US 20240200234A1

(19) **United States**
(12) **Patent Application Publication**
Flamini et al.
(10) **Pub. No.: US 2024/0200234 A1**
(43) **Pub. Date: Jun. 20, 2024**

(54) **SYSTEMS AND METHODS FOR FIBER ZONE-DRAWING AND/OR ZONE-ANNEALING**

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(21) Appl. No.: **18/557,099**

(22) PCT Filed: **Apr. 25, 2022**

(86) PCT No.: **PCT/US2022/026179**
§ 371 (c)(1),
(2) Date: **Oct. 25, 2023**

Related U.S. Application Data

(60) Provisional application No. 63/179,890, filed on Apr. 26, 2021.

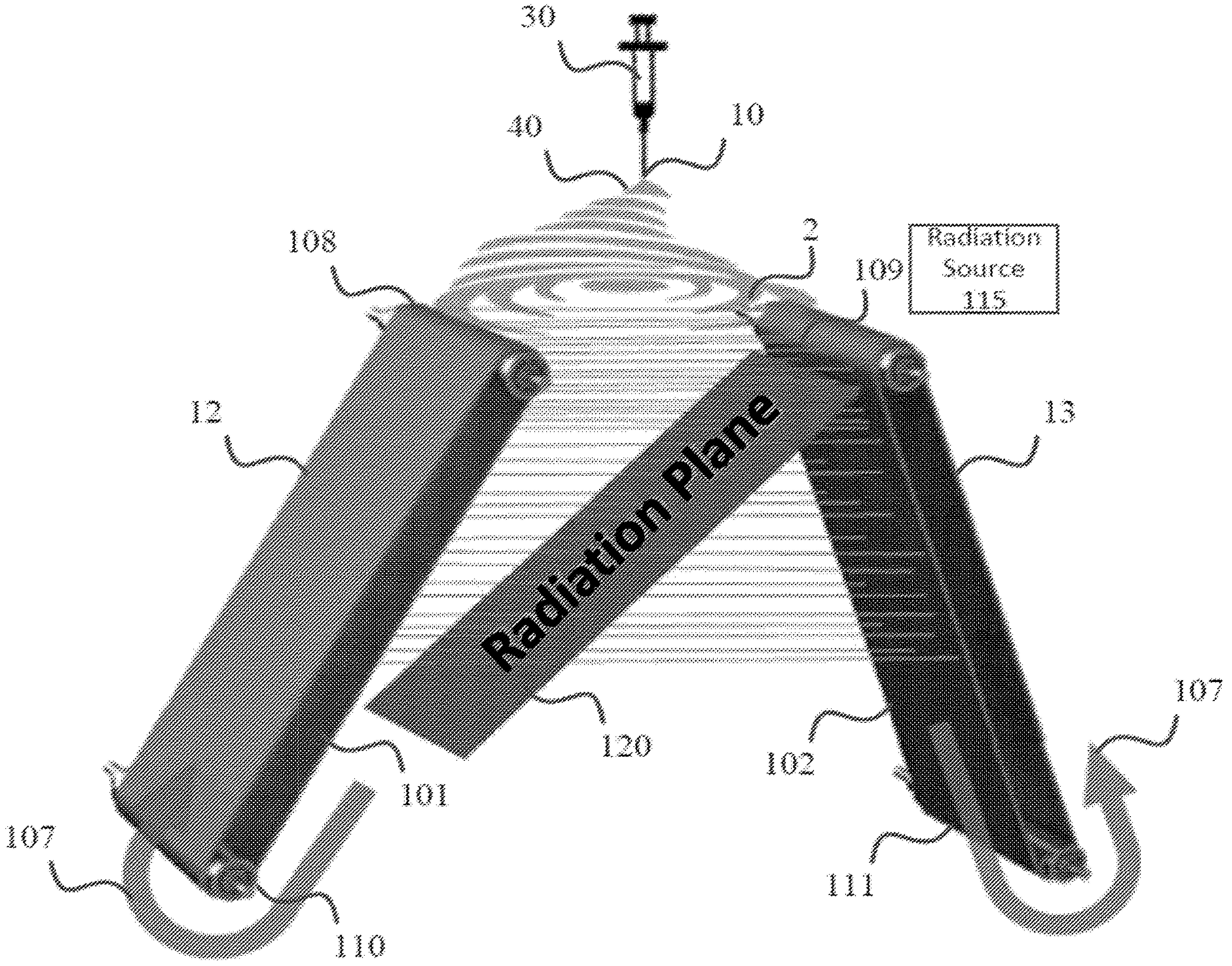
Publication Classification

(51) **Int. Cl.**
D01F 9/22 (2006.01)

(52) **U.S. Cl.**
CPC ***D01F 9/22*** (2013.01); *D10B 2101/12* (2013.01)

(57) **ABSTRACT**

In one aspect, the present disclosure is related to system and method of manufacturing nanomaterials and particularly to system and method for zone-drawing and/or zone-annealing fibers.



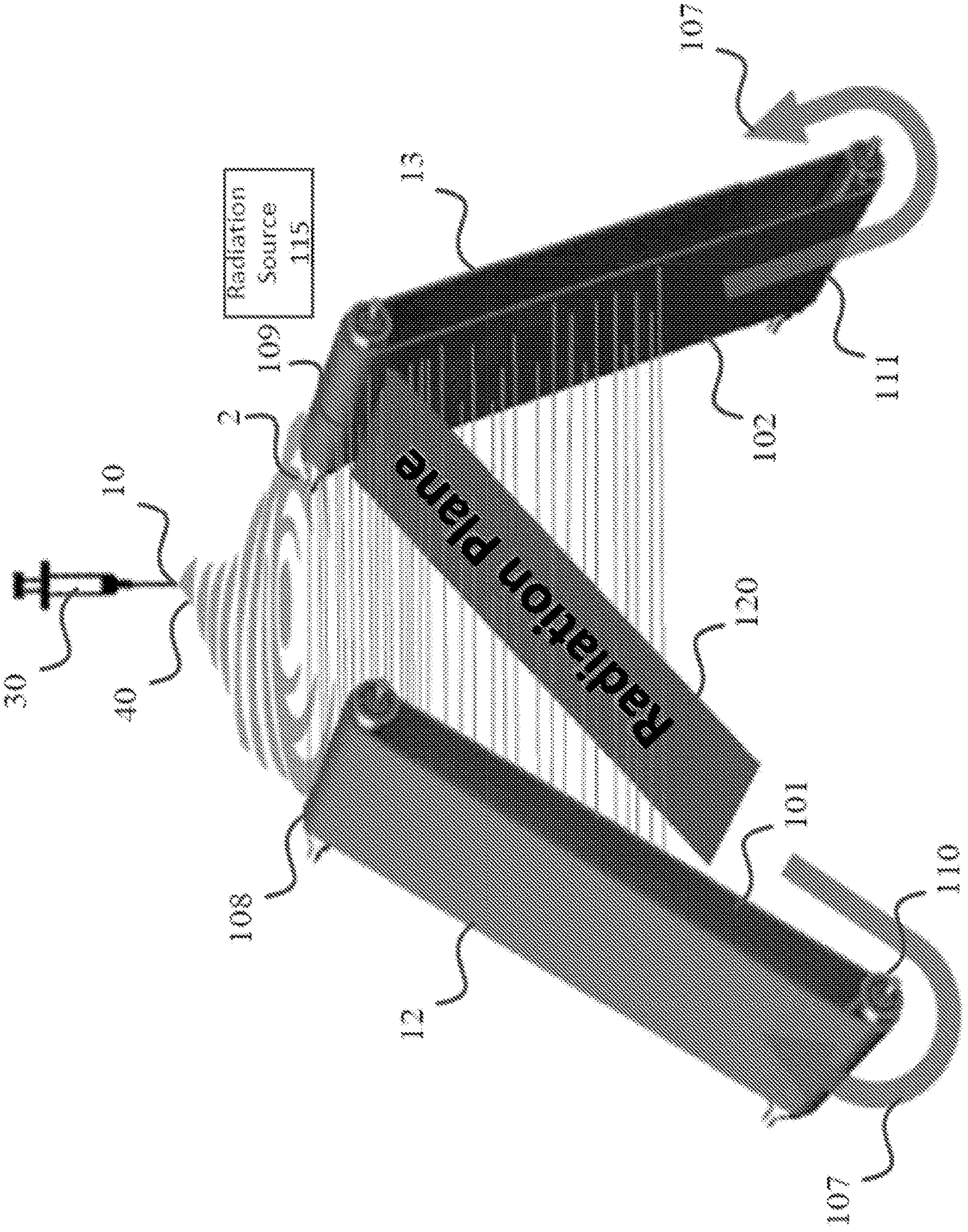

30
40
10
2
109
Radiation Source 115
13
107
111
102
120
Radiation plane
101
110
108
12
107

