

LIDS FOR IMPROVED DENDRITIC WEB GROWTH

This invention relates to lids for a susceptor which enhance the thermal environment of dendritic webs adjacent thereto.

Forming a ribbon crystal by dendritic web growth is controlled by crystallography and surface tension force rather than the shape defining dyes. Ribbons of indium antimonide, gallium arsenide, germanium and silicon and other crystalline materials may be produced by providing a liquid pool of the crystalline material and placing a dendritic seed of the crystalline material which is super-cooled a few degrees into the molten pool and as the temperature in the pool falls, the seed first spreads laterally to form a button. The seed is then raised causing two secondary dendritic boundaries to propagate from each end of the button and extend into the pool. The button and dendritics form a frame which support a liquid film of the molten material which crystallizes to form a web generally 0.1 to 0.2 mm. thick. The web and bordering dendritics can theoretically be propagated indefinitely by replenishing the liquid pool as the dendritic ribbon is pulled from the pool. The ribbon width and growth velocity are determined by the thermal conditions in the melted pool and the environment adjacent the emerging dendritic ribbon. For a more detailed description of dendritic web formation, reference may be made to an article by R. G. Seidensticker (one of the inventors) and R. H. Hopkins, entitled,

"Silicon Ribbon Growth by the Dendritic Web Process", published in the Journal of Crystal Growth, Vol. 50, 1980, pages 221 to 235.

Accordingly, the present invention resides in a
5 lid for a susceptor in which a crystalline material is melted, said lid being in the form of a plate having in inboard side and an outboard side and a centrally disposed slot through which a dendritic web of essentially a single crystal of said material is pulled, a pair of openings
10 aligned with an disposed adjacent opposite ends of said slot and a groove extending between said slot and each opening and extending inwardly from the outboard side to adjacent the inboard side of said lid, whereby said slot, opening and grooves cooperate to control the radiation of
15 heat from said dendritic web to produce a generally flat distribution of isotherms across the width of the web adjacent the location where the material crystallizes.

In order that the invention can be more clearly understood, convenient embodiments thereof will now be
20 described, by way of example, with reference to the accompanying drawings in which:

Figure 1 is a partial isometric view of a lid for a susceptor utilized to form a molten pool of silicon from which essentially a single crystal dendritic web is
25 withdrawn;

Figs. 2 and 3 are schematic views showing heat radiation losses from the pool and dendritic web;

Fig. 4 is a plan view of a lid for a susceptor made in accordance with this invention;

30 Fig. 5 is a sectional view taken on line III-III of Fig. 2;

Fig. 6 is a partial isometric view of the slot openings and grooves shown in Figs. 1 and 2; and

35 Fig. 7 is a partial isometric view of an alternative embodiment.

Referring now to the drawings in detail and in particular to Fig. 1, there is shown a susceptor 1 made of

molybdenum or other material which is heated by an induction coil 3. Centrally disposed in the susceptor 1 is a cavity 5 in which is disposed a quartz crucible 7 which lines the cavity 5 of the susceptor 1. A lid 9 formed from a flat plate of molybdenum covers the crucible 7. The lid has a generally flat outboard and inboard surface 11 and 13, respectively, and a centrally disposed slot 15 extending therethrough. Aligned with the slot 15 and disposed adjacent each end thereof is an opening 17 which extends through the lid 9 and has a generally round cross-section. A groove 19 extends between and into the slot 15 and each opening 17. The groove 19 extends into the lid 9 from the outboard side 11 to adjacent the inboard side 13 leaving a thin strip 21 on the inboard side of the groove 19. A plurality of heat shield sheets 23 and 25 are disposed adjacent the outboard side of the lid 9 each heat shield sheet has a slot 27 and 29, respectively, which registers with the slot 15 and opening 17 in the lid 9. Each of the slots 27 and 29 is wider and longer than the slot 15 and opening 17 and the outboard slot 29 is wider and longer than the inboard slot 27.

A pool or melt 31 of silicon or other crystalline material is formed in the crucible 7 and essentially a single crystal dendritic web 33 of silicon or other crystalline material is pulled or withdrawn from the melt 31.

