June 18, 1963 N. E. HAMILTON 3,094,006

PULL AND ROTATION MECHANISM FOR CRYSTAL GROWING APPARATUS

Filed June 15, 1960 2 Sheets-Sheet 1

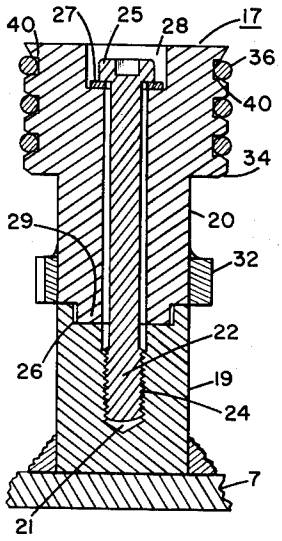


FIG. 2

FIG. 1

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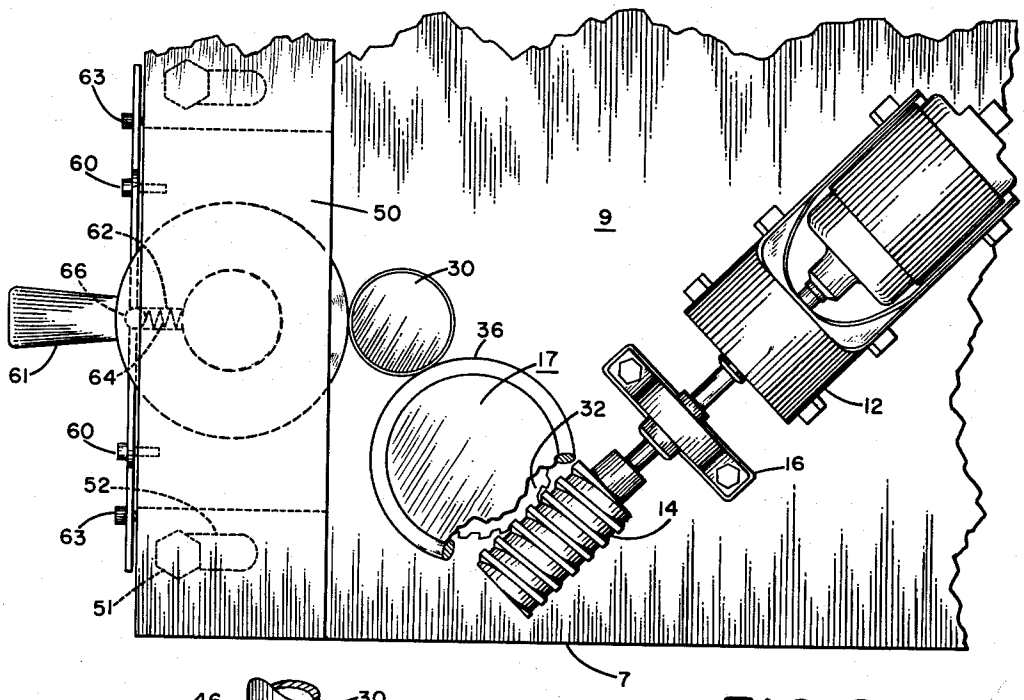