FIG. 1

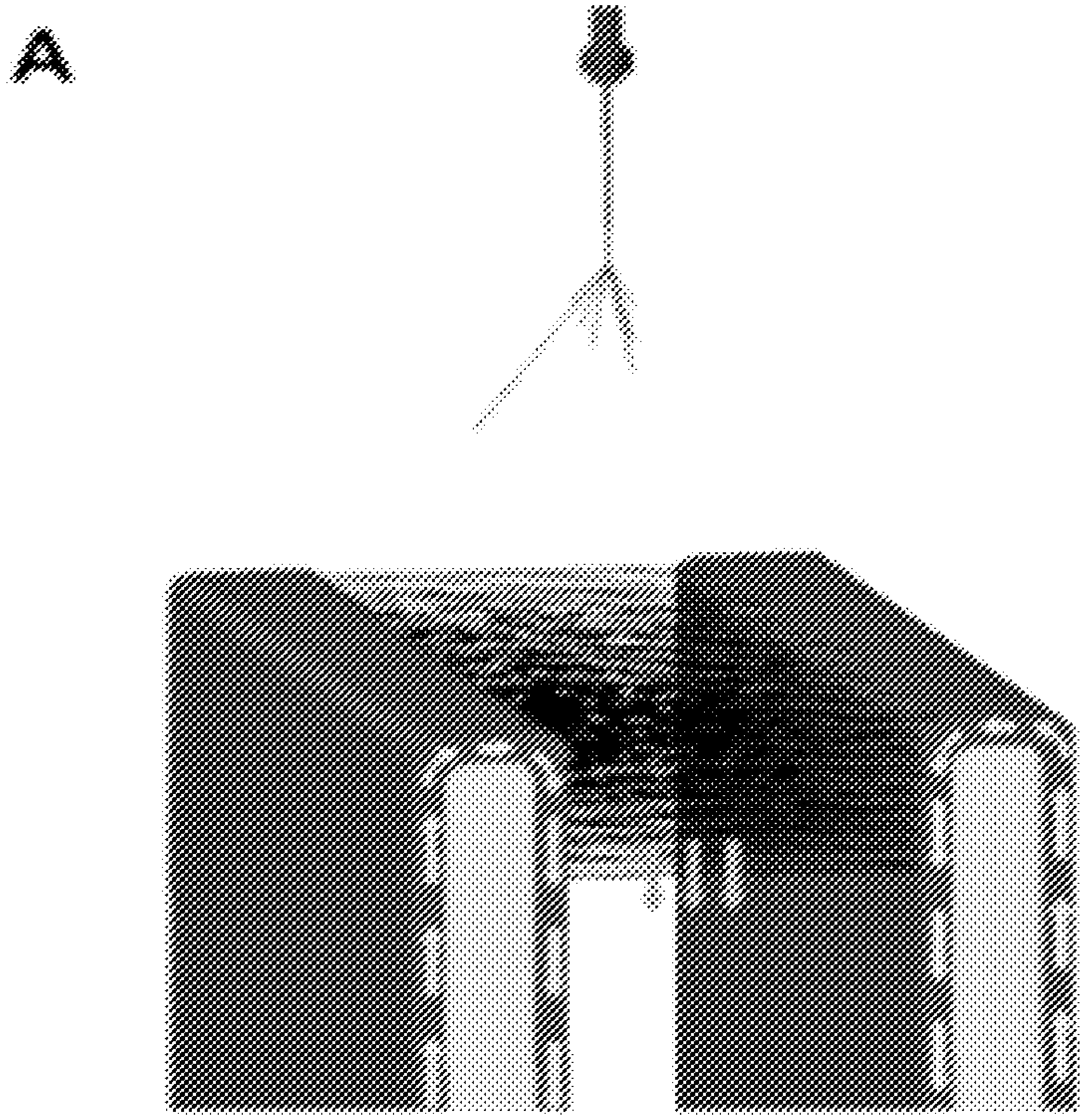


FIG. 2A

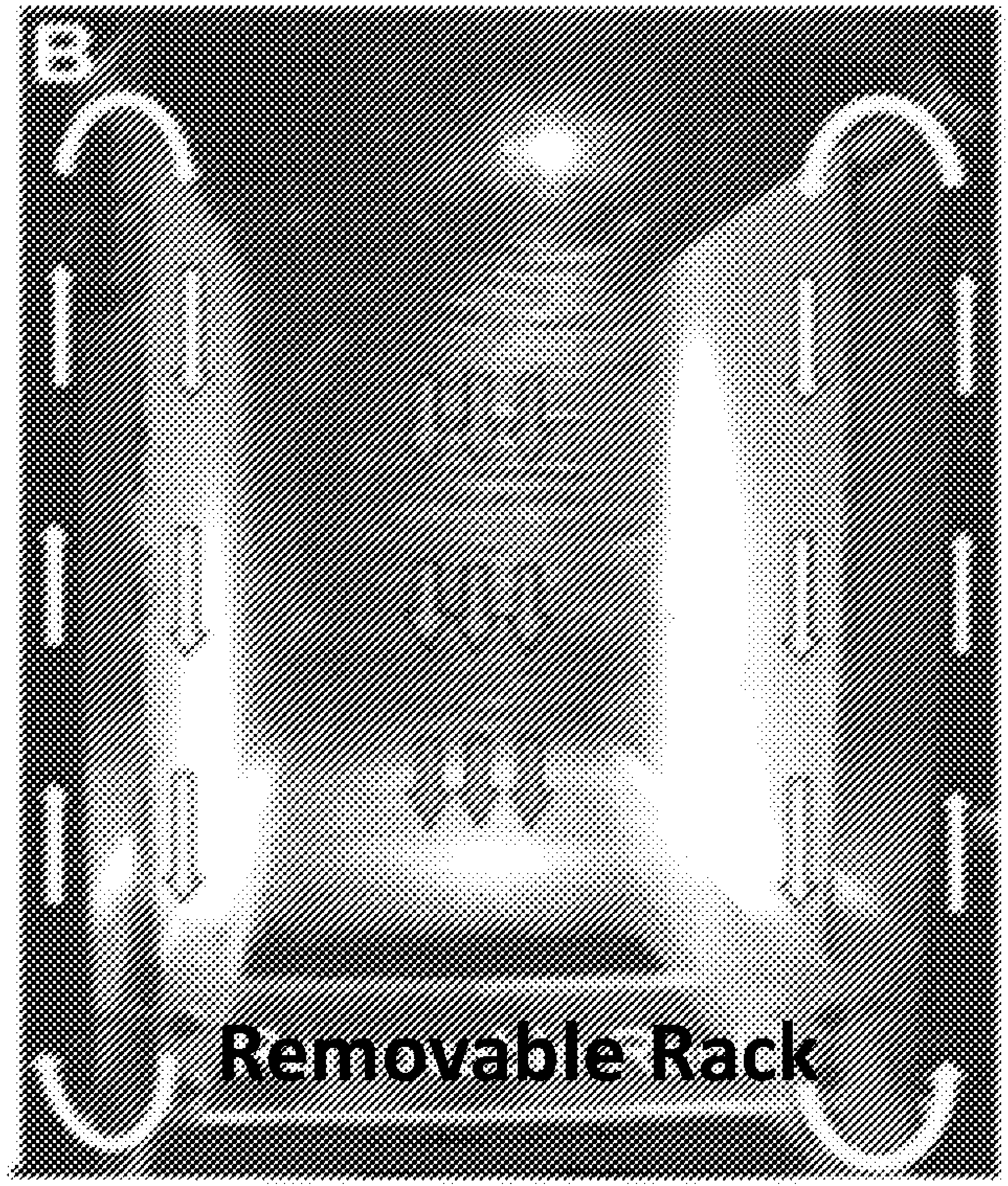


FIG. 2B

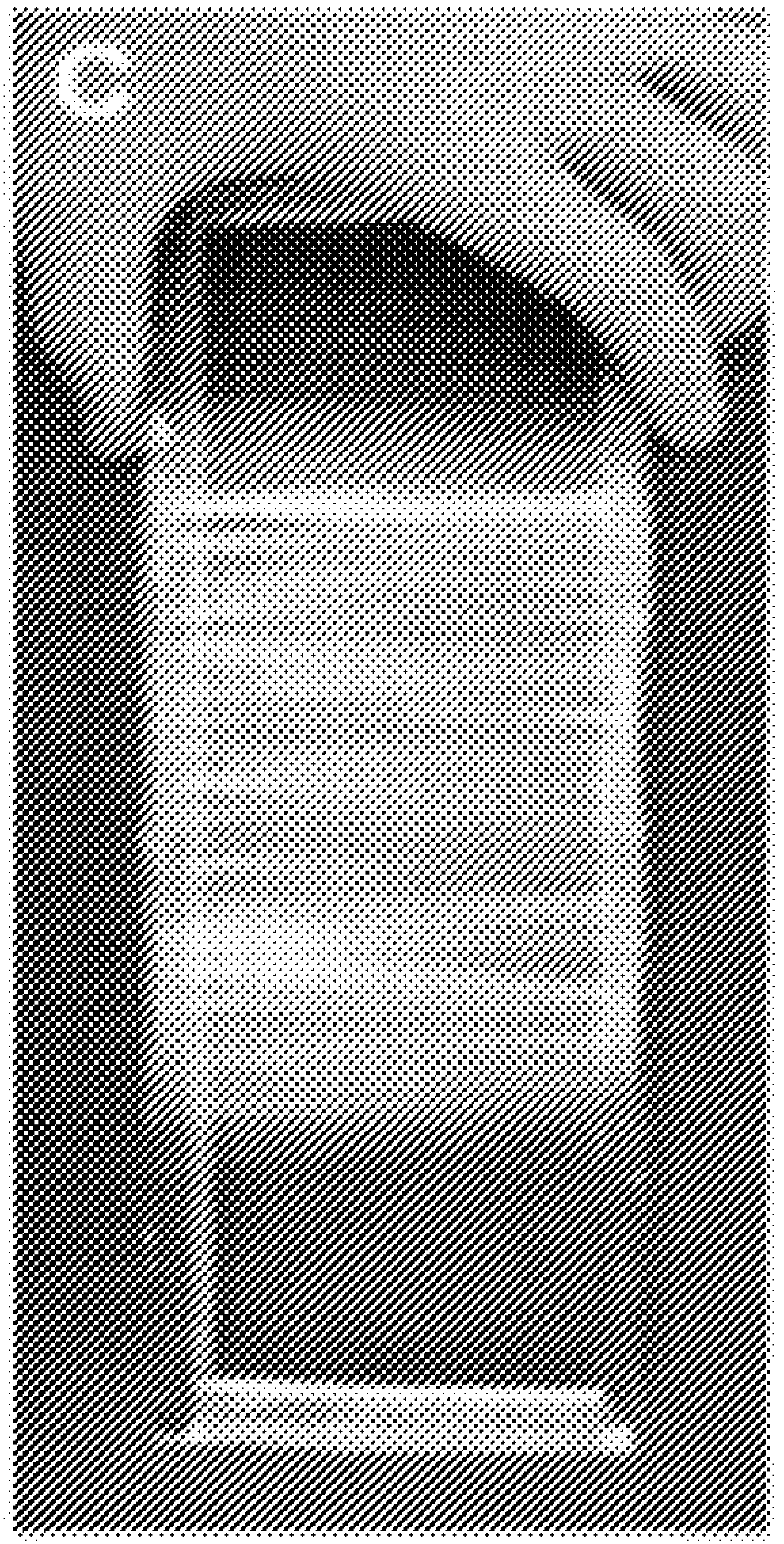


FIG. 2C

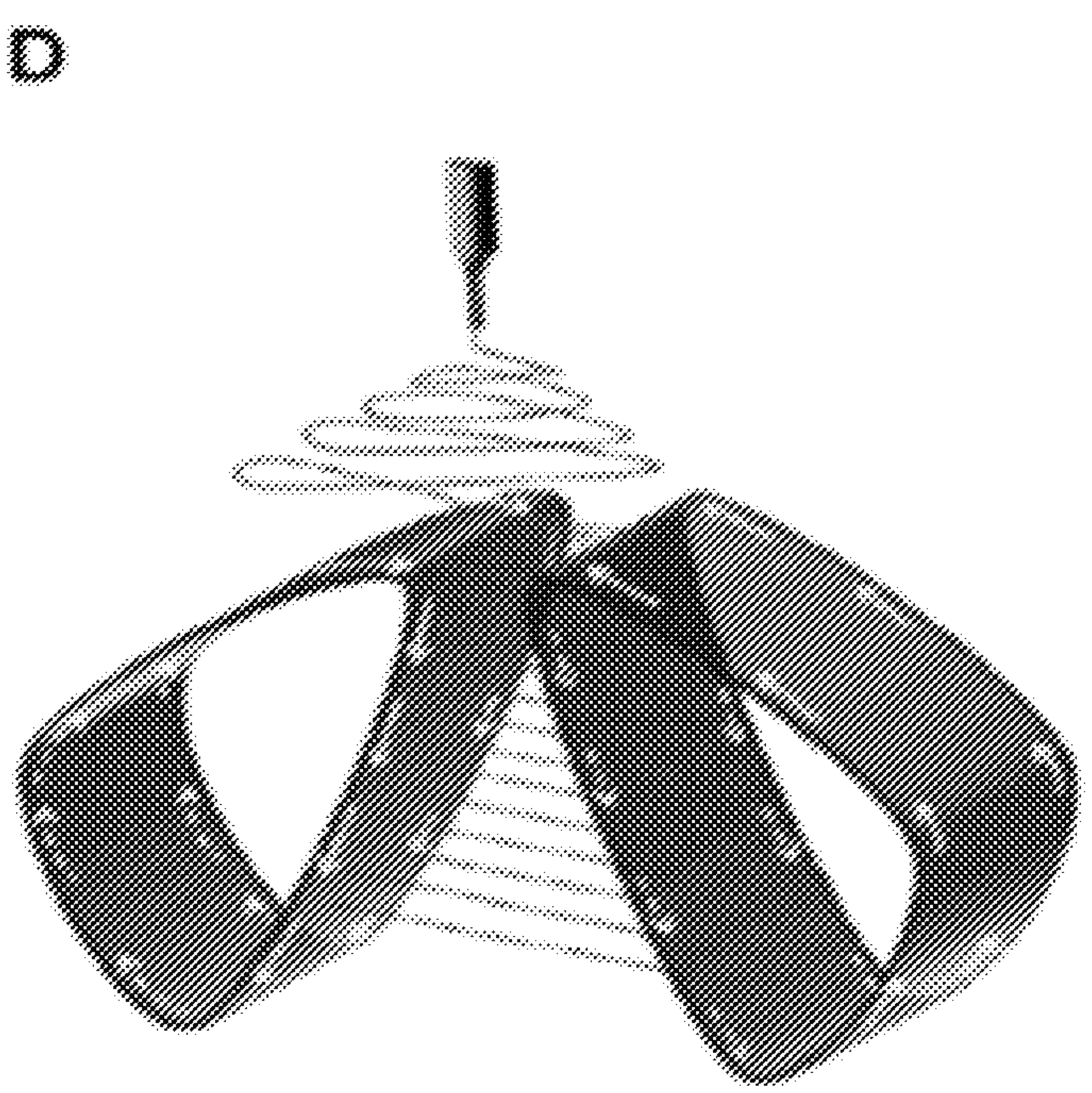


FIG. 2D

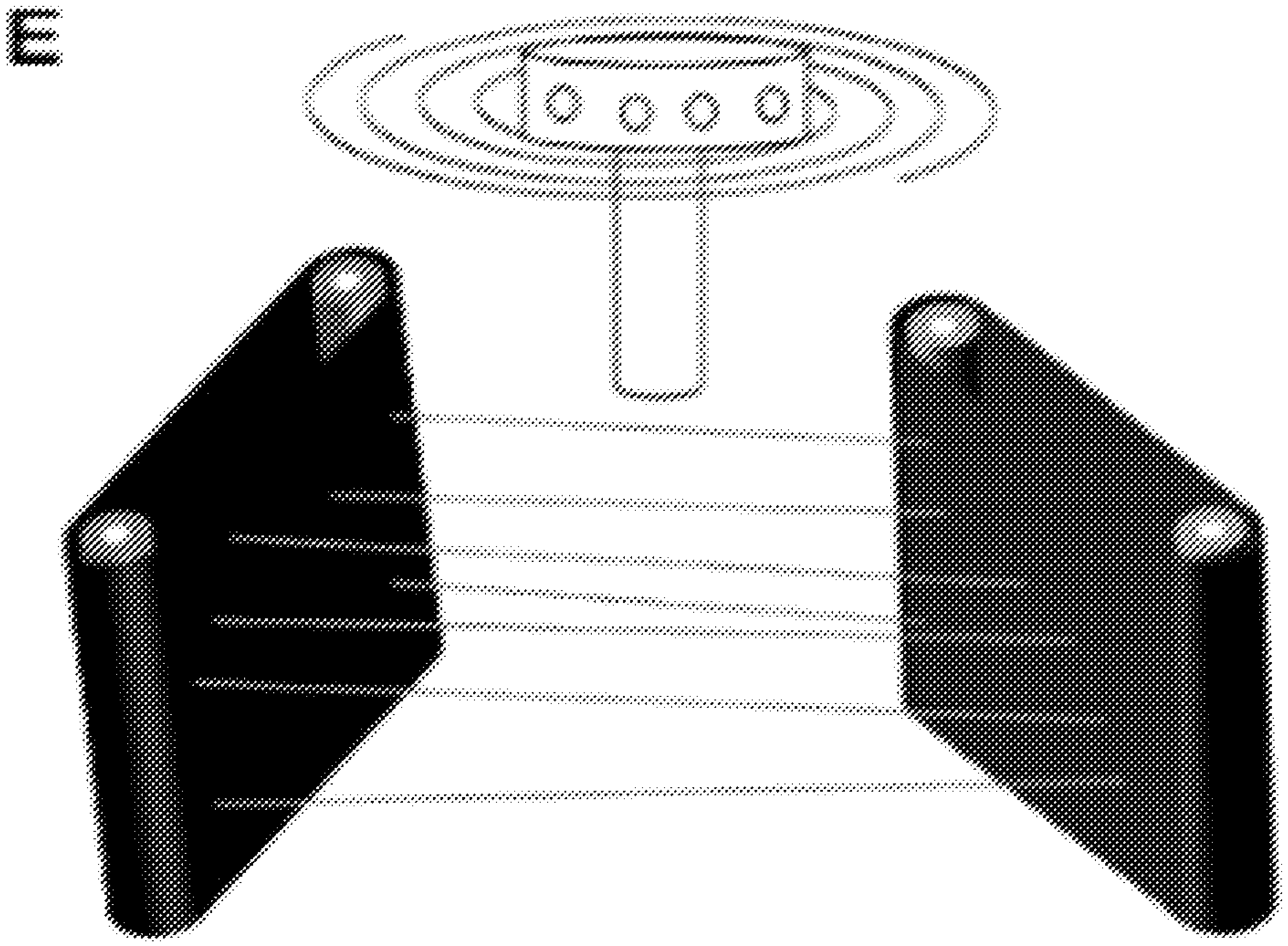


FIG. 2E

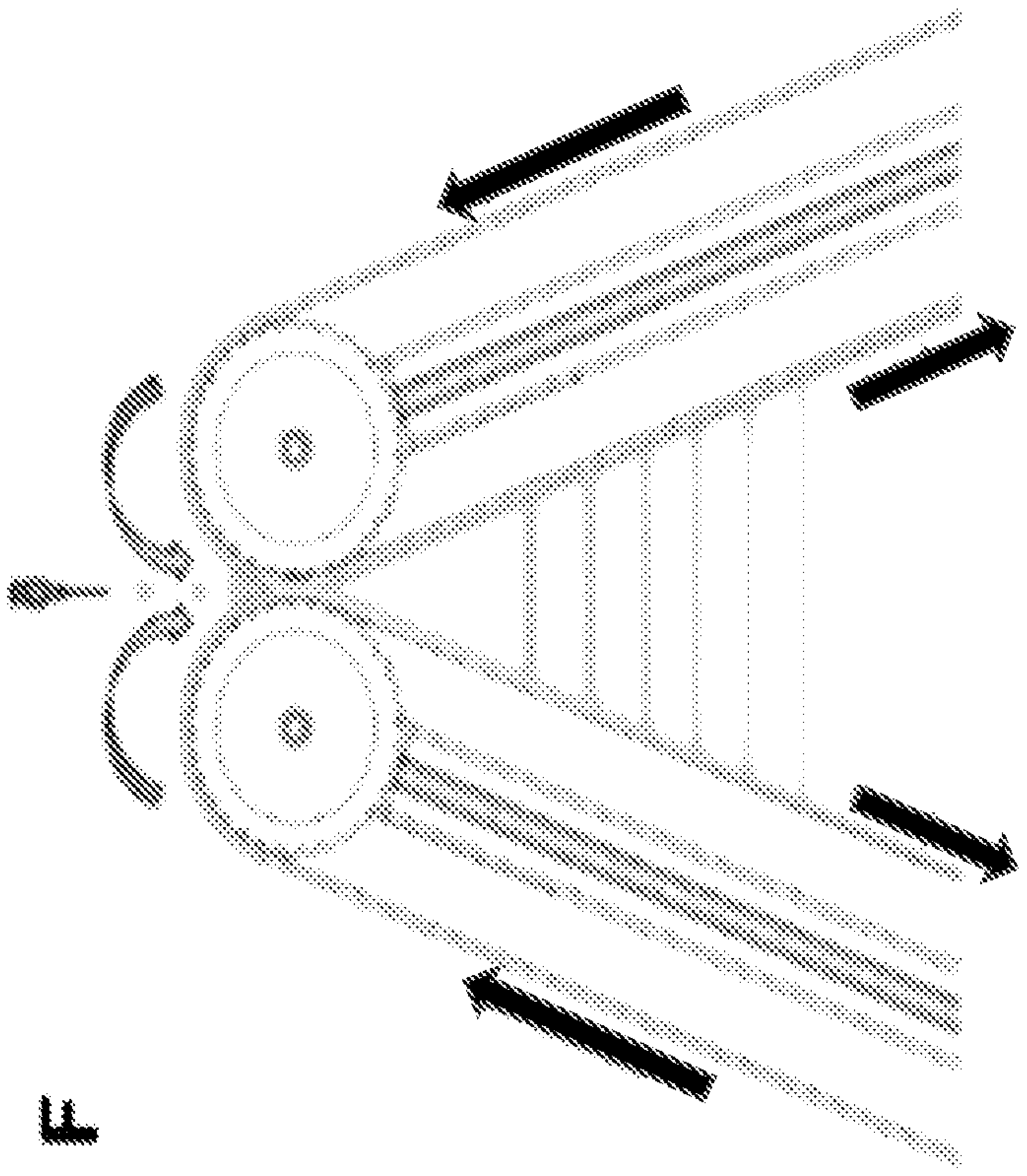


FIG. 2F

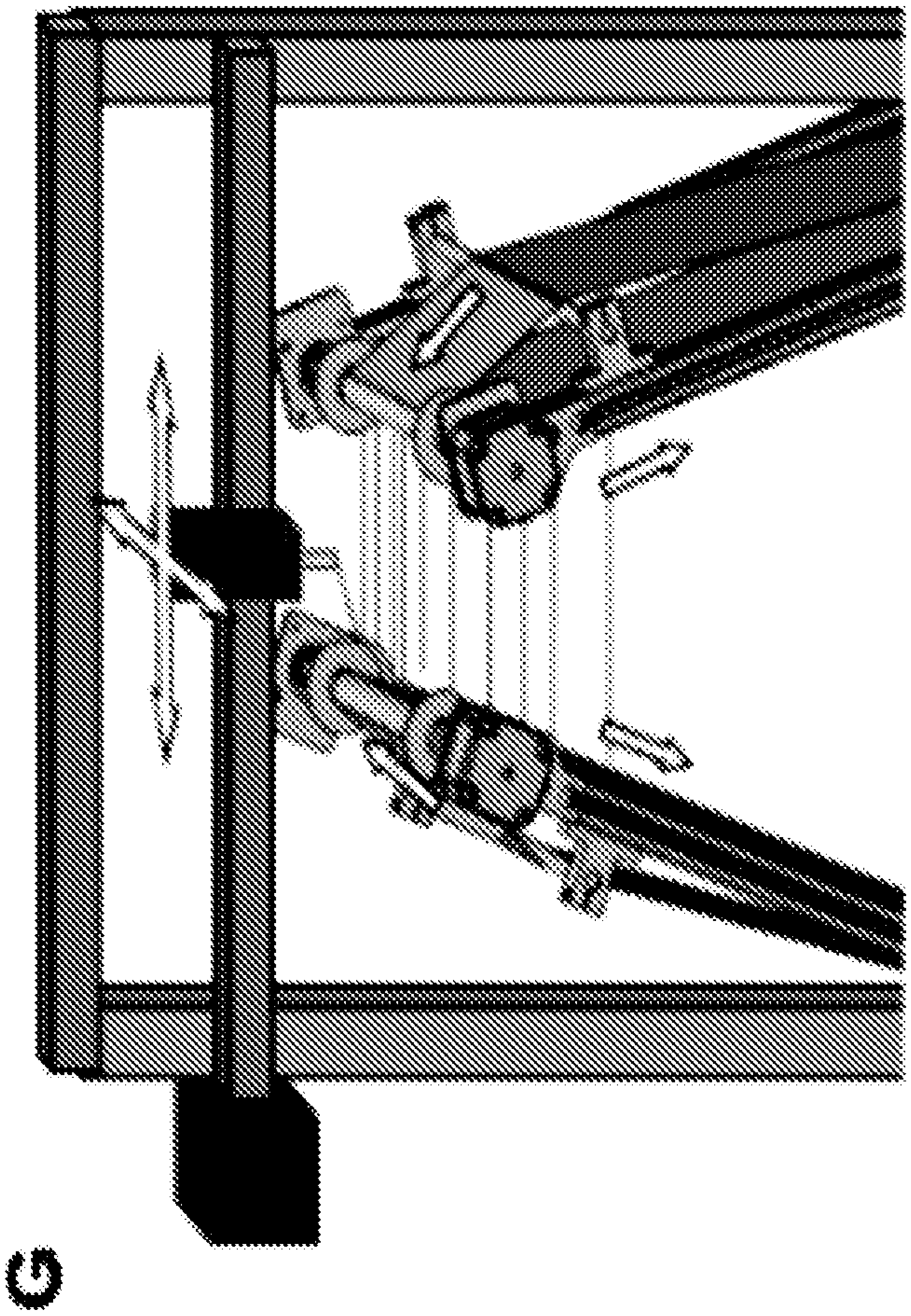
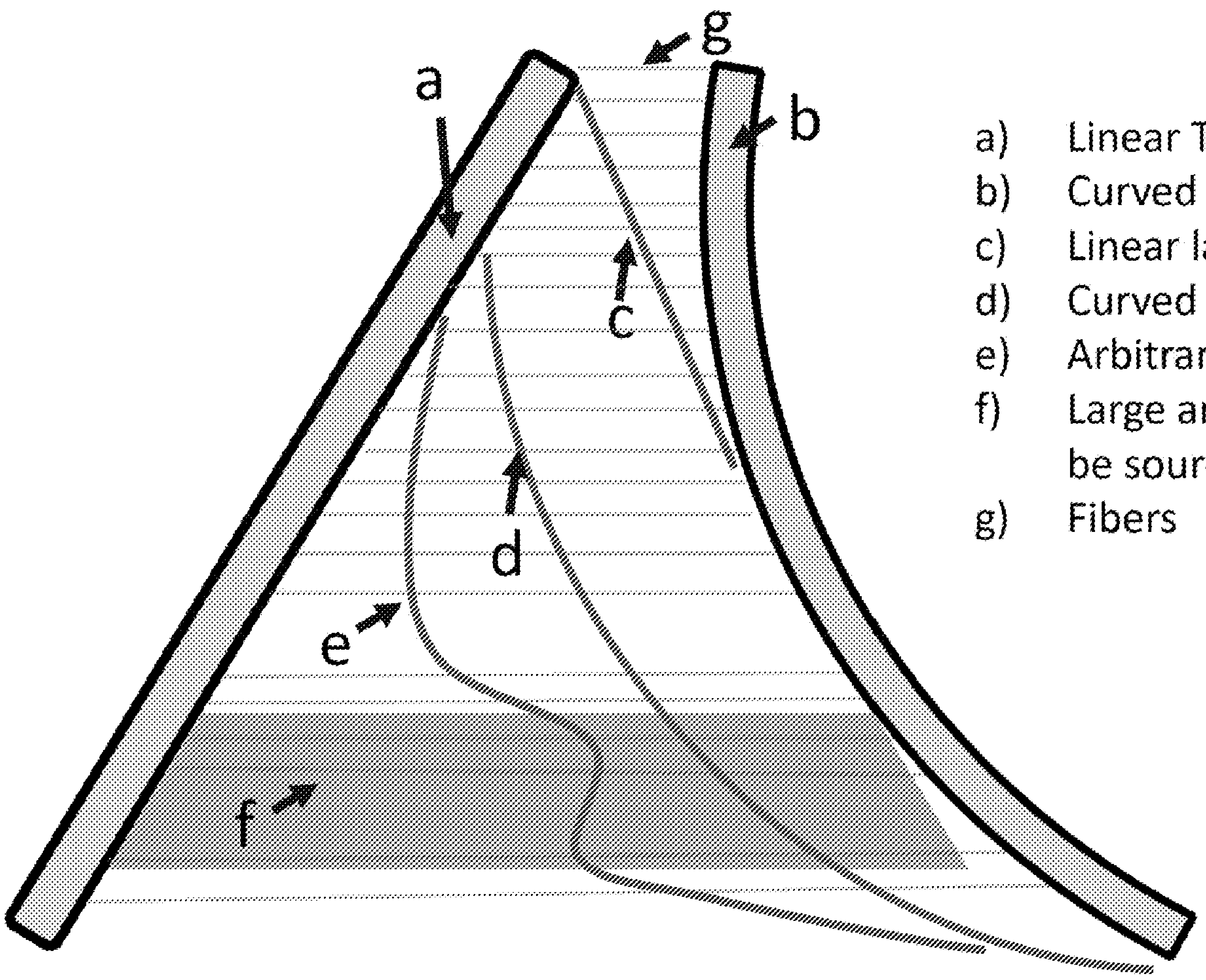


FIG. 2G



a) Linear Track
b) Curved (or arbitrary geometry) Track
c) Linear laser Treatment
d) Curved Laser Treatment
e) Arbitrary Laser Treatment
f) Large area heating (may or may not be sourced from a laser)
g) Fibers

FIG. 3

SYSTEMS AND METHODS FOR FIBER ZONE-DRAWING AND/OR ZONE-ANNEALING

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. § 119(e) to U.S. Provisional Application No. 63/179,890, filed Apr. 26, 2021, which is hereby incorporated by reference in its entirety.

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0002] This invention was made with Government support under Grant Number 1653329 awarded by the National Science Foundation. The Government has certain rights in the invention.

BACKGROUND

