the heated sheet and crystallizes on the oriented crystal as the melt is moved away from the vicinity of the heated sheet through movement of the carriage.

The carriage 11, on which the substrate is mounted, is adapted to travel on tracks 13 or guides, or it may have smooth, sliding surfaces coadjacently disposed in slidable contact with the tracks or guides. The carriage is moved by any convenient means 20 that provides a smooth, controlled displacement of the substrate while it passes the heating element. Alternately, another embodiment of this invention arranges a heating source to move over a powder layer spread on a stationary substrate. An inductively heated sheet moving on rods or guides has its lower end partly submerged in powder to melt it as the heated sheet moves slowly over the fixed substrate.

The powdered substance to be crystallized, such as germanium or silicon, is first spread out evenly on the flat surface or substrate to any desired depth, usually about 2 to 4 millimeters. The seed crystal which is of the same chemical substance as the powdered form, is placed at one end of the substrate so that one of its faces contacts the powder substance. The inductively heated sheet which is fixed over the substrate is brought initially near to the point of contact between powder and seed crystal, and the sheet is heated sufficiently to melt a portion of the seed crystal and a portion of the powder adjacent to the crystal. The substrate is then moved slowly so that relatively narrow portions of the powder near the crystal will melt and subsequently, upon leaving the heated sheet, the molten material will cool and crystallize as part of the single crystal structure.

In growing single crystals, such as germanium or silicon, the process is best carried out in a protective atmosphere that prevents oxidation and protects the growing crystal from impurities. The apparatus therefore, should be enclosed in a suitable chamber (not shown for simplification of the drawings) or confined within a space in which the atmosphere surrounding the heated parts is an inert gas or some gaseous component which prevents oxidation. The enclosed system may also operate effectively in a rarified atmosphere.

The size of the crystal is not critical, although care should be taken to position the heat source so as to melt a portion of but not the entire seed crystal, since the solid material is needed to provide the oriented surface necessary for crystal growth. An advantageous method found particularly useful in initiating crystal growth is to contact powder on one side of the seed crystal and then to fan out or spread the powder layer from there, broadening it to the width that is desired for the crystal. Initially, the seed crystal and the powder contacting it melt along this narrow width and then proceed to spread out until they are equal to the width of the powder layer on the substrate. This method improves the chances of initiating crystal growth, and then gradually, by introducing more and more molten material to the growing crystal, the crystallizing surface expands to any desired dimension.

The inductively heated sheet is constructed of a material which is chemically inert with the molten mass with which it is in contact. Such a sheet must also be suitable for inductive heating, and it must be mounted so that it will withstand movement and vibrations that might interfere with the crystallizing process. The sheet should be adjustably mounted to allow for lowering or raising it in the powder layer. Such adjustments may be required depending on the thickness of the powder layer, the melting temperature of the powder and the speed with which

the substrate is moving relative thereto during the operation.

A modification of the apparatus of FIG. 1, as shown in FIG. 2, comprises a resistance-heated element 23 or hot wire, suitably mounted between uprights 24 and adapted to be imbedded somewhat in the powdered material. The wire should be sufficiently long to extend across the width of the powder layer and should be heated sufficiently to melt a relatively narrow transverse portion of powder. It is desirable to melt the powder layer uniformly across a transverse line so that crystallization may proceed approximately at an even rate along the interface of the growing crystal. It is desirable to heat the powder uniformly along the transverse section so that crystallization will proceed approximately at an equal rate along the entire face of the crystal. This is more easily accomplished in a relatively thin crystal as described in the present invention than in massive crystals grown in containers that may cool unevenly and cause strains and breaks to develop during the crystal growth.

The movement of the carriage is relatively slow, in general about 0.2 millimeter per minute so that the apparatus is maintained relatively free from vibrations or mechanical oscillations which may disrupt the crystal growth. When the carriage has traversed the length of the track or guide, the powder layer has been completely melted and crystallized into a single crystal and the process has been completed.

Although the present invention has been described with reference to germanium and silicon crystals, the apparatus can also be used to grow alkali metal halide crystals, for instance, rock salt (NaCl) and potassium chloride (KCl). For example, a rock salt crystal can be grown by spreading a layer of salt (NaCl) to about 7 millimeters in thickness on the substrate and embedding in the salt a heated resistance wire, as shown in FIG. 2. Sufficient current is passed through the resistance wire to provide a molten strip about 1/4 inch on each side of the heated wire. The temperature of the molten material at the interface is about 801° C. The substrate is moved at a rate of 0.2 millimeter per minute to insure sufficient heating for melting a narrow portion of powder and for proper orientation of the molten material to promote crystal growth. A crystal slab having a thickness of about 4 millimeters will be developed by the above procedure.

The thin crystals which are manufactured by this invention are particularly useful where wafers or slabs of crystalline structures are required. Considerable amount of material and effort can be saved in the electrical and also the optical industry by cutting these crystal sheets into

any required dimension without any loss of material which usually results when dealing with the massive crystal growths.

Obviously many modifications and variations of the present invention are possible in the light of the above teachings. It is therefore to be understood that within the scope of the appended claims the invention may be practiced otherwise than as specifically described.

What is claimed is:

1. An apparatus for growing a thin crystal which comprises a substrate having essentially a flat planar surface which is adapted to support a seed crystal and a powder layer of a selected material, a heat-transfer sheet having a narrow edge, said sheet being positioned over said substrate with said narrow edge arranged in close proximity and equidistant to said planar surface and means for progressively moving said substrate parallel to said planar surface whereby a relatively narrow portion of powder adjacent to said crystal is maintained as a melt, which crystallizes progressively along the length of said substrate.

2. An apparatus for growing a thin crystal which comprises a substrate having essentially a flat planar surface which is adapted to support a seed crystal and a powder layer of a selected material, a resistance-heated wire positioned parallel to and over said substrate and arranged in close proximity to said planar surface and means for progressively moving said substrate parallel to said planar surface whereby a relatively narrow portion of powder adjacent to said crystal is maintained as a melt, which crystallizes progressively along the length of said substrate.

3. An apparatus for growing a thin crystal which comprises a substrate having essentially a flat planar surface which is adapted to support a seed crystal and a powder layer of a selected material, a heating element being positioned over said substrate, said heating element having a relatively narrow surface, said narrow surface being adapted to be arranged in close proximity to said planar surface at equidistant points from the substrate and means for progressively moving said substrate parallel to said planar surface whereby a relatively narrow portion of powder adjacent to said crystal is maintained as a melt, which crystallizes progressively along the length of said substrate.

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