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(54) **ADDITIVE MANUFACTURING OF IMPREGNATED SEGMENTS FOR A DRILL BIT AND/OR MULTILAYER IMPREGNATION OF A DRILL BIT**

(57) A method for manufacturing an impregnated segment includes forming a base tier by depositing one or more layers of molten metallic material. The base tier has a plurality of cavities. The method further includes inserting at least one superhard particle into each cavity and forming an additional tier on top of the base tier by depositing one or more layers of the molten metallic material. The additional tier has a plurality of cavities. The method further includes repeating the insertion of the superhard particles and the formation of additional tiers to form an impregnated cage.

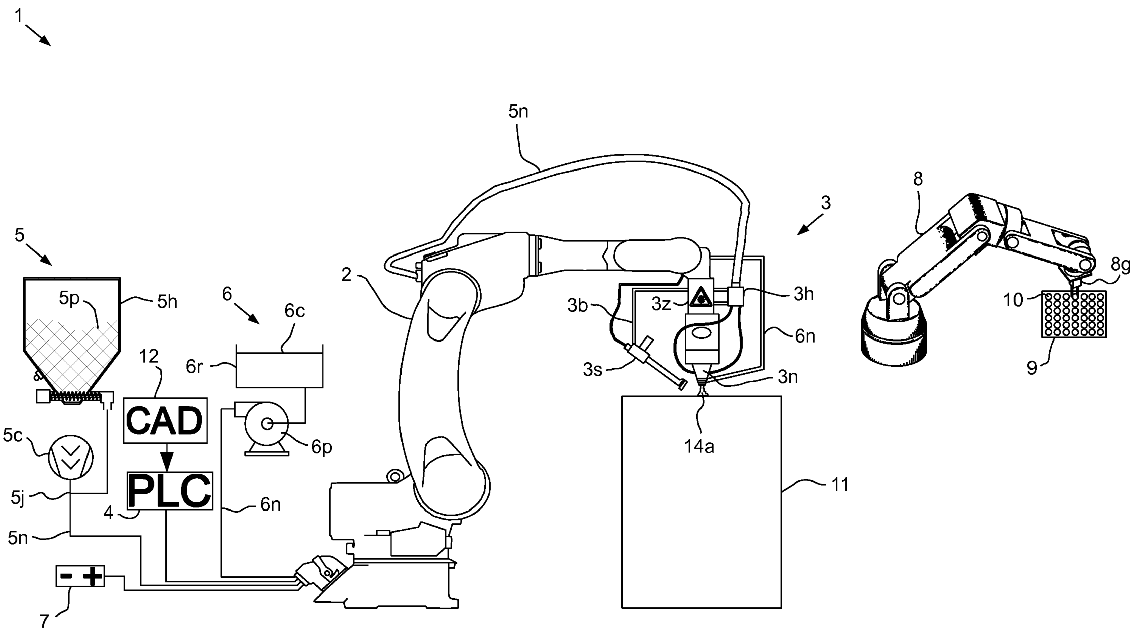

FIG. 1

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Description

BACKGROUND OF THE DISCLOSURE

Field of the Disclosure

[0001] The present disclosure generally relates to additive manufacturing of impregnated segments for a drill bit and/or multilayer impregnation of a drill bit.

Description of the Related Art

[0002] US 3,885,637 discloses boring tools in which the cutting elements defined by coarse abrasive grains are embedded at 1/2-2/3 of the height of the cutting grains in the matrix layer containing embedded fine abrasive grains, while the remaining portion of the grains is located in a metallic layer of the matrix arranged outside over the rock-destroying surface of the tool. The advantage of such boring tools is that their wear resistance is 20-30 percent greater than that of the known boring tools.

[0003] US 5,957,006 discloses a method of fabricating rotary bits for subterranean drilling by layering techniques such as are employed in rapid prototyping technology. Thin layers of powder may be sequentially deposited and fused or otherwise bonded to define the bit body, or thin sheets of material may be stacked, bonded and cut. Bit body components may also be formed by the method and subsequently assembled with other components made in like manner or by other methods to produce a bit body. Bits fabricated according to the method are also disclosed.

[0004] US 6,742,611 discloses a laminated cutting element for use on a rotary-type earth-boring drill bit for drilling subterranean formations preferably including at least one first segment formed of a hard, continuous-phase material impregnated with a particulate superabrasive material laminated to and including at least one second segment formed of a continuous-phase material having essentially no particulate superabrasive material impregnated therein. Alternatively, the at least one second segment may have superabrasive and/or abrasive material impregnated therein which is less abrasive than the superabrasive material impregnated in the at least one first segment. Preferably, the continuous-phase material in which the at least one first segment and the at least one second segment are made is a metal matrix material. A further alternative of the present invention includes a single segment formed of a continuous-phase material in which a particulate superabrasive material is impregnated. The alternative single segment has a relatively thin cross-sectional thickness and is securable to a support member preferably fabricated from a tough and ductile material. The support member further includes a bit attachment portion securable to a bit body and a segment-receiving portion adapted to receive and support the superabrasive impregnated segment during drilling. A yet further alternative of the present invention includes a composite segment formed of a continuous-phase material wherein a preselected portion of the segment is impregnated with a particulate superabrasive material.

[0005] US 8,220,567 discloses a diamond impregnated drill bit features layered encapsulation of the diamond grit where the innermost layer is hardest or most abrasion resistant while succeeding layers are generally softer and less wear resistant. This can be accomplished by manipulating several variables in the encapsulation layers such as particle size or hard particle concentration. The outer layers can have added binder to make them softer. The encapsulated grit can be sintered or pre-sintered to make it less friable when handled.

[0006] US 8,997,897 discloses depositing a layer of matrix powder within a mold opening. A layer of super-abrasive particles is then deposited over the matrix powder layer. The super-abrasive particles have a non-random distribution, such as being positioned at locations set by a regular and repeating distribution pattern. A layer of matrix powder is then deposited over the super-abrasive particles. The particle and matrix powder layer deposition process steps are repeated to produce a cell having alternating layers of matrix powder and non-randomly distributed super-abrasive particles. The cell is then fused, for example using an infiltration, hot isostatic pressing or sintering process, to produce an impregnated structure. A working surface of the impregnated structure that is oriented non-parallel (and, in particular, perpendicular) to the super-abrasive particle layers is used as an abrading surface for a tool.

[0007] US 2015/0008046 discloses a drill bit including a bit body having an end face for engaging a rock formation. The end face is defined by a HIP pressed center structure formed of a metal matrix impregnated with super abrasive particles. The HIP pressed center structure includes a central region located at a center axis of said drill bit and finger regions extending radially from the central region. The end face is further defined by infiltrated ribs formed of a metal matrix impregnated with super abrasive particles. Certain ones of the infiltrated ribs are configured to form radial extensions from the finger regions of the HIP pressed center structure.

SUMMARY OF THE DISCLOSURE

[0008] The present disclosure generally relates to additive manufacturing of impregnated segments for a drill bit and/or multilayer impregnation of a drill bit. In one embodiment, a method for manufacturing an impregnated segment includes forming a base tier by depositing one or more layers of molten metallic material. The base tier has a plurality of cavities. The method further includes inserting at least one superhard particle into each cavity and forming an additional tier on top of the base tier by depositing one or more layers of the molten metallic material. The additional tier has a plurality of cavities. The method further includes repeating the insertion of the superhard particles and the formation of additional tiers to form an impregnated cage.

[0009] In another embodiment, a method for manufacturing an impregnated blade piece or blade includes stacking a second layer of atop a first layer. Each layer includes a plurality of superhard particles coated with a carbide material. The method further includes welding selected particles of the first and second layers together and stacking an additional layer atop the second layer. The additional layer includes a plurality of superhard particles coated with a metallic material. The method further includes: welding selected particles of the additional and second layers together; repeating the stacking and welding to form a conglomerate; and removing the non-welded particles from the conglomerate.

[0010] In another embodiment, a drill bit includes: a shank having a coupling formed at an upper end thereof; a bit body mounted to a lower end of the shank; a gage section forming an outer portion of the drill bit; and a cutting face forming a lower end of the drill bit. The cutting face includes a plurality of blades protruding from the bit body, each blade extending from a center of the cutting face to the gage section and made from a matrix material impregnated by superhard particles; and a plurality of segments mounted along each blade, each segment made from a matrix material impregnated by superhard particles. At least one segment of each blade is anisotropic. Each anisotropic segment has an outer portion optimized to drill a first formation and an inner portion optimized to drill a second formation. One of the formations is a hard formation and the other of the formations is a soft formation.

[0011] In another embodiment, a method for manufacturing an impregnated drill bit includes placing a metallic blank and a displacement within a mold having an inner surface formed into a negative shape of facial features of the drill bit. The mold is part of a casting assembly. The method further includes: packing a first layer of matrix power and superhard particles into the mold at cavities thereof corresponding to blades of the drill bit; packing a second layer of matrix powder and superhard particles into the mold at the cavities; loading matrix powder into the mold to fill a remaining chamber thereof; placing a binder alloy into the casting assembly over the mold; inserting the casting assembly into a furnace; and operating the furnace to melt the binder alloy, thereby infiltrating the powders with the binder alloy. Each layer has parameters of particle size, particle density, and matrix hardness. At least one parameter of the first layer is different from at least one parameter of the second layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

Figures 1 and 2A-2C illustrate an automated system manufacturing an impregnated cage, according to one embodiment of the present disclosure.

Figure 3A illustrates insertion of the cage into a mold and pouring of matrix powder into the cage. Figure 3B illustrates a casting assembly including the cage.

Figure 4A illustrates the casting assembly placed in a furnace for infiltration of the cage to form an impregnated segment. Figure 4B illustrates the fabricated impregnated segment having a cylindrical shape. Figure 4C illustrates an alternative fabricated impregnated segment having a truncated ellipsoid shape.

Figure 5 illustrates a drill bit equipped with the impregnated segments.

Figure 6A illustrates delivery of a layer of coated superhard particles onto a pedestal of the automated system, according to another embodiment of the present disclosure. Figure 6B illustrates delivery of a second layer to the pedestal and stacking upon the first layer. Figure 6C illustrates welding together of selected particles from the first and second layers. Figure 6D illustrates repeating the delivery and welding for additional layers to form a conglomerate of particles. Figure 6E illustrates removal of non-welded particles from the conglomerate.

Figure 7A illustrates insertion of the conglomerate into a mold and pouring of the matrix powder into the conglomerate. Figure 7B illustrates a casting assembly including the conglomerate. Figure 7C illustrates the casting assembly placed in the furnace for infiltration of the conglomerate to form a blade piece or blade. Figure 7D illustrates a drill bit equipped with a plurality of the blade pieces. Figure 7E illustrates a drill bit equipped with a plurality of the blades.

Figure 8A illustrates an anisotropic impregnated cage, according to another embodiment of the present disclosure. Figure 8B illustrates insertion of the anisotropic cage into a mold and pouring of different matrix powders into the anisotropic cage.

Figure 9A illustrates a casting assembly including the anisotropic cage. Figure 9B illustrates the casting assembly placed in a furnace for infiltration of the anisotropic cage to form an anisotropic impregnated segment.

Figure 10A illustrates drilling of soft and hard formations using a drill bit equipped with the anisotropic impregnated segments. Figure 10B illustrates an alternative drill bit having selective placement of different types of anisotropic segments.

Figures 11A-12B illustrate manufacture of a drill bit with anisotropic impregnated blades.

DETAILED DESCRIPTION

[0013] Figures 1 and 2A-2C illustrate an automated system 1 manufacturing an impregnated cage 13, according to one embodiment of the present disclosure. The automated system 1 may include a fabrication robot 2, a deposition head 3, a programmable logic controller (PLC) 4, a material supply system 5, a cooling system 6, an electrical power supply 7, a delivery robot 8, a tray 9 of superhard (aka superabrasive) particles 10, and a pedestal 11. The superhard particles 10 may be diamond or cubic boron nitride, may be synthetic, and may be monocrystalline or polycrystalline. If polycrystalline, the superhard particles 10 may be thermally stable.

[0014] Each robot 2, 8 may include a base, one or more arms, and an actuator (not shown) for each arm. Each base may mount the respective robot 2, 8 to a floor of a manufacturing facility (not shown). A first arm of each robot 2, 8 may be supported from the respective base and may be rotated relative to the base by a respective first actuator. Each robot 2, 8 may include one or more additional arms pivotally connected to the respective first arm and articulated relative thereto by one or more respective actuators. The deposition head 3 may be fastened to an end of the fabrication robot 2 distal from the base. A gripper 8g and gripper actuator may be fastened to an end of the delivery robot 8 distal from the base.

[0015] The deposition head 3 may include a laser 3z, a nozzle 3n, and a feedback sensor 3s, such as a pyrometer. An upper end of the laser 3z may be fastened to the distal end of the fabrication robot 2. An upper end of the nozzle 3n may be fastened to a lower end of the laser 3z. A bracket 3b may be fastened to an outer surface of the laser 3z and the feedback sensor 3s may be fastened to the bracket adjacent to a lower end of the nozzle 3n.

[0016] Alternatively, the deposition head 3 may include an electron beam generator instead of a laser. Alternatively, if the tiers 14b are to be made of a metal or alloy, a welding head may be used instead of the deposition head 3 and a rod feeding system may be used instead of the material supply system 5.

