United States Patent

[11] 3,580,324

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[21] Appl. No. 806,823
[22] Filed Mar. 13, 1969
[45] Patented May 25, 1971
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[54] **DOUBLE-ORIENTED SINGLE CRYSTAL CASTINGS**
10 Claims, 5 Drawing Figs.

[52] **U.S. Cl.** **164/60,** 164/127, 164/338, 164/353
[51] **Int. Cl.** **B22d 25/06**
[50] **Field of Search** 164/60, 122, 125, 127, 338, 353, 361

[56] **References Cited**

UNITED STATES PATENTS

3,342,455	9/1967	Fleck et al.	253/77
3,485,291	12/1969	Piearcey	164/127
3,494,709	2/1970	Piearcey	416/232
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ABSTRACT: An apparatus and method by which to produce single crystal parts in which the orientation of the dendrite growth in two planes at right angles to one another is described. In effect this produces an orientation in all three right angle planes of the cast article.

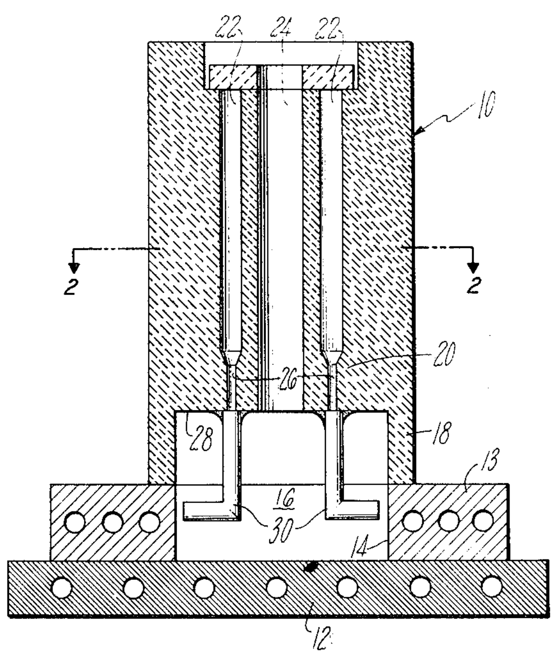

FIG. 1

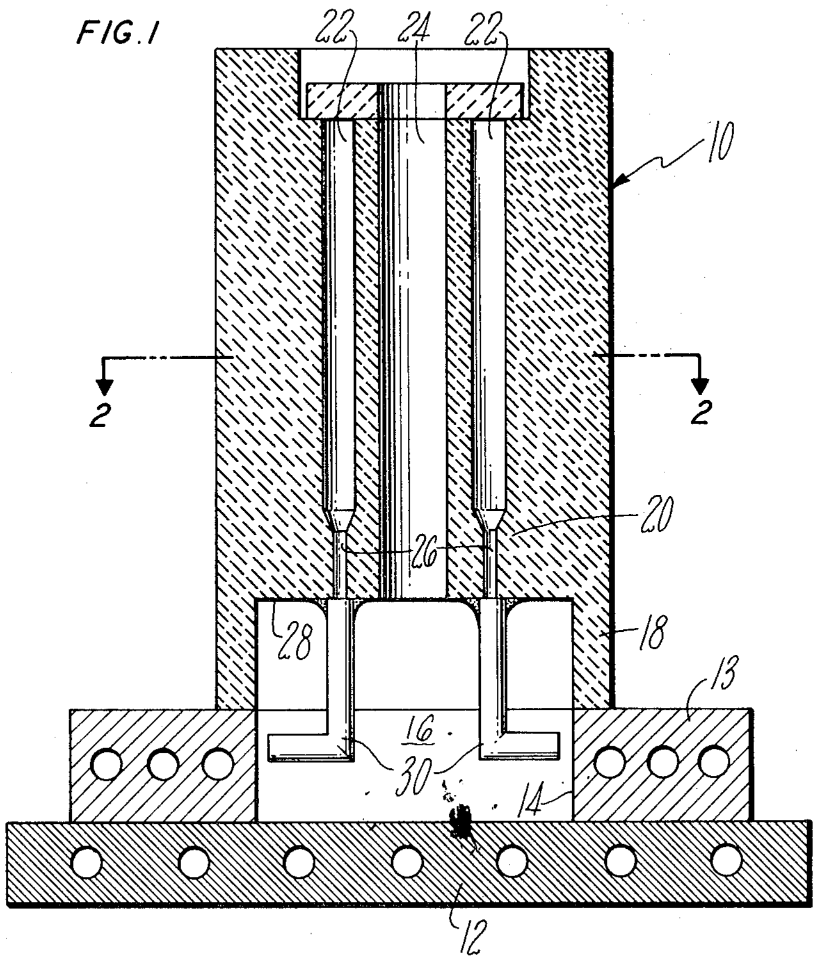

FIG. 2

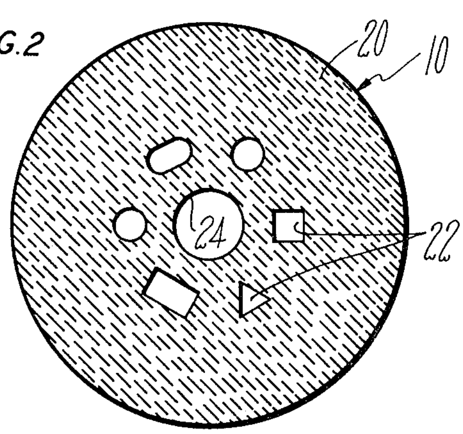

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FIG. 3

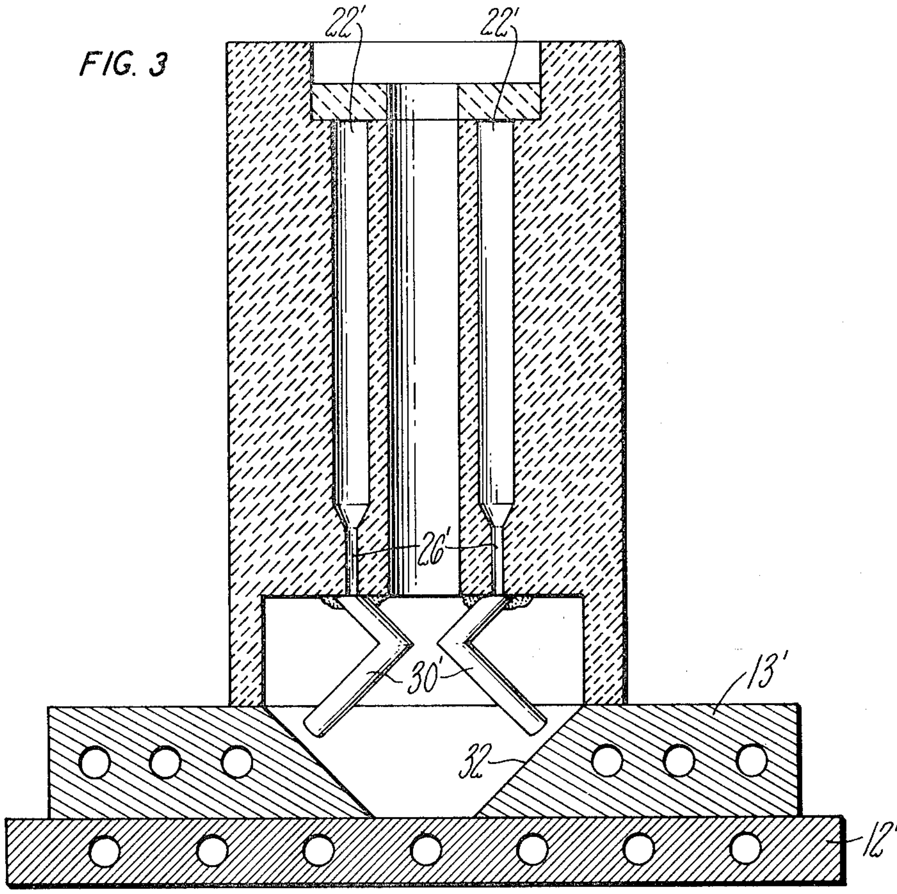
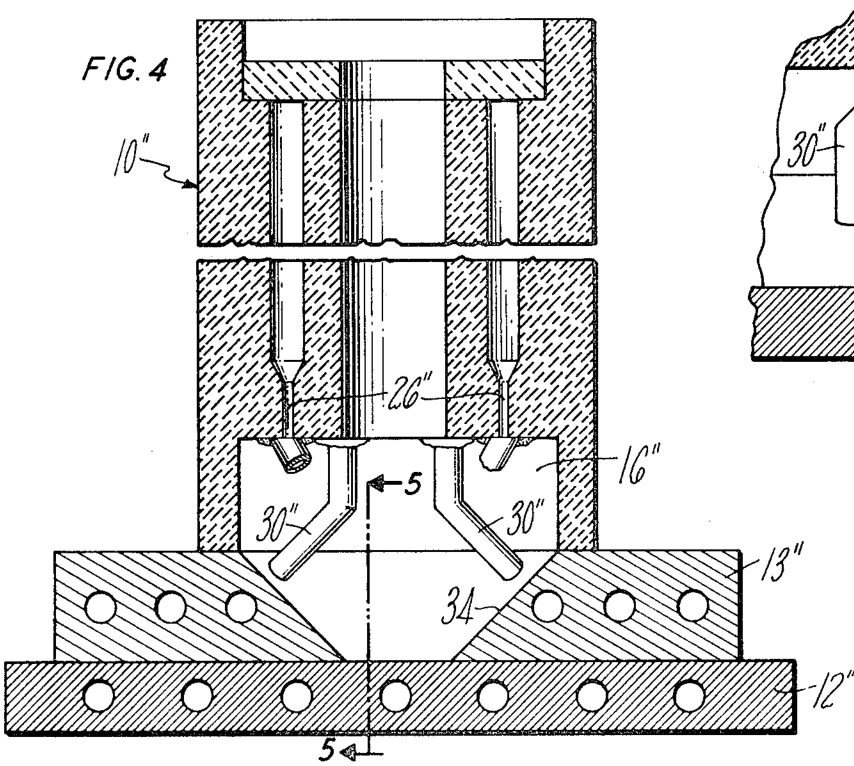


FIG. 4



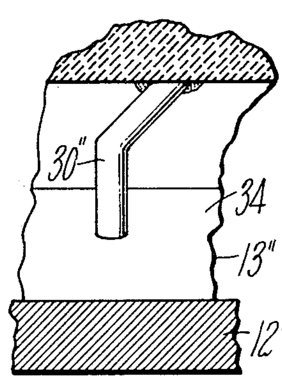


FIG. 5

DOUBLE-ORIENTED SINGLE CRYSTAL CASTINGS

BACKGROUND OF THE INVENTION

The copending application of Piearcey, Ser. No. 540,114, filed Feb. 17, 1966, now U.S. Pat. No. 3,494,709, and assigned to the same assignee as this application, describes the casting of single crystal parts in which the dendrite growth is oriented with respect to the longitudinal axis of the cast part. However, for certain devices, a more precise orientation of the dendrites in a plane at right angles to the longitudinal axis may be essential and may produce, in some particularly stressed parts a superior strength, since the strength of the single crystal castings varies in accordance with the orientation of the dendrites.

The copending application of Kear et al., Ser. No. 806,869, filed Mar. 13, 1969, describes one device and process for producing doubly oriented single crystal articles, and another application of Barrow et al., Ser. No. 806,874, filed Mar. 13, 1969, describes a modification or improvement of the first-mentioned application. Both these and the present application have a common assignee.