[0003] The drawing and annealing of polymer fibers imbues them with enhanced molecular alignment and crystallization compared to as-spun fibers. Frequently, heat treatment is applied during the drawing and annealing process in order to facilitate the drawing and crystallization. A highly effective way to heat-draw the fiber is to heat at just one location along the fiber at a time, instead of the entire fiber at once. This is called zone-drawing/zone-annealing. Heating a small portion allows the fiber to deform or anneal at the precise location the experimenter wants and allows the time and area of heating to be precisely controlled. One way to do this is to use a CO_2 laser to heat just a small portion of the fiber while it is under tension in a process called laser zone-drawing/zone-annealing (ZDZA).

[0004] Laser ZDZA in general is commonly referenced as a method for creating high performance fibers, due to its ability to create fibers with high degrees of molecular alignment and straight chain crystals. However, laser zone-drawing is not commonly used in large scale manufacturing processes because of technical challenges, slow rate, and small batch size. Part of the technical difficulty is that, if a fiber breaks in a typical manufacturing spinline, the spinning process is halted and needs to be restarted, therefore, it is imperative for the spinline to remain intact. Laser ZDZA is much more likely to cause a break in the spinline than traditional heating methods. It has also to date never been used on single nanofibers because of the minute tension required, their delicacy, and the difficulty of handling them.

[0005] In general, it has been challenging to post draw nanofibers in any capacity. This is unfortunate, because nanofibers, in addition to the useful properties that their nanoscale dimensions provide, can include high theoretical strength. Therefore, the use of ZDZA on nanofibers may allow for the creation of high tensile strength polymer fibers.

BRIEF SUMMARY

[0006] The present disclosure provides a system for manipulating fibers.

[0007] In certain embodiments, the system comprises a first collection surface and a second collection surface, each having a proximate end and a distal end, wherein the proximate ends define a proximate gap, and the distal ends define a distal gap.

[0008] In certain embodiments, the system comprises a radiation source adapted and configured to project radiation through a least a portion of a distance defined between the proximate gap and the distal gap.

[0009] In certain embodiments, the distal gap has a different distance as compared to the proximate gap.

[0010] In certain embodiments, the distal gap has the same distance as the proximate gap.

[0011] In certain embodiments, the radiation is projected at an angle relative to a center axis defined by the first collection surface and the second collection surface.

[0012] In certain embodiments, the angle ranges from about 0 to about 90 degrees.

[0013] In certain embodiments, the angle is about 0 or about 90 degrees.

[0014] In certain embodiments, the radiation source comprises a laser radiation or a non-laser radiation.

[0015] In certain embodiments, the radiation source is further adapted and configured to scan the projected radiation at one or more different angles relative to the first collection surface and the second collection surface.

[0016] In certain embodiments, the laser radiation is polarized.

[0017] In certain embodiments, the angle between the polarized laser polarization direction and the fiber axis ranges from about 0 to about 90 degrees.

[0018] In certain embodiments, the laser radiation is polarized at a frequency from about 0 to about 100 GHz.

[0019] In certain embodiments, the system further comprises a nozzle adapted and configured to deposit a fiber onto the first collection surface and second collection surface.