[0017] The material supply system 5 may include a compressor 5c, a metering hopper 5h, a delivery flowline 5n, and a transport junction 5j. The metering hopper 5h may be loaded with metallic powder 5p. The metallic powder 5p may be a metal, alloy, or cermet, such as stainless steel, nickel-chromium alloy, or tungsten carbide-cobalt. A discharge of the metering hopper 5h and a discharge of the compressor 5c may each be connected to a respective inlet of the transport junction 5j. A discharge of the transport junction 5j may be connected to the delivery flowline 5n. The delivery flowline 5n may enter the fabrication robot 2 at the base and the robot may have one or more fluid swivels to accommodate routing of the flowline therethrough. The delivery flowline 5n may exit the fabrication robot 2 at one of the additional arms and lead to a header 3h supported from an outer surface of the laser 3z. A plurality of feed lines may extend from the header 3h to respective ports of the nozzle 3n for delivery of the metallic powder 5p toward the focal point of the laser 3z.

[0018] The cooling system 6 may include a reservoir 6r of coolant 6c, such as water, a pump 6p, and a delivery line 6n. An intake of the pump 6p may be connected to the reservoir 6r and the delivery flowline 6n may be connected to a discharge of the pump. The delivery flowline 6n may enter the fabrication robot 2 at the base and the fabrication robot may have one or more fluid swivels to accommodate routing of the flowline therethrough. The delivery flowline 6n may exit the fabrication robot 2 at the end of at one of the additional arms and lead to the nozzle 3n for application of the coolant thereto.

[0019] The electrical power supply 7 may be in electrical communication with the laser 3z and the arm actuators of each robot 2, 8 via a power cable (only one shown) extending through the respective robot. The feedback sensor 3s and arm actuators may be in electrical communication with the controller 4 via a respective data cable (only one shown) extending through the respective robot 2, 8.

[0020] In operation, the cage 13 may be designed on a computer aided design (CAD) system to generate a CAD design model 12. The CAD design model 12 may be converted to a computer aided manufacturing (CAM) format and supplied to the controller 4. The controller 4 may then operate the fabrication robot 2 to begin deposition of a base tier 14b onto the pedestal 11. Heat generated by the laser 3z may melt the powder 5p (or metal portion thereof, if a cermet) as the fabrication robot 2 moves the deposition head 3 along the pedestal 11, thereby depositing a layer 14a of molten material thereon. The fabrication robot 2 may repeat deposition of layers until the base tier 14b has been formed. A refractory liner (not shown) may be placed over the pedestal 11 to facilitate removal of the cage 13.

[0021] Once the base tier 14b has been deposited onto the pedestal 11, the controller 4 may operate the delivery robot 8 to grab a particle 10 from the tray, transport the particle 10 to the pedestal 11, and release the particle into a cavity of the base tier 14b. Operation of the delivery robot 8 may be repeated until one of the particles 10 has been placed into each cavity of the base tier 14b. Once impregnation of the base tier 14b has been completed, the controller 4 may operate the fabrication robot 2 to deposit one or more additional layers 14c onto the base tier 14b until a second tier has been formed and operation of the delivery robot 8 may be repeated to impregnate cavities of the second tier with additional particles 10. The tier formation and impregnation may be repeated until the cage 13 has been formed. The cage 13 may be cylindrical.

[0022] Alternatively, although one particle 10 is shown inserted into each cavity, a plurality of particles may be inserted into each cavity depending on the size of the cavity. The size of the cavity may be determined by granulometric distribution of the particles 10 and the trade-off between having unfilled volume and being too far apart for one particle.

[0023] Each cavity may be in communication with one or more adjacent cavities via one or more longitudinal passages 14p formed in each tier 14b and one or more transverse passages (not shown) formed therein. The passages 14p may be formed during deposition of the layers 14a by the fabrication robot 2. The longitudinal passages 14p may also be formed in a top of the cage 13.

[0024] Figure 3A illustrates insertion of the cage 13 into a mold 15 and pouring of matrix powder 16 into the cage. Once formation of the cage 13 has been completed, the cage may be removed from the pedestal 11 and inserted into the mold 15. The mold 15 may be located in a process container 17. A spacer 18 may be disposed between the mold 15 and the process container 17. Each of the mold 15, process container 17, and spacer 18 may be made from a refractory material. The mold 15 may have a cylindrical cavity formed therein conforming to the outer surface of the cage 13. Once the cage 13 has been inserted into the mold 15, the matrix powder 16 may be poured into the cage while compacting thereof, such as by vibrating the process container 17. The matrix powder 16 may be a ceramic, a cermet, or a mixture of a ceramic and a cermet. The ceramic may be a carbide, such as tungsten carbide, and may be cast and/or macrocrystalline. The cermet may include a carbide, such as tungsten carbide, cemented by a metal or alloy, such as cobalt.

[0025] Figure 3B illustrates a casting assembly 19 including the cage 13. Once the cage 13 has been filled with the matrix powder 16, a funnel 20 may be inserted into the process container 17 and set atop the mold 15 and the cage. The funnel 20 may be made from a refractory material and have a frustoconical opening aligned with the cage 13. Additional matrix powder (not shown) may be poured into the funnel opening. Once the funnel 20 has been placed in the process container 17, binder 21 may be loaded into the process container atop the funnel. The binder 21 may be metallic, such as a copper based alloy, and be in the form of pellets or chunks. A melting temperature of the binder 21 may be substantially less than a melting temperature of the metallic powder 5p. A lid 22 may then be set atop the process container 17 and connected thereto by a lap joint, thereby completing the casting assembly 19.

[0026] Figure 4A illustrates the casting assembly 19 placed in a furnace 24 for infiltration of the cage 13 to form an impregnated segment 23. Figure 4B illustrates the fabricated impregnated segment 23 having a cylindrical shape. The furnace 24 may include a housing 24h, a heating element 24e, a controller 24c, such as a PLC, a temperature sensor 24t, and a power supply (not shown). The furnace 24 may be preheated to an infiltration temperature greater than or equal to a melting temperature of the binder 21 and substantially less than a melting temperature of the metallic powder 5p. The casting assembly 19 may be inserted into the furnace 24 and kept therein for an infiltration time 24m. As the casting assembly 19 is heated by the furnace 24, the binder 21 may melt and flow into the cage 13. The molten binder may infiltrate the matrix powder 16 in the cage 13 to fill interparticle spaces therein. A sufficient excess amount of binder 21 may have been loaded into the process container 17 such to create pressure to drive the molten binder into the cage 13. Once the binder 21 has infiltrated the cage 13, the casting assembly 19 may be removed from the furnace 15 and cooled, such as by quenching with water.

[0027] A controlled inert atmosphere may be maintained in the furnace 24 during infiltration. Alternatively, an uncontrolled atmosphere may be present in the furnace 24 during infiltration and a flux material may be coated onto the binder material and/or added to the excess matrix powder in the funnel 20.

[0028] Upon cooling, the binder 21 may solidify and fuse the matrix powder 16, particles 10, and tiers 14b of the cage 13 together into the coherent segment 23. The funnel and slag may be removed from the segment 23. The segment 23 may be ejected from the mold 15 without destruction of the mold and/or process container 17.

[0029] Figure 4C illustrates an alternative fabricated impregnated segment 25 having a truncated ellipsoid shape. Due to the additive manufacturing process of producing the cage 13, a segment 25 of a more complex shape, such as the truncated ellipsoid shape, is within the capability of the system 1. For the more complex shape, the mold may be split and assembled around the cage (see mold 39 of Figure 7A). Further, the distribution and/or orientation of the particles 10 may be varied for each particle or each tier of particles in either of the segments 23, 25. Alternatively, the fabricated impregnated segment 23 may be a polyhedron or teardrop instead of a cylinder.

[0030] Figure 5 illustrates a drill bit 26 equipped with the impregnated segments 23. The drill bit 26 may include a bit body 27, a shank (not shown, see shank 28 in Figure 10A), a cutting face, and a gage section. The cutting face may include one or more (four shown) primary blades 29p, one or more (twelve shown) secondary blades 29s, fluid courses formed between the blades, the impregnated segments 23, one or more (twelve shown) studs 30, and a center port 31. The cutting face may have one or more sections, such as an inner cone, an outer shoulder, and an intermediate nose between the cone and the shoulder. The blades 29p,s may be disposed around the cutting face and each blade may be formed during molding of the bit body 27 and may protrude from the bit body. The primary blades 29p may each extend from a location adjacent the center port 31, across the cone and nose sections, along the shoulder section, and to the gage section. The secondary blades 18s may each extend from an intermediate location of the inner cone section, across the nose section, along the shoulder section, and to the gage section. Each blade 29p,s may extend radially across the cutting face.

[0031] The bit body 27 may be made from the matrix powder 16 infiltrated by the binder 21. The blades 29p,s may be made from a mixture of the matrix powder 16 and the particles 10 infiltrated by the binder 21. The center port 31 may be formed in the bit body 27 and may extend from a plenum thereof and through the bottom of the bit body to discharge drilling fluid 54 (Figure 10A) along the fluid courses.

[0032] A set of impregnated segments 23 may be mounted in pockets formed along each blade 29p,s during molding thereof. Each segment 23 may be transversely oriented in the respective pocket (having a longitudinal axis perpendicular to a longitudinal axis of the bit body 27). A stud 30 may be mounted to each primary blade 29p in a respective pocket located adjacent to the center port 31 during molding thereof. A stud 30 may also be mounted to some of the secondary blades 29s. Each stud 30 may be longitudinally oriented in the respective pocket (having a longitudinal axis parallel to the longitudinal axis of the bit body 27). Each stud 30 may be performed from a mixture of the matrix powder 16 and the particles 10 infiltrated by the binder 21. The studs 30 may be made in a similar fashion as the impregnated segments 23 or made by hot isostatic pressing of a mixture of the matrix powder 16, particles 10, and binder 21.

[0033] The gage section may include a gage pad 32p for each blade 29p,s, fluid courses formed between the gage pads, a plurality of gage ribs 32r, and junk slots formed between the gage ribs. The junk slots may be in fluid communication with the fluid courses. Each gage pad 32p may be made from the same material as the blades 29p,s and each gage pad may be formed integrally with a respective blade. Each gage pad 32p may extend longitudinally straight along an outer surface of the bit body 27 and each gage rib 32r may extend helically along the outer surface of the bit body. Each gage rib 32r may extend from every other gage pad 32p and the gage ribs may be made from the same material as the bit body 27.

[0034] Alternatively, the blades 29p,s may extend spirally across the cutting face. Alternatively, the drill bit 26 may be equipped with the segments 25 instead of the segments 23. Alternatively, the gage ribs 32r may be straight instead of helical.

[0035] Although each tier 14b is shown as resembling the other tiers, each tier may be significantly different from the other tiers, such as having a different number of cavities and/or differently sized cavities. The configuration of each tier 14b may be determined by the required volume of superhard particles 10 and point loading determined by the radial position of the impregnated segment 23 on the drill bit 26.

[0036] Figure 6A illustrates delivery of a layer 33a of coated superhard particles 34 onto the pedestal 11, according to another embodiment of the present disclosure. In preparation of manufacture, a plurality of layers 33a-d may be formed. Each layer 33a-d may include a metallic mesh 35 and a plurality of coated particles 34 embedded in the mesh. Each particle 34 may include the superhard particle 10 encapsulated by a carbide coating 34c, such as ceramic tungsten carbide. The mesh 35 may have regularly spaced openings sized slightly smaller than the coated particles 10. Adhesive (not shown) may be applied to the mesh 35 and then the coated particles 10 may be set in the openings and the adhesive may be allowed to cure, thereby forming the layer 33a. The layers 33a-d may be stacked in the tray 9 for handling by the delivery robot 8. Once the tray 9 has been loaded, the controller 4 may operate the delivery robot 8 to transport the first layer 33a to the pedestal 11.

[0037] Figure 6B illustrates delivery of the second layer 33b to the pedestal 11 and stacking upon the first layer 33a. Figure 6C illustrates welding together of selected particles 34 from the first 33a and second 33b layers. The delivery robot 8 may then transport the second layer 33b from the tray 9 to the pedestal 11 and stack the second layer upon the first layer 33a. The layers 33a,b may be preheated using a heater (not shown), such as a heat lamp. The controller 4 may then operate the fabrication robot 2 to weld 36 selected particles 34 of the two layers 33a,b using a beam 37 of the laser 3z. The particles 34 may be selected using the CAD design model 12 supplied to the controller 4. The material supply system 5 may be shutoff during the laser welding of the selected particles 34. Each weld 36 may occupy only a slight portion of the adjacent coatings 34c, thereby leaving gaps between the adjacent particles 34.

[0038] Figure 6D illustrates repeating the delivery and welding for additional layers 33c,d to form a conglomerate 38 of particles 34. Once the selected particles 34 of the first 33a and second 33b layers have been welded 36 together, the delivery robot 8 may transport the third layer 33c from the tray 9 to the pedestal 11 and stack the third layer upon the second layer 33b. The controller 4 may then operate the fabrication robot 2 to weld 36 selected particles 34 of the two layers 33b,c using the beam 37 of the laser 3z. The process may then be repeated for one or more additional layers 33d to form the conglomerate 38 of particles 34. Once the conglomerate 38 has been formed, the heater may again be operated to control cooing thereof. The conglomerate 38 may have a cylindrical shape, truncated ellipsoid shape, teardrop shape, or polyhedron shape.