FIG. 3

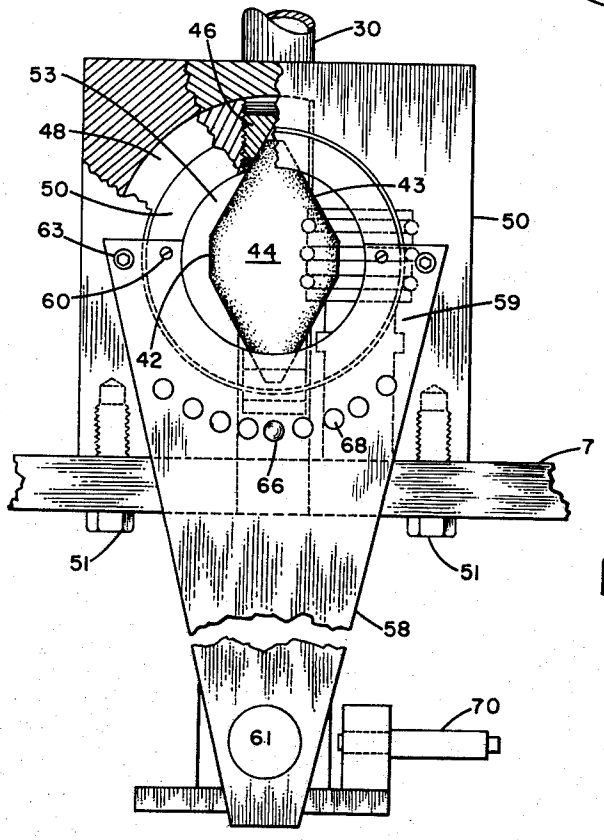


FIG. 4

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PULL AND ROTATION MECHANISM FOR CRYSTAL GROWING APPARATUS

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5 Claims. (Cl. 74—22)

This invention relates to an improved pull and rotation mechanism adapted to be employed in a crystal growing apparatus, or the like.

A number of crystal growing methods are well-known in the prior art. For illustrating the applicability of the present invention let it be assumed that the crystal growing method necessitates the provision of an apparatus including a seed holder to which a crystal seed is secured. The seed holder is longitudinally movable to slowly immerse the crystal seed into a molten mass of semiconductive material allowing the melt to adhere to the seed. The withdrawal of the seed from the melt occurs at a very slow speed to permit the molten material to crystallize on the seed. The seed is rotated during the growing process to improve characteristics in the growing crystal, for instance the symmetrical cross-section.

The pulling and rotating action is of utmost critical nature as can be readily deduced from the fact that pulling rates of .001 up to .006 inch per second are conventionally in use. Heretofore, such requirements have necessitated pull and rotation mechanisms unusually complex and cumbersome in structure.

One of the principal objects of this invention is to provide a mechanism of utmost simplicity for pulling a crystal seed out of the melt and for simultaneously rotating the seed holder during the pulling and/or immersing cycle. The device in accordance with the invention is of simple nature, enabling the elimination of numerous mechanical parts previously required. The simplification has not only affected the initial cost, the maintenance of the device, but also in addition thereto has enabled the construction of a crystal growing apparatus of substantially reduced heights as compared to conventional systems.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawings, and its scope will be pointed out in the appended claims.

Briefly, an aspect of the invention is in the provision of a pull and rotation mechanism for a crystal growing apparatus which comprises driving means, a shaft rotatably driven by the driving means, annular frictional coupling member formed of elastic material and surrounding portions of the shaft, a pull rod, a mounting member for securing the pull rod for rotation and longitudinal displacement and maintaining the pull rod in frictional engagement with the frictional coupling member, a roller rotatably mounted and in driving engagement with the pull rod, means securing the roller for angular variation of the longitudinal axis of the roller in respect to the axis of the pull rod so that upon changing the angular relation of the axes a force component is exerted on the pull rod to longitudinally displace the latter.

FIGURE 1 is a vertical partly sectional view of the present invention and includes pertinent portions of a crystal growing apparatus;

FIGURE 2 is an enlarged cross-sectional view taken on the line 2—2 of FIGURE 1, illustrating the shaft assembly;

FIGURE 3 is a top plane view of the pull and rotation mechanism; and

FIGURE 4 is a side elevational view, partly in section, illustrating the gimbal mounted roller arrangement and the handle for angular adjustment of the gimbal.

This invention is primarily concerned with solutions to problems concerning a pull and rotation mechanism, and hence, the following description is generally restricted to such subject matter; reference to the crystal growing apparatus is only included where necessary to clarify the present invention.

