CRYSTAL GROWING APPARATUS

Filed Sept. 23, 1970 2 Sheets-Sheet 1

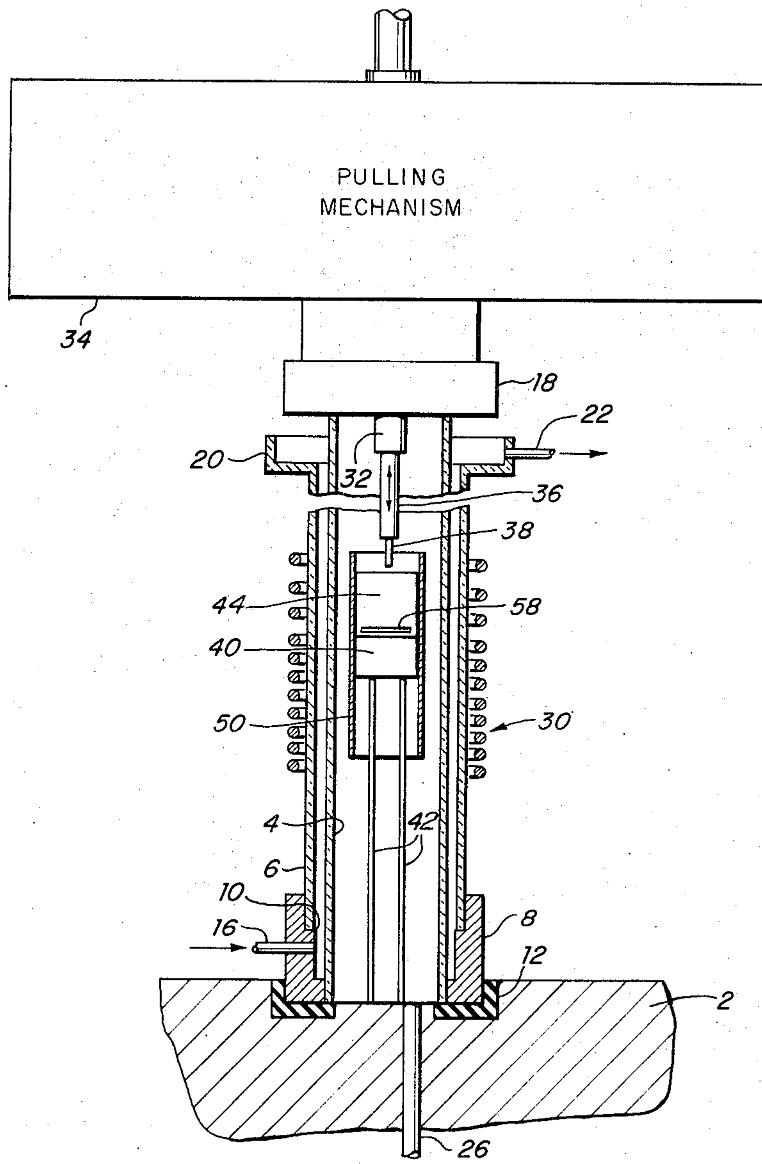

FIG. 1.

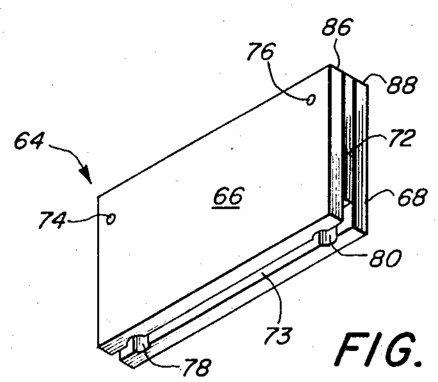

FIG. 3.

