

March 2, 1971

S. O'HARA

3,567,397

APPARATUS FOR OBTAINING A DROSS-FREE CRYSTALLINE GROWTH MELT

Filed Oct. 11, 1967

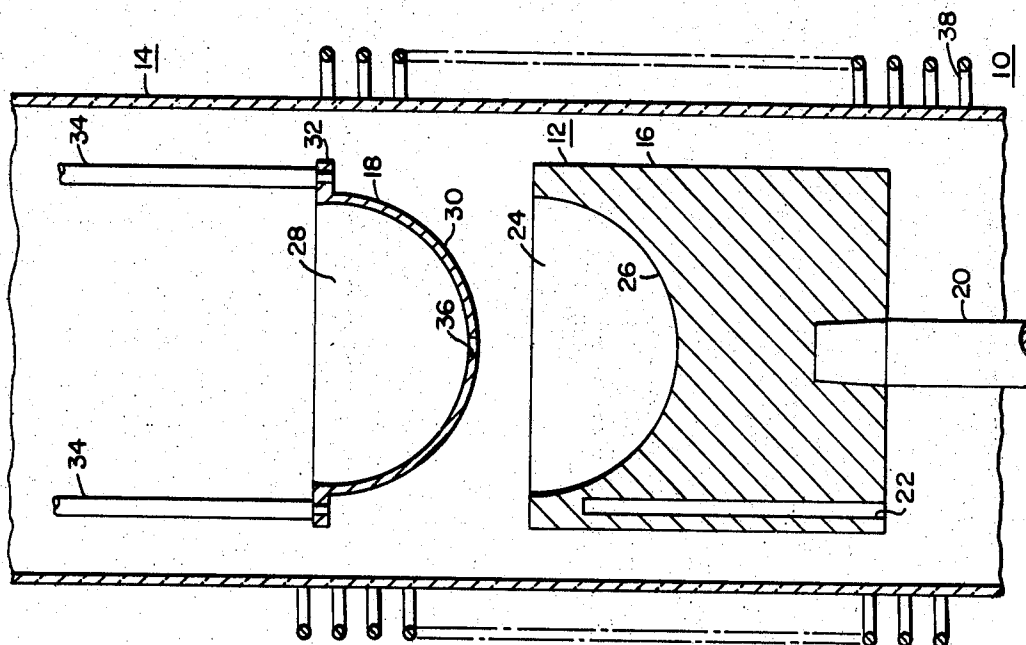


FIG. 1

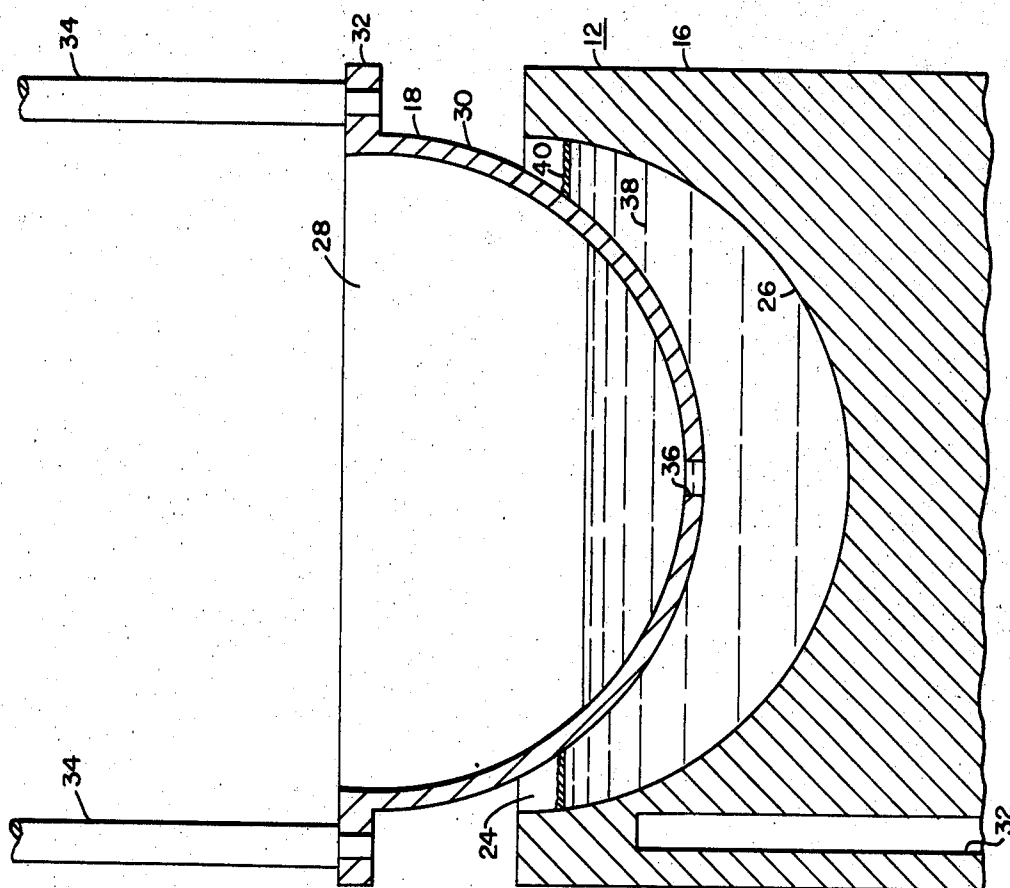


FIG. 2

1

3,567,397

APPARATUS FOR OBTAINING A DROSS-FREE CRYSTALLINE GROWTH MELT

Sydney O'Hara, Menlo Park, Calif., assignor to Westinghouse Electric Corporation, Pittsburgh, Pa.

Filed Oct. 11, 1967, Ser. No. 674,448

Int. Cl. B01j 17/00

U.S. Cl. 23—273

7 Claims

ABSTRACT OF THE DISCLOSURE

This invention provides apparatus for growing webbed dendritic semiconductor material from a melt substantially free of any dross on the surface of the melt. The apparatus comprises a two component crucible, consisting of an inner shell and an outer shell. The melt is formed in the outer shell. The inner shell, axially aligned with the outer shell, has a vertical displacement means attached to it. The inner shell is lowered into the melt of the outer shell and dross free melt is forced through an aperture in the apex of a cavity of the inner shell forming a pool of dross free melt therein. From this dross free melt the webbed dendritic semiconductor material is grown.

BACKGROUND OF THE INVENTION

(1) Field of the invention

This invention relates to apparatus for producing a dross-free crystalline growth melt.

(2) Description of the prior art

The process of producing webbed dendritic growths of semiconductor materials is hampered by the formation of a scum, or dross, on the surface of the melt from which the web is grown. As a result the quality of the surfaces of the web is poor.

To prevent the formation of scum, or dross, on the melt, purely chemical approaches such, for example, as the use of atmospheres of very pure hydrogen and carbon monoxide during the growth of indium antimonide webbed dendritic material have been tried, but the use of selective atmosphere has not always reduced the scum formation.

SUMMARY OF THE INVENTION

This invention provides apparatus for growing webbed dendritic semiconductor material comprising a crucible consisting of an outer shell member and an inner shell member, the shell members being axially aligned with respect to each other, a cavity disposed in the top surface of the outer shell member, the apex of the cavity coinciding with the aligned axis, the inner shell member consisting of a bowl-shaped member, the apex of the bowl coinciding with the aligned axis, an outwardly extending brim integral with the peripheral edge of the bowl, an aperture axially disposed in the apex portion of the bowl, means for displacing the inner shell member vertically along the aligned axis, and means for heating the crucible.

An object of this invention is to provide a melt of semiconductor material for the growth of webbed dendritic semiconductor material wherein the surface of the melt is essentially free of the formation of dross thereon.

Another object of this invention is to provide apparatus for growing webbed dendritic semiconductor material wherein the melt is contained in a two component crucible suitable for providing a dross free melt for growth therefrom.

