

[54] APPARATUS FOR MAKING FIBERS

[76] Inventor: **John P. Glass**, 718 Lorraine Ave., Ardmore, Pa.

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[58] Field of Search **23/273, 294, 381, 23/209.1 F; 264/24; 156/150; 117/93.4, 93.41, 93.42, 93.43, 93.44; 204/181**

[56] References Cited

UNITED STATES PATENTS

2,338,570	1/1944	Childs	204/181
2,048,651	6/1933	Norton	264/24
2,260,746	10/1941	Hanawalt	23/294
2,385,873	10/1945	Melton	264/24
2,545,271	3/1951	Gartner	23/273
2,754,259	7/1956	Robinson	23/294
3,024,009	3/1962	Booth	23/294
3,147,085	9/1964	Gatti	23/294

FOREIGN PATENTS OR APPLICATIONS

111,300	12/1961	Pakistan	23/301
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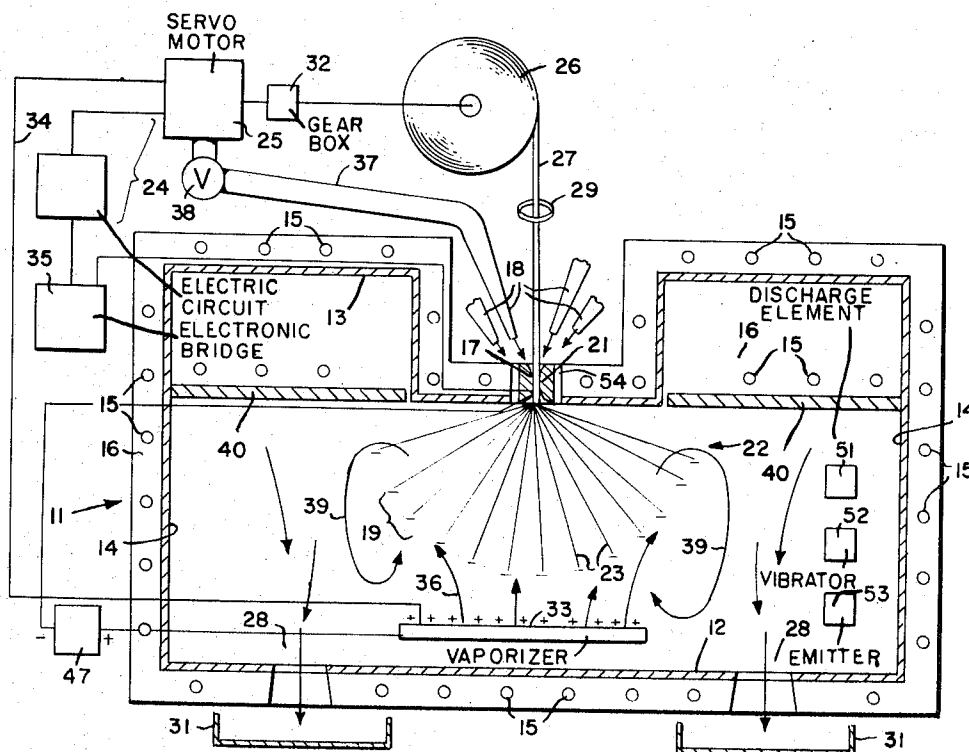
Primary Examiner—Norman Yudkoff

