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(54) **CARTRIDGE-BASED 3D PRINTING SYSTEM**

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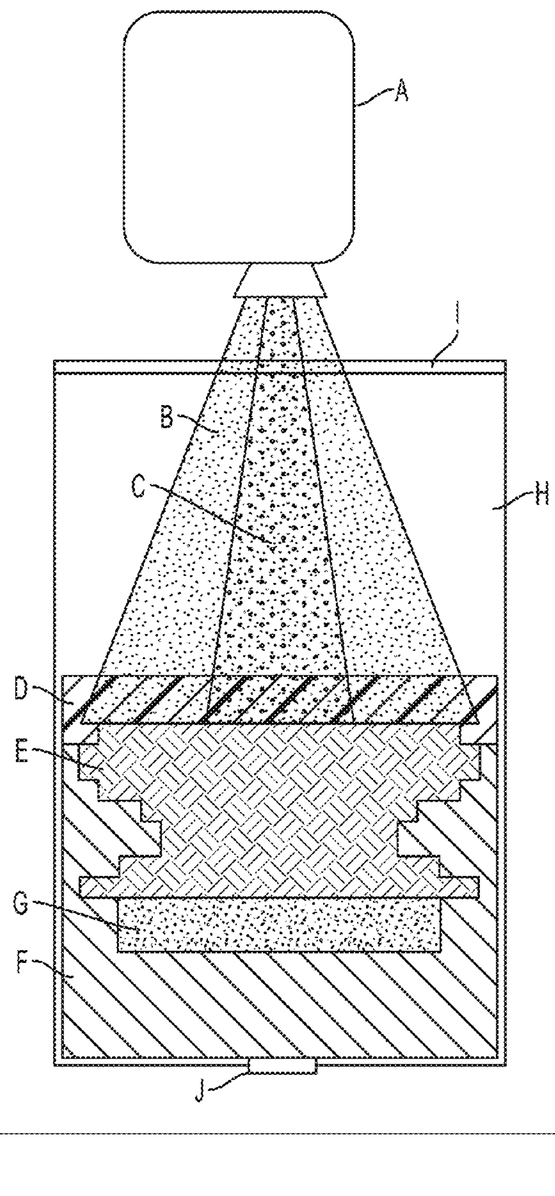
CPC ***B29C 67/0066*** (2013.01); ***B29C 67/0085*** (2013.01); *B33Y 10/00* (2014.12)

(57) **ABSTRACT**

Embodiments of the invention are directed to a 3D printing system that directs projected light at tunable wavelengths to cure a polymer resin from monomers or oligomers which floats on a dense liquid platform in which the curing occurs within a prepackaged vessel which facilitates the layer is printed at any given time.