Referring now to the drawings, numeral 1 denotes a crystal growing apparatus having a base portion 3 providing a crucible assembly, a tubular structure member 5 is connected on one end to the base 3 and at the other end to a support plate 7 upon which a pull and rotation mechanism assembly 9 is mounted. The latter assembly 9 includes a pull rod 30 the lower end of which protrudes into the tubular structure member 5 and is axially movable therein to transport a crystal seed 8 carried in seed holder 10, connected to the pull rod 30, to and from the crucible assembly 3.

More particularly, the pull and rotation mechanism 9 comprises a single constant speed non-reversible motor and speed reducing unit 12, see FIGURE 3, suitably mounted to the support plate 7. The motor speed reducing unit 12 is mechanically coupled to a worm 14 by means of a conventional coupler and support brushing 16 to rotate a shaft member 17. The shaft member 17 is rotatably mounted with its axis perpendicular to the horizontal support plate 7. The shaft includes annular frictional coupling means 36 which surrounds a portion of the shaft 17 and which frictionally engages the pull rod member 30 to rotate the same, as hereinafter explained.

The shaft 17, refer to FIGURE 2, is formed by a cylindrical base 19, suitably welded to the support plate 7, and another cylindrical member 20 is rotatably mounted on the cylindrical base 19. The base 19 and member 20 are axially aligned and a central bore 21 extends through member 20 and into portions of base 19 to receive a partially threaded bolt 22 therethrough. The bolt 22 rotatably connects member 20 to the base 19 by extending into threaded portion 24 with the bolt head 25 loosely abutting against a washer 27 which is interposed between a shoulder 28 and the head 25 of the bolt 22. To effect suitable axial alignment of member 20 and base 19, member 20 has an end 29 of reduced diameter which extends in a closely registering axial bore 26 of base 19. This arrangement permits relative axial movement of member 20 with respect to the base without permitting longitudinal movement.

A gear 32 is secured to shaft member 20 by soldering it thereto. The gear 32 is in meshing engagement with the corresponding worm 14 translating rotary motion from the motor to drive shaft member 20 of the shaft 17. A radial shoulder 34, integrally provided on shaft member 20, forms a radial enlarged portion into which three radial grooves 40 are machined to receive in each groove a friction drive O-ring 36. The inside diameter of the O-rings 36 is substantialy equal to the minimum base diameter of the groove 40 to provide a tight fitting O-ring arrangement, while the thickness of the O-rings is such to extend the latter radially beyond the outermost radial surface of the worm gear 32 to enable the O-rings to frictionally engage the pull rod 30. The O-rings 36 are resilient and yield in the direction of travel and they also can roll slightly in their grooves. This permits flexible driving conditions to adjust for the relative longitudinal movement of the drive shaft as it pulls the seed crystal while simultaneously rotating it. This arrangement generally pre-supposes that the pull rod is positioned so that its longitudinal axis is nominally parallel with respect to the longitudinal axis of the shaft 17.

The longitudinal movement of the pull rod **30** is effected by a roller **44** rotatably secured in adjustable bearings **46** which are mounted within a gimbal ring **48**, the latter being angularly displaceable with respect to the longitudinal axis of the pull rod **30**.

A frame **50** is movably attached to the support plate **7** by screws **51** extending through slots **52** in plate **7**, as illustrated in FIGURE 3. The frame has a square-like configuration and provides a central opening **53** to receive gimbal ring **48** therein. The wall **54** defining the aperture **53** is angularly inclined, see FIGURE 1, and the outside diameter of the ring-like gimbal **48** varies inversely with respect to angular dimensions of wall **54**. The tolerance between gimbal ring **48** and frame **50** is such that the gimbal ring may suitably be angularly displaced within the frame to vary the angularity of the roller **44** with respect to the pull shaft.

The roller **42** is made of elastic material, a cloth filled micarta material has been found suitable, and forms a cone-like configuration at opposite ends **43** with the center portion **42** of the roller being substantially cylindrical. The conical ends **43** of the roller **44** radially protrude into an aperture **56** of the gimbal ring provided at opposite ends near the axial center thereof. Each aperture **56** is threaded to receive the cylindrical bearing-like disk **46** made of bearing bronze and provided with a conical indentation **47** to rotatably receive the conical end portion **43** of the roller **44**. The cylindrical center **42** of the roller frictionally engages, as aforementioned, the pull rod member **30**.