Another object of this invention is to provide apparatus for growing webbed dendritic semiconductor material

2

in which means are provided to control the thermal gradient in the melt and in the web being grown.

Other objects will, in part, be obvious and will, in part, appear hereinafter.

DRAWINGS

For a better understanding of the nature and objects of this invention reference should be made to the following detailed drawings, in which:

FIG. 1 is a view, partly in cross-section of apparatus suitable for growing webbed dendritic semiconductor material from a dross-free melt; and

FIG. 2 is a view in cross-section of a two component crucible made in accordance with the teachings of this invention.

DESCRIPTION OF THE INVENTION

With reference to FIG. 1, there is shown apparatus 10 for growing dendrites of semiconductor material. The apparatus 10 comprises a two-piece crucible 12 disposed within a quartz shield 14. The crucible 12 consists of an outside shell member 16 and an inside shell member 18. The members 16 and 18 are each made of a suitable material, such, for example, as quartz, platinum and graphite. The shield 14 serves both as a means to contain a preferred environment and also as a heat reflector.

The outside shell member 16 may be supported within the shield 14 by a support 20. The member 16 has a passage 22 contained therein for the insertion of a temperature sensing device for determining the temperature of a melt disposed within a cavity 24 of the member 16. The cavity 24 has a curved surface 26 and is centrally disposed in the upper surface of the member 16.

The inside shell member 18 has a cavity 28, an outer surface 30 of which is curved and conforms to the curvature of the surface 26 of the outside shell member 16. The inside shell member 18 has an integral outwardly extending brim 32 which permits the surface 30 to become contiguous with the surface 26 when the member 18 has been lowered as far as possible into the cavity 24. Two or more supports 34 may be affixed to the brim 32 to provide means for the vertical displacement of the member 18 as required. A passageway 36 is provided in the center of the surface 30 to provide a means for liquified material to flow from one side of the cavity 28 to the other side of the cavity 28.

The crucible 12 is heated by a suitable means, such, for example, as an induction coil 38 disposed about the outer periphery of the shield 14. Preferably the crucible 12 is heated in a preferred atmosphere. Therefore, the shield 14 may have end plates of suitable material enclosing the crucible therein and a means for providing the necessary atmosphere within the enclosed shield 14.

With reference to FIG. 2, there is shown the outer shell member 16 containing a melt 38 of semiconductor material in the cavity 28. On the surface of the melt is a layer 40 of dross. The presence of this dross layer 40 gives rise to poor quality surfaces on webbed dendritic semiconductor material grown from the melt 38.

The inner shell member 18 is lowered into the melt 38 within the cavity 24. As the surface 30 of the member 18 enters the melt 38, it pushes aside substantially all of the layer 40 of dross and a portion of the melt 38 is forced through the passageway 36 and into the cavity 28. During the growth of webbed dendritic material from the melt 38 in the cavity 28, a layer of dross will also form on the original dross free surface. When the dross becomes intolerable, it is only necessary to stop the growth process, remove the inner shell member 18 and replace it with a clean member. The dendritic growth process can then be resumed. The inner member 18 and the outer member 16 should be so constructed as to enable one to have a

depth of melt of at least one half inch in the center of the cavity 28 and a surface of one inch minimum diameter.

Another cause of undesirable surface defects on the webbed dendritic semiconductor material being grown is generally attributable to an excessive temperature gradient along a short length of the web as it emerges from the melt 38 as well as sub-surface defects, such, for example, as discontinuities in the twin planes, which are attributable to thermal conditions in the crystal growth regions of the melt 38.

To minimize the effect, the inner shell member 18 has on the thermal conditions of the melt 38, it is desirable to make the walls of the cavity 28 of the member 18 as thin as possible. This minimizes the thermal relaxation which occurs and consequently the sufficiently short period of thermal relaxation which occurs does not give rise to hunting (dimensional oscillation) of the webbed dendritic structure being grown. The wall of the cavity 28 of the member 18 is preferably $\frac{1}{64}$ of an inch in thickness.

