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SINGLE CRYSTAL GROWING APPARATUS

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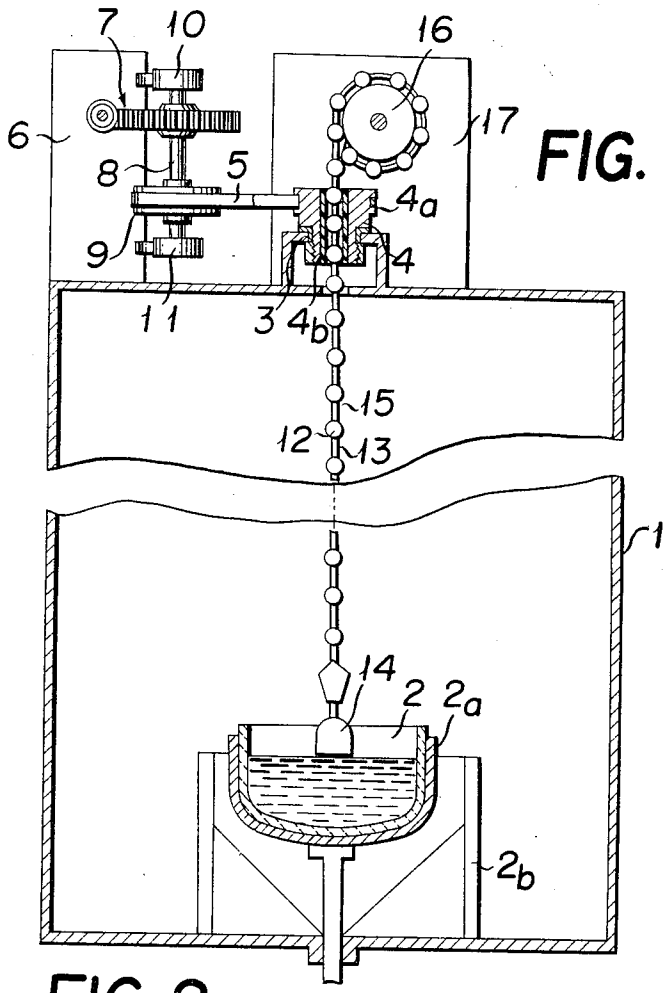


FIG. 1

FIG. 2

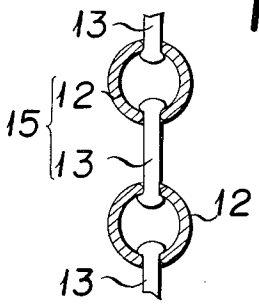


FIG. 3

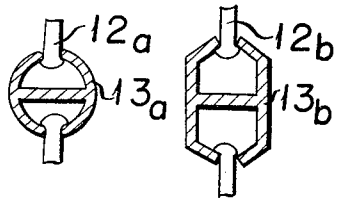


FIG. 4

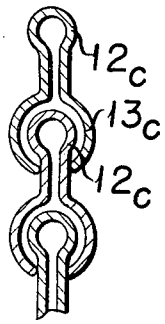


FIG. 5

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# SINGLE CRYSTAL GROWING APPARATUS

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U.S. Cl. 23—273 3 Claims

## ABSTRACT OF THE DISCLOSURE

The invention concerns itself with a crystal growing apparatus having a seed crystal suspending means to suspend the seed crystal at the lower end for bringing the seed crystal in contact with the surface of a mother liquor to be grown into a single crystal and gradually drawing up the seed crystal while rotating it as it progressively grows, wherein said seed crystal growing means is constructed by a plurality of spheres serially connected to each other in a so-called ball and chain, thereby preventing the seed crystal from executing vibratory motion or pendulum motion due to rotation and upward movement of a conventional rigid bar suspending means and obtaining exact rotation of the seed crystal completely free from gyroscopic motion.

The present invention relates to an apparatus for growing single crystals by causing a seed crystal suspended by a suspending means to touch the surface of mother liquor and gradually drawing up the seed crystal while rotating the same so as to progressively crystalize the mother liquor, and more particularly, to an apparatus for growing semiconductive single crystals.

In conventional crystal growing apparatus, the seed crystal suspending means consists of a bar member whose stroke usually extends to about 25 centimeters, so that when the bar member is drawn up its lower end is brought into pendulum motion or sometimes into gyroscopic motion in case torque is imparted to the bar member, and as a result the grown crystal hanging down from the bar member tends to break or the direction of growth sometimes deviates in an undesired manner.

In order to assure proper growth of the single crystal it is thus necessary to keep vertical the seed crystal suspending means.