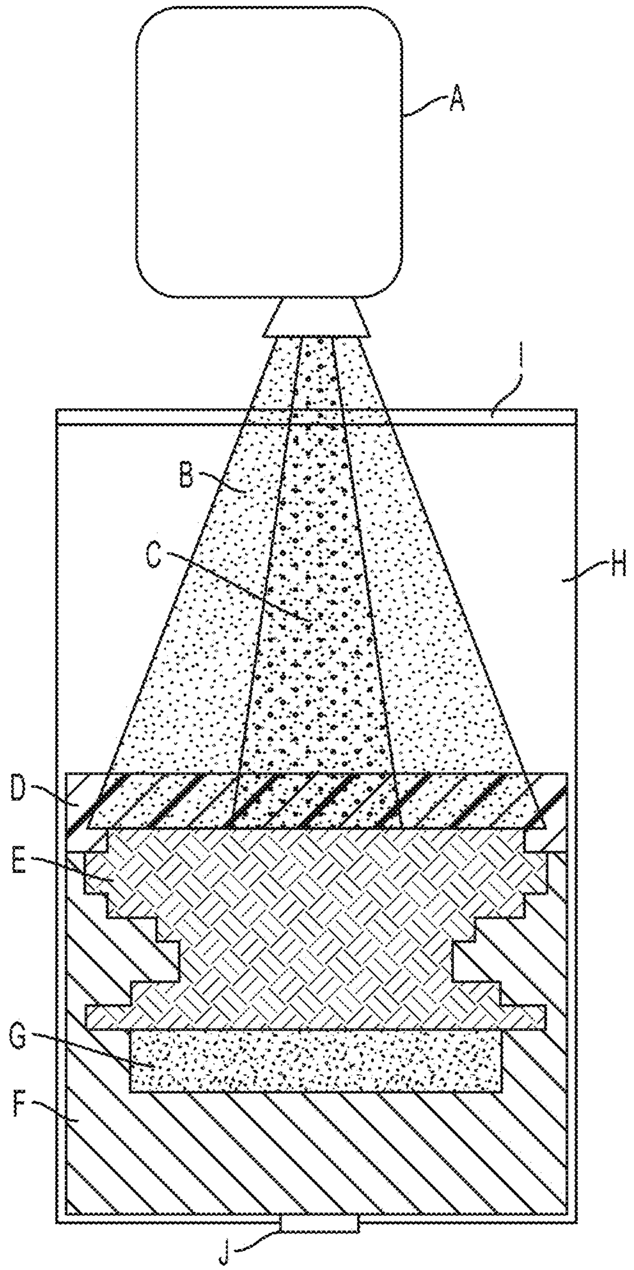


FIG. 1

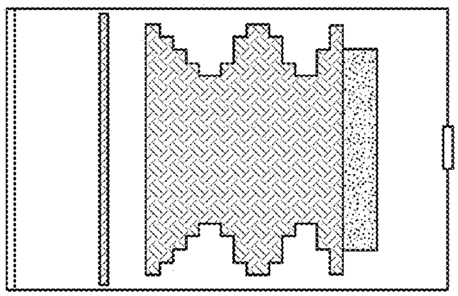


FIG. 2E

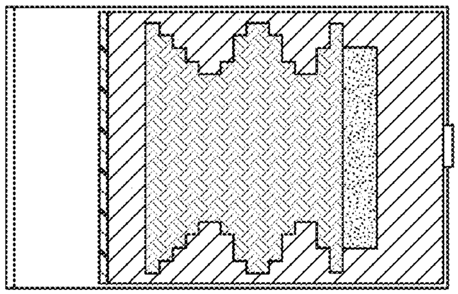


FIG. 2D

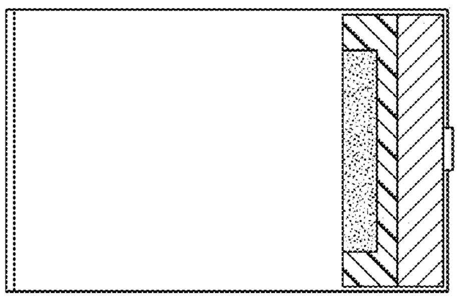


FIG. 2C

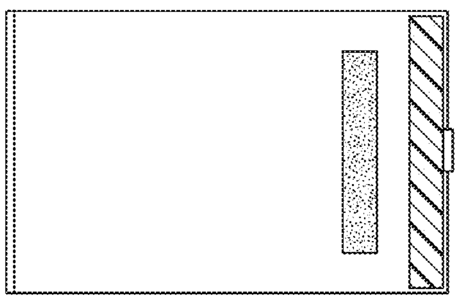


FIG. 2B