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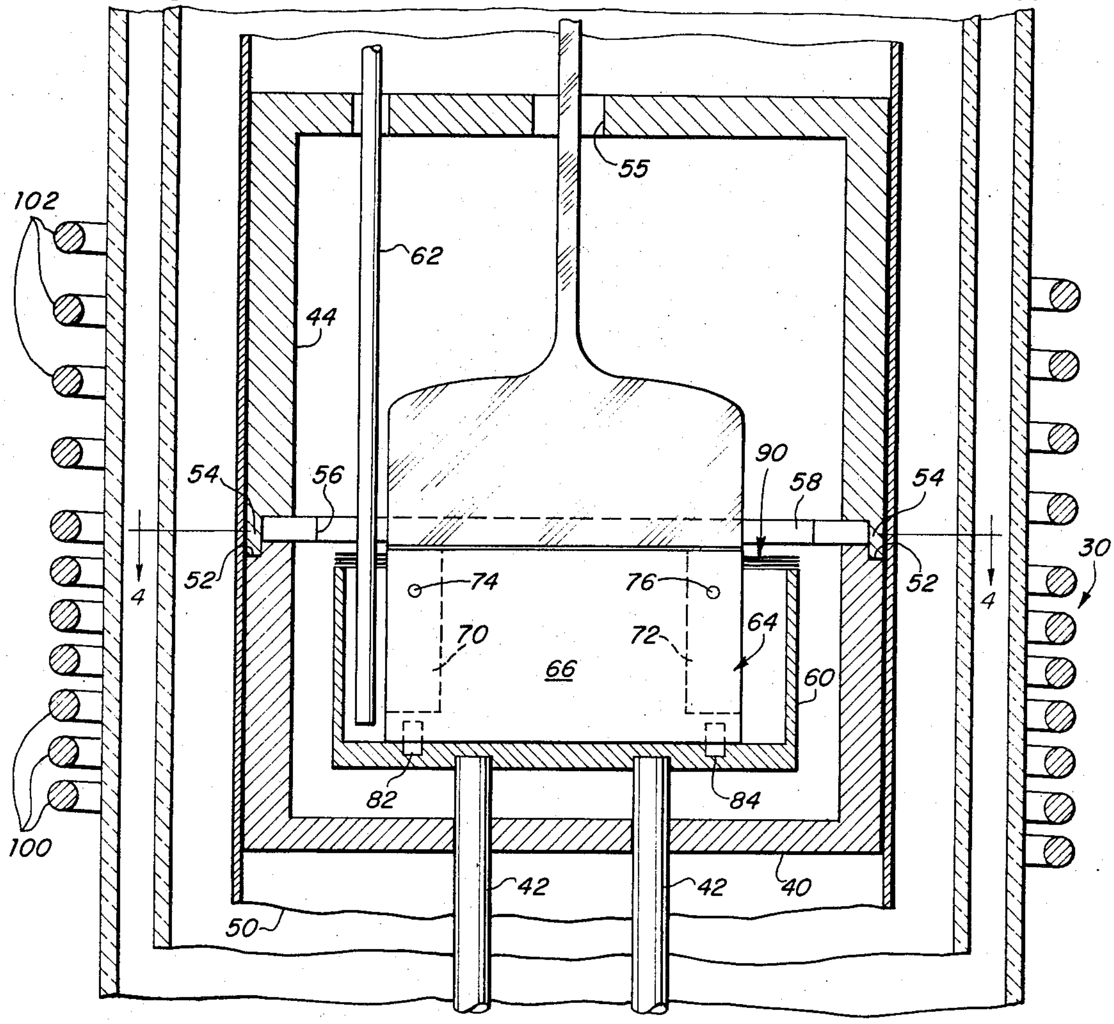

FIG. 2.

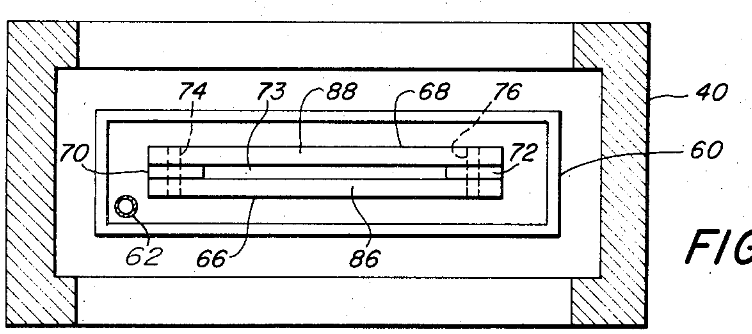

FIG. 4.

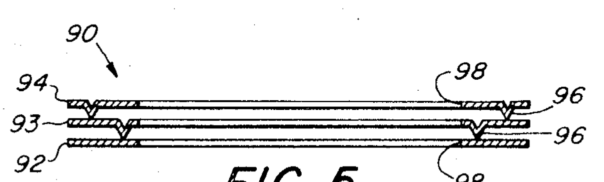

FIG. 5.

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CRYSTAL GROWING APPARATUS

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Int. Cl. B01j *17/18*
U.S. Cl. 23—301 SP 12 Claims

ABSTRACT OF THE DISCLOSURE

Apparatus for use in growing large size monocrystalline plates of materials such as alumina. The apparatus consists of a forming member for which the plate is grown and heat susceptor means shaped so as to provide a temperature pattern symmetrical with the edge configuration of the plate.