SUMMARY OF INVENTION

One feature of the invention is an apparatus by which to selectively orient the dendrite growth and thus the strength characteristics in a particular relation to the part in each of two directions. that is to say, in both a vertical and a horizontal direction with respect to the part as cast. Another feature is a method by which this orientation may be obtained. A particular feature is an arrangement by which the orientation is not necessarily in a vertical or horizontal plane.

A principal object of the invention is the production of single crystal castings in which the crystalline orientation, the dendrite growth, is selectively oriented in each of two directions at right angles to one another.

One feature of the operation is an arrangement by which to produce several doubly oriented parts in one casting process, utilizing the technique described in the copending application of Piearcey, Ser. No. 540,114, filed Feb. 17, 1966, for producing single crystal articles. To this extent the present invention constitutes an extension of the invention of said application. This copending application and the present application have a common assignee.

In accordance with the invention, the casting is made in a mold having associated therewith a pair of chill plate surfaces at right angles to one another to establish columnar grain growth perpendicularly to each chill surface. The intersecting grain growths produce a vertical grain growth in which the dendritic growth is positioned at right angles to both chill surfaces and thus doubly oriented. From this doubly oriented growth a single crystal is selected to grow into the effective mold portion.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a vertical sectional view through a device embodying the invention.

FIG. 2 is a transverse sectional view along line 2–2 of FIG. 1.

FIG. 3 is a vertical sectional view of a modification for producing a casting with [110] orientation.

FIG. 4 is a view similar to FIG. 3 of a modification producing a casting with [111] orientation.

FIG. 5 is a fragmentary view looking in the direction of the arrow 5 in FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENT

The doubly oriented casting is made in a ceramic mold **10** resting on a chill plate assembly consisting of the usual horizontally surfaced chill plate **12** and a secondary chill plate **13** having a vertical surface **14** exposed to and forming a wall of a solidification controlling cavity **16**. The bottom wall of this cavity is the conventional chill plate **12**.

The mold **10** has a depending flange **18** resting on the upper surface of the secondary chill plate **13** and has a relatively heavy wall **20** extending upwardly from the flange and in which a plurality of article casting cavities **22** are formed. These cavities preferably have their longitudinal axes vertical within the mold and the several cavities surround a central vertical opening **24** in the mold. This opening **24** provides for filling the mold with molten alloy and also serves to control the cooling rate of the alloy in the several article casting cavities **22**. Each cavity **22** has a restricted passage **26** at the bottom of the cavity terminating in the bottom surface **28** of the main wall of the mold.

Attached to this bottom surface and communicating with the lower end of the restricted passage **26** for each article casting cavity is a small ceramic tube **30** with a 90° bend in it. This tube is connected to the mold in such a way that the bottom end of the tube is positioned adjacent to the vertical wall of the secondary chill but spaced therefrom to allow the flow of alloy into the tube to fill the mold. The portion of the tube **30** below the 90° bend is also at right angles to the vertical chill.

In the arrangement shown both legs of the right angle tube **30** are shown as being in the plane of the drawing and in this way the dendritic growth will be in two planes at right angles to one another and at right angles to the effective chill surfaces.

In operation, the mold is heated as described in the VerSnyder U.S. Pat. No. 3,260,505. When the proper mold temperature is obtained the mold is filled with molten alloy through the central opening. During this filling the alloy flows upwardly from the solidification controlling cavity through the tubes **30** to fill the several article casting cavities. When the mold is properly filled the chill plates are made effective and the temperature of the mold is gradually reduced beginning at the bottom of the mold to produce a thermal gradient in the mold that will control the rate of solidification and will cause a controlled rate of the upward movement of the liquid-solid in face in both the center opening and the article casting cavities. This technique is described in the VerSnyder Pat. and for single crystal casting in the Piearcey application, Ser. No. 540,114.