[0039] Figure 6E illustrates removal of non-welded particles 34 from the conglomerate 38. Once the conglomerate 38 has cooled, the layers 33a-d may be removed from the pedestal 11 and the non-welded particles

34 may be removed from the conglomerate by breaking the mesh 35, such as by using a steel brush (not shown).

[0040] Figure 7A illustrates insertion of the conglomerate 38 into a mold 39 and pouring of matrix powder 16 into the conglomerate. Once the non-welded particles 34 have been removed from the conglomerate 38, a split mold 39 may be assembled around the conglomerate and inserted into the process container 17. The split mold 39 may have a cavity formed therein conforming to the outer surface of the conglomerate 38. The matrix powder 16 may then be poured into the conglomerate 38 while compacting thereof, such as by vibrating the process container 17.

[0041] Figure 7B illustrates a casting assembly 40 including the conglomerate 38. Once the conglomerate 38 has been filled with the matrix powder 16, the funnel 20 may be inserted into the process container 17 and set atop the split mold 39 and the conglomerate. Additional matrix powder (not shown) may be poured into the funnel opening. Once the funnel 20 has been placed in the process container 17, the binder 21 may be loaded into the process container atop the funnel. The lid 22 may then be set atop the process container 17 and connected thereto by the lap joint, thereby completing the casting assembly 40.

[0042] Figure 7C illustrates the casting assembly 40 placed in the furnace for infiltration of the conglomerate 24 to form a blade piece 41 p or blade 41 d. Figure 7D illustrates a drill bit 41 a equipped with a plurality of the blade pieces 41 p. Figure 7E illustrates a drill bit 41 b equipped with a plurality of the blades 41 d. The furnace 24 may be preheated to the infiltration temperature greater than or equal to a melting temperature of the binder 21. The casting assembly 40 may be inserted into the furnace 24 and kept therein for an infiltration time 24m. As the casting assembly 40 is heated by the furnace 24, the binder 21 may melt and flow into the conglomerate 38. The molten binder may infiltrate the matrix powder 16 in the conglomerate 38 to fill interparticle spaces therein. A sufficient excess amount of binder 21 may have been loaded into the process container 17 such to create pressure to drive the molten binder into the conglomerate 38. Once the binder 21 has infiltrated the conglomerate 38, the casting assembly 40 may be removed from the furnace 15 and cooled, such as by quenching with water. As discussed above, the furnace 24 may be operated with an inert or uncontrolled atmosphere.

[0043] Upon cooling, the binder 21 may solidify and fuse the matrix powder 16 and particles 34 together into the coherent blade piece 41 p or blade 41 d. The funnel and slag may be removed from the blade piece 41 p or blade 41 d. The blade piece 41 p or blade 41 d may be ejected from the mold 15 without destruction of the mold and/or process container 17.

[0044] The drill bit 41 a may be similar to the drill bit 26 except for having the blade pieces 41 p instead of the segments 23 and having straight gage ribs instead of the helical gage ribs 32r. Each blade of the drill bit 41 a may be formed of a shell of impregnated matrix material and a plurality of the blade pieces 41 p disposed in a cavity of the respective shell and mounted therein, such as by infiltration during molding of the drill bit 41 a or brazing after molding of the drill bit.

[0045] The drill bit 41 b may be similar to the drill bit 26 except for having the blades 41 d instead of the segments 23, the blades 41 d being spiral instead of radial, and having a plurality of ports dispersed about the cutting face. Each blade 41 d may be mounted to the bit body of the drill bit 41 b, such as by infiltration during molding of the drill bit or brazing after molding of the drill bit.

[0046] Alternatively, a mixture of the matrix powder 16 and binder 21 may be poured into the cage 13 or conglomerate 38 and the respective segment 23, 25, blade piece 41 p, or blade 41 b may be fused by hot isostatic pressing. Alternatively, the cage 13 or conglomerate 38 may be infiltrated during manufacture of the respective drill bit 26, 41 a,b instead of pre-infiltrating. Alternatively, any of the segments 23, 25 may be brazed into pockets after manufacture of the bit body 27 and blades 29p,s. Alternatively, either of the segments 23, 25, blade piece 41 p or blade 41 b may be used to repair a worn drill bit by brazing the segments, blade piece, or blade 41 b onto the blades of the bit. Alternatively, the method using the cage 13 may be used to make the blade pieces 41 p or blades 41 d instead of the segments 23, 25. Alternatively, the method using the conglomerate 38 may be used to make the segments 23, 25 instead of the blade pieces 41 p or blades 41 d. Alternatively, the blades 41 d may be radial instead of spiral.

[0047] Advantageously, use of the precisely organized impregnated segments 23, 25, blade pieces 41 p, or blades 41 d is expected to significantly improve rate of penetration (ROP) and durability of the segments, blade pieces, or blades versus prior art randomly organized segments or blades. Only the optimum amount of superhard material is set, thereby improving the segment stiffness versus prior art random mixing, where, due to differential thermal dilatation and lack of physical link between the diamond and the carbide, the overall stiffness and shock resistance of the segment or blade decreases as the diamond to matrix ratio increases. Specifically regarding the segments 23, 25, the overall stiffness of the segment is also improved by the metallic cage 13 taking the bulk load on the segment. Only the optimum amount of superhard material is placed, thereby improving ROP over excessive diamond concentration in prior art segments or blades that tends to reduce the point loading of individual crystals and leads to a limitation of failure in formations having a certain compressive strength. The setting of the superhard material in tiers or layers ensures a better cuttings removal due to no regrinding and clogging that is not only a lack of efficiency, but also the main cause of dulling by excessive erosion around the individual superhard particles. Layers or tiers may also be angled relative to the blade path (aka side-rake) so cuttings and flow are directed out of the segment, thereby avoiding subsequent regrinding. The organization of the superhard particles simplifies analysis of cutting performance as the ROP is equal to the product of each individual particle indentation and the number of layers versus the difficulty in predicting the performance of prior art segments or blades with random distribution. A full and even coverage of superhard particles is ensured over the complete bit profile, at any stage of dulling, and in accordance with the volume of superhard particles needed which may be predicted by geotechnical algorithms for the formation in question at the expected drilling parameters. Factors that may be considered in the design of the impregnated segments 23, 25, blade pieces 41 p, or blades 41 d include expected formation strength, dip angle and abrasiveness along the path of the wellbore, the bit radius, and expected drilling parameters.

[0048] Figure 8A illustrates an anisotropic impregnated cage 42, according to another embodiment of the present disclosure. The anisotropic impregnated cage 42 may be similar to the cage 13 except for having an outer portion 42o isolated from an inner portion 42n. The outer portion 42o may include similar tiers to that of the cage 13 except for being isolated from the inner portion 42n by the omission of transverse passages therebetween. Each tier or the inner portion 42n may include a plurality of (three shown) sub-tiers. Each sub-tier may have a plurality of cavities and a small particle 43 may be disposed in each sub-tier. The anisotropic cage 42 may be formed in a similar fashion to the cage 13 except for more frequent operation of the delivery robot 8 after each sub-tier is formed and the automated system 1 including a second tray (not shown) of small particles 43. The large particles 10 may be better suited for drilling a soft formation 44s (Figure 10A) and the small particles 43 may be better suited for drilling a hard formation 44h. The anisotropic cage 42 may have a cylindrical shape, truncated ellipsoid shape, teardrop shape, or polyhedron shape.

[0049] Figure 8B illustrates insertion of the anisotropic cage 42 into the mold 15 and pouring of different matrix powders 16, 45 into the anisotropic cage. Once formation of the anisotropic cage 42 has been completed, the cage may be removed from the pedestal 11 and inserted into the mold 15. Once the anisotropic cage 42 has been inserted into the mold 15, the matrix powder 16 may be poured into the outer portion 42o and a hard matrix powder 45 may be poured into the inner portion 42n while compacting thereof, such as by vibrating the process container 17. The hard matrix powder 45 may be a ceramic, a cermet, or a mixture of a ceramic and a cermet. The ceramic may be a carbide, such as tungsten carbide, and may be cast and/or macrocrystalline. The cermet may include a carbide, such as tungsten carbide, cemented by a metal or alloy, such as cobalt. The hard matrix powder 45 may be formulated differently from the soft matrix powder 16, such as having more ceramic than cermet and/or having more macrocrystalline ceramic. The soft matrix powder 16 may be better suited for drilling the soft formation 44s and the hard matrix powder 45 may be better suited for drilling the hard formation 44h.

[0050] Figure 9A illustrates a casting assembly 46 including the anisotropic cage 42. Once the anisotropic cage 42 has been filled with the matrix powders 16, 45, a funnel 47 may be inserted into the process container 17 and set atop the mold 15 and the cage. The funnel 47 may be made from a refractory material and have a frustoconical opening aligned with both the inner 42n and outer 42o portions. Additional matrix powders (not shown) may be poured into respective portions of the funnel opening. Once the funnel 47 has been placed in the process container 17, the binder 21 may be loaded into the process container atop the funnel. The lid 22 may then be set atop the process container 17 and connected thereto by a lap joint, thereby completing the casting assembly 46.

[0051] Figure 9B illustrates the casting assembly 46 placed in the furnace 24 for infiltration of the cage 42 to form an anisotropic impregnated segment 48 (Figure 10A). The furnace 24 may be preheated to an infiltration temperature greater than or equal to a melting temperature of the binder 21 and substantially less than a melting temperature of the metallic powder 5p. The casting assembly 46 may be inserted into the furnace 24 and kept therein for an infiltration time 24m. As the casting assembly 46 is heated by the furnace 24, the binder 21 may melt and flow into the anisotropic cage 42. The molten binder may infiltrate the matrix powders 16, 45 in the anisotropic cage 42 to fill interparticle spaces therein. A sufficient excess amount of binder 21 may have been loaded into the process container 17 such to create pressure to drive the molten binder into the anisotropic cage 42. Once the binder 21 has infiltrated the anisotropic cage 42, the casting assembly 46 may be removed from the furnace 15 and cooled, such as by quenching with water. As discussed above, the furnace 24 may be operated with an inert or uncontrolled atmosphere. Upon cooling, the binder 21 may solidify and fuse the matrix powders 16, 45, particles 10, 43, and tiers of the anisotropic cage 42 together into the coherent anisotropic segment 48. The funnel and slag may be removed from the segment 48. The segment 48 may be ejected from the mold 15 without destruction of the mold and/or process container 17. The anisotropic impregnated segment 48 may have a cylindrical shape, truncated ellipsoid shape, or polyhedron shape.

[0052] Figure 10A illustrates drilling of soft 44s and hard 44h formations using a drill bit 49 equipped with the anisotropic impregnated segments 48. The drill bit 49 may be similar to the drill bit 26 except for having the anisotropic segments 48 instead of the segments 23 and having straight gage ribs instead of the helical gage ribs 32r. The drill bit 49 may be assembled with one or more drill collars 50, such as by threaded couplings, thereby forming a bottomhole assembly (BHA) 51. The BHA 51 may be connected to a bottom of a pipe string 52, such as drill pipe or coiled tubing, thereby forming a drill string.

The pipe string 52 may be used to deploy the BHA 51 into a wellbore 53. The drill bit 49 may be rotated, such as by rotation of the drill string from a rig (not shown) and/or by a drilling motor (not shown) of the BHA 51, while drilling fluid 54, such as mud, may be pumped down the drill string. A portion of the weight of the drill string may be set on the drill bit 49. The drilling fluid 54 may be discharged by the drill bit 49 and carry cuttings up an annulus 55 formed between the drill string and the wellbore 53 and/or between the drill string and a casing string and/or liner string 56. A thickness of the outer portions 42o of the segments 48 may be selected to drill the soft formation 44s and the outer portions may be worn away when the drill bit encounters the hard formation 44h, thereby exposing the inner portions 42n to optimally drill the hard formation.

[0053] Alternatively, the blades of the drill bit 49 may extend spirally across the cutting face. Alternatively, the drill bit 49 may have the helical gage ribs instead of the straight gage ribs.

[0054] Figure 10B illustrates an alternative drill bit 57 having selective placement of different types 58a-c of anisotropic segments 48. The drill bit 57 may be similar to the drill bit 49 except for having a combination of anisotropic segments 48 and segments 23. Each type 58a-c of anisotropic segments 48 may be one or more rings of the segments extending around the cutting face of the drill bit 57. The first type 58a of anisotropic segments 48 may be located on the primary blades adjacent to the studs thereof in the cone section of the cutting face. The second type 58b of anisotropic segments 48 may be located on both the primary and secondary blades in the nose section of the cutting face. The third type 58c of anisotropic segments 48 may be located on both the primary and secondary blades in the shoulder section of the cutting face. Each type 58a-c may have different thicknesses of the inner 42n and outer 42o portions based on the expected wear thereof for the hard 44h and soft 44s formations. The thicknesses of the inner 42n and outer 42o portions may be determined by computer simulation or dull grading of previously used drill bits in similar formations. For the type(s) 58c that have more than one ring, the anisotropic segments 48 in the different rings may have slightly different thicknesses of the inner 42n and outer 42o portions.