This invention relates to apparatus for growing elongate monocrystalline plates from a melt.

Various methods have been developed for growing monocrystalline bodies from a melt. The present invention concerns apparatus for use in growing crystalline bodies according to what is called the edge-defined, film fed, growth technique (also known as EFG process.) Details of this process are described in Argentine Pat. No. 165,996 dated Apr. 7, 1969 and in the corresponding copending U.S. patent application of Harold A. La Belle, Jr. Ser. No. 700,126, filed Jan. 24, 1968 for Method of Growing Crystalline Materials.

In the EFG process the shape of the crystalline body is determined by the external or edge configuration of the end surface of a forming member which for want of a better name is called a die. An advantage of the process is that complex shapes can be produced commencing with the simplest of seed crystal geometries, namely, a round small diameter seed crystal. The process involves growth on a seed from a liquid film of feed material sandwiched between the growing body and the end surface of the die, with the liquid in the film being continuously replenished from a suitable melt reservoir by action of capillary rise in a capillary in the die member. Surface tension at the periphery of the film causes it to spread across the full expanse of the end surface of the die until it reaches the edge thereof formed by intersection with another surface of the die. The angle of intersection of the aforesaid surfaces of the die is such relative to the contact angle of the liquid film that the liquid's surface tension will prevent it from overrunning the edge of the die's end surface. Preferably the angle of intersection is a right angle which is simplest to achieve and thus most practical to have. The growing body grows to the shape of the film which conforms to the edge configuration of the die's end surface. Since the liquid film has no way of discriminating between an outside edge and an inside edge of the die's end surface, a continuous hole may be grown in the crystalline body by providing in that surface an appropriate hole of the same shape as the hole desired in the growing body, provided, however, that any such hole in the die's end surface is made large enough so that surface tension will not cause the film around the hole to fill in over the hole. From the foregoing brief description it is believed clear that the term "edge-defined, film-fed growth" denotes the essential feature of the process—the shape of the growing crystalline body is defined by the edge configuration of the die and growth takes place from a film of liquid which is constantly replenished.

The primary object of the present invention is to provide an improvement in apparatus and method for growing relatively large size monocrystalline plates of materials such as alumina, by the EFG process. Heretofore it has been found that growth of rectangular plates of

sapphire (α-alumina) by the EFG process has been hampered in several ways. For one thing, in growing relatively large size plates, e.g. 3 inches wide by ⅜ inch thick and 4–6 inches long, it is difficult to control the temperature of the film and the growing body so as to avoid large temperature gradients in a direction transverse to the pulling axis, with the result that the plate produced is characterized by a number of sub-grains and facets. Another problem has been a tendency of the plate to crack on cooling due to internal strain. Accordingly, a specific object of this invention is to grow rectangular plates that have a minimum number of sub-grains, are free of internal strains, and do not crack on cooling. Described briefly the invention consists of improved means for providing a symmetrical temperature distribution about the melt, the growth zone, and the growing body with provision for two-stage heating.

Other features and many of the attendant advantages of this invention are set forth or rendered obvious in the following detailed description which is to be considered together with the accompanying drawing wherein:

FIG. 1 is a fragmentary elevational view, partly in section, of a furnace embodying the present invention;

FIG. 2 is an enlarged view of a portion of the apparatus of FIG. 1;

FIG. 3 is a perspective view of a die assembly for growing rectangular plates that forms part of the apparatus shown in FIG. 2;

FIG. 4 is a cross-sectional view taken substantially along line 4—4 of FIG. 2; and

FIG. 5 is a cross-sectional view of a radiation shield assembly used in the apparatus of FIG. 2.

The present invention may be used to produce rectangular plates of various congruently melting materials that solidify in crystalline form. One such material is α-alumina and the following description describes apparatus for growing sapphire plates, i.e. monocrystalline plates of α-alumina.