[0020] In certain embodiments, one end of the fiber is deposited on the first collection surface and another end of the fiber is deposited onto the second collection surface.

[0021] In certain embodiments, the system is adapted and configured to promote zone-annealing or zone-carbonizing of the fiber.

[0022] In certain embodiments, the first collection surface and the second collection surface are configured or adapted to collect one or more fibers at the respective proximate ends.

[0023] In certain embodiments, the first collection surface and the second collection surface are configured or adapted to transport the one or more fibers from the respective proximate ends towards the respective distal ends.

[0024] In certain embodiments, the radiation source is further adapted and configured to project radiation onto a section of a fiber deposited on the first collection surface and the second collection surface.

[0025] In certain embodiments, the section of the fiber is dependent on a position of the fiber along a length of the first collection surface and a length of the second collection surface.

[0026] In certain embodiments, the radiation source is further adapted or configured to project radiation onto a respective section of a plurality of fibers.

[0027] In certain embodiments, the respective section for each of the plurality of fibers is dependent on a position of the corresponding fiber along a length of the first collection surface and a length of the second collection surface.

[0028] The present disclosure further provides a method of zone-annealing and/or zone-carbonization fibers.

[0029] In certain embodiments, the method comprises depositing a first end of a fiber onto a proximate end of a first collection surface and a second end of the fiber onto a proximate end of a second collection surface.

[0030] In certain embodiments, the method comprises transporting the fiber distally away from the proximate end of the first collection surface and the proximate end of the second collection surface.

[0031] In certain embodiments, the method comprises projecting radiation onto a section of the fiber via a radiation source.

[0032] In certain embodiments, the section receiving the radiation is dependent on a position of the fiber with respect to the proximate end of the first collection surface and the proximate end of the second collection surface during the transporting.

[0033] In certain embodiments, the method comprises electrospinning, centrifugal spinning, track spinning (mechanical pulling), or 3D printing the fiber prior to the depositing.

[0034] In certain embodiments, the method comprises modifying a length of the fiber during the transporting.

[0035] In certain embodiments, the method comprises depositing a plurality of fibers onto the first collection surface and the second collection surface.

[0036] In certain embodiments, a first end for each of the plurality of fibers is deposited onto the first collection surface and a second end for each of the plurality of fibers is deposited onto the second collection surface.

[0037] In certain embodiments, the plurality of fibers can be electrically coupled to the first collection surface and the second collection surface simultaneously.

[0038] In certain embodiments, two or more of the plurality of fibers receive radiation from the radiation source simultaneously.

[0039] In certain embodiments, a section receiving the radiation for each of two or more of the plurality of fibers is dependent on a position of each of the two or more fibers with respect to the proximate end of the first collection surface and the proximate end of the second collection surface during the transporting.

[0040] In certain embodiments, the first collection surface comprises a first conveyor belt and wherein the second collection surface comprises a second conveyor belt.

[0041] In certain embodiments, the method further comprises heating the section of fiber via the projected radiation.

[0042] In certain embodiments, the heating the section of fiber exceeds at least one of the glass transition temperature of the fiber and the melting temperature of the fiber.

[0043] In certain embodiments, the fiber comprises polyacrylonitrile (PAN).

BRIEF DESCRIPTION OF THE DRAWINGS

[0044] FIG. **1** illustrates a system for radiation treatment of track-carried fibers, according to the present disclosure.

[0045] FIGS. **2A-2G** illustrate a non-limiting system for radiation treatment of track-carried fibers, according to the present disclosure. FIG. **2A** depicts automated tracks were used to collect aligned electrospun nanofiber arrays that are (FIG. **2B**) sheared off of the tracks onto a (FIG. **2C**) removable rack to form an aligned fiber array. Angled automated tracks can facilitate post-drawing of (FIG. **2D**) electrospun, (FIG. **2E**) centrifugal spun, (FIG. **2F**) track spun (mechanical pulling) and (FIG. **2G**) 3D printed fibers via "stringing" effect.

[0046] FIG. **3** illustrates various modifications and variations to the system described elsewhere herein, for example in FIG. **1** and FIGS. **2A-2G**. In certain embodiments, the tracks can take a (a) linear or (b) non-linear geometry. In a non-limiting example, a curved geometry can be used to maintain a constant fiber strain rate when the tracks are moving at a uniform speed. In certain embodiments, the projected or scanned laser path can also take a (c) linear or (d-e) non-linear geometry. In certain embodiments, the track geometry can also be orthogonal to the fiber to produce no drawing. In certain embodiments, multiple treatment can be applied sequentially as the fiber travel down the tracks (c-e). In certain embodiments, these treatment can treat a zone of the fiber (c-d) at a time or the bulk of a grouping of fiber simultaneously (e). In a non-limiting example, one treatment can thin the fiber diameter to a certain extent and the next treatment can thin it further. A subsequent treatment can anneal the fiber with or without drawing or heat the fiber for some other purpose such as carbonization.

DETAILED DESCRIPTION

[0047] In one aspect, the present disclosure is related to system and method of manufacturing nanomaterials and particularly to system and method for zone-drawing and/or zone-annealing fibers.

[0048] This disclosure is not limited to particular systems, methodologies, or protocols described, as these can vary. The terminology used in this description is for the purpose of describing the particular versions or embodiments only, and is not intended to limit the scope.

[0049] As used in this document, any word in singular form, along with the singular forms "a," "an" and "the," include the plural reference unless the context clearly dictates otherwise. Unless defined otherwise, all technical and scientific terms used herein have the same meanings as commonly understood by one of ordinary skill in the art. All publications mentioned in this document are incorporated by reference. Nothing in this document is to be construed as an admission that the embodiments described in this document are not entitled to antedate such disclosure by virtue of prior disclosure. As used herein, the term "comprising" means "including, but not limited to."

[0050] Systems and methods for radiation treatment of track-carried fibers are described herein. The system can collect fibers between two opposing conveyer belts, with each end of the fiber stuck to either belt, such that each fiber bridges the belts. The belts are set at an angle to each other, and when run, the fibers can be drawn out and carried toward a final collecting tray. Many thousands of these fibers can be processed in parallel, so even with a slow rate of draw, the method can be high throughput. Until now, the drawing process has occurred under isothermal conditions, which has produced the strongest polycaprolactone (PCL) nanofibers in the literature, however the molecular properties suggest there is still headroom for improvement, especially with respect to polymers that have a high glass transition temperature.

[0051] FIG. **1** depicts a system for radiation treatment of track-carried fibers, according to certain embodiments described herein. The system can include a fiber collecting device, which can include two automated tracks **12**, **13** separated by an air gap. In some cases, an electrospinning nozzle **10** can be loaded with any polymeric composition **30** suitable for use in an electrospinning process. It should be noted that this present disclosure is not limited to electrospinning, as discussed elsewhere herein. Upon applying a suitable voltage to the needle, the repulsive electrostatic forces induced at the liquid/air interface will overcome the surface tension forces and a jet **40** of liquid will be ejected. The jet **40** travels toward the deposition area **2** and collection compartment. In the collection compartment, fibers are traveling with each end adhering to the surface of each of the parallel tracks and suspended between them. As fibers are moved away from the collecting location by the automated tracks, more fibers are subsequently collected.

[0052] The system can include a track system can include collection surfaces **101** and **102**. In some cases, the collections surfaces **101** and **102** can be conductive surfaces, such as for the collection of fibers. It should be noted that the present disclosure is not limited to any specific kind of fiber(s), regardless of how it/they was/were generated and/or drawn. Electrospun fibers are provided herein as non-limiting embodiments, and one skilled in the art would have contemplated that the present disclosure is applicable to any other types of fibers, such as but not limited to electrospun, centrifugal spun, track spun (mechanical pulling), 3D printed, and so forth.

[0053] The tracks or collection surfaces **101** and **102** can be at a distance from and facing each other. The two conductive collection surfaces define a space in between that includes the deposition area **2** and the collection compartment. The two collection surfaces **101** and **102** each has two ends: a proximate end **108**, **109** and a distal end **110**, **111** that is opposite to the proximate end. In certain embodiments, the collection surfaces **101** and **102** are aligned to each other, in particular, the proximate end **108** of surface **101** corresponds to the proximate end **109** of surface **102** and the distal end **101** of surface **101** corresponds to the distal end **111** of surface **102**. In certain embodiments, one or both the tracks are linear. In certain embodiments, one or both the tracks has a curved and/or arbitrarily selected geometry.

[0054] In certain embodiments, the deposition area can be proximate to the proximate end **108**, **109** of each of the collection surfaces, specifically, the deposition area can be defined as a gap between the two collection surfaces **101**, **102**, which are separated by the gap at their proximate ends. The collection compartment follows the deposition area. In certain embodiments, the two collection surfaces **101** and **102** are facing each other at a track angle θ, which is formed where both collection surfaces **101** and **102** extend at their proximate ends **108** and **109** and intersect.