[0055] Alternatively, each type 58a-c may have different particle sizes, matrix material, and/or particle density for the inner 42n and outer 42o portions. Alternatively, either of the segments 25, 41 may be used instead of the segments 23 with the drill bit 57.

[0056] Figures 11A-12B illustrate manufacture of a drill bit with anisotropic impregnated blades. A casting assembly 59 (Figure 12A) may include a thick-walled mold 60, a displacement 61, a funnel (not shown), and a binder pot (not shown). Each of the mold 60, the displacement 61, the funnel, and the binder pot may be made from a refractory material. The mold 60 may be fabricated with a precise inner surface forming a mold chamber using a CAD design model. The precise inner surface may have a shape that is a negative of what will become the facial features of the drill bit. The funnel may rest atop the mold and may be connected thereto, such as by a lap joint.

[0057] The displacement 61 may be placed within the chamber of the mold 60. The displacement 61 may be removed after infiltration to form a bore, plenum, and center port of the drill bit. Once the displacement 61 has been placed, a blank 62 may be placed within the casting assembly 59. The blank 62 may be tubular and may be metallic, such as being made from steel. The blank 62 may be centrally suspended within the mold 60 around the displacement 61. Once the displacements 61 and the blank 62 have been positioned within the mold 59, a first layer 63a of impregnated matrix material may be packed into the mold at cavities thereof corresponding to the blades of the drill bit. Once the first layer 63a has been packed, a second layer 63b of impregnated matrix material may be packed into the mold atop the first layer into the mold cavities corresponding to the blades of the drill bit. The first layer 63a may include a mixture of the large particles 10 and the soft matrix powder 16. The second layer 63b may include a mixture of the small particles 43 and the hard matrix powder 45.

[0058] Once packing of the second layer 63b has finished, body powder 64 may be loaded into the mold 59 onto a top of the second layer 63b to fill the remaining mold chamber. The body powder 64 may be similar to either of the matrix powders 16, 45. Once loading of the body powder 64 has finished, the binder pot may be rested atop the funnel and may be connected thereto, such as by a lap joint. The binder pot may have a cavity formed therein and a sprue formed through a bottom thereof providing communication between the cavity and the funnel chamber. The binder 21 may then be placed into the cavity and through the sprue of the binder pot.

[0059] The casting assembly 59 may be inserted into the preheated furnace 24 and kept therein for the infiltration time. As the casting assembly 59 is heated by the furnace 24, the binder 21 may melt and flow into the body powder 64 and layers 63a,b through the sprue of the binder pot. The molten binder may infiltrate the body powder 64 and layers 63a,b fill interparticle spaces therein. A sufficient excess amount of binder 21 may have been loaded into the binder pot such that the molten binder fills a substantial portion of the funnel volume, thereby creating pressure to drive the molten binder into the body powder 64 and layers 63a,b. As discussed above, the furnace 24 may be operated with an inert or uncontrolled atmosphere.

[0060] Once the binder 21 has infiltrated the body powder 64 and layers 63a,b, the casting assembly 59 may be controllably cooled. Upon cooling, the binder 21 may solidify and fuse the particles of the body powder 64 and layers 63a,b together into a respective coherent matrix body and coherent impregnated anisotropic blades. The binder 21 may also bond the body to the blank 62. Once cooled, the casting assembly 59 may be removed from the furnace 24. The mold 60, funnel, binder pot, and displacement 61 may then be broken away from the body and blades. A thread may be formed in an inner surface of the upper portion of the blank 62 and a threaded tubular extension screwed therein, thereby forming a shank. The threaded connection between the extension and the blank 62 may be secured by a weld.

[0061] Additionally, any of the anisotropic segments or blades may include three or more portions or layers configured for optimal drilling of three or more different types of formations. Additionally, any or all of: particle size, particle density, and matrix hardness, may be varied for different layers or portions of the anisotropic segments or blades.

[0062] Alternatively, any of the segment manufacturing techniques discussed above may be used to produce inserts for roller cone drill bits in a conical or chisel shape.

[0063] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof, and the scope of the invention is determined by the claims that follow.

Claims

1. A method for manufacturing an impregnated segment, comprising:

forming a base tier by depositing one or more layers of molten metallic material, the base tier having a plurality of cavities;
inserting at least one superhard particle into each cavity;
forming an additional tier on top of the base tier by depositing one or more layers of the molten metallic material, the additional tier having a plurality of cavities; and
repeating the insertion of the superhard particles and the formation of additional tiers to form an impregnated cage.

2. The method of claim 1, further comprising:

filling the impregnated cage with matrix material; and
fusing the metallic material, the particles, and the matrix material together to form the impregnated segment.

3. The method of claim 2, wherein the segment is fused by infiltration with a molten binder.

4. The method of claims 2 or 3, wherein:

an outer portion of the impregnated cage is filled with a matrix material having a first hardness,
an inner portion of the impregnated cage is filled with a matrix material having a second hardness, and
the first hardness is different from the second hardness.

5. The method of any preceding claim, wherein:

a superhard particle of a first type is inserted into outer cavities of the tiers,
a superhard particle of a second type is inserted into inner cavities of the tiers, and
the first type is different from the second type.

6. The method of claim 5, wherein one of the type particles is larger than the other of the type particles.

7. The method of any preceding claim, wherein the impregnated cage is a cylinder, teardrop, truncated ellipsoid, or polyhedron.

8. The method of any preceding claim, wherein the metallic material is stainless steel, nickel-chromium alloy, or a cermet.

9. A drill bit having impregnated segments made according to any preceding claim, comprising:

a shank having a coupling formed at an upper end thereof;
a bit body mounted to a lower end of the shank;
a gage section forming an outer portion of the drill bit; and
a cutting face forming a lower end of the drill bit and comprising:

a plurality of blades protruding from the bit body, each blade extending from a center of the cutting face to the gage section and made from a matrix material impregnated by superhard particles; and
a plurality of the impregnated segments mounted along each blade.

10. A method for manufacturing an impregnated blade piece or blade, comprising:

stacking a second layer of atop a first layer, each layer comprising a plurality of superhard particles coated with a carbide material;
welding selected particles of the first and second layers together;
stacking an additional layer atop the second layer, the additional layer comprising a plurality of superhard particles coated with a metallic material;
welding selected particles of the additional and second layers together;
repeating the stacking and welding to form a

conglomerate; and
removing the non-welded particles from the conglomerate.

11. The method of claim 10, further comprising:

filling the conglomerate with matrix material; and
fusing the particles and the matrix material together to form the impregnated blade piece or blade.

12. A drill bit, comprising:

a shank having a coupling formed at an upper end thereof;
a bit body mounted to a lower end of the shank;
a gage section forming an outer portion of the drill bit; and
a cutting face forming a lower end of the drill bit and comprising:

a plurality of blades protruding from the bit body, each blade extending from a center of the cutting face to the gage section and made from a matrix material impregnated by superhard particles; and
a plurality of segments mounted along each blade, each segment made from a matrix material impregnated by superhard particles,

wherein:

at least one segment of each blade is anisotropic,
each anisotropic segment has an outer portion optimized to drill a first formation and an inner portion optimized to drill a second formation, and
one of the formations is a hard formation and the other of the formations is a soft formation.

13. The drill bit of claim 12, wherein:

each portion has parameters of particle size, particle density, and matrix hardness, and
at least one parameter of the outer portions is different from at least one parameter of the inner portions.

14. The drill bit of claim 12, wherein:

a first type of anisotropic segments is located in a cone section of the cutting face,
a second type of anisotropic segment is located in a nose section of the cutting face,
a third type of anisotropic segments is located in a shoulder section of the cutting face, and
each type is different.

15. A method for manufacturing an impregnated drill bit, comprising:

placing a metallic blank and a displacement within a mold having an inner surface formed into a negative shape of facial features of the drill bit, wherein the mold is part of a casting assembly;
packing a first layer of matrix power and superhard particles into the mold at cavities thereof corresponding to blades of the drill bit;
packing a second layer of matrix powder and superhard particles into the mold at the cavities;
loading matrix powder into the mold to fill a remaining chamber thereof;
placing a binder alloy into the casting assembly over the mold;
inserting the casting assembly into a furnace; and
operating the furnace to melt the binder alloy, thereby infiltrating the powders with the binder alloy,
wherein:

each layer has parameters of particle size, particle density, and matrix hardness, and
at least one parameter of the first layer is different from at least one parameter of the second layer.

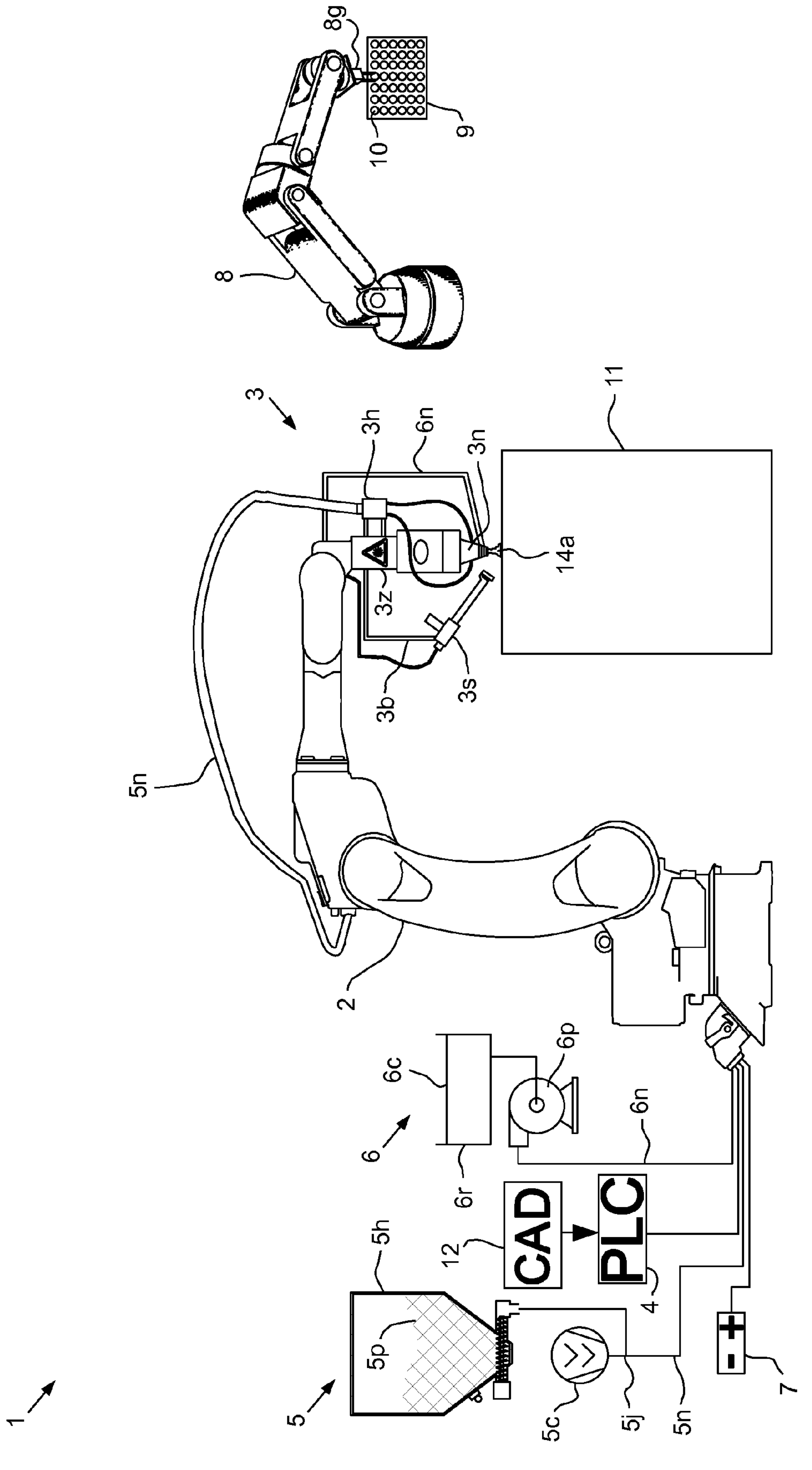
1
2
3
3h
6n
3n
14a
3z
3b
3s
5n
8
8g
9
10
11
5
5h
5p
5c
5j
7
12
CAD
PLC
4
6
6c
6r
6p