Referring now to FIG. 1, there is shown a furnace adapted for use in growing monocrystalline rectangular plates from the melt. The furnace consists of a vertically moveable horizontal bed **2** which engages a stationary furnace enclosure comprising two concentric spaced tubes **4** and **6** which have a rectangular shape in cross-section. Tube **6** is made of quartz and tube **4** is made of quartz or pyrex glass. Attached to the bottom end of the outer tube **6** is a rectangular metal spacer ring **8**. The latter has a shoulder **10** as shown which engages the bottom end surface of tube **6** and its inner edge is secured to the outer surface of tube **4**. The ring **8** is secured to both tubes by means of a suitable cement such as Silastic which also forms a water tight seal. The ring **8** is sized so as to seat snugly in a gasket **12** positioned in bed **2**. Ring **8** is provided with an inlet port fitted with a flexible pipe **16**. The upper end of tube **4** is affixed to a head **18** and support means (not shown) are provided for holding the upper end of tube **6** so that it can not move relative to tube **4**. Such support means may connect tube **6** to tube **4** or head **18**. The upper end of tube **6** terminates in a trough **20** which is provided with an outlet port fitted with a flexible pipe **22**. Pipes **16** and **22** are connected to a pump (not shown) that continuously circulates cooling water through the space between the two quartz tubes. The circulating water maintains the inner quartz tube at a safe temperature and absorbs infrared energy so as to make visual observation of crystal growth more comfortable to the observer. The interior of the furnace enclosures is connected by a pipe **26** to a vacuum pump or to a regulated source of inert gas such as argon or helium. The furnace enclosure also is surrounded by an R.F. heating coil identified generally at **30** that is coupled to a controllable R.F. power supply (not shown) of conventional construction. The coil **30** has rectangularly-shaped turns sized so as to be evenly spaced from each of the four sides of tube **6**. Means (not shown) are provided for supporting the coil in a selected position along the length of the furnace enclosure.

The head **18** is adapted to provide entry into the furnace enclosure of an elongate pulling rod **32** that is connected to and forms part of a conventional crystal pulling mechanism represented schematically at **34**. It is to be noted that the type of crystal pulling mechanism is not critical to the invention and that the construction thereof may be varied substantially. Preferably the crystal pulling mechanism is hydraulically controlled since it offers the advantage of being vibration free and providing a uniform pulling speed. Hence, regardless of the exact construction of the pulling mechanism it is to be understood that that mechanism is adapted to move the pulling rod **32** axially at a controlled rate. The pulling rod is disposed coaxially with the quartz tubes **4** and **6** and its lower end has an extension in the form of a metal rod **36** that is adapted to function as a holder for a seed crystal **38**.

Located within the furnace enclosure is an assembly constructed according to the present invention. Essentially this assembly comprises a heat susceptor **40** made of carbon. The susceptor **40** is supported on a pair of tungsten support rods **42** that are mounted in bed **2**. The susceptor **40** supports a second heat susceptor **44** which also is made of carbon. As explained hereinafter the two susceptors **40** and **44** surround the melt and the growth zone and cooperate to provide a symmetrical temperature distribution about the melt, the growth zone, and the growing crystalline body. Optionally as seen in FIG. 1, the susceptors are surrounded by a radiation shield **50** made of carbon cloth and held in place by carbon yarn (not shown) that is wrapped around it and tied. The purpose of the carbon cloth is to greatly reduce the heat loss from the two carbon susceptors **40** and **44** so as to reduce the amount of R.F. power required to reach a given temperature level. Thus, for example, it has been found that the radiation shield **50** will increase the susceptor temperature by as much as 500° C. for a given power setting for the heating coil **30**.

Referring now to FIGS. 2 and 4, the susceptor **40** is formed in the shape of a rectangular box open at the top. The upper end of the side walls of susceptor **40** are undercut to provide a continuous peripheral groove **52**. The susceptor **44** also is formed in the shape of a rectangular box and the bottom ends of its side walls are undercut to form a rib or tongue extension **54** whereby it will fit together with the susceptor **40** in a tongue and groove connection. The susceptor **44** has a hole **55** at the top for introduction of a seed and also is slotted as shown at **56** so as to provide at its opposite long sides elongate narrow apertures **58** that function as viewing ports whereby the operator may observe growth of a rectangular plate from the melt. The carbon cloth shield has a rectangular configuration in cross section so that it lies flat against the side walls of the susceptors and, although not shown, it is to be understood that the shield also is cut away to form elongate slots that are aligned with aperture **58** so that the operator may look at the growth zone.

Referring again to FIG. 2, the support rods **42** extend through the susceptor **40** and supported on their upper ends is a rectangular crucible **60** made of tungsten. The height of the crucible is such that the upper end thereof is at or slightly below the level of the viewing apertures **58**. The crucible may be made large enough to contain sufficient feed material to enable growth of a plate of desired size. As an alternative measure, means may be provided to add more feed material to the crucible during plate growth. Such means may be a filler pipe **62** which extends down into the crucible through an opening in susceptor **44**. Although not shown, it is to be understood that above the susceptor **42**, the filler pipe is angulated and extends out through suitable fittings in the quartz tubes **4** and **6** to a point exterior of the furnace enclosure where it is accessible to the operator for introduction of feed material. The feed material is preferably introduced in powdered or granular form so that it will pass readily down through the filler pipe into the bottom end of the crucible.