As shown in Figs. 2 and 3, the radiation heat loss from the dendritic web 33 is different when there is a groove 19 than when there is no groove. The groove 19 in this susceptor lid 9 provides a view from the edge of the growing web 33 that is substantially the same as the view of the surrounding area from the central portion of the web 33. Because the groove 19 does not penetrate completely through the lid 9, but leaves the strip 21, the heat loss from the melt 31 is controlled in nearly the same manner as the lid 9 without the groove shown in Fig. 2. However, once the dendritic web crystal 33 is slightly above the inboard side of the lid 9, the slot 15 is

essentially much larger in Fig. 3. In Fig. 2, the heat radiation from the melt is intercepted by the inboard side 13 of the lid 9 while the heat radiation from the web 33 near the end of the slot 15 is intercepted by the vertical wall portion 35 of the slot 15. Thus, the heat loss is non-uniform across the width of the web and in fact, will lead to an isotherm distribution across the web 33 which is smiling or turned upwardly adjacent the edges. This results in high thermal stresses in the web whereas as shown in Fig. 3, when the grooves 19 are provided, the heat radiation from the melt 31 is intercepted by the strip 21 the same as shown in Fig. 2, however, the radiation heat loss near the edge of the web 33 in the area adjacent the inboard side of the lid 9 is relatively constant across the entire width of the web due to the groove 19. This in turn leads to a generally flat distribution of isotherms across the width of the web 33 or one which is slightly turned downwardly on the ends, frowning, which results in reduced thermal stresses in the web 33. Because of the reduced thermal stresses in the web 33, the web 33 does not deform resulting in crystal growth which can produce a wider web which is thinner and can be withdrawn faster to substantially increase the allowable growth rate of the web 33.

Figs. 4, 5 and 6 show the slot enlarged on the ends by circular openings 35 which form a dog-bone shaped slot 15a. The slot 15a and openings 17 are counterbored as indicated at 45 and 47, respectively, generally one-half the thickness of the lid 9. The counterbores 45 and 47 originate on the inboard side 11 of the lid 9. A feed port 49 through which additional silicon or other crystalline material is added to the melt pool 31 to make the process continuous is disposed adjacent at least one side of the lid 9. The grooves 19 are generally the same width as the slot 15a.

Fig. 7 shows the slot 15 and its counterbored portion 45, the opening 17 and their counterbored portion 47, the grooves 19 and the strips 21. The slot 15, opening

17, and grooves 19 merge into a single enlarged slot with the strips 21 sealing off portions of the inboard side of the lid inboard of the ends of the enlarged slot-like opening.

- 5 The slots 15 and 15a, opening 17 and grooves 19 cooperate to control the heat radiated from the web 33 adjacent the inboard side 13 of the lid 9 to produce a generally flat isotherm across the web 33 adjacent the inboard side 13 of the lid 9 which results in reduced stresses in the web 33 reducing the deformation in the crystalline growth which allows the production of a wider web at a higher pull rate to substantially increase the allowable growth rate of the dendritic web.
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CLAIMS:

1. A lid for a susceptor in which a crystalline material is melted, said lid being in the form of a plate having in inboard side and an outboard side and a centrally disposed slot through which a dendritic web of essentially a single crystal of said material is pulled, a pair of openings aligned with an disposed adjacent opposite ends of said slot and a groove extending between said slot and each opening and extending inwardly from the outboard side to adjacent the inboard side of said lid, whereby said slot, opening and grooves cooperate to control the radiation of heat from said dendritic web to produce a generally flat distribution of isotherms across the width of the web adjacent the location where the material crystallizes.
2. A lid according to claim 1, wherein the slot has an enlarged portion on each end thereof and is generally dog-bone shaped.
3. A lid according to claim 2, wherein the enlarged portions are generally circular.
4. A lid according to claim 1, 2 or 3, wherein the slot and openings are counterbored from the outboard surface thereof.
5. Lids for a susceptor in which a crystalline material is melted, said lids being as claimed in claim 1 and substantially as described herein with particular reference to Figs. 1 to 6 or Fig. 7 of the accompanying drawings.