When the outer shell member 18 is fully submerged in the melt 38, the temperature gradients which occur in the melt are relatively small. Consequently, the webbed dendritic material grown has large dendrites but only a very thin web of material extends between them. In some instances, no web growth occurs, only large dendrites with a void between them. This latter effect arises from the fact that when a small gradient exists, relatively less heat may be discharged through the melt, and the dendrites which grow deeper in the melt, grow in preference to the web, which is growing at a comparatively higher location.

Almost complete removal of the member 18 from the melt 38 produces steeper temperature gradients within the melt 38. As a result of this supercooling of the melt 38, the surface of the melt 38 is cooler thereby supporting the growth of thicker webs.

Additionally, the walls of the member 18 provide a means for partially controlling the thermal conditions within the cavity 28 at a point immediately above the surface of the melt in the webbed dendritic material as it is withdrawn from the melt. The walls help to maintain a thermal gradient in the webbed dendritic material which is most conducive to producing an improved quality of webbed material. Additionally, that portion of the induction coil 38 which extends above the crucible 12 during the growth of material may be separated from the main body of the coil 38 and separately controlled as to position and power. This separate controlling of this portion of the coil 38 will allow the operator too have a better control of the thermal gradient within the web being grown.

The result of practicing this invention has provided webbed dendritic semiconductor material having excellent semiconductor quality and also substantially free of surface imperfections previously encountered in material produced in prior art apparatus.

While the invention has been described with particular reference to specific embodiments and examples of the invention, it will be understood, of course, that modifications, substitutes and the like may be made therein without departing from its scope.

I claim as my invention:

1. Apparatus for growing semiconductor material from a melt comprising

a crucible comprising an outer shell member and an inner shell member axially aligned with respect to each other and being so dimensioned that during crystal growing from a melt the inner shell member floats in the melt of the semiconductor material and is separated by a layer of the melt from the walls of the outer shell member during crystal growing;

said outer shell member having walls defining a cup-shaped cavity with the open end of the cavity opening into the top surface of the member;

a freely separable bowl shaped member having walls about $\frac{1}{64}$ of an inch in thickness forming said inner shell member and having an aperture disposed in the lower apex portion of said bowl, said apex coinciding with said aligned axes, said thin walls minimizing the thermal relaxation of a melt when growing material therefrom;

an outwardly extending brim integral with the peripheral edge of said walls of said inner member;

means attached to said inner shell member for displacing said inner shell member vertically along the aligned axes, the inner and outer shells being so constructed and arranged that during crystal growing, semiconductor material is fed into the space between the shells and dross floats to the top of such space while pure material flows through the aperture to the inner shell; and

means for heating the crucible.

2. Apparatus of claim 1 in which the material comprising the crucible is one selected from the group consisting of quartz, platinum and graphite.

3. Apparatus of claim 1 in which the outer shell member has temperature sensing means disposed therein.

4. Apparatus of claim 1 in which the outer surface of the bowl of said inner member conforms to the inner surface of the cavity of the outer shell member.

5. Apparatus of claim 1 in which the means for heating the crucible is an electrical resistance coil.

6. Apparatus of claim 5 in which the electrical resistance coil is divided into separate portions, each portion having a separate control means, one portion of said coil being suitable to control the thermal gradient of the material grown by use of the apparatus.

7. Apparatus of claim 6 in which said one portion of said coil to control the thermal gradient of the material grown is vertically displaced above the other portion of said coil and about a portion of the apparatus above the outer shell member.

References Cited

UNITED STATES PATENTS

2,892,739	6/1959	Rusler	23—273
2,944,875	7/1960	Leverton	23—273
2,956,863	10/1960	Goorissen	23—273
3,041,133	6/1962	Hicks et al.	23—273
3,058,915	10/1962	Bennett	23—273
3,154,384	10/1964	Jones	23—273
3,291,571	12/1966	Dohmen et al.	23—273

WILBUR L. BASCOMB, Jr., Primary Examiner

R. T. FOSTER, Assistant Examiner

U.S. Cl. X.R.

75—24; 148—173