Mounted within the crucible **60** is a rectangular die assembly identified generally by the numeral **64** which is made of tungsten. As seen in FIGS. 2, 3, and 4, the rectangular die assembly **64** consists of a pair of flat rectangular plates **66** and **68** which are spaced from one another by a pair of spacer blocks **70** and **72** so as to form a passageway **73** which is rectangular in cross-section. The two plates **66** and **68** and the spacer blocks **70** and **72** are secured together by a pair of pins **74** and **76**. The bottom end of each of the plates **66** and **68** is formed with two circularly curved, vertically extending slots **78** and **80** which are sized so that the corresponding slots of the two plates form short entry holes for a pair of pins **82** and **84** that are mounted in the bottom of the crucible. The pins **82** and **84** serve to hold the die assembly fixed within the crucible **60**.

In order for the die assembly to satisfy the requirements of the EFG process, the spacing between the two plates **66** and **68** must be such that the passageway **73** will function as a capillary for the melt. Additionally, the relationship between the height of capillary passageway **73** and the aforesaid spacing must be such that the melt in the crucible can rise in the passageway by capillary action to the level of the upper surfaces **86** and **88** of the two plates. For a given melt material the spacing required between plates **66** and **68** to give a predetermined amount of capillary rise or the amount of capillary rise that can be achieved with a predetermined spacing between the two plates can be approximated by the equation

$$h=\frac{2T(w+t)}{Dg(wt)}$$

where h is the distance in centimeters that the liquid will rise, T is the surface tension of the melt in dynes/cm., D is the density of the melt material in gms./cc., g is the gravitational constant in cm./sec.^{2}, w is the width of the capillary in centimeters (i.e., the distance between spacer blocks **70** and **72**), and t is the depth of the capillary in centimeters (i.e., the distance between plates **66** and **68**). For alumina, T is 690 dynes/cm. and D is 3 grams/cm. at the melting point. In this connection it is to be noted that relatively long columns of alumina can be achieved by capillary action. By way of example, if an elongate capillary of circular cross-section has a diameter of 0.75 mm., a column of molten alumina may be expected to rise more than 11 cm. therein. Therefore, it is believed to be apparent that (depending upon the spacing between plates **66** and **68**) the overall length of capillary **73** may be of substantial magnitude and still achieve the required amount of capillary rise. As seen in FIG. 2, the die assembly **64** preferably rises to above the level of the crucible **60**, although it may terminate flush with or below the upper end of the crucible. The important thing is that the upper surfaces **86** and **88** of the die assembly be above the level of the melt in the crucible at all times and that the differential in height between the level of the melt and said surfaces never exceed the height to which the melt can rise by capillary action. In practice it is preferred that the difference in height between the surfaces **86** and **88** and the bottom of the crucible be less than the maximum height that the melt can rise in capillary **73**, so that crystal growth can be continued until the melt in the crucible is almost completely consumed.

It is to be noted that the spacer plates **70** and **72** are shown flush with the upper end surfaces **86** and **88** of the plates **66** and **68**. However, this is not necessary and the spacer plates may actually terminate below the level of surfaces **82** and **84**. In fact, it is also contemplated that the die assembly may be formed without the use of spacer plates **70** and **72**. Instead one of the two plates may be formed with a vertical groove therein, such as would result if the spacer plates **70** and **72** were integral with plate **86** or plate **88** and the two plates locked together by rivets or other means, whereby the groove would provide a capillary passageway between the two plates for feeding of melt to the upper surfaces of the die assembly. A further possible modification is to secure the two plates **66** and **68** together solely at their bottom ends so that for a major portion of its length including its upper end, the capillary is open along the vertically extending side edges of the two plates. In such case the spacing required between the two plates to achieve the desired capillary rise or the length of the capillary may be approximated according to the equation

$$h=\frac{2T(w)}{Dg(wt)}$$

where h, T, D, g, w, and t are as previously defined. However, in such a case the spacing t between the two plates must be relatively small. It is to be noted also that the top end surfaces **86** and **88** are co-planar and that they intersect the side surface of plates **66** and **68** at right angles.