FIG. 1

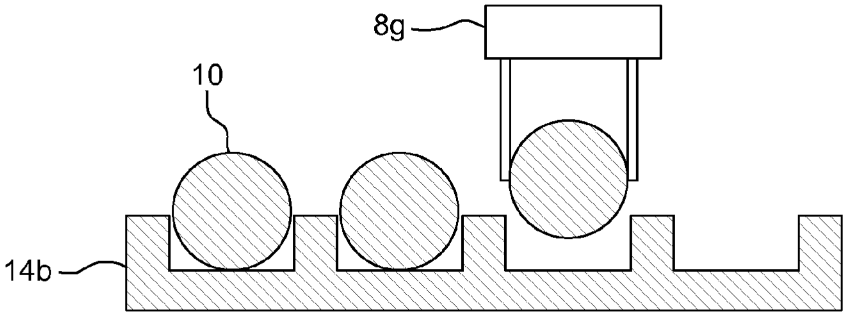

FIG. 2A

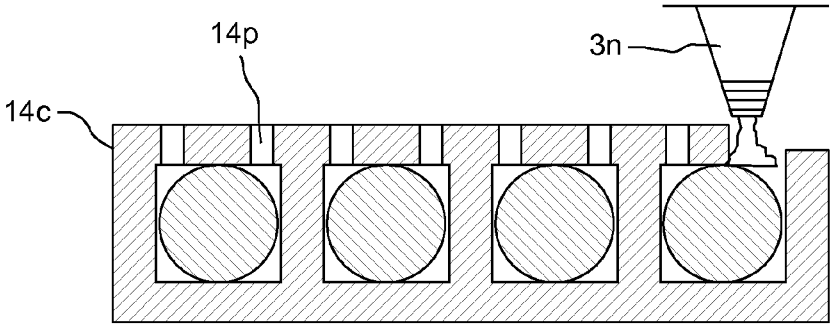

FIG. 2B

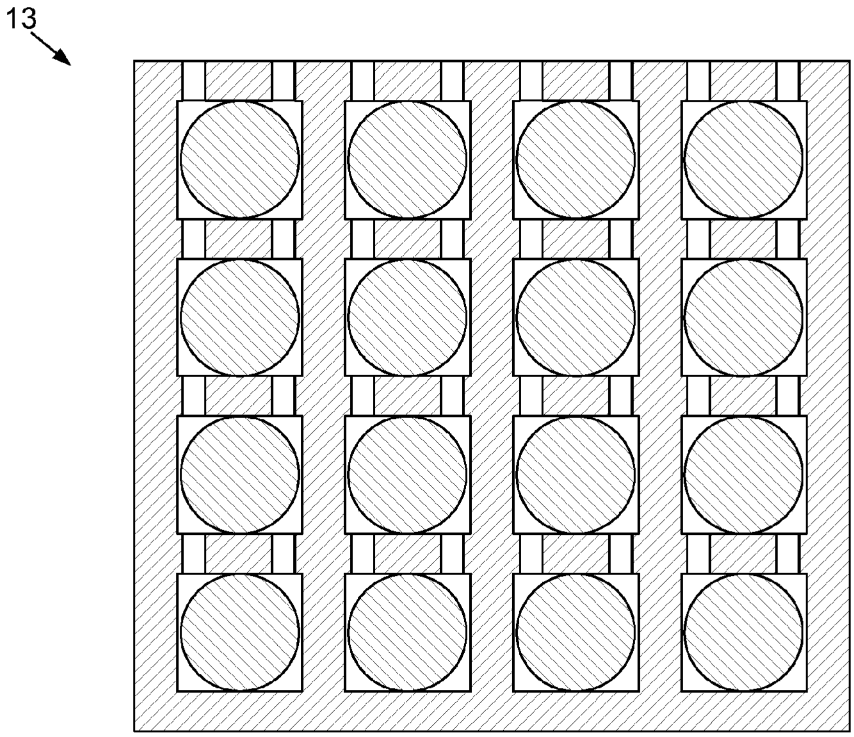

FIG. 2C

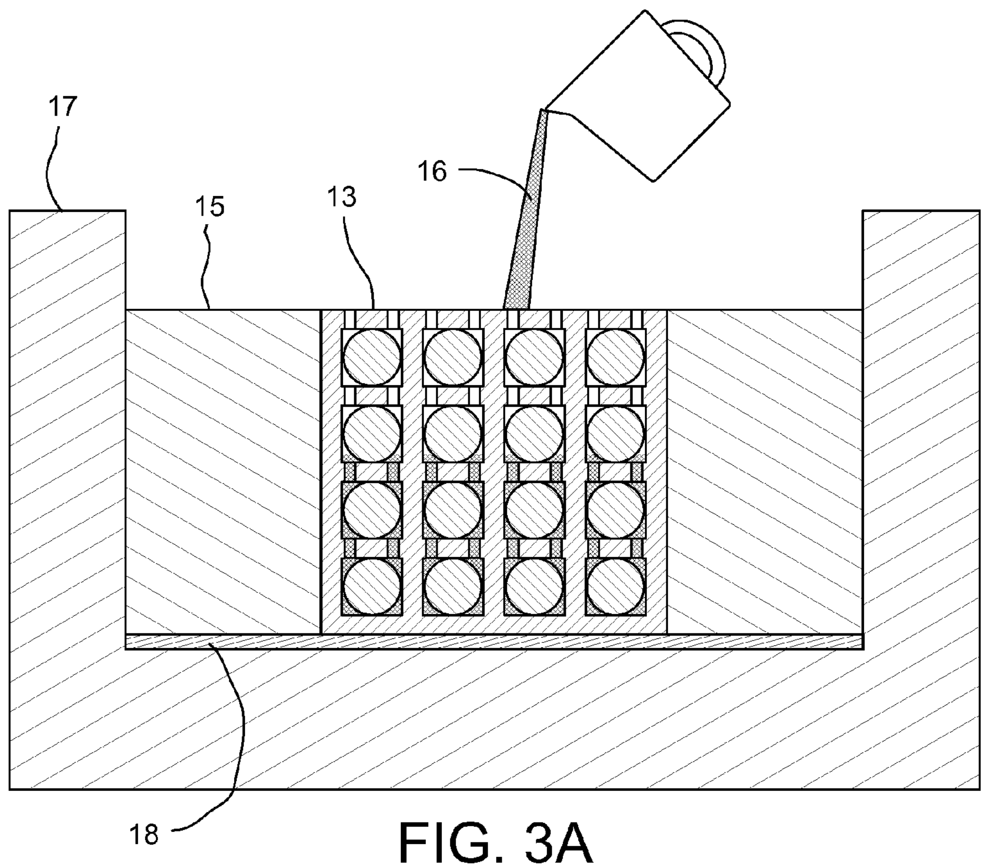

FIG. 3A

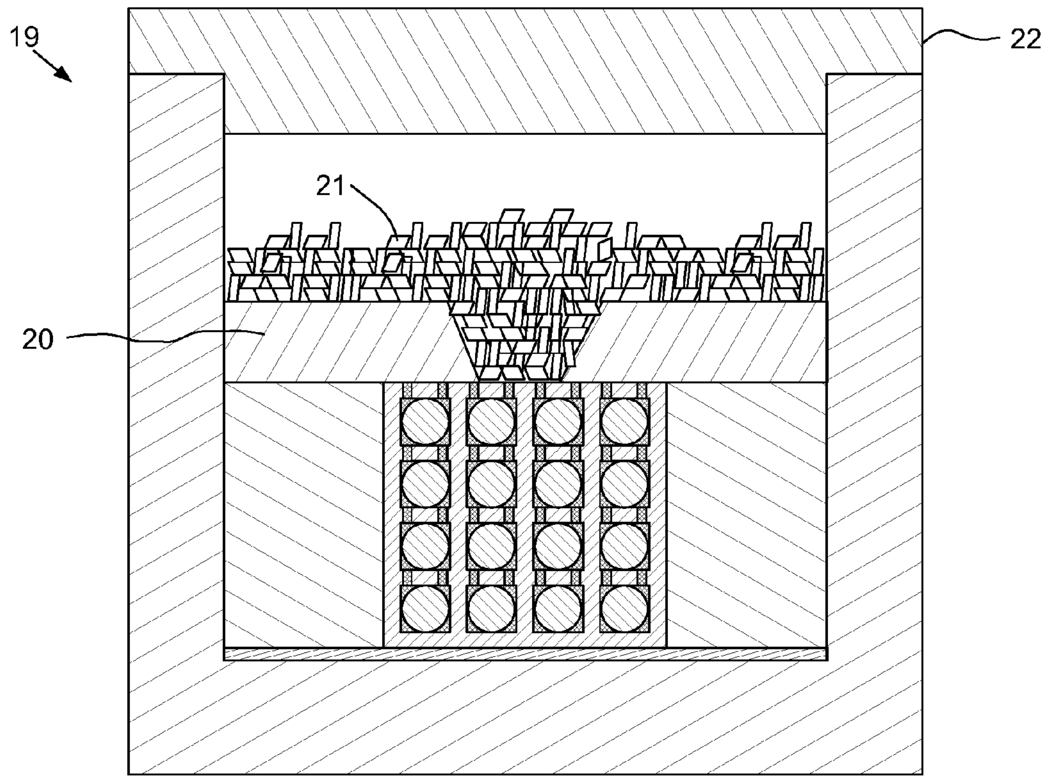

FIG. 3B

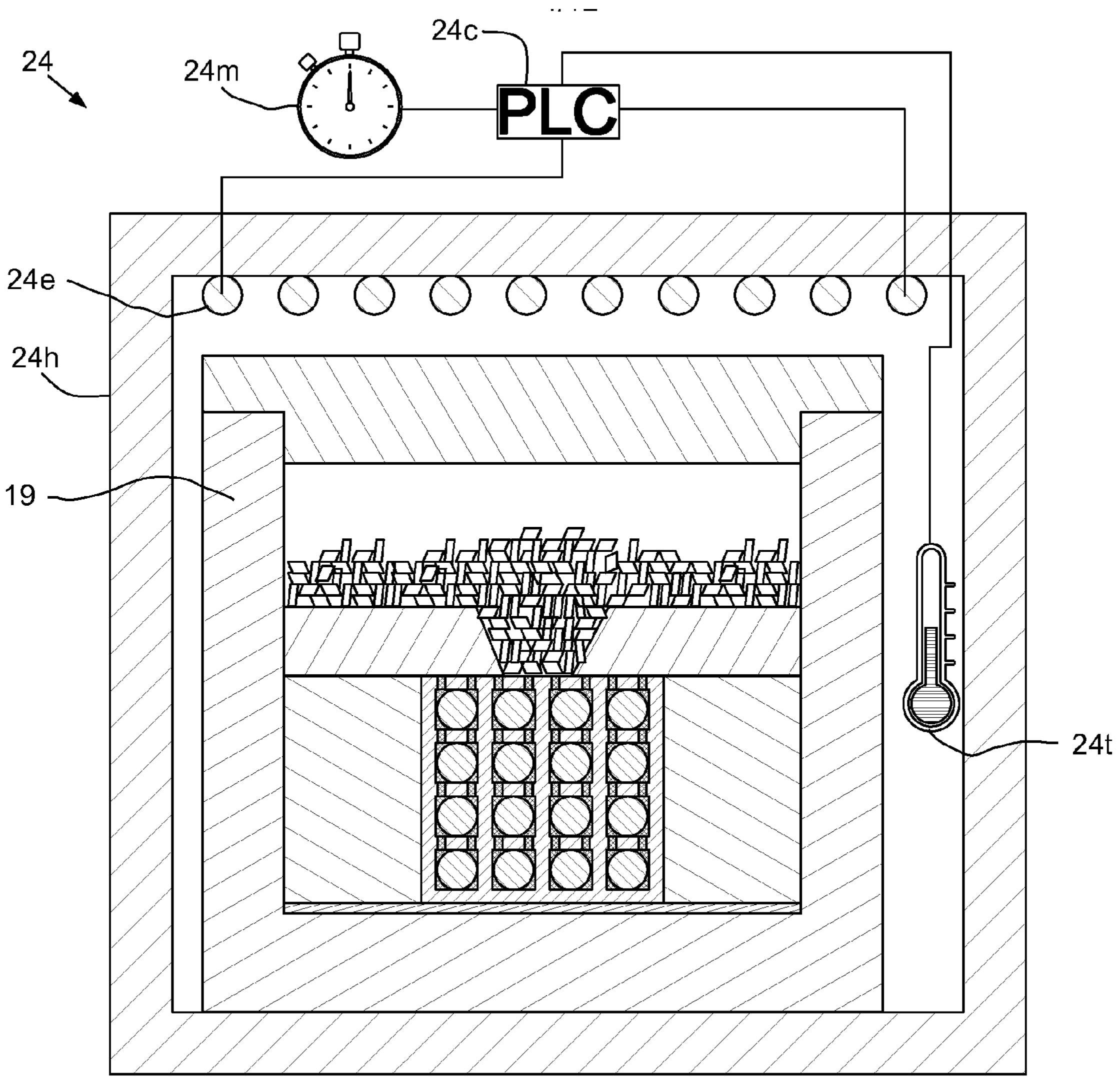

FIG. 4A

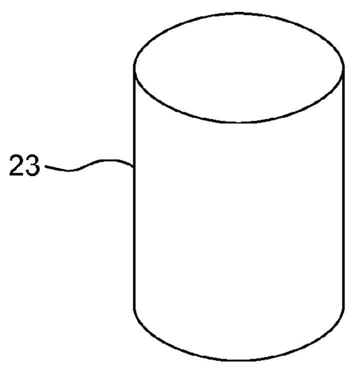

FIG. 4B

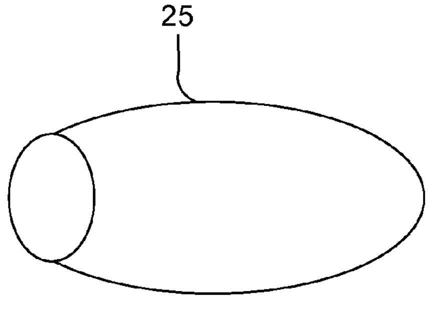

FIG. 4C

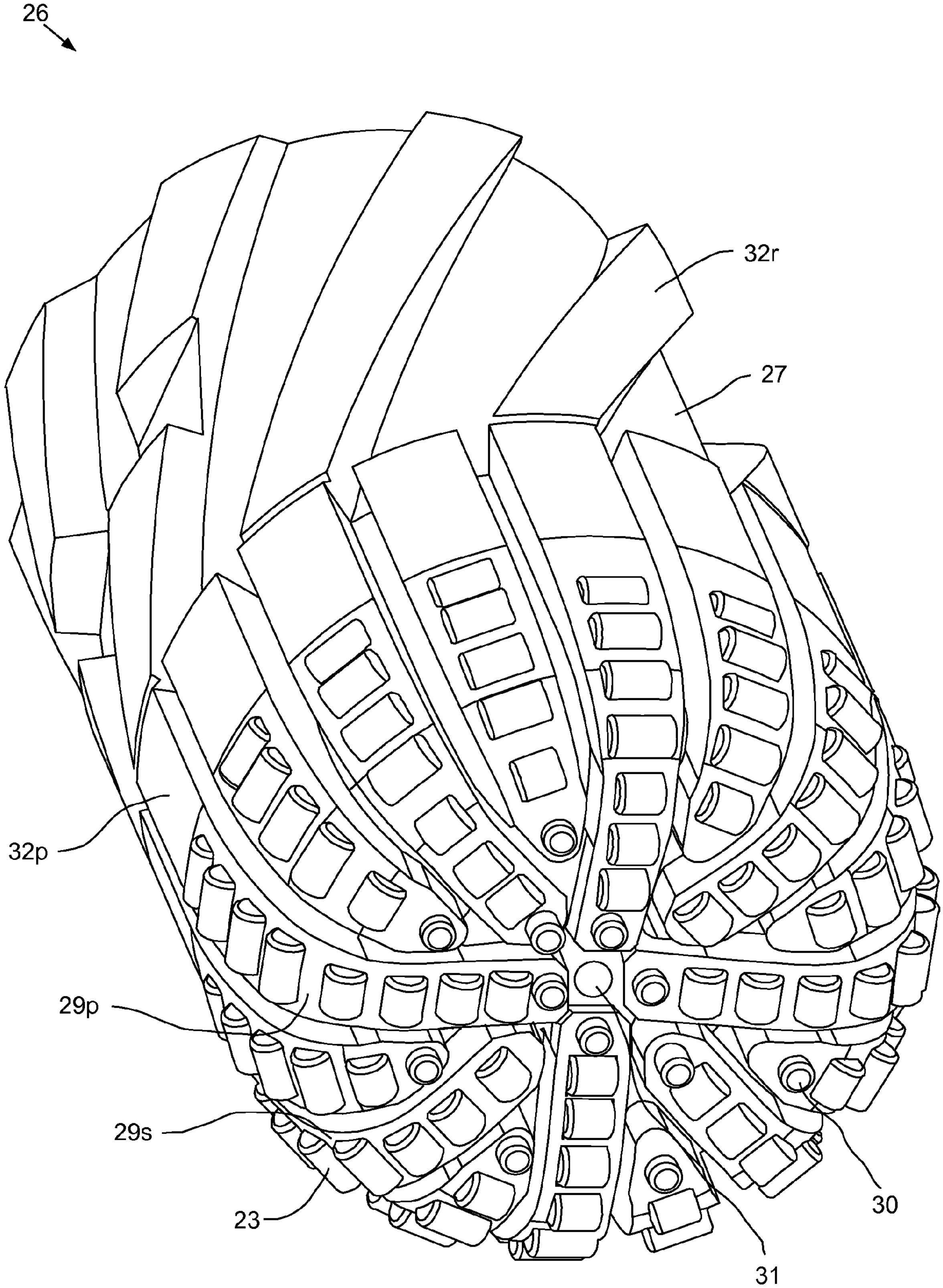

FIG. 5

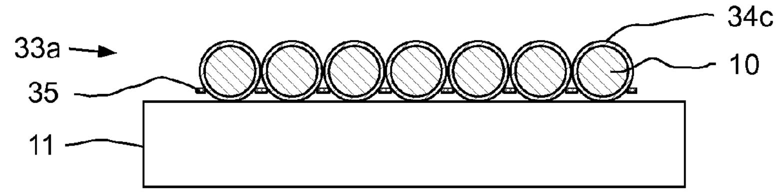

FIG. 6A

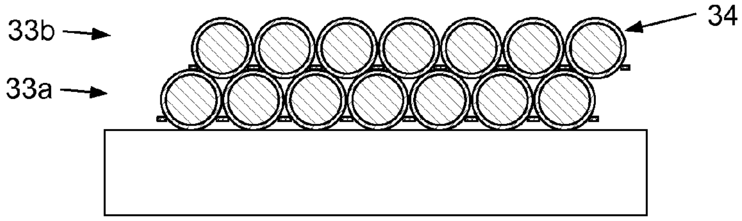

FIG. 6B

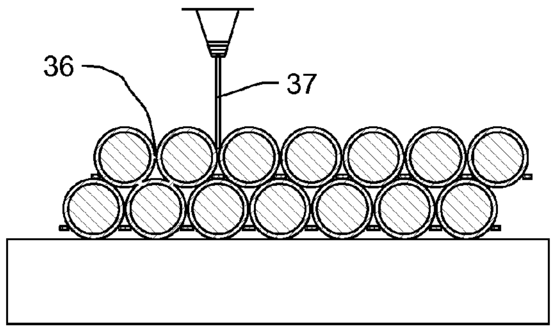

FIG. 6C

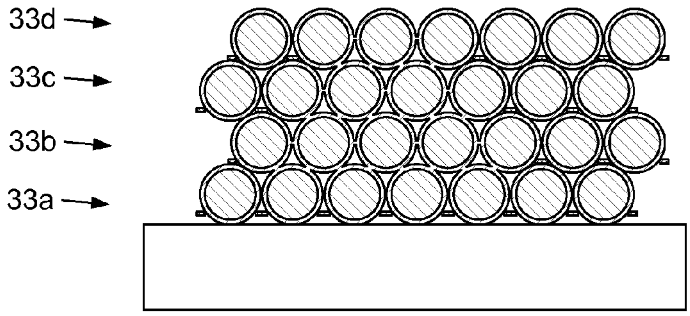

FIG. 6D

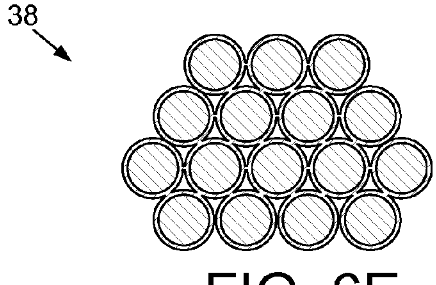

FIG. 6E

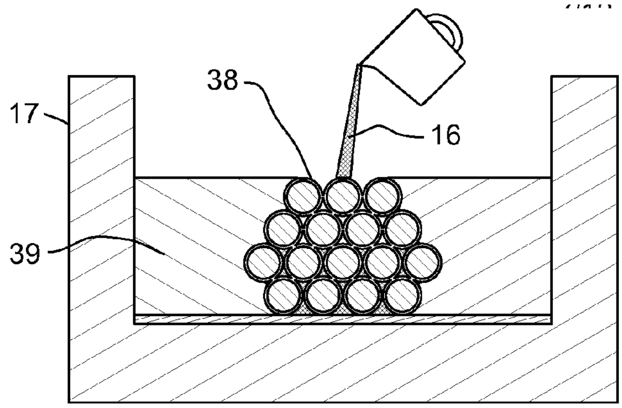

FIG. 7A

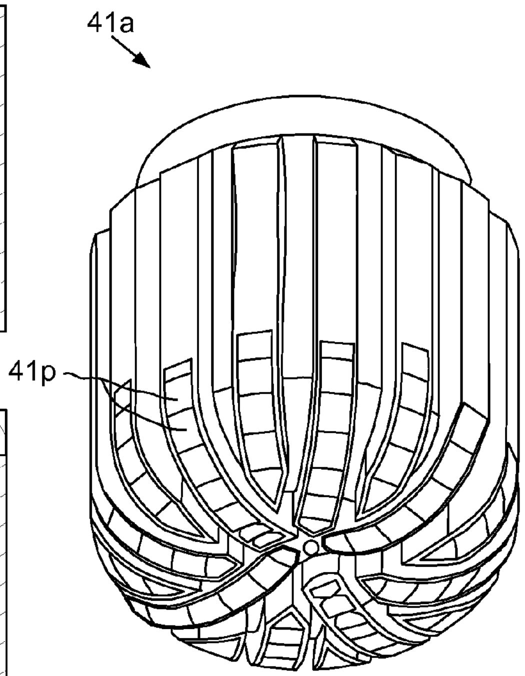

FIG. 7D

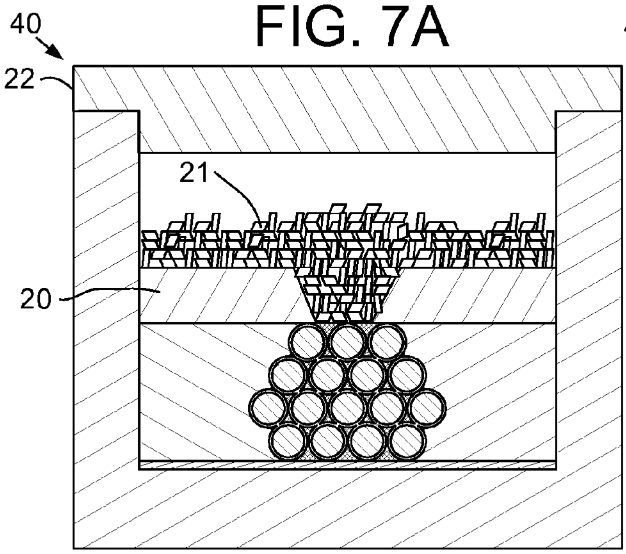

FIG. 7B

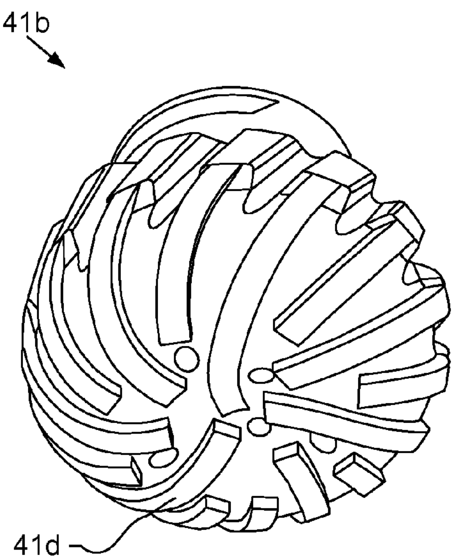

FIG. 7E

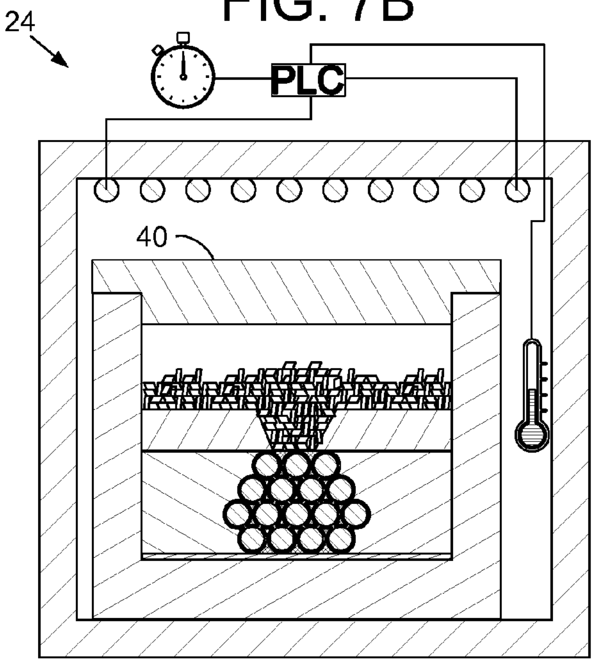

FIG. 7C

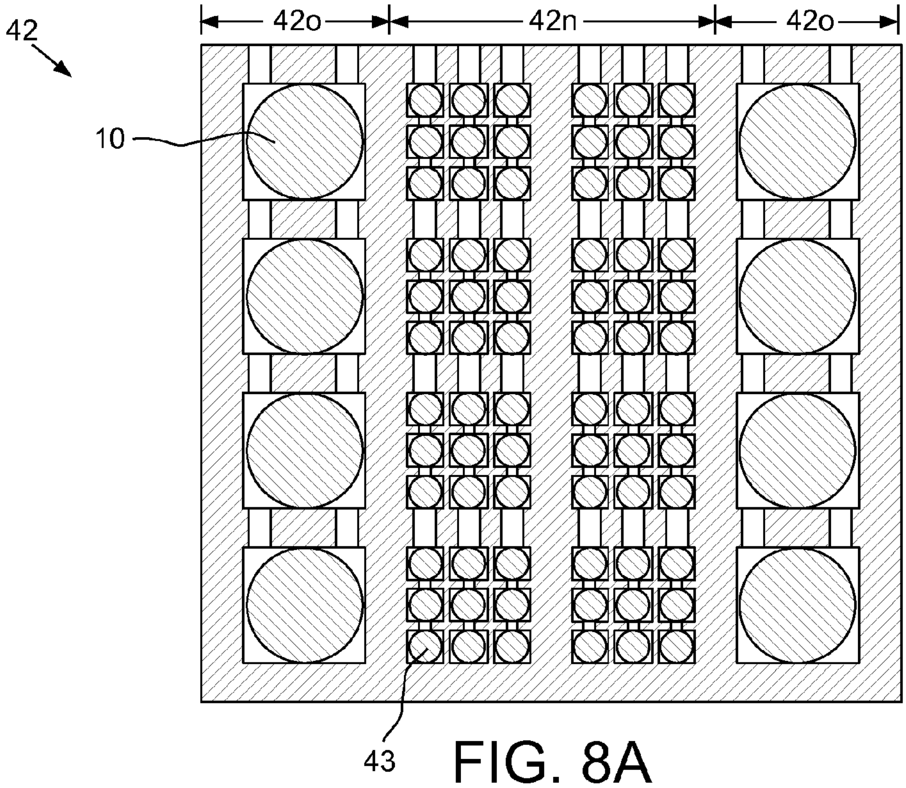

FIG. 8A

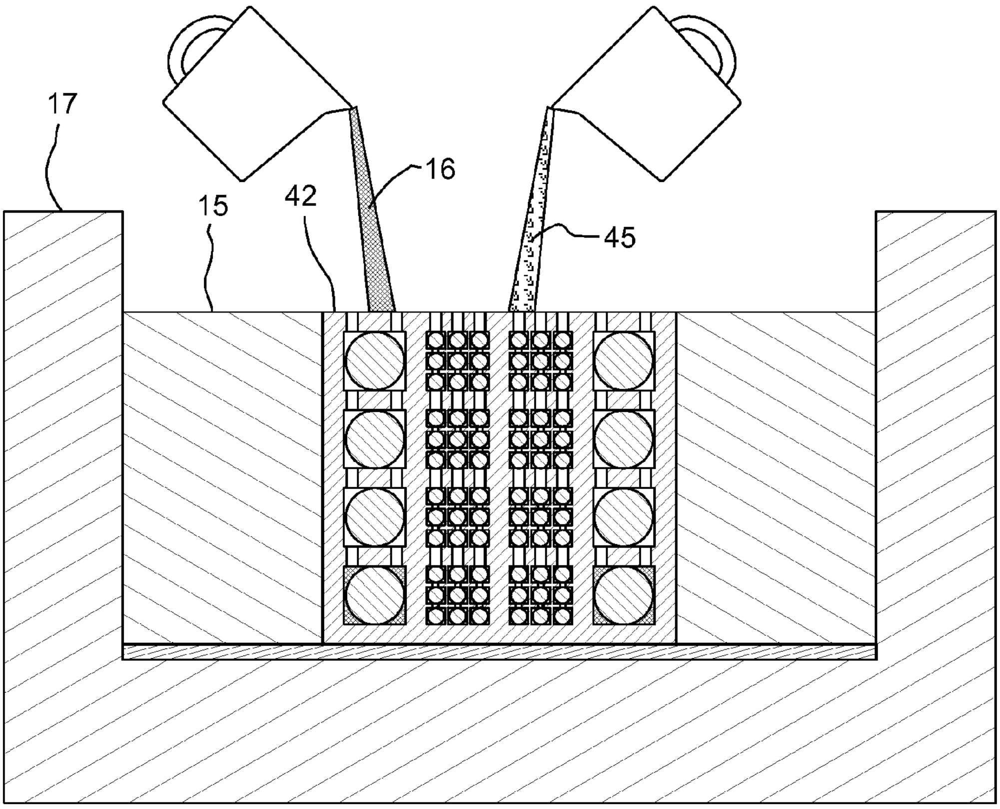

FIG. 8B

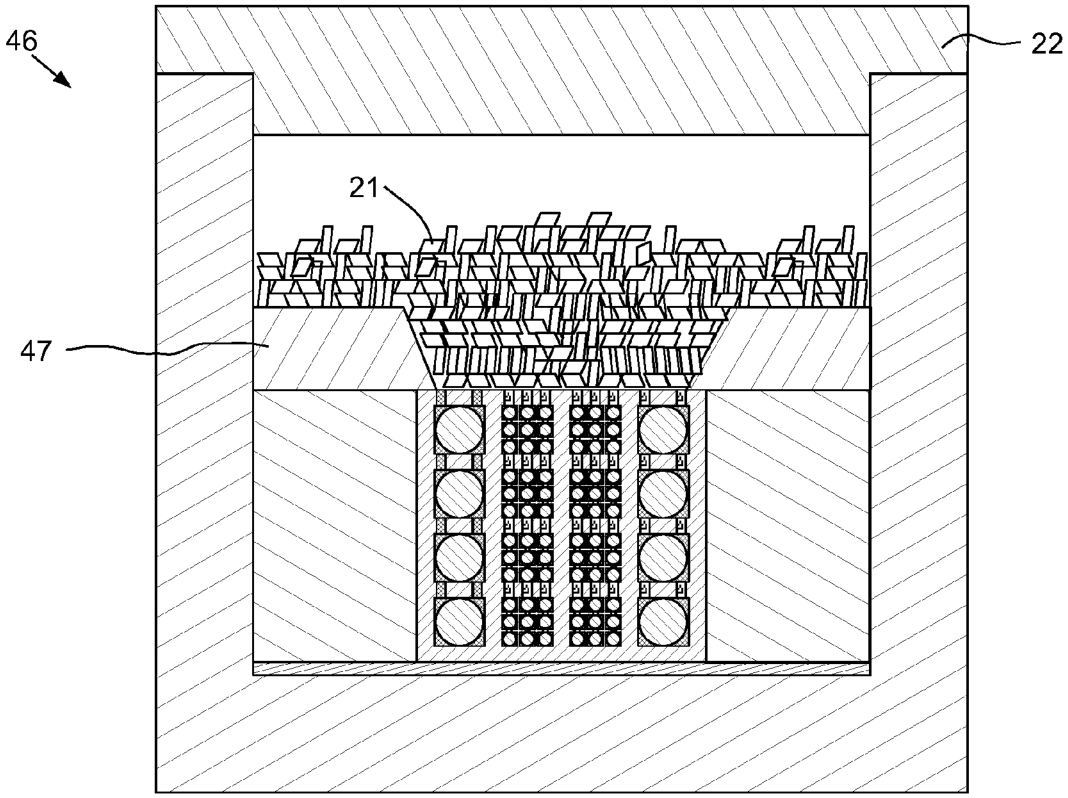

FIG. 9A

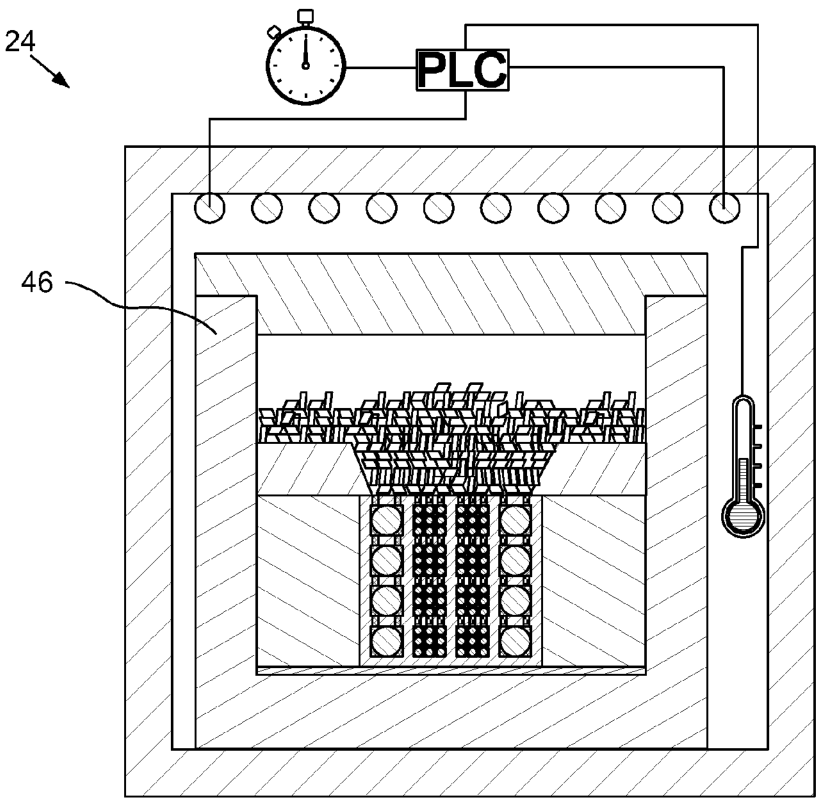

FIG. 9B

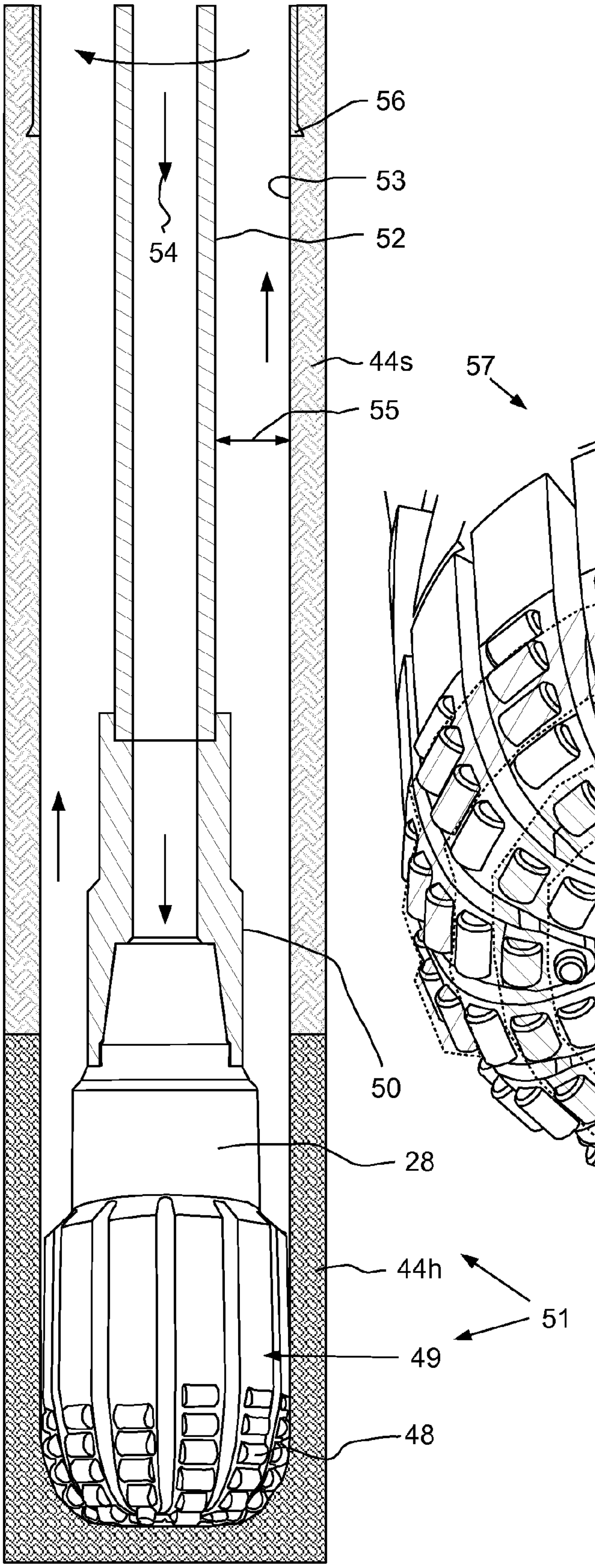

FIG. 10A

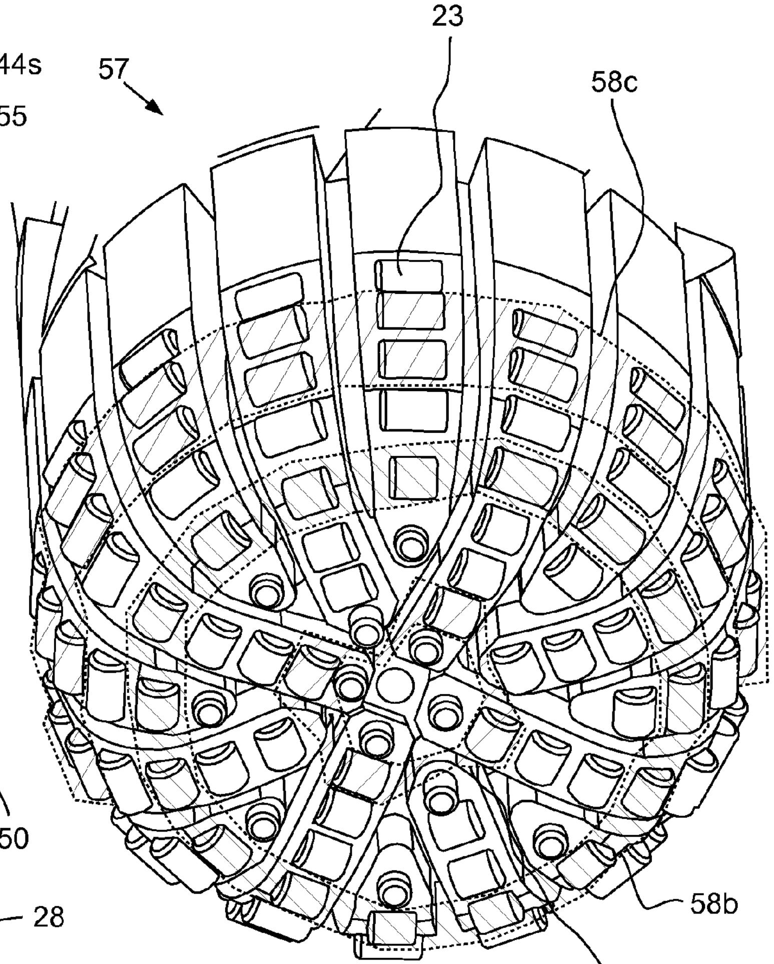