As solidification begins directional solidification occurs at right angles to both effective surfaces of the chill plates thereby assuring a vertical growth of dendrites at right angles to the main chill plate and a horizontal growth at right angles to the vertical secondary plate. The ceramic tube **30** for each casting cavity selects only a few crystals in the horizontal portion, and at the 90° bend permits vertical growth of only a small number of these grains. The restriction **26** then selects a single crystal that continues to grow into and through the article cavity, with the dendritic growth necessarily oriented at right angles to the two chill plate surfaces. The resultant orientation in the cast article is [100]. The larger bulk of metal in the central cavity serves primarily to control the rate of solidification in the article cavities thereby assuring the desired grain size and freedom of imperfections in the finished casting. Obviously the article cavities are made whatever the desired shape of the finished article. Such molds are conventionally made by the lost-wax process. A cover plate **31** is shown for each of the several article cavities to minimize heat loss. Much of the casting done by this process and apparatus utilizes the well-known vacuum casting technique.

The arrangement of FIG. **3** is similar to FIG. **1** in many respects. The conventional chill **12'** presents the horizontal chill surface but the secondary chill **13'** has a chill surface **32** extending at an angle of 45° to the horizontal chill surface. The mold has the same type of article casting cavities **22'** but the thin ceramic tube **30'** is arranged with its lower leg at right angles to the 45° surface of the secondary chill plate and the upper leg extends at right angles to the lower leg, and, in the arrangement shown, the entire tube is in the same plane as the vertical section of the drawing.

The operation of this modification is much the same as above described. The directionally solidified growth in the solidification controlling chamber is vertical from the main chill plate, and also at right angles to the 45° surface of the secondary chill plates. Thus the dendritic growth entering the tube **30'** is at right angles to this 45° chill surface. At the bend in the tube a few crystals having a direction parallel to the upper leg of the tube grow therein to the restriction **26'** which then selects a single crystal to grow through the restriction and into the casting cavity. Thus the dendritic growth is in two directions parallel to the two legs of the tube and is so continued into the cast article. This produces a [110]orientation.

The arrangement of FIG. **4** has the mold **10''** resting on chill plates consisting of the horizontal chill plate **12''** and the secondary chill plate **13''**. The latter has an operative surface **34** extending at an acute angle to the horizontal, the angle in this case being 55°. This surface **34** forms a part of the sidewall of the solidification controlling cavity **16''**. A thin ceramic tube **30''**, which may be made of aluminum oxide, is cemented to the mold at the lower end of the restricted passage **26''** but in this configuration the upper leg of the tube is not in the same vertical plane as the lower leg but is, in fact, at an angle to a vertical plane, as shown in FIG. **5**. Thus this leg, shown in phantom in FIG. **4** extends out of the plane of this FIG., although the angle of the tube is still a right angle. This arrangement permits the selection of another orientation of crystal or dendritic growth.

The operation is the same as described above. Directionally solidified growth begins both vertically from plate **12''** and angularly at right angles to the surface of plate **13'**. The tube **30''** selects a few directionally solidified grains which grow through the lower leg parallel to its axis. At the bend, the crystalline growth continues into the upper leg from a few of these grains, with the dendritic growth parallel to this leg of the tube, thus establishing a doubly oriented dendritic growth parallel to the two legs of the tube. The restriction **26''** selects one of these doubly oriented grains and this grain propagates through the restriction and into the article cavity with the same doubly oriented dentritic structure. This arrangement produces a [111] orientation, the [100] and the [010] orientations being parallel to the two legs of the tube. Obviously the acute angle of the secondary chill may be changed to control the particular angle of dendritic growth in the lower leg of the tube, and the angle between the upper leg of the tube and vertical plane determines the second angle of dendritic growth. Thus any desired orientation of the crystalline structure, the dendritic angles, may be selected by the position of the thin-walled tube.

It will be understood that the tube **30** (or **30'** or **30''**) need not be as small in diameter as the restriction **26** above the tube and thus there is only a short-restricted passage through which the molten alloy must flow in filling the article cavities. Further, the tube is not subjected to any pressure differential as the molten alloy will be at substantially the same level both within and outside the tube during filling of the mold, and thus it may have a very thin wall so that there will be no substantial temperature difference in the metal inside of and outside of the tube during the solidification process.