[0055] In certain embodiments, the angle θ can range from 0 to 90 degrees. In this case, if the distance between the proximate ends **108**, **109** remains unchanged, the larger the track angle θ is, the farther apart the distal ends of the two collection surfaces are from each other. Similarly, the smaller the track angle θ is, the closer the distal ends of the two collection surfaces are from each other. In certain embodiments, the angle θ is 90 degrees, i.e. the collection surfaces **101** and **102** are orthogonal to each other. In other embodiments, the angle θ can be less than 90 degrees. In other embodiments, the angle θ can be zero, in which case the two collection surfaces **101** and **102** are parallel to each other.

[0056] Alternatively and/or additionally, the collection surfaces **101** and **102** are aligned such that they form two lateral sides of an isosceles trapezoid. In certain embodiments, an electrospinning nozzle **10** can be placed proximate to the proximate ends **108** and **109** of each of the two collection surfaces, or a shorter base of the isosceles trapezoid. Alternatively and/or additionally, the system can also include a collection rack that is placed inside the collection compartment, and typically positioned near the distal end **110**, **111** of the collection surfaces **101**, **102**.

[0057] In certain embodiments, the two collection surfaces **101** and **102** can be capable of motion in the direction marked by the arrows **107**. As a fiber **104** is deposited into the deposition area **103** (e.g., from the electrospinning nozzle **106**), each end of the nanofiber is adhered to the collection surfaces **101** and **102**, thus the fiber travels down with the movement of the tracks in the direction of the arrows **107**. This allows the fiber that is deposited in the deposition area to be moved away from the deposition area and into the collection compartment and at the same time elongated/stretched while in the collection compartment. Elongation refers to the stretching or post-drawing of a fiber that is moving with the collection surfaces **101**, **102** and the stretching occurs in a direction that is perpendicular to the movement of the fiber in the collection compartment. Due to the motion of the angled collection surfaces **101** and **102**, successively formed fibers are aligned, spaced apart from one another and elongated within the collection compartment, and finally collected. In certain embodiments, the formed fibers can be removed from the collection compartment into the collection rack.

[0058] In some cases, the optional electrospinning nozzle **10** can define an axis along the nozzle, and the collection compartment can define a plane that is parallel to the axis of the electrospinning nozzle **10**. In other embodiments, the plane defined by the collection compartment can be normal to the axis of the electrospinning nozzle. In certain embodiments, the collection surfaces **101** and **102** can be endless travelling belts. Additionally, the traveling belts can be laminated. Further, the speed of the belts or the motion of the collection surfaces can be independently controlled.

[0059] The system can also include a radiation source **115**. The radiation source **115** can be configured to emit radiation in a direction through at least a portion of the gap between the collection surfaces **101** and **102**. Further, the radiation source **115** can emit radiation in a discreet direction, such as with collimated radiation. In certain embodiments, the radiation source provides a linear radiation beam. In certain embodiments, the radiation source provides a non-linear radiation beam. In certain embodiments, the radiation source provides an arbitrarily shaped radiation beam. In certain embodiments, only one radiation source is used within the disclosure herein. In certain embodiments, two or more radiation sources are independently used within the disclosure herein. In certain embodiments, only one radiation beam is used within the disclosure herein. In certain embodiments, two or more radiation beams are independently used within the disclosure herein. In some cases, the radiation source **115** can be any type of laser, such as but not limited to a CO_2 laser. Suitable laser light sources include gas-based lasers (such as HeNe, Ar, Kr, Xe, CO_2, and the like): dye-based lasers (using dyes such as stilbene, coumarin, rhodamine 6G and the like): metal vapor lasers (such as HeCd, HeHg, HeSe, strontium vapor, copper vapor, gold vapor, manganese vapor, and the like): solid-state lasers (such as ruby, Nd:YAG, Er:YAG, Ti:sapphire, and the like): and semiconductor lasers (such as GaN and InGaN, and the like). In some cases, the radiation source **115** can be any type of non-laser radiation, such as but not limited to neon light, xenon lamps and infrared radiation.

[0060] In some cases, the radiation can be emitted in a static direction, such as direction **120** as shown in FIG. **1**. Alternatively, in some cases the radiation source **115** can reposition the direction of radiation, (e.g., by rotating the emission end of the radiation source **115**, actuating the radiation source **115** with respect to the collection surface **101** and **102**, and the like).

[0061] As a fiber is deposited on the collection surfaces, the tracks can carry the fiber away from proximal ends. As the fiber travels along the collection surfaces, the fiber length can be modified based on the change in gap distance between the collection surfaces. Further, the radiation source **115** can emit radiation through the defined gap between the collection surfaces. As the fiber travels along the surfaces, a portion of the fiber can pass through the emitted radiation, which can heat the fiber portion. Further, as the fiber continues to travel along the length of the collection surfaces, different portions of the fiber can pass through the emitted radiation, thereby heating different portions of the fiber as the fiber travels.

[0062] The systems and methods described herein can facilitate remarkable control over the final internal structure of the processed fiber and result in exceptional mechanical strength. The utilization of automated tracks allows for controlled laser zone-drawing of the delicate nanofibers. Further, the rapid heating and cooling of fibers, due to their high surface area-to-volume ratio, facilitates alignment of polymer chains at elevated temperatures that are locked in place during rapid cooling before chain relaxation can occur, thereby enhancing mechanical behavior. In certain embodiments, the heating the section of fiber exceeds the glass transition temperature of the fiber. In certain embodiments, the heating the section of fiber exceeds the melting temperature of the fiber.

[0063] The method described herewith, with reference to FIG. **1**, can be applied to various processes for manufacturing nanofibers and various parameters can be controlled depending on the materials. This includes adjusting the geometry of the tracks by moving the rollers, adjusting the initial length, the speed of the tracks, the maximum distance between the tracks over the initial length, i.e. the draw ratio, the temperature, the radiation direction, the radiation wavelength, intensity, pulsating frequency, and the like.

[0064] FIGS. **2A-2G** illustrate a non-limiting system for radiation treatment of track-carried fibers, according to the present disclosure. FIG. **2A** depicts automated tracks were used to collect aligned nanofiber arrays that are (FIG. **2B**) sheared off of the tracks onto a (FIG. **2C**) removable rack to form an aligned fiber array. Angled automated tracks can facilitate post-drawing of (FIG. **2D**) electrospun, (FIG. **2E**) centrifugal spun, (FIG. **2F**) track spun (mechanical pulling) and (FIG. **2G**) 3D printed fibers via “stringing” effect.

[0065] FIG. **3** illustrates various modifications and variations to the system described elsewhere herein, for example in FIG. **1**. In certain embodiments, the tracks can take a (a) linear or (b) non-linear geometry. In a non-limiting example, a curved geometry can be used to maintain a constant fiber strain rate when the tracks are moving at a uniform speed. In certain embodiments, the projected or scanned laser path can also take a (c) linear or (d-e) non-linear geometry. In certain embodiments, the track geometry can also be orthogonal to the fiber to produce no drawing. In certain embodiments, multiple treatment can be applied sequentially as the fiber travel down the tracks (c-e). In certain embodiments, these treatment can treat a zone of the fiber (c-d) at a time or the bulk of a grouping of fiber simultaneously (e). In a non-limiting example, one treatment can thin the fiber diameter to a certain extent and the next treatment can thin it further. A subsequent treatment can anneal the fiber with or without drawing or heat the fiber for some other purpose such as carbonization.

ENUMERATED EMBODIMENTS

[0066] The following enumerated embodiments are provided, the numbering of which is not to be construed as designating levels of importance.

[0067] Embodiment 1: A system for manipulating fibers, the system comprising: a first collection surface and a second collection surface, each having a proximate end and a distal end, wherein the proximate ends define a proximate gap, and the distal ends define a distal gap: and a radiation source adapted and configured to project radiation through a least a portion of a distance defined between the proximate gap and the distal gap.

[0068] Embodiment 2: The system of Embodiment 1, wherein the distal gap has a different distance as compared to the proximate gap.

[0069] Embodiment 3: The system of Embodiment 1, wherein the distal gap has the same distance as the proximate gap.

[0070] Embodiment 4: The system of any one of Embodiments 1-3, wherein the radiation is projected at an angle relative to a center axis defined by the first collection surface and the second collection surface.

[0071] Embodiment 5: The system of Embodiment 4, wherein the angle ranges from about 0 to about 90 degrees.

[0072] Embodiment 6: The system of any one of Embodiments 4-5, wherein the angle is about 0 or about 90 degrees.