The assembly of FIG. 2 is completed with a horizontal radiation shield assembly illustrated schematically at 90 made of tungsten. FIG. 5 illustrates a preferred form of horizontal shield assembly. This preferred design comprises a plurality of like size rectangular plates, with the bottom plate **92** being flat and resting on the upper end of the crucible **60**, and the other plates **93** and **94** being dimpled as shown at **96** so as to provide spacing between the several plates. Each of the plates **92–94** has a rectangular aperture **98** sized so that the radiation shield assembly will accommodate and extend close to the die assembly **64**.

As seen in FIG. 4, the susceptor **40**, crucible **60**, and die assembly **64** are symmetrically disposed so that the long sides of the susceptor and crucible extend parallel to the long sides of the plates making up the die assembly. If the filler pipe **62** is used, it is positioned so as to extend down into one corner of the crucible in order that delivery of additional feed material will not unduly disturb the melt in the crucible.

An additional feature of the apparatus of FIG. 2 resides in the disposition of the rectangular heating coil **30**. The latter is arranged so as to provide two stage heating, one for the crucible **60** and the susceptor **40** and the other for the susceptor **42**. This is achieved by closely spacing a number of its turns surrounding susceptor **40** as shown at **100**, while the turns surrounding susceptor **44** are relatively widely spaced as shown at **102**. With this arrangement, for a given R.F. power input to the coil, the rate of heat input to the susceptor **40** and crucible **60** will be greater than the rate of heat input to the susceptor **44**, with the result that the temperature of the melt in the crucible and in the growth zone just above the die assembly will be substantially greater than the temperature of the crystal body **104**. The crystal body **104** is kept at an average temperature below its melting point which will relieve strains, i.e. anneal it, and thereby protect it from cracking on cooling. Obviously, the same result can be achieved by using two separate heating coils, one disposed around susceptor **40** and the other disposed around susceptor **44**, with both coils connected to a suitable power supply through separate controllers so that they may be operated to provide different rates of heat input in the manner described above with respect to coil **30**. In this connection it is to be noted that the two susceptors function as heaters or heat radiators, with susceptor **40** serving to supply heat to the crucible and the die, and susceptor **44** serving to supply heat to the crystal body pulled from the melt film on the die.

It is essential that the crucible and the die assembly be made of a metal that will withstand the operating temperature and will not react with the melt. Thus in growing sapphire plates the crucible, the die assembly, and the radiation shield **90** are made of molybdenum or tungsten as noted above. However, the support rods cannot be made of molybdenum because they contact the carbon susceptor **40** and because molybdenum and carbon have a eutectic and will react at the operating temperature required to grow sapphire plates. If tungsten is used, the crucible is made by welding together flat sheets by electron beam or T.I.G. (tungsten in gas) techniques.

As indicated above the heat susceptor **44** functions as an afterheater for the crystal body that is grown. Without it the crystal body tends to dissipate heat rapidly and will have a sharp temperature gradient in a lateral direction and also in a direction parallel to the pulling axis, notwithstanding the heat input from the turns **102** of coil **30**. Depending on the rate of heat loss by radiation this temperature gradient may be great enough to cause small cracks to appear in the crystal body due to thermal shock. More importantly, the high rate of heat loss from the crystal body makes it difficult to control the temperature of the film on the upper surface of the die assembly with the result that the power input to the coil **30** has to be adjusted as the crystal body increases in size. These problems are obviated or at least minimized by the presence of susceptor **44**. Since its sides extend parallel to corresponding sides of the crystal body, the susceptor **44** functions to minimize temperature gradients and keep the crystal body at a selected temperature suitable to achieve annealing. As indicated above, the temperature of the crystal body can be adjusted by varying the spacing or the number of the turns of coil **30** surrounding susceptor **44** and the power input to the coil. The lower susceptor **40** functions in a similar manner to minimize temperature gradients in the melt along the plane of the liquid film from which the body is grown. A temperature gradient across the same film, i.e. vertically in FIG. 1, results naturally due to heat loss from the top surface of the film by absorption by the crystal body which functions as a heat sink and also because of the difference in the rate of heat input by the closely spaced heating coil turns **100** as compared to the rate of heat input by more widely spaced turns **102**. The thickness of the film is dependent upon its temperature and its rate of heat loss to the crystal body, and as a general statement, its thickness can be increased by increasing its temperature or the pulling speed and can be lowered by decreasing the temperature or pulling speed.