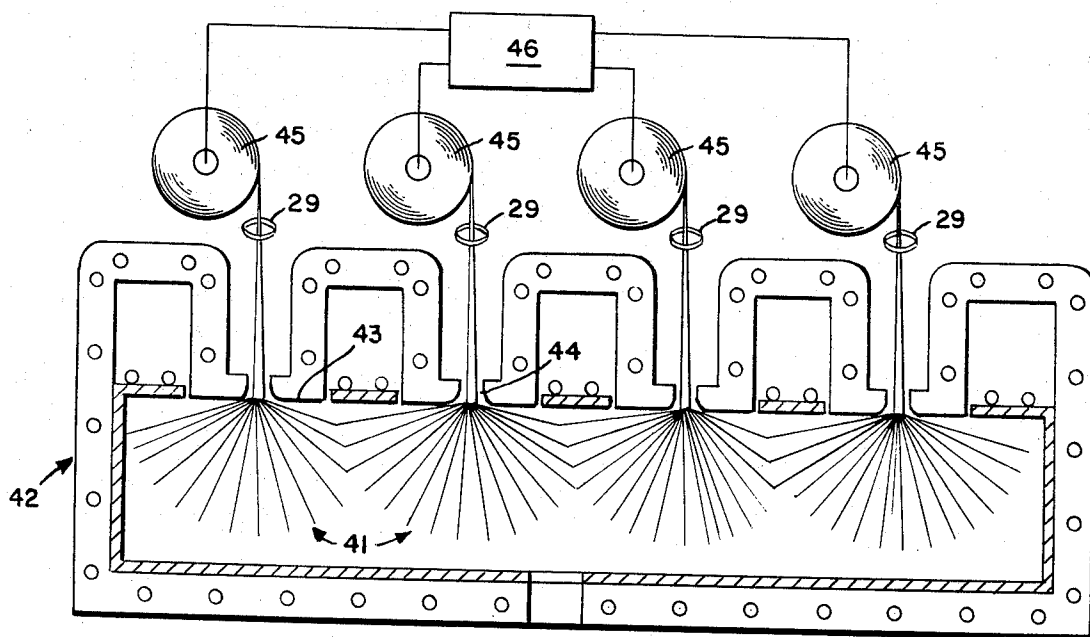
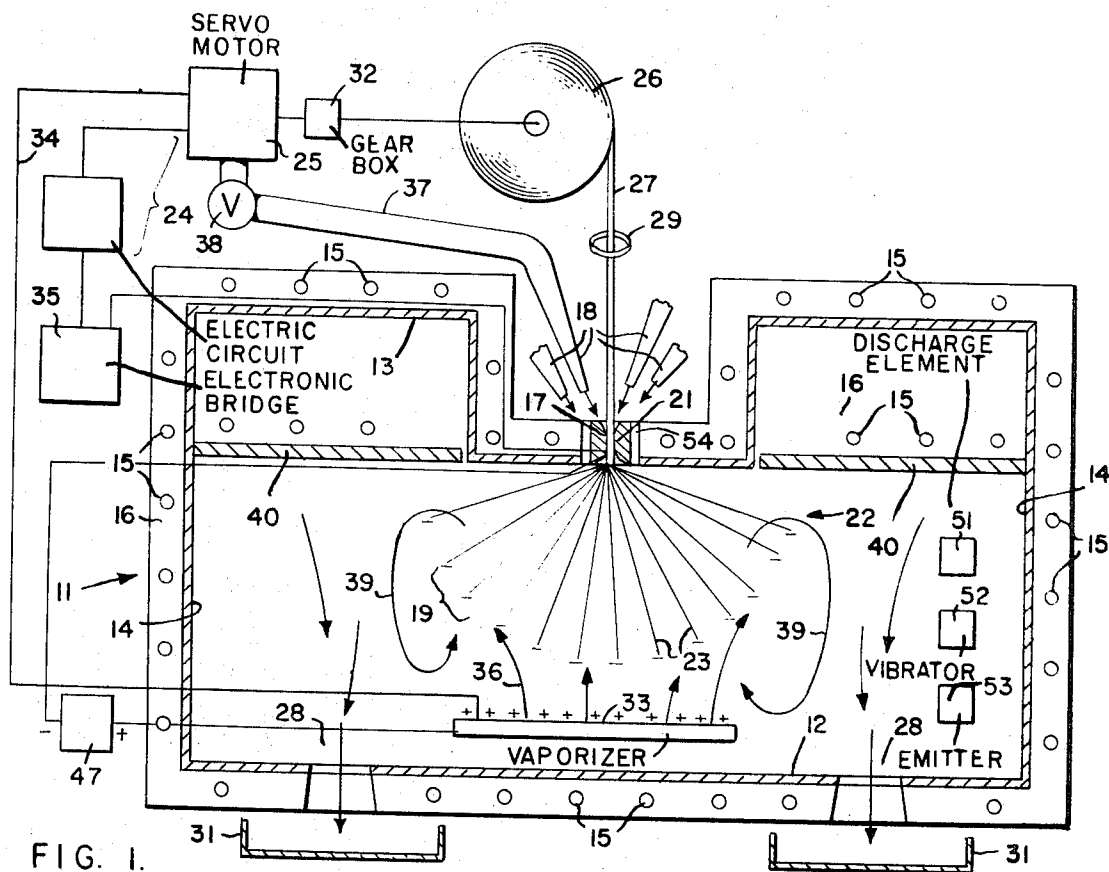
Attorney—Smith, Harding, Earley & Follmer

[57] ABSTRACT

Apparatus for making crystal fibers by condensing a material from a vapor phase comprising a chamber, a vaporiser for supplying a vapor which is condensed and crystalized into fibers, heating elements around the chamber to maintain the vapor, cooling apparatus located at an exit orifice of the chamber, said cooling apparatus directing a stream of gas into the chamber to provide a cooler region where the vapor condenses to form solid fibrous materials, apparatus for applying an electrostatic charge to the growing fibers to fan out the ends of the fibers so that the ends are separated and individually exposed to the vapor, a reel for withdrawing the fibers through the exit opening, servo motor apparatus for operating the reel, an electric circuit for measuring the electrostatic charge on the fibers and actuating the reel in response thereto, and apparatus for coordinating the speed of rotation of the reel with the speed of producing fibers.

29 Claims, 3 Drawing Figures





INVENTOR
JOHN P. GLASS
BY *Busser Smith & Harding*
ATTORNEYS

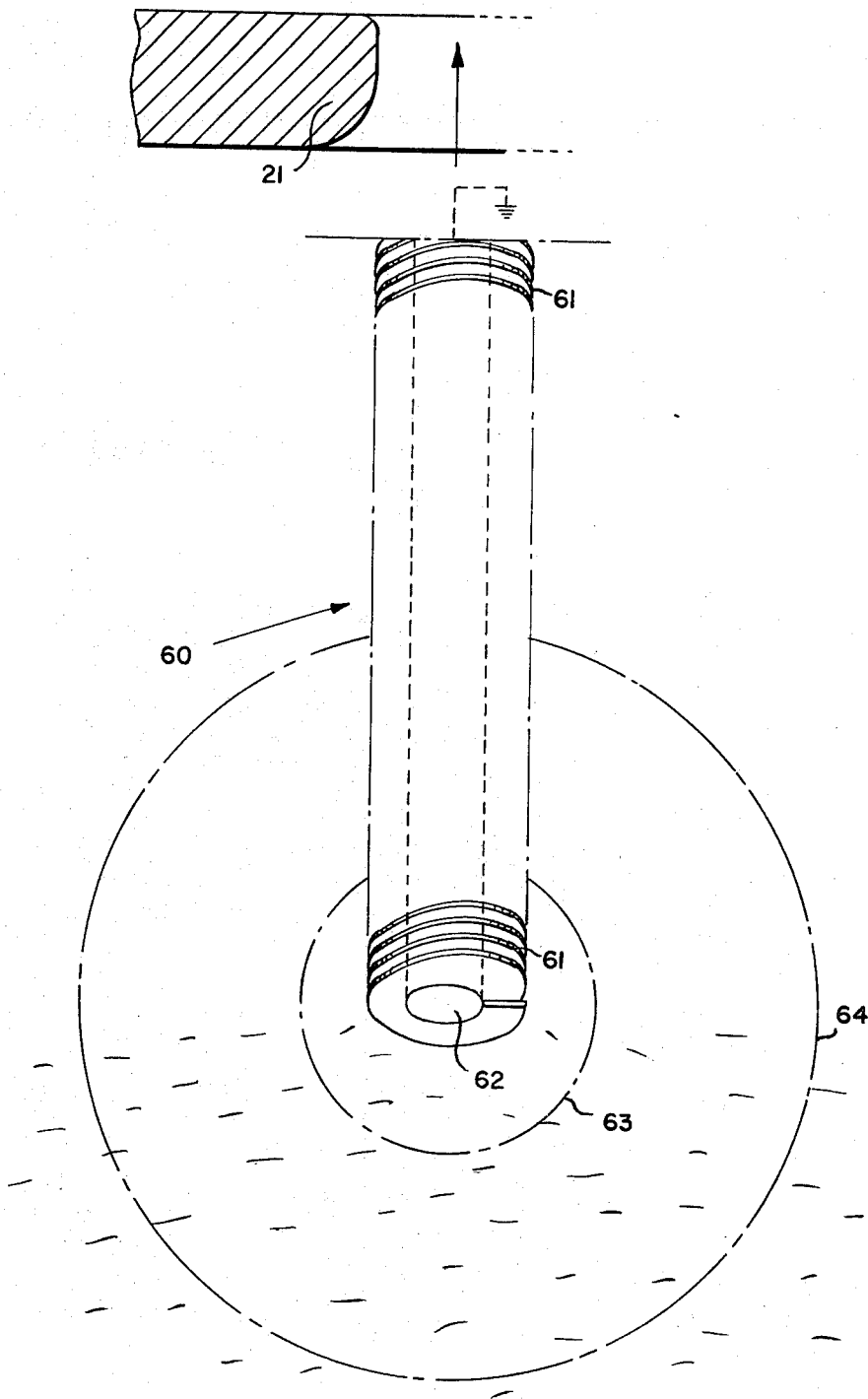


FIG. 3.

INVENTOR
JOHN P. GLASS
BY
Russell Smith & Harding
ATTORNEYS

APPARATUS FOR MAKING FIBERS

This invention relates to a method and apparatus for making fibers, and more particularly concerns a method and apparatus for making fibers by condensation of material from a vapor phase.

It has long been known that the strength of crystal structures without stress-concentrating faults, dislocations, notches, etc., is astonishingly high, being of the order of ten times the normal gross strength that is usually observed in the same material, and it has been known that in order to develop this high strength it is necessary to form the crystalline material into long, needle-like linear crystals, technically called "whiskers." It has not previously been possible to produce these whiskers except in quite limited length, primarily because the necessary conditions for growth at their ends have not been maintained without interruption over a sufficient time or volume. Also, it has not previously been possible to produce whiskers with any great deal of consistency, because so many things in this field are unknown.

There are also certain processes which take place which tend to terminate the growth at the ends. It has previously not been possible to produce, from vapor in a continuous process, a slender, long fiber having a crystalline structure which is substantially free from defects so that the fiber exhibits a strength near its very high theoretical strength. Much work is being done today to increase the strength and length of fibers made of graphite, aluminum oxide and the like. Until now, unusual strengths of these materials have been available only in laboratory quantities. It is an object of this invention to provide an improved method and apparatus for making these fibers. It is also an object of this invention to provide a method and apparatus for making the fibers in long lengths and large quantities economically.

It is another object of this invention to provide such method and apparatus which are adapted to withdraw the growing fibers from the zone where they are condensed in accordance with the rate of growth of the fibers, or to control the rate of growth of the fibers to correspond to the rate at which they are being withdrawn.

Other objects and advantages of this invention, including its simplicity and economy, as well as the ease with which it may be adapted to existing equipment, will further become apparent hereinafter and in the drawings, in which:

FIG. 1 is a schematic view of apparatus for making fibers constructed in accordance with this invention;

FIG. 2 is a partial view in vertical section of another embodiment of the invention; and

FIG. 3 is an enlarged diagrammatic view illustrating the manner in which a whisker grows.

Although specific terms are used in the following description for clarity, these terms are intended to refer only to the structure shown in the drawings, and are not intended to define or limit the scope of the invention.

Turning now to the specific embodiments of the invention selected for illustration in the drawings, FIG. 1 shows a chamber 11 having heated walls 12-14 on all sides, said walls being heated by such materials as molybdenum heating elements 15 in order to secure high temperatures. The heating elements 15 are protected from oxidation by any of the usual means including the use of an inactive gas envelope shielding the heating el-

ements from the atmosphere. The temperatures of the walls are not necessarily held at uniform temperature, it being desirable that the heating element near the point of introduction of the material to be vaporized, or near the material in vapor form, be the hotter part of the chamber and that the great bulk of the chamber be held at a temperature to maintain the vapor in an undersaturated condition. At a selected point of points in the walls, preferably in the top wall 13, a cold spot 17 is produced by any of the usual means of cooling locally this spot, such as directing against it a current 18 of relatively cooler gas. Concentrically in this cold spot, an orifice 21 permits a bundle 22 of nucleating fibers 23 to be withdrawn from the chamber 11 as the ends of the fibers grow.

An electrostatic charge is applied to the growing fibers 23, and an electrical circuit 24 provides means for measuring the value of the electrostatic capacitance of the fibers to ground. This value controls the operation of a servo motor 25 in circuit 24 which operates a reel 26 for withdrawing the fibers 23 in the form of a strand 27 from chamber 11. Instead of operating the reel 26, the servo motor may operate a servo valve 38 which controls the rate of formation of the fibers. In some circumstances, the servo motor 25 may be eliminated when the rate of fiber withdrawal has been regulated to coincide with the rate of fiber formation.

The electrostatic charge on the fibers 23 fans out the ends of the fibers so that the ends are separated and individually exposed to the vapor to promote the growth of the individual fibers.

In addition, it is surmised that the high potential gradients at the ends of the fibers promote their growth. In the case of growth of graphite whiskers there is no problem with electrical conduction along the axis of the fibers 23 to maintain the charge on the ends of the fibers. Even in normally non-conducting materials such as aluminum oxide, which is an excellent insulator at even quite high temperatures, it is well known that when the temperature is raised sufficiently, thermal agitation gives sufficient energy to the electronic structure of the material so that there is sufficient energy for the electrons to cross the forbidden zone representing non-conduction, and at the temperatures at which chamber 11 and this apparatus operate there is little problem in maintaining a charge on the ends of even aluminum oxide fibers.

It is further surmised that the dislocation in the screw growth mode aids in nucleation. In the present process, a stable growing zone 19 is set up by the current 18 of cool gas as it passes through orifice 21 into chamber 11. Zone 19 defines a limiting terminus for the fibers 23, and they cannot grow beyond this zone because the higher temperatures in the chamber at large would reverse the reaction and cause the fibers to evaporate or vaporize. However, it is possible to pull the fibers too rapidly up into the shielding mantle 19 of relatively cool gas and thereby terminate the process. To prevent this occurrence the capacitance of the electrostatically dispersed fibers 23 is measured continuously by superimposing a small alternating current charge and measuring the capacitance of the dispersed bundle 22 of fibers 23 to ground by any of the well known electronic methods, and controlling some phase of the reaction to insure the proper growth rate. In the case of graphite, in which the fibers are conducting at a low temperature, it is desirable to separate the capacitance of the

reel 26 from the capacitance of the fibers 23 that I wish to measure. Accordingly I introduce reluctance, iron rings 29, between zone 19 and the reels.

Thus if the fibers become withdrawn through the cold region so that they cease to grow due to the lack of condensing vapor, the capacitance of fibers 23 falls and the introduction of cold vapor through conduit 37, for example, is reduced by servo actuated means such as valve 38. Likewise the control may be the reduction of the influent vapor material to vaporizer 33 or through conduit 37 as the capacitance of the growing cluster becomes too large, and/or the rate of withdrawal may be changed by controlling the speed of the reel. Any other parameter controlling the rate of growth such as the introduction of one of the growth promoting phases of an active element may be controlled. Any or all such controls may be in turn controlled by measurements of the capacitance of the growing cluster of fibers. Further, if all ingredients are properly adjusted, the inherent stability of zone 19 makes possible the elimination of servo control of this inherently stable process.

In order to prevent the walls, or any portion of the oven chamber 11, from becoming a nuisance by reason of wild nucleation in undesired regions, the oven walls 12-14 may be either maintained at a sufficiently high temperature to prevent whiskers forming, or they may be made semi-permeable and the inactive gas shielding the heating elements may be allowed to seep through the walls establishing a zone poor in vapor phase adjacent to the walls. By reason of both this diffusion process and by reason of the introduction of carrier gases and cooling gases around the stem or strand 27 of the growing cluster or bundle 22, exits 28 are provided for the spent or used gas and vapor mixtures. Inasmuch as immediately upon exiting from the chamber, the loss of heat causes supersaturation and crystalization, it is desirable that these exits be at the bottom of the chamber 11 and sufficiently heated at their orifices so that no extraneous nucleating takes place within the chamber 11. Moreover, by controlling the temperature gradients as the gas is cooled exiting from the bottom wall 12 of the chamber 11, the condensate may be made in the form of short fibers or whiskers and these collected by suitable separate collecting means 31 below the main chamber 11.

Servo motor 25 is also connected to vaporizer 33 by electrical conductors 34 which provide means for controlling the rate of creating vapor in chamber 11.

Electronic bridge 35 in electrical circuit 24 provides means for measuring the rate of growth of fibers 23 by measuring the growth of the capacitance of the charged fibers to the rest of the chamber 11.

Orifice 21 includes edges which are streamlined, non-sticking and relatively cool.

In one form of operation, vaporizer 33 produces a vapor stage of fiber-producing materials in chamber 11. A plurality of growing elongated fibers 23 are formed by condensing fibrous crystals from the vapor. The rate of growth of the fibers 23 is measured by applying an electric potential to the growing fibers 23 and measuring the rate of growth of the electric capacitance. The fibers 23 are withdrawn from chamber 11 by the reel 26 which is operated by servo motor 25 at a speed which responds to the value of the electric capacitance of the fibers 23, the unbalance in capaci-

tance being detected by the electronic bridge 35 which actuates servo motor 25.

The electrostatic charging of fibers 23 fans out the ends of the fibers so that the ends are separated and individually exposed to vapor.

Fibers 23 are gathered together at a constricting position defined by orifice 21 which is spaced away from the fiber ends.

In one form of the apparatus, the vapor emitted from vaporizer 33 is hot and rises as indicated by the arrows 36 toward growing zone 19. Also, the electrostatic charge on fibers 23 may be negative, and a positive charge may be impressed upon the hot vapor as it leaves the vaporizer 33. Accordingly, the vapor is propelled from vaporizer 33 toward drawing zone 19 by the hot temperature of the vapor and also by the electrical charge which is attracted to the opposite electrical charge of the fibers 23.

The excess vapor is forced downwardly by pressure and escapes through the exit ports 28 in bottom wall 12.

A shield 40 is provided in chamber 11 below ceiling wall 13 and is physically separated from the depressed portion of wall 13. The separation is as small as possible in order to prevent unwanted escape of the gas within the lower portion of chamber 11. The physical separation prevents electrical conduction between the lower portion of ceiling wall 13 and shield 40. The shields 40 help prevent nucleation in the zone above the shields, and help confine the growth of the fibers to the nucleating zone defined by zone 19.

The introducing of cool gas through orifice 21, or adjacent thereto, into zone 19 increases the rate of growth of the whiskers. By introducing a cooling gas into zone 19, growth of the whiskers along their stems or root is prevented and the growth of the whiskers is confined to the ends. Also the electrostatic potential introduced for separating purposes promotes fiber growth at the ends. Accordingly, the radially inward flow of heat is counteracted by the radially outward flow of a cooling gas so that nucleation of the roots of the fibers within zone 19 is prevented. Where the cooling gas contains a hydrocarbon for the production of carbon whiskers, the temperature near orifice 21 is too low so that there is a scarcity of carbon near orifice 21 and the heat near the fiber ends causes the hydrocarbons to crack and deposit carbon on the radiantly heated ends of the whiskers.

When a cold gas flows radially outwardly from orifice 21 along the whiskers 23 which are heated by the radiant energy within chamber 11, a stable nucleating zone 19 is formed so that servoing is not required.

The operation and rate of growth of the whiskers are controlled preferably in response to the cooling rate of the gas directed toward orifice 21, or in response to the rate of vaporization within chamber 11, rather than in response to the rate of withdrawal of the fibers by reel 26.

The electrostatic charge on the whiskers within zone 19 may be utilized to aid the growth of the whiskers by making the electrostatic charge opposite to a charge placed on the hot gas ions so that the gas ions are attracted to zone 19. For example, placing a negative electrostatic charge on whiskers or fibers 23 sets up gross currents in a uniform space, thereby attracting the hot gas from vaporizer 33 towards fibers 23. Fur-

ther, the very high electrical gradients at the ends of the fibers promote growth.

The apparatus of the present invention is adapted to produce many types of crystals, including silica, aluminum oxide, carbon, and so forth.

The apparatus of the present invention is adapted for making fibers by nucleation from a vapor phase wherein a bundle of nucleating fibers 23 is constrained and passed from chamber 11 through orifice 21, with the nucleating ends of the fibers 23 being dispersed and held apart by electrostatic forces. A relatively cooler passive gas is introduced approximately concentric to orifice 21 through which fibers 23 exit, and the gas flows approximately radially outwardly from orifice 21 and forms a buffer zone which is both low in temperature and low in saturation of the condensing vapor, whereby a more or less hemispherical zone of super-saturation is maintained in a chamber of vapor dispersed in an inactive gas which is held above temperatures required for saturation.

In one form, the apparatus for making fibers comprises a heated chamber 11 containing a desired condensate material in an under-saturated vapor phase dispersed in an inactive gas, an orifice 21 leading from chamber 11, a bundle of nucleating fibers 23 being withdrawn through the orifice 21 and having nucleating ends dispersed and held fanned out by electrostatic force, and an approximately hemispherical super-saturation zone 19 at the ends being maintained by a flow of relatively cooler gas flowing radially from sources nearly adjacent to the fiber withdrawal orifice 21.

If desired, the cooling gas introduced adjacent to the fiber withdrawal orifice 21 may contain an active element which promotes the reaction in the approximately hemispherical growth zone 19 at the ends of the nucleating fibers.

In another form of the invention, the principal active element is a hydrocarbon with a buffer material such as hydrogen or nitrogen introduced near orifice 21 and flowing radially outward along the fibers until the fibers heated from outside the cluster are hot enough to cause the hydrocarbon to crack, the carbon depositing on the ends of the fibers and the hydrogen proceeding into the heated chamber. Means for promoting dendritic growth from the ends of the nucleating fibers may be introduced into chamber 11. Such means may comprise a sound shock wave caused by an electrical discharge from an electrical discharge element 51 located somewhere within chamber 11. The dendritic growth promoter may be the application of a vibration to chamber 11 from vibrator 52, or it may be the introduction of suitable growth promoting materials, such as a small amount of contaminant material from emitter 53.

In FIG. 2, a plurality of electrostatically charged groups 41 of fibers are shown in a chamber 42 having a ceiling wall 43. The groups 41 are withdrawn through ceiling wall 43 through a plurality of exit openings 44 and are pulled therethrough by a plurality of reels 45 which are operated by a servo motor control 46. The inverted umbrella shape of the ends of the groups 41 of fibers is distorted somewhat by adjacent groups. The ends of the groups 41 of fibers form a guard ceiling that protects ceiling wall 43 of chamber 42 against the forming of unwanted fibers thereon.

In another form of operation, the material to be crystalized may be introduced into chamber 11 by conduit 37 which is directed at orifice 21 or at concentric port 54. In this operation, vaporizer 33 is not used but chamber 11 is heated. For example, acetylene or methane is passed from conduit 37 into chamber 11 through orifice 21. The heat of the chamber cracks the acetylene or methane into its products of carbon and hydrogen. The carbon deposits on the growing fibers and the hydrogen is burned for heat or is recirculated over the carbon as a buffer. Nitrogen and argon may also be used as a buffer.

Instead of controlling the nucleation in zone 19 by controlling the speed of reel 26 so that it withdraws fibers 23 at a rate which corresponds to the rate of growth of the fibers, the servo motor 25 may operate valve 38 to control the amount of vapor being introduced through conduit 37 into the chamber to be crystalized, or to control the amount of cool gas being introduced into zone 19 through conduit 37 to oppose the vapor being emitted from emitter 33.

FIG. 3 is useful in explaining what may be referred to as the screw dislocation theory of whisker growth. When a crystal grows, the molecules of the material to be crystalized have to find their way into the niches of the adjacent crystalized layer. The crystalized layer has a curb to which the molecules of the forming layer attach themselves so that the curb grows into another crystalized layer.

Each whisker 60 as illustrated in FIG. 3, has a screw formation similar to the construction of a spiral stairway around a post which may often be found in libraries. The growth of the spiral 61 does not stop but the diameter of the substrate 62 or core within the spiral does not get any larger.

It is surmised the spiral 61 is electrically conductive so that the electrostatic charge on the whisker 60 sets up a high electrical gradient 63 in ionized gas zone 64 on the end of whisker 60. Additionally, the electrically conductive spiral 61 forms the physical counterpart of mathematical sinks which promote growth.

The gas molecules in zone 64 are charged oppositely to the charge on whisker 60. In FIG. 3, the gas molecules are charge negatively and the whisker 60 is charged positively. Substrate 62 is connected to ground at orifice 21 to disperse the negative charge which would otherwise build up on the end of whisker 60 as the gas ions deposit on the end of the whisker during the growth process. If this negative charge on the end of the whisker were not dissipated, the gas ions would be repelled thereby and whisker growth would stop.

Electrical gradient 63 at the end of whisker 60 promotes growth of the whisker.

The whiskers of the present invention are of very high purity without contaminants such as the sulphur in graphite.

It is to be noted that the electrostatic charge on the whiskers serves two purposes: (1) it separates the ends of the whiskers in the growth zone so that each end is open to receive the material to be crystalized, and (2) it promotes the growth of the whiskers.

It is to be understood that the form of the invention herewith shown and described is to be taken as a presently preferred embodiment. Various changes may be made in the shape, size, and arrangement of parts. For example, equivalent elements may be substituted for those illustrated and described herein, parts may be re-

versed, and certain features of the invention may be utilized independently of the use of other features, all without departing from the spirit or scope of the invention as defined in the subjoined claims.

I claim:

1. In apparatus for making fibers, a chamber, means for forming a plurality of elongated fibers by condensing fibrous crystals from a vapor stage of fiber-producing material in the chamber, and means for electrostatically charging the fibers to fan out the ends of the fibers so that the ends are separated and individually exposed to vapor.

2. In apparatus for making fibers, a chamber, means for forming a plurality of growing elongated fibers by condensing fibrous crystals from a vapor stage of fiber-producing materials in the chamber, means for applying an electrostatic charge to the fibers to fan out their ends, and means for gathering the fibers together at a constricting position spaced away from the fiber ends so the fiber ends are held separated.

3. In apparatus for making fibers, a chamber having an electrostatically charged group of fibers in the chamber, a reel for withdrawing the fibers from the chamber, and servo motor means actuated in response to the electrostatic charge on the fibers for operating the reel.

4. In apparatus for making fibers, a chamber having a plurality of electrostatically charged groups of fibers in the chamber, and a plurality of reels for withdrawing the fibers from the chamber, said reels being operated by servo motor means actuated in response to the electrostatic charge on the fibers.

5. In apparatus for making fibers, apparatus for controlling the length of the fibers comprising means for applying an electrostatic charge to growing fibers in a growing zone, and means for withdrawing the fibers from the growing zone when the value of the electrostatic charge reaches a predetermined level.

6. In apparatus for making fibers, a chamber, means for creating a vapor of fiber-producing material in the chamber, means for condensing the vapor into fibrous crystals to form a plurality of growing elongated fibers, said chamber having an exit opening formed therein, a reel for withdrawing the fibers from the chamber through the opening, servo motor means for operating the reel, and means for feeding back the rate of rotation of the reel to the vapor creating means to control the rate of creating vapor in the chamber.

7. Apparatus for making fibers comprising a chamber, means for producing a vapor of fiber-producing material in the chamber, means for condensing the vapor to form a plurality of growing elongated fibers, means for applying an electrostatic charge to the growing fibers, means for measuring the value of the electrostatic charge, and means for withdrawing the fibers from the chamber in response to predetermined measured values.

8. Apparatus for making fibers comprising a chamber, heated means positioned in the bottom portion of the chamber for producing a vapor of fiber-producing material in the chamber, means for condensing the vapor to form a plurality of growing elongated fibers, means for applying an electrostatic charge to the growing fibers to fan out the ends of the fibers so that the ends are separated and individually exposed to vapor, a guard ring for gathering the fibers together at a constricting position spaced away from the fiber ends, said

chamber having an exit opening formed therein above the guard ring, a reel for withdrawing the fibers from the chamber through the opening in the form of a strand of fibers, servo motor means for operating the reel, electric circuit means for measuring the electrostatic charge on the fibers and actuating the reel in response thereto, and means for feeding back the rate of rotation of the reel to the vapor producing means to control the rate of producing vapor in the chamber.

9. The apparatus according to claim 8 wherein the electric circuit means includes an amplifier and an electronic bridge connected in circuit with the servo motor.

10. Apparatus for making fibers comprising vaporizing means to supply vapor to be condensed and crystallized into fibers in a chamber, heating means around said chamber to maintain said vapor, cooling means located at an exit orifice of said chamber, said cooling means being in the form of a stream of gas being directed into said chamber to provide a less heated region where vapor condenses to form solid fibrous materials, means for withdrawing the fibrous materials from the chamber, and means for feeding back the rate of material withdrawal to the vaporizing means to control the rate of producing vapor in the chamber, said feedback means including an electrical circuit having a servo motor that responds to withdrawal rate and actuates a valve to control the amount of vapor being supplied to the chamber.

11. In apparatus for making fibers by nucleation from a vapor phase, a chamber, an orifice in the chamber through which nucleating fibers are drawn and constrained, means directing a cooling gas through the orifice and into the chamber, means distributing vaporized particles within the chamber, and means electrostatically charging the particles opposite to the charge on the nucleating fibers, whereby vaporized particles condense on the nucleating fibers.

12. In apparatus for making fibers by nucleation from a vapor phase, a chamber, constraining means in the chamber through which fibers are constrained, charging means electrostatically charging the ends of the fibers to disperse and hold apart said ends, and distributing means distributing vaporized particles within the chamber.

13. The apparatus of claim 12 wherein said constraining means is an orifice in the chamber through which the fibers are drawn and constrained.

14. The apparatus of claim 13 including means directing a cooling gas through the orifice and into the chamber.

15. The apparatus of claim 14 wherein said cooling gas contains an active element promoting a reduction of metal chloride.

16. The apparatus of claim 12 including means electrostatically charging the particles opposite to the charge on the fibers.

17. The apparatus of claim 12 wherein said distributing means distributes a vaporized phase of hydrocarbon.

18. The apparatus of claim 17 wherein said hydrocarbon is diluted by an inactive ingredient.

19. The apparatus of claim 17 wherein means are provided for cracking the hydrocarbon into its products, and means are provided for recirculating the products of cracking to aid in heating the chamber.

20. The apparatus of claim 12 including means in the chamber for promoting dendritic growth from the ends of the fibers.

21. The apparatus of claim 20 wherein said means for promoting dendritic growth comprises means for producing an electrical discharge.

22. The apparatus of claim 20 wherein said means for promoting dendritic growth comprises means for applying vibration to the chamber.

23. The apparatus defined in claim 20 wherein said means for promoting dendritic growth comprises means for introducing growth promoting materials into the chamber.

24. The apparatus defined in claim 12 including means for measuring the rate of growth of the fibers, and means responsive to said measuring means for controlling the rate of fiber growth.

25. The apparatus defined in claim 24 wherein said measuring means comprises means for measuring the electrical capacity of the fibers.

26. In apparatus for making fibers, apparatus for controlling the length of the fibers comprising means for applying an electrostatic charge to growing fibers in a growing zone, means for withdrawing the fibers from the growing zone when the value of the electrostatic charge reaches a predetermined level, and means for controlling the rate of growth of the fibers to correspond with the rate of withdrawal by servoing the introduction of cooling gas into the fiber-making apparatus.

27. In apparatus for making fibers, apparatus for controlling the length of the fibers comprising means for applying an electrostatic charge to growing fibers in a

growing zone, means for withdrawing the fibers from the growing zone when the value of the electrostatic charge reaches a predetermined level, and means for controlling the rate of growth of the fibers to correspond with the rate of withdrawal by servoing the introduction of active ingredients into the fiber-making apparatus.

28. In apparatus for making fibers by nucleation from a vapor phase, a chamber, constraining means in the chamber through which fibers are constrained, charging means electrostatically charging the ends of the fibers to disperse and hold apart said ends, distributing means distributing vaporized particles within the chamber, means for measuring the rate of growth of the fibers, and means responsive to said measuring means for controlling the rate of fiber growth, wherein said control means comprises servo means controlling the rate of distribution in the chamber of the vaporized particles.

29. In apparatus for making fibers by nucleation from a vapor phase, a chamber, constraining means in the chamber through which fibers are constrained, charging means electrostatically charging the ends of the fibers to disperse and hold apart said ends, and distributing means distributing vaporized particles within the chamber, means for measuring the rate of growth of the fibers, and means responsive to said measuring means for controlling the rate of fiber growth, wherein said control means comprises servo means controlling the rate of distribution in the chamber of the vaporized particles.

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