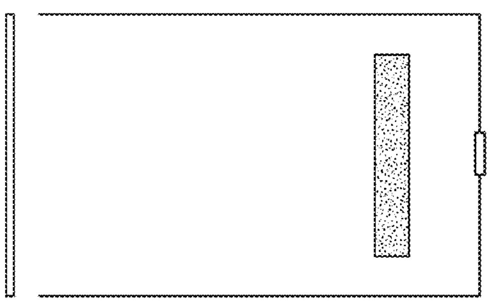


FIG. 2A

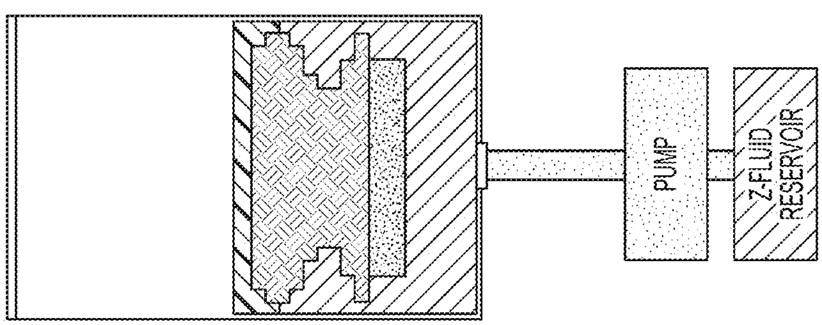


FIG. 3A

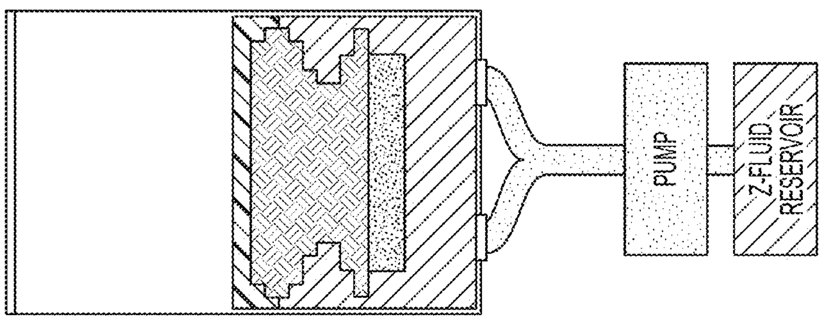


FIG. 3B

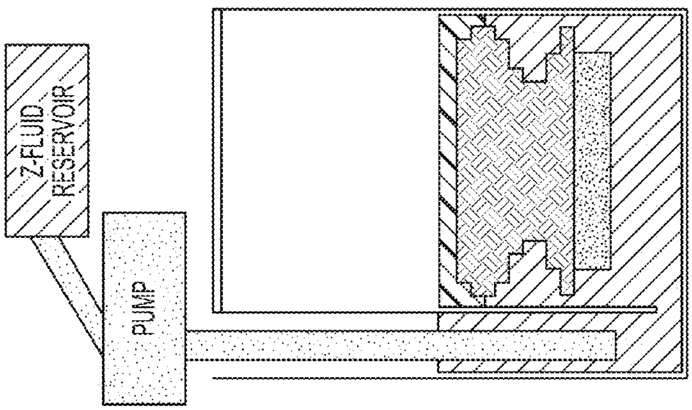


FIG. 3C

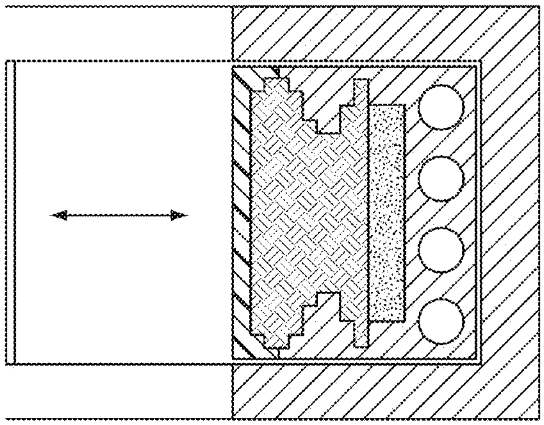


FIG. 3D