FIG. 10B

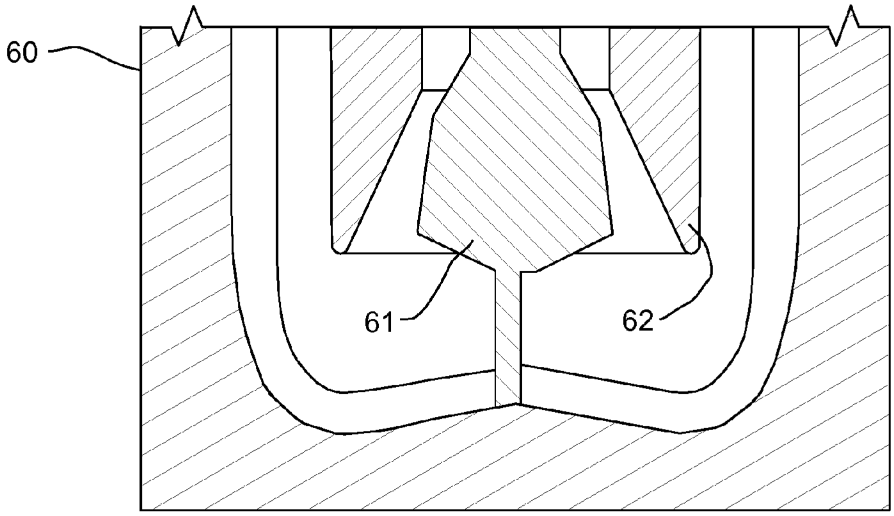

FIG. 11A

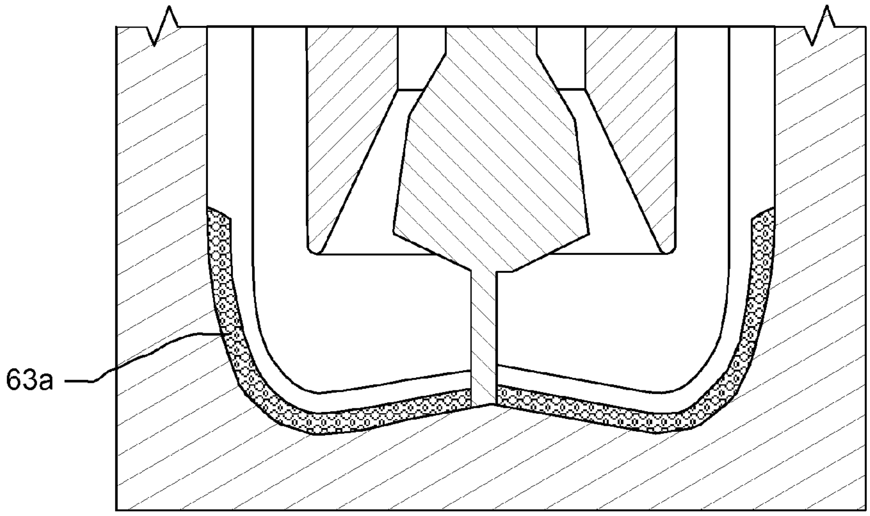

FIG. 11B

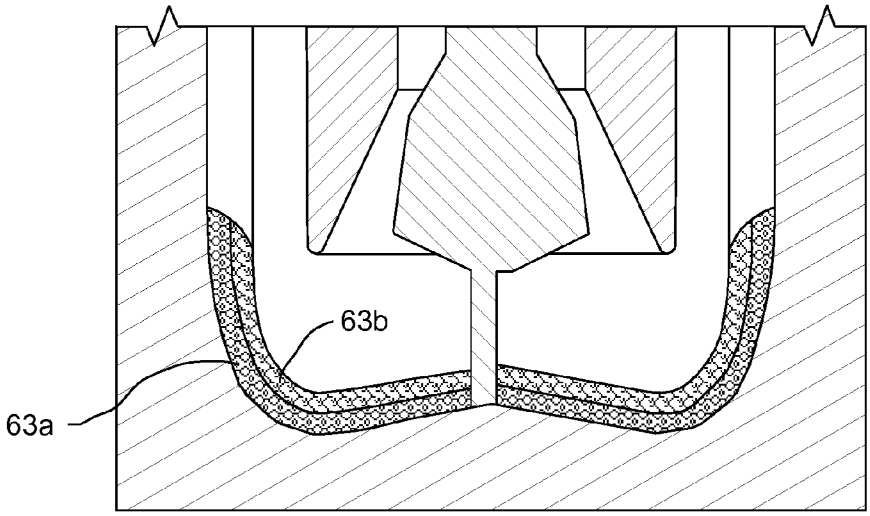

FIG. 11C

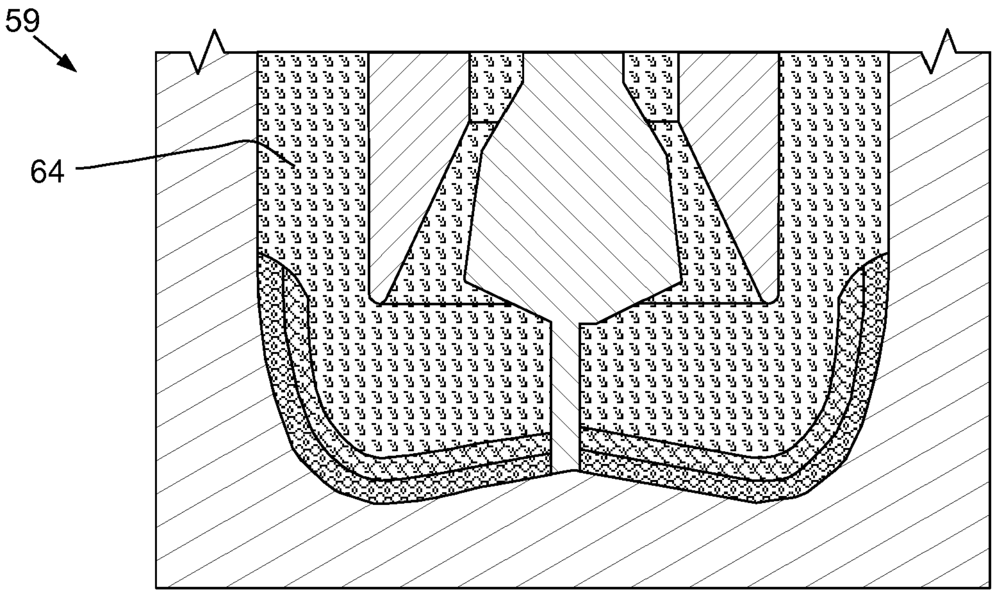

FIG. 12A

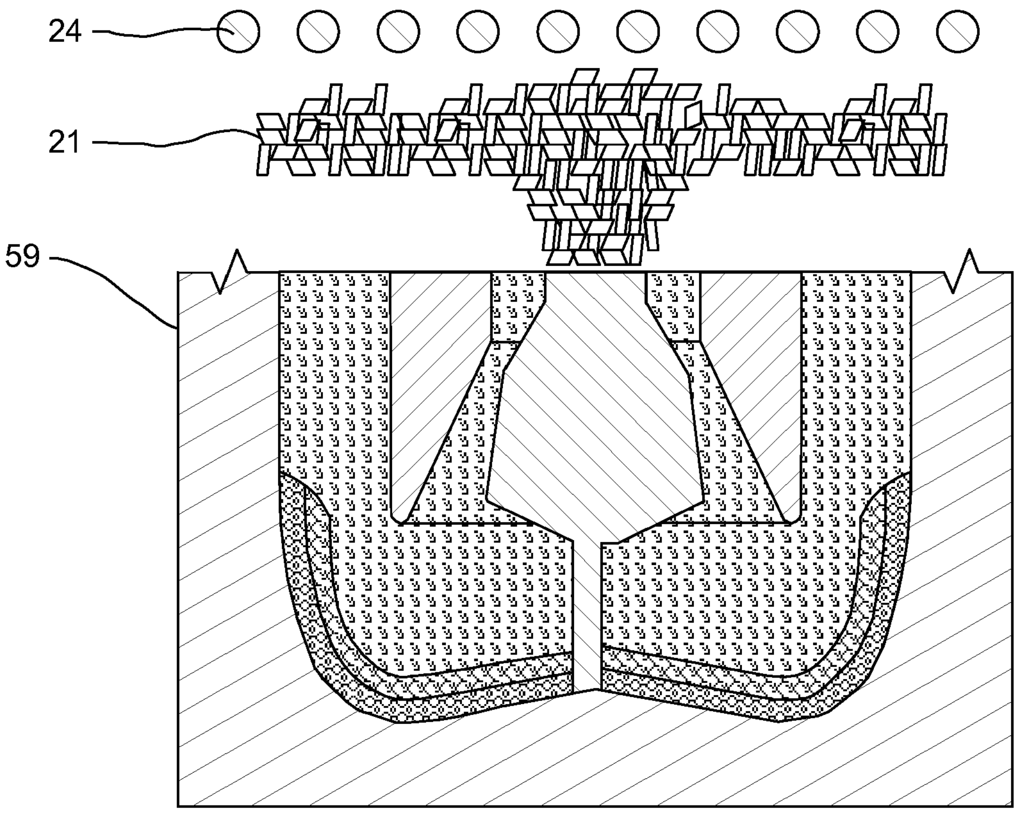

FIG. 12B

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EUROPEAN SEARCH REPORT

Application Number
EP 16 30 6189

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
Y A	US 2011/293905 A1 (SUNG CHIEN-MIN [US]) 1 December 2011 (2011-12-01) * paragraphs [0002] - [0003], [0018] - [0023], [0038] - [0040], [0045] - [0069]; claims; figures; examples *	1,5-9 2-4, 12-14	INV. C22C1/10 B22D19/16 B22D23/06 C22C26/00 E21B10/00 ADD. B22D19/06 B22D19/14 C22C29/08
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Y	US 6 454 030 B1 (FINDLEY SIDNEY L [US] ET AL) 24 September 2002 (2002-09-24) * column 1, line 7 - line 21 * * column 6, line 42 - column 8, line 21 * * column 15, line 15 - column 18, line 42 *	1,5-11	TECHNICAL FIELDS SEARCHED (IPC) C22C B22D E21B B22F
A	DE 10 2013 224139 A1 (SIEMENS AG [DE]) 28 May 2015 (2015-05-28) * the whole document *	10,11	
A	US 2014/087202 A1 (WANG JINHUA [CN] ET AL) 27 March 2014 (2014-03-27) * paragraphs [0015] - [0020]; examples *	10,11	