In FIGURE 4 there is shown a flat plate lever arm **58** made of steel or other suitable rigid material. One end **59** of the plate has cut out therefrom a semicircular portion with a radius substantially equal to the inside radius of the gimbal ring. Lever arm end **59** is attached to the gimbal ring **48** by means of rivets or machine screws **60**. Set screws **63** extend through lever arm **58** near the upper and outermost corner of end **59** and abut against the frame member **50**. The arm **58** extends downwardly from the gimbal ring and provides at its lower end a handle **61** to angularly manipulate the gimbal ring. In order to adjust the pressure between the roller **44** and the pull rod **30** the set screws **63** are adjusted to force the gimbal ring to its extreme outer position, as shown in FIGURE 1, and the screws **51** are loosened and the frame **50** is moved on the support plate to its outermost position. The combined adjustment affords a simple and effective pressure control means.

The frame **50** carries a spring **64** (see FIGURE 3) and a detent ball **66** within aperture **62**. The location of aperture **62** is determined to provide a common longitudinal axis with opening **53** of frame **50**. The detent ball **66** is engaged and urged by the spring **64** against the lever arm **58** to maintain the arm in a predetermined angular position. This is accomplished by providing a plurality of openings **68** (see FIGURE 4) in circular array on the lever arm **58** and axially aligning the center thereof with the axial center of the aperture **62** of the frame **50**. The radius of each opening **68** is slightly less than the radius of the detent ball **66**. Consequently, when handle **58** is moved until a preselected opening **68** registers with detent ball **66**, the spring **64** causes portions of the ball to protrude into and partially through the opening **68** of the lever arm. The larger diameter of the ball precludes the complete projection of the ball through the opening **68**, whereby a predetermined locking position of the frame with respect to the gimbal ring is achieved.

With the parts constructed and arranged as above described the mode of effecting longitudinal movement of the pull shaft is as follows: When the longitudinal axis of the roller **44** is substantially parallel to the longitudinal axis of the pull rod **30**, the aforementioned roller is in neutral position and only rotary movement of the pull shaft is possible. By turning the location of the longitudinal axis of the roller **44** with respect to the longitudinal axis of the pull shaft, while the roller frictionally engages the pull shaft, a force component is exerted on the pull shaft producing a longitudinal displacement of the pull rod **30**. In other words, by swinging the lever arm **58** secured to the gimbal ring **48** the skew angle between the roller and the pull shaft may be varied, thereby varying the lead or pull per revolution on the pull shaft. Since the mechanical lock of the lever arm to the frame by means of detent ball **66** and springs **64** in an aperture **62** is a fairly loose one, a further refinement of the angular position may be effected by adjusting the lower portion of the lever arm by means of a micrometer spindle stop assembly **70** (FIGURE 4).

Since the changing weight of the growing crystal during the pulling process changes the pull rate, the position of the frame **50** is adjustable with respect to the top plate as aforestated to vary the force of the roller **44** bearing against the pull shaft. This influences the slippage between the elastic roller and the pull shaft. Since the slippage is also a function of longitudinal thrust on the pull shaft, the resultant pull rate is a function of the crystal weight and this function is variable by the force between the roller and the pull shaft. Similarly, by suitably matching the force with which the roller frictionally engages the pull shaft the device can provide compensation for the otherwise normal change in crystal composition which occurs with the depletion of the liquid semiconductive melt volume. Herein, the system responds directly to liquid volume via crystal weight as opposed to time in conventionally programmed systems, where the normal variation in crystal size causes appreciable drift of the desired program from the preset actual program.