The present invention has its object to provide a single crystal growing apparatus having a rosary-type i.e., spherocylindrical suspending means passing through and making a snug and frictional engagement with a hollow sleeve member rotatable about a vertical axis so as to impart torque to the suspending means through the frictional force interacting between the hollow sleeve member and the spheres of the suspending means, whereby the seed crystal is vertically suspended on the surface of the mother liquor and drawn up while rotating it about a vertical axis to gradually grow a single crystal below the seed crystal.

The present invention has as its object to provide a single crystal growing apparatus having a seed crystal suspending means consisting of a plurality of hollow spherical members successively connected to one another by connecting pins, each of which has both ends universally joined to two adjacent spherical members in such a manner that the centers of a series of suspended spherical members all lie along a vertical straight line.

The invention is now described in conjunction with a preferred embodiment with reference to the accompanying drawings, in which:



FIG. 1 is a diagrammatical cross sectional view illustrating one embodiment of the apparatus according to the invention;

FIG. 2 is a section illustrating a portion of a seed crystal suspending means; and

FIGS. 3 to 5 show cross sections similar to FIG. 2 illustrating a modification of the seed crystal suspending means.

Referring to the drawing, the reference numeral 1 indicates a gas-tight vessel on the bottom of which is disposed a crucible 2 filled with a mother liquor to be grown into a crystal. Although not shown in the figure, the gas-tight vessel 1 is provided with a suitable window for inserting and removing the crucible into and out of the vessel 1. The vessel 1 may be evacuated by an evacuating means and the evacuated vessel may in turn be filled with non-oxidizing gas such as nitrogen, hydrogen and the like. The vessel 1 is further provided with an aperture 3 on its top wall directly above the crucible 2 for installing therein a hollow sleeve member 4 such that it can be rotated about its vertical axis. The sleeve member 4 is formed with an outer annular groove on its portion extending above the top wall of the vessel 1 to receive an endless belt 5 to transmit power from an electric motor 6 mounted on top of the vessel 1 through a transmission line including a reduction mechanism 7 and a pulley 9 fixedly mounted on a vertical shaft 8 journalled in bearings 10 and 11 at both upper an lower ends. It is preferred to install the hollow sleeve member 4 in the aperture 3 through a bearing. In such a case, however, it is necessary to provide packing means between the bearing and the sleeve and between the bearing and the brim of the aperture in order to achieve gas-tight seal. The inside of the sleeve member 4 is lined with a lining 4*b* having a large friction coefficient and a good heat-resistant property, such as polyfluoroethylene resinous material (commonly termed Teflon). There extends through the sleeve member 4 into the vessel 1 a seed crystal suspending means such as generally indicated at 15 in FIG. 2 and adapted to suspend a seed crystal 14 at its lower end. The rosary-type, sphero-cylindrical seed crystal suspending means 15 comprises a plurality of hollow sphero-cylindrical or spherical members 12 (or sphero-cylindrical members) having such an outer diameter that they make snug and frictional engagement with the surface of the cylindrical hollow of the sleeve member lining 4*b*, which spherical members 12 being successively connected pins 13, each of which has both ends universally joined to adjacent two spherical members 12, in such a manner that centers of a series of suspended spherical members all lie along a vertical straight line. Above the sleeve member 4 the seed crystal suspending means 15 is wound on a rotary drum 16 provided above the vessel 1 so that it may be downwardly lowered or upwardly taken up by the forward or reverse rotation of the drum 16 by operating a drive means 17.

The crucible 2 is preferably made of quartz surrounded by an outer receptacle 2*a* molded from carbon and serving as the heater energized through carbon members 2*b* to indirectly heat the crucible 2 to keep mother liquor filled therein in molten state.

With the apparatus of the construction as described in the foregoing, pendulum motion and gyroscopic motion of the suspending means caused by rotating or vertically moving it and vibratory motions externally transmitted to it are all absorbed between the spherical members and the connecting pins, so that the transmission of any objectionable vibration, pendulum motion or gyroscopic motion through the suspending means to the seed crystal may be prevented and only torque imparted to spherical members in frictional engagement with the sleeve member 4 in rotation is transmitted to the lower hanging portion of the seed crystal suspending means.

Consequently, the portion of the seed crystal suspending means below the sleeve member 4 extends vertically and makes exact rotation about its vertical center line, while it is being gradually drawn up by the rotation of the drum 6, with the seed crystal being attached at its lower end, so that an ideal growth of a single crystal may be obtained.