Following is an example of growing rectangular sapphire plates using the above-described apparatus. A tungsten crucible **60** with a molybdenum die member **64** disposed therein is filled to a suitable level with powdered alumina and an -alumina seed crystal is mounted in holder **36**. The die assembly has an overall height of about 5.0 cm. and projects about 0.2 above the crucible. The upper end surfaces of the two plates of the die assembly measure 7.5 cm. wide and 0.8 cm. thick. The spaces **70** an **72** are flush with surfaces **86** and **88** and provide a gap between the plates of 0.05 cm. The seed crystal is in the form of a round rod with a diameter of 0.3 cm. so as to melt into the capillary region. The crucible is then mounted within susceptor **40** on support rods **42**. It is to be noted that access to the interior of the furnace enclosure is achieved by lowering bed **2** away from quartz tubes **4** and **6**. The radiation assembly **90** (made of molybdenum) is then positioned on the crucible. Then the susceptor **44** is mounted on susceptor **40** as shown. The bed is then raised so as to seal off the furnace enclosure which is then filled with argon via pipe **28** to a pressure of about 1 atmosphere. Coil **30** is then energized from a 500 kc. R.F. supply. The power input to coil **30** is adjusted so that the heat input is sufficient to melt the alumina in the crucible and hold the temperature of the upper end surfaces of the capillary member to a temperature slightly above the melting point of alumina, i.e. above about 2072° C. The coil turns **102** above the level of the upper surfaces of the die assembly are spaced so as to heat the susceptor **44** to a temperature preferably to within the range of 1850 to 1950° C.

Initially the capillary fills with molten alumina to a height even with the level of the melt in the crucible and then the alumina rises by capillary action to the top of the capillary. Once the capillary is filled, the seed is lowered through hole **55** into contact with the upper surfaces of the die assembly and its end is melted as a result of such contact to form a small area film of melt. After about one minute the seed is raised slowly (at a rate of about 6 inches/hour). If the seed pulls away from the melt film on the upper end of the die assembly, the power input is adjusted to lower the temperature of the upper end surface of the die member as required and then the seed is reintroduced into contact with the melt on the upper end surface of the die assembly. The power setting required to achieve a film temperature at which crystal growth will occur is established by trial and error. Once the correct temperature is achieved, growth will appear on the end of the seed, i.e., the seed will not come free of the melt film. Initially the crystal growth will be to about the same diameter as the seed crystal as shown at **106** but then it is made to increase laterally by decreasing the film thickness. This is achieved by decreasing the pulling speed and/or the temperature of the film; however, in no event is the temperature of the upper end of the die assembly lowered to below 2072° C. Once the film has spread to the full area of the upper end of the die member, the height of the growth interface above the die surface (i.e. the film thickness) is maintained constant by controlling the average temperature in this region. The average temperature at the growth interface is monitored by a recording pyrometer which is used to control the R.F. power setting. Considerable increases in R.F. power input are required to maintain a constant film thickness as the crystal body increases in size due to the increasing heat sink capacity of the latter. The crystal body will grow in cross-sectional area as the film expands and when the film has spread out to cover the full expanse of end surfaces **86** and **88**, the growing crystal body **104** will have a rectangular cross-section with one dimension approximately the same as the width of plates **66** and **68** and the other dimension approximately the same as the combined thickness of plates **66** and **68** and the spacer **70** (or **72**). The film is constantly replenished with melt via capillary **73**. The crystal body **104** will continue to grow to the full size of the end of the die until the melt in the crucible as been consumed to the extent that the film is no longer replenished as above described. However, pulling is continued after crystal growth has terminated until the trailing end of the crystal body has been exposed to the annealing temperature for at least four hours. Then the power is lowered slowly to produce a temperature drop of about 50° C./hour to about 1400° C., and then the power is dropped faster to produce a temperature drop of about 100° C./hour to 900° C., and then shut off and the furnace allowed to cool to a point where the crucible and crystal body can be removed.

Preferably, once the crystal body has expanded in cross-section to the full area of the die member, the pulling speed is adjusted to about 1 inch/hour so as to optimize optical clarity of the product.

Operating according to the procedure just described, it is possible with the apparatus of the present invention to producee sapphire plates that are substantially monocrystalline and do not crack when cooled. The same apparatus has also been used to grow plates of other materials such as spinel, and barium titanate, with appropriate changes made in materials of construction and operating conditions according to the reactivity and melting points of the materials to be grown.