To effect a smooth and suitable longitudinal movement of the pull rod **30** a combined bearing sleeve **72** of non-contaminating material, for instance graphite, is co-axially disposed with respect to the seed holder **10** and pull rod **30**. The bearing sleeve **72** is substantially cylindrical and a shoulder **74** thereof is adapted to receive a weight compensating spring **76**. Tubular portion **78** of bearing sleeve **72** provides a bearing surface **80** to guide the seed holder **10** and simultaneously establishes a protective sleeve around the critical area.

While there have been described what at present are considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is aimed, therefore, in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

I claim as my invention:

1. A pull and rotation mechanism for crystal growing apparatus comprising, in combination; driving means; shaft means rotatably driven by said driving means; annular frictional coupling means formed of elastic material surrounding portions of said shaft means; pull rod means mounted for rotation and longitudinal displacement; mounting means maintaining said pull rod means in frictional engagement with said frictional coupling means; roller means rotatably mounted and in driving engagement with said pull rod means; gimbal means rotatably constructed and arranged to carry said roller means for angular variation of the longitudinal axis of the roller in respect to said axis of the pull rod means so that upon changing the angular relation of the axes a force component is exerted on the pull rod means to longitudinally displace and rotate said pull rod means.

2. A pull and rotation mechanism for crystal growing apparatus comprising, in combination; driving means; shaft means rotatably driven by said driving means; at least one radial groove on said shaft means; elastic O-ring means carried rollably within said groove; pull rod means; mounting means securing said pull rod means for rotation and longitudinal displacement and holding portions of said pull rod means in frictional engagement with said

O-ring; elastic roller means rotatably mounted and adapted to drivingly bear against said pull rod means; said pull rod means being frictionally suspended between said elastic O-ring and said elastic roller means; means for mounting said roller means for angular variation of the longitudinal axis of said roller in respect to the axis of said pull rod means so that upon changing the angular relation of the axes a force component is exerted on said pull rod means to longitudinally displace said pull rod means.

3. A pull and rotation mechanism for crystal growing apparatus comprising, in combination; driving means; shaft means rotatably driven by said driving means and having a radially arranged groove; elastic annular means rollably surrounding said groove; a pull rod means having a longitudinal axis substantially parallel with the longitudinal axis of the shaft means; mounting means securing said pull rod means for rotation and for longitudinal displacement and maintaining said pull rod means in frictional driving engagement with said annular means; roller means rotatably mounted and in driving engagement with said pull rod means; gimbal means constructed and arranged to rotatably carry said roller means for angular variation of said longitudinal axis of the roller in respect to said axis of the pull rod means so that upon changing the angular relation of the axes a force component is exerted on said pull rod means to longitudinally displace and rotate said pull rod means.

4. A pull and rotation mechanism for crystal growing apparatus comprising, in combination; driving means; shaft means engaging said driving means; gear means mounted on said shaft means and in operative contact with said driving means to rotate said shaft means; O-ring means surrounding portions of said shaft means; pull rod means having a longitudinal axis substantially parallel with the longitudinal axis of the shaft means; mounting

means securing said pull rod means for rotation and for longitudinal displacement and maintaining said pull rod means in frictional engagement with said O-ring means; gimbal means spacedly mounted from said pull rod means carrying said roller means; frame support means coaxially and slidably securing said gimbal means; and a lever arm attached to said gimbal means adapted to rotate said gimbal means with respect to said frame means.

5. A pull and rotation mechanism for a crystal growing apparatus comprising, in combination: driving means; shaft means rotatably driven by said driving means; annular frictional coupling means formed of elastic material surrounding portions of said shaft means; pull rod means; means securing said pull rod means for rotation and longitudinal displacement; elastic roller means rotatably mounted and in driving engagement with said pull rod means; said pull rod means having a longitudinal axis displosed parallel to the same axis of said shaft means and being frictionally suspended between said frictional coupling means and said roller means; means securing said roller means for angular variation of the longitudinal axis of said roller in respect to said axis of said pull rod means so that upon changing the angular relation of said axes a force component is exerted on the pull rod means to longitudinally displace said pull rod means.

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