WE claim:

1. Apparatus for casting doubly oriented single crystal articles including a mold having at least one article forming cavity therein, a solidification controlling cavity vertically parallel to said article cavity and extending below the article cavity to an open lower end, chill plates at angles to one another closing said open lower end, said article cavity having a constricted lower end opening into said solidification cavity, a ceramic tube extending from said constricted opening to a point adjacent the surface of one of said chill plates and having substantially a rectangular bend therein, said solidification cavity having an open top end by which the mold is filled.

2. Apparatus as in claim **1** in which the chill plate surfaces are vertically and horizontally positioned and the ceramic tube end is adjacent to and spaced from the vertical surface.

3. Apparatus as in claim **1** in which the surface of one chill plate makes an acute angle with the horizontal and the ceramic tube end is adjacent to and spaced from said chill plate surface.

4. Apparatus for casting doubly oriented single crystal castings, including a mold having a plurality of vertically positioned article forming cavities thereon in spaced relation to one another, and a vertically positioned solidification cavity in parallel relation to and adjacent to the article forming cavities, all of said cavities terminating at and opening into a larger base cavity open at the bottom of the mold, at least two chill plates arranged with their operative surfaces at an angle to one another and closing the open bottom of the mold, and ceramic tubes positioned in said base cavity and extending from the open ends of the article forming cavities to points adjacent to and spaced from one of said chill plates, each tube having substantially a right-angle bend therein between its ends, the position of the tube and the chill plates determining the orientation of the dendritic growth in the tubes and the article cavities.

5. Apparatus as in claim **4** in which the chill plate surfaces are respectively vertical and horizontal and the portions of the ceramic tubes are respectively at right angles to the chill plate surfaces.

6. Apparatus as in claim **3** in which one chill plate has its operative surface at an acute angle to the horizontal and the portions of the ceramic at opposite sides of the right-angle bend are respectively perpendicular to and parallel to said surface.

7. The method of casting doubly oriented single crystal articles, including:

1. providing a mold having an article forming portion therein with an open lower end,
2. providing a chill plate having an operative surface at an angle to the horizontal,
3. connecting the open end of the mold by a ceramic tube having substantially a right-angle bend thereon to a point adjacent to the chill plate,
4. surrounding the tube by a casting cavity,
5. filling said article forming portion, said casting cavity and said tubes with molten alloy and
6. cooling the alloy and mold to induce columnar growth in said tube at right angles to the chill plate while the alloy in the casting cavity is solidifying, and
7. continuing to solidify the alloy to induce a further crystalline growth in the tube and into the article forming cavity.

8. The method of claim **7** in which the casting cavity extends upwardly in parallel relation to the article forming cavity with the additional step of controlling the rate of vertical solidification in the article forming portion by the rate of solidification in said casting cavity.

9. The method of casting doubly oriented single crystal articles, the steps of:

a chill plate having a surface extending at an angle to the horizontal,

forming a mold having parallely extending solidification and article forming cavities both terminating at the bottom in an enlarged casting cavity closed by said chill plate,

connecting the open end article forming cavity by a thin walled tube located in said casting cavity to a point adjacent to the chill plate surface,

providing a rectangular bend in said tube and positioning the portion of the tube from the bend to the open lower end

at right angles to the chill plate surface,

heating the mold,

pouring molten alloy into said mold to fill the cavities therein and the ceramic tube,

and causing solidifying to occur from the chill plate upwardly with columnar growth at right angles to said chill plate surface.

10. The method of claim **9** with the added steps of:

providing cooperating surfaces on the chill plate at right angles to one another, positioning the tube with the portions thereof in substantially perpendicular relation to the two chill plate surfaces, and forming the open end of the article forming portion to select a single crystal from the doubly oriented crystalline growth within the tube.