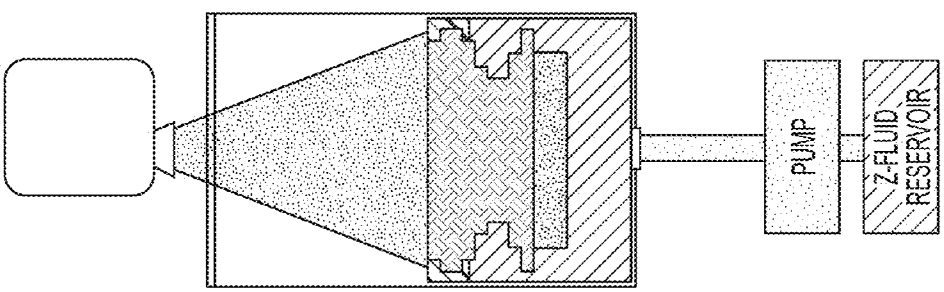


FIG. 4A

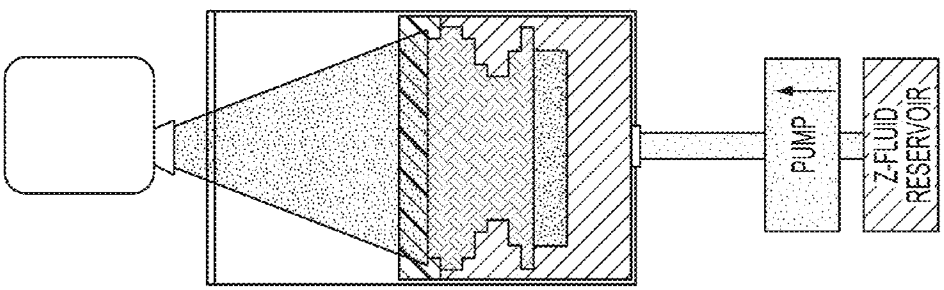


FIG. 4B

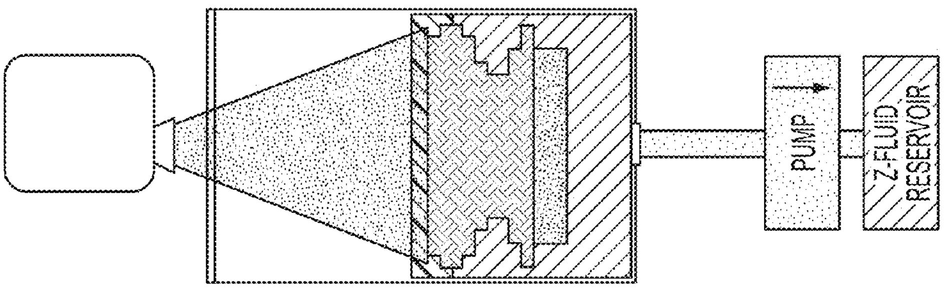


FIG. 4C

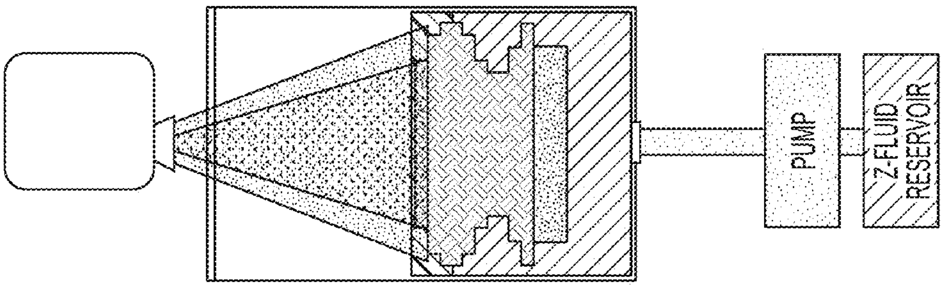


FIG. 4D

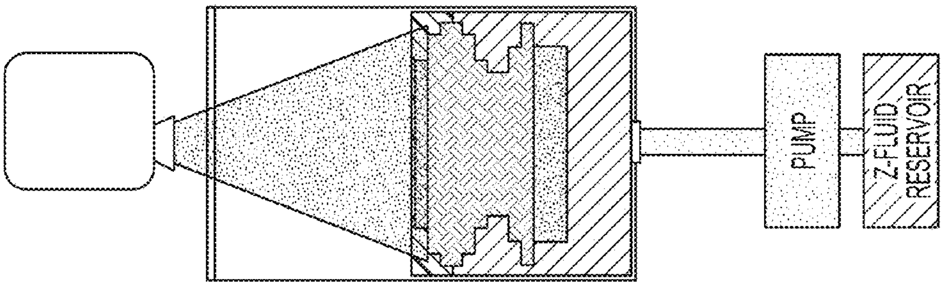


FIG. 4E