A	WO 2010/027504 A1 (MAT & ELECTROCHEM RES CORP [US]; LOUTFY RAOUF O [US]; WITHERS JAMES C) 11 March 2010 (2010-03-11) * the whole document *	1-14	

~~The present search report has been drawn up for all claims~~

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Place of search	Date of completion of the search	Examiner
The Hague	24 March 2017	Ceulemans, Judy

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

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Application Number
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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing claims for which payment was due.

- [ ] Only part of the claims have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due and for those claims for which claims fees have been paid, namely claim(s):

- [ ] No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for those claims for which no payment was due.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

see sheet B

- [ ] All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.

- [ ] As all searchable claims could be searched without effort justifying an additional fee, the Search Division did not invite payment of any additional fee.

- [ ] Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid, namely claims:

- [X] None of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims, namely claims:

  1-14

- [ ] The present supplementary European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims (Rule 164 (1) EPC).

LACK OF UNITY OF INVENTION SHEET B

Application Number
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The Search Division considers that the present European patent application does not comply with the requirements of unity of invention and relates to several inventions or groups of inventions, namely:

1. claims: 1-14

method of manufacturing impregnated segments of blades or blade pieces with ordered sets of superabrasive particles and correspondig drill bit.

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2. claim: 15

method of making an impregnated drill bit by infiltrating layers of matrix powder and superhard particles.

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 16 30 6189

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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24-03-2017

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

REFERENCES CITED IN THE DESCRIPTION

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- US 20150008046 A **[0007]**