It is to be understood that the end surfaces **86** and **88** of the die effectively constitute a single rectangular film supporting surface with a hole therein formed by capillary **73**, and that the capillary may extend to the die's full width (the horizontal dimension as seen in FIG. 4) or be narrower in the form of a rectangular groove or even be a round hole sized to function as a capillary. The die also may be formed with one or more capillaries communicating with its top end surface.

It is to be noted also that the high degree of crystal perfection in the crystal plate produced as above described cannot be achieved if the susceptors **40** and **42** (or the coils of heater **30**) are made cylindrical since then certain portions thereof would be spaced further from the melt film and the crystal body than other portions thereof, with the result that substantial thermal gradients transverse to the pulling axis would be present in the melt film and the growing body and such gradients would produce uneven growth across the growth interface between the film and the growing crystal plate.

What is claimed is:

1. Apparatus for use in a furnace for growing a monocrystalline plate of a selected material that crystallizes on solidification onto a seed from a liquid film of said material having a rectangular edge configuration, said apparatus comprising a crucible that is open at the top and is adapted to contain a melt of said material without reacting chemically therewith, a die disposed in said crucible, said die having a top end surface with a generally rectangular edge configuration for supporting said film and a capillary leading from said top end surface to a point adjacent to the bottom of said crucible for feeding said melt from said crucible to said top end surface, and heat susceptor means surrounding said crucible and extending above said crucible a distance sufficient to surround at least a portion of a monocrystalline plate grown from said film, said heat susceptor means having a vertically extending inside surface of rectangular configuration that is spaced from and is symmetrical with the edge configuration of said top end surface of said die.

2. Apparatus according to claim **1** wherein said susceptor comprises a lower section and an upper section that are separably joined at approximately the level of the top end surface of said die.

3. Apparatus according to claim **1** wherein said heat susceptor has an end wall at its top end, said end wall having an opening for withdrawal of said seed.

4. Apparatus according to claim **1** further including an electrical heater coil surrounding said susceptor, said coil being adapted to supply heat at a first input rate to that portion of said susceptor located below the level of said end surface and at a second lower input rate to that portion of said susceptor located above the level of said end surface.

5. Apparatus according to claim **1** wherein said susceptor has at least one viewing aperture disposed at approximately the level of said top end surface so that an observer may view the solid-liquid interface of a solid growing from a film of melt on said top end surface.

6. Apparatus according to claim **2** wherein said upper section is supported by said lower section, and further wherein said upper and lower sections cooperate to provide a viewing aperture at approximately the level of the top end surface of said die.

7. Crystal growing apparatus adapted to grow a substantially monocrystalline body of a selected material onto a seed from a film of a melt of said material by the EFG process so that in cross-section said body has a relatively short first dimension transverse to the axis of growth and a relatively long second dimension transverse to the axis of growth and at a right angle to said first dimension, said apparatus comprising a crucible for containing a supply of said melt, a die mounted in said crucible having a rectangular top end surface for supporting said film and a capillary for feeding melt to said end surface from said crucible by action of capillary rise, said top end surface terminating in a sharp edge and hollow susceptor means surrounding and spaced from said crucible and also extending above said crucible so as to radiate heat to said crucible, said die, the film on said die and the crystal body being pulled from said film, said susceptor means comprising a lower section and an upper section joined at approximately the level of the said top end surface of said die, said susceptor means having an inside surface whose configuration in cross-section is similar to the edge configuration of said top end surface.

8. Crystal growing apparatus according to claim **7** including heating means for supplying heat to said susceptor, said heating means comprising an electrical heating coil surrounding said susceptor, the spacing between the turns of said coil being greater above said crucible than at the level of said crucible.

9. In the method of growing a rectangular monocrystalline plate of a selected crystalline material from a liquid film thereof that has a rectangular edge configuration and covers a die surface of corresponding edge configuration and which is continually replenished by feeding additional liquid from a reservoir by capillary action, the improvement comprising surrounding said film and said die surface with heat susceptor having a vertically extending inside surface of rectangular configuration that is spaced from and is symmetrical with the edge of said die surface so as to minimize heat gradients transversely of the direction of growth.

10. A method according to claim **9** further including supplying heat to said film and plate at different rates so that the liquid in said film is maintained at a temperature above the melting point of said material and said growing plate is maintained at a temperature below said melting point sufficient to relieve it of internal stresses.

11. A method according to claim **9** wherein said material is alumina and said plate is maintained at a temperature in the range of 1850 to 1950° C.

12. A method according to claim **9** wherein successive grown portions of said plate are maintained at 1850 to 1950° C. for a period of at least 4 hours.

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