Further, as the seed crystal suspending means is wound on the rotary drum, the vertical dimension of this embodiment is reduced to about a half of that required for the conventional crystal growing apparatus using a bar member as the seed crystal suspending means.

Furthermore the adjustment of the frictional force interacting between the sleeve member and the spherical members of the suspending means may be made by altering the inner diameter of the sleeve lining by applying a force to its upper end to subject it to a plastic deformation to such an extent as to compensate the wear.

Although in the preceding embodiment means for imparting torque to the seed crystal suspending means and means for vertically displacing the suspended portion of the seed crystal suspending means are provided directly on top of the gas-tight vessel, other suitable constructions may also be employed.

For example, according to a modification of the seed crystal suspending means shown in FIG. 3, each of the spherical members **12***a* has a partition wall which lies in a direction substantially perpendicular to the direction of alignment of the connecting pins **13***a* in order to more positively maintain the interior of the vessel vacuum tight which otherwise tend to be broken due to the openings formed in the respective spherical members, through which the connecting pins are universally journalled to the spherical members. In FIG. 4, each of the members **12***b* take a form of a hollow cylinder whose ends are closed except openings formed in the closed end walls of the member and which serves to universally journal connecting pins **13***b* with the result that the area of the contact face between the cylinder **12***b* and the inner wall of the lining is increased thereby positively enhancing the vacuum tight condition of the vessel. Further in FIG. 5, the seed crystal suspending means consists of a number of members each formed of a spherical member portion **13***c* and a connecting pin portion **12***c* which are integrally formed to constitute a single member and which respectively have hollow portions communicating with each other, the end of the hollow connecting pin portion being closed. In producing serially connected members, an explosive is first inserted in the tip end of the closed hollow portion of the connecting pin and such explosive containing portion of the pin is then placed in the hollow portion **13***c* of the other spherical member portion, where said pin portion is expanded by means of explosion molding, whereby two of the members are universally journalled. This operation is repeated to form a sufficient length of serially connected members of the seed crystal suspending means.

It is desired that at least the spherical members or member portions are made of a material having a heat-proof property at about 1100° C., such as stainless steel, Inconel, platinum or the like.

It is to be observed for want of a better expression, the rosary-type suspension means has been described as having sphero-cylindrical or spherical members. The shape of these members will be better understood from the drawing.

What is claimed is:

**1.** A single crystal growing apparatus, comprising in combination:

(a) a gas-tight vessel;

(b) mounting means for supporting a crucible in said vessel;



(c) crucible means supported in said vessel by said mounting means, said crucible means being designed to hold a mother liquor;

(d) a seed crystal suspending means vertically moveable and rotatably arranged above said gas-tight crucible vessel for implanting a seed in said mother liquor to produce a single crystal, said seed crystal suspending means having a plurality of spherical or sphero-cylindrical members serially connected to one another by connecting pins, each of which has both ends universally joined to two adjacent members so that the centers of all suspended members lie along a vertical straight line;

(e) vertical moving lifting means to vertically lift said suspending means, including a rotary drum on which the upper portion of said seed crystal suspending means is wound; and

(f) rotating means to rotate said suspending means from above said crucible means including a hollow sleeve with a lining therein with a large friction coefficient and good heat resistant properties, said hollow sleeve being rotatable about a vertical axis, said suspending means passing through the interior hollow portion of said hollow sleeve so that a torque is imparted to said suspending means through frictional force interacting between said hollow sleeve and said members of said suspending means in engagement with said hollow sleeve, the outer spherical surfaces of said suspending means members creating a gas-tight seal for said hollow sleeve.

**2.** A single crystal growing apparatus comprising in combination; a gas-tight vessel, a crucible for holding a mother liquor disposed in said vessel, a seed crystal suspending means vertically and rotatably arranged above said crucible and which has a plurality of spherical or sphero-cylindrical members serially connected to one another and universally joined by connecting pins, so that the centers of all suspended members lie along a vertical straight line, means to vertically lift said suspending means including a rotary drum on which the upper portion of said seed crystal suspending means is wound, and means to rotate said suspending means from above said crucible including a hollow sleeve with a lining therein with a large friction coefficient property, said hollow sleeve being rotatable about a vertical axis, said suspending means passing through the interior hollow portion of said hollow sleeve so that a torque is imparted to said suspending means through frictional force acting between said hollow sleeve and said member of said suspending means in engagement with said hollow sleeve, the outer spherical surfaces of said members creating a gas-tight seal for said hollow sleeve.

**3.** A single crystal growing apparatus claimed in claim **2** in which said connecting pins are integrally formed with the respective suspended members and universally connected with the adjacent suspended members.


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