[0073] Embodiment 7: The system of any one of Embodiments 1-6, wherein the radiation source comprises a laser radiation or a non-laser radiation.

[0074] Embodiment 8: The system of any one of Embodiments 1-7, wherein the radiation source is further adapted and configured to scan the projected radiation at one or more different angles relative to the first collection surface and the second collection surface.

[0075] Embodiment 9: The system of any one of Embodiments 7-8, wherein the laser radiation is polarized, and wherein the angle between the polarized laser polarization direction and the fiber axis ranges from about 0 to about 90 degrees.

[0076] Embodiment 10: The system of any one of Embodiments 7-9, wherein the laser radiation is polarized at a frequency from about 0 to about 100 GHz.

[0077] Embodiment 11: The system of any one of Embodiments 1-10, further comprising a nozzle adapted and configured to deposit a fiber onto the first collection surface and second collection surface, wherein one end of the fiber is deposited on the first collection surface and another end of the fiber is deposited onto the second collection surface.

[0078] Embodiment 12: The system of any one of Embodiments 1-11, which is adapted and configured to promote zone-annealing or zone-carbonizing of a/the fiber.

[0079] Embodiment 13: The system of any one of Embodiments 1-12, wherein the first collection surface and the second collection surface are configured or adapted to:

collect one or more fibers at the respective proximate ends: and transport the one or more fibers from the respective proximate ends towards the respective distal ends.

[0080] Embodiment 14: The system of any one of Embodiments 1-13, wherein the radiation source is further adapted and configured to project radiation onto a section of a fiber deposited on the first collection surface and the second collection surface, wherein the section of the fiber is dependent on a position of the fiber along a length of the first collection surface and a length of the second collection surface.

[0081] Embodiment 15: The system of any one of Embodiments 1-14, wherein the radiation source is further adapted or configured to project radiation onto a respective section of a plurality of fibers.

[0082] Embodiment 16: The system of Embodiment 15, wherein the respective section for each of the plurality of fibers is dependent on a position of the corresponding fiber along a length of the first collection surface and a length of the second collection surface.

[0083] Embodiment 17: A method of zone-annealing or zone-carbonization fibers, the method comprising: depositing a first end of a fiber onto a proximate end of a first collection surface and a second end of the fiber onto a proximate end of a second collection surface; transporting the fiber distally away from the proximate end of the first collection surface and the proximate end of the second collection surface: and projecting radiation onto a section of the fiber via a radiation source, wherein the section receiving the radiation is dependent on a position of the fiber with respect to the proximate end of the first collection surface and the proximate end of the second collection surface during the transporting.

[0084] Embodiment 18: The method of Embodiment 17, further comprising electrospinning, centrifugal spinning, track spinning (mechanical pulling), or 3D printing the fiber prior to the depositing.

[0085] Embodiment 19: The method of any one of Embodiments 17-18, further comprising modifying a length of the fiber during the transporting.

[0086] Embodiment 20: The method of any one of Embodiments 17-19, further comprising: depositing a plurality of fibers onto the first collection surface and the second collection surface, wherein a first end for each of the plurality of fibers is deposited onto the first collection surface and a second end for each of the plurality of fibers is deposited onto the second collection surface, and wherein the plurality of fibers can be electrically coupled to the first collection surface and the second collection surface simultaneously.

[0087] Embodiment 21: The method of Embodiment 20, wherein two or more of the plurality of fibers receive radiation from the radiation source simultaneously.

[0088] Embodiment 22: The method of any one of Embodiments 17-21, wherein a section receiving the radiation for each of two or more of the plurality of fibers is dependent on a position of each of the two or more fibers with respect to the proximate end of the first collection surface and the proximate end of the second collection surface during the transporting.

[0089] Embodiment 23: The method of any one of Embodiments 17-22, wherein the first collection surface comprises a first conveyor belt and wherein the second collection surface comprises a second conveyor belt.

[0090] Embodiment 24: The method of any one of Embodiments 17-23, further comprising heating the section of fiber via the projected radiation.

[0091] Embodiment 25: The method of Embodiment 24, wherein the heating the section of fiber exceeds at least one of the glass transition temperature of the fiber and the melting temperature of the fiber.

[0092] Embodiment 26: The method of any one of Embodiments 17-25, wherein the fiber comprises polyacrylonitrile (PAN).

[0093] The features and functions, as well as alternatives, disclosed herein can be combined into many other different systems or applications. Various presently unforeseen or unanticipated alternatives, modifications, variations or improvements can be made by those skilled in the art, each of which is also intended to be encompassed by the disclosed embodiments.

1. A system for manipulating fibers, the system comprising:

a first collection surface and a second collection surface, each having a proximate end and a distal end, wherein the proximate ends define a proximate gap, and the distal ends define a distal gap; and

a radiation source adapted and configured to project radiation through a least a portion of a distance defined between the proximate gap and the distal gap.

2. The system of claim **1**, wherein the distal gap has a different distance as compared to the proximate gap.

3. The system of claim **1**, wherein the distal gap has the same distance as the proximate gap.

4. The system of claim **1**, wherein the radiation is projected at an angle relative to a center axis defined by the first collection surface and the second collection surface.

5. The system of claim **4**, wherein the angle ranges from about 0 to about 90 degrees.

6. The system of claim **4**, wherein the angle is about 0 or about 90 degrees.

7. The system of claim **1**, wherein the radiation source comprises a laser radiation or a non-laser radiation.

8. The system of claim **1**, wherein the radiation source is further adapted and configured to scan the projected radiation at one or more different angles relative to the first collection surface and the second collection surface.

9. The system of claim **7**, wherein the laser radiation is polarized, and wherein the angle between the polarized laser polarization direction and the fiber axis ranges from about 0 to about 90 degrees.

10. The system of claim **7**, wherein the laser radiation is polarized at a frequency from about 0 to about 100 GHz.

11. The system of claim **1**, further comprising a nozzle adapted and configured to deposit a fiber onto the first collection surface and second collection surface, wherein one end of the fiber is deposited on the first collection surface and another end of the fiber is deposited onto the second collection surface.

12. The system of claim **11**, which is adapted and configured to promote zone-annealing or zone-carbonizing of the fiber.

13. The system of claim **1**, wherein the first collection surface and the second collection surface are configured or adapted to:

collect one or more fibers at the respective proximate ends; and transport the one or more fibers from the respective proximate ends towards the respective distal ends.

14. The system of claim **1**, wherein the radiation source is further adapted and configured to project radiation onto a section of a fiber deposited on the first collection surface and the second collection surface, wherein the section of the fiber is dependent on a position of the fiber along a length of the first collection surface and a length of the second collection surface.

15. The system of claim **1**, wherein the radiation source is further adapted or configured to project radiation onto a respective section of a plurality of fibers.

16. The system of claim **15**, wherein the respective section for each of the plurality of fibers is dependent on a position of the corresponding fiber along a length of the first collection surface and a length of the second collection surface.

17. A method of zone-annealing or zone-carbonization fibers, the method comprising:

depositing a first end of a fiber onto a proximate end of a first collection surface and a second end of the fiber onto a proximate end of a second collection surface;

transporting the fiber distally away from the proximate end of the first collection surface and the proximate end of the second collection surface; and

projecting radiation onto a section of the fiber via a radiation source, wherein the section receiving the radiation is dependent on a position of the fiber with respect to the proximate end of the first collection surface and the proximate end of the second collection surface during the transporting.

18. The method of claim **17**, further comprising electrospinning, centrifugal spinning, track spinning (mechanical pulling), or 3D printing the fiber prior to the depositing.

19. The method of claim **17**, further comprising modifying a length of the fiber during the transporting.

20. The method of claim **17**, further comprising:

depositing a plurality of fibers onto the first collection surface and the second collection surface,

wherein a first end for each of the plurality of fibers is deposited onto the first collection surface and a second end for each of the plurality of fibers is deposited onto the second collection surface, and

wherein the plurality of fibers can be electrically coupled to the first collection surface and the second collection surface simultaneously.

21. The method of claim **20**, wherein two or more of the plurality of fibers receive radiation from the radiation source simultaneously.

22. The method of claim **21**, wherein a section receiving the radiation for each of two or more of the plurality of fibers is dependent on a position of each of the two or more fibers with respect to the proximate end of the first collection surface and the proximate end of the second collection surface during the transporting.

23. The method of claim **17**, wherein the first collection surface comprises a first conveyor belt and wherein the second collection surface comprises a second conveyor belt.

24. The method of claim **17**, further comprising heating the section of fiber via the projected radiation.

25. The method of claim **24**, wherein the heating the section of fiber exceeds at least one of the glass transition temperature of the fiber and the melting temperature of the fiber.

26. The method of claim **17**, wherein the fiber comprises polyacrylonitrile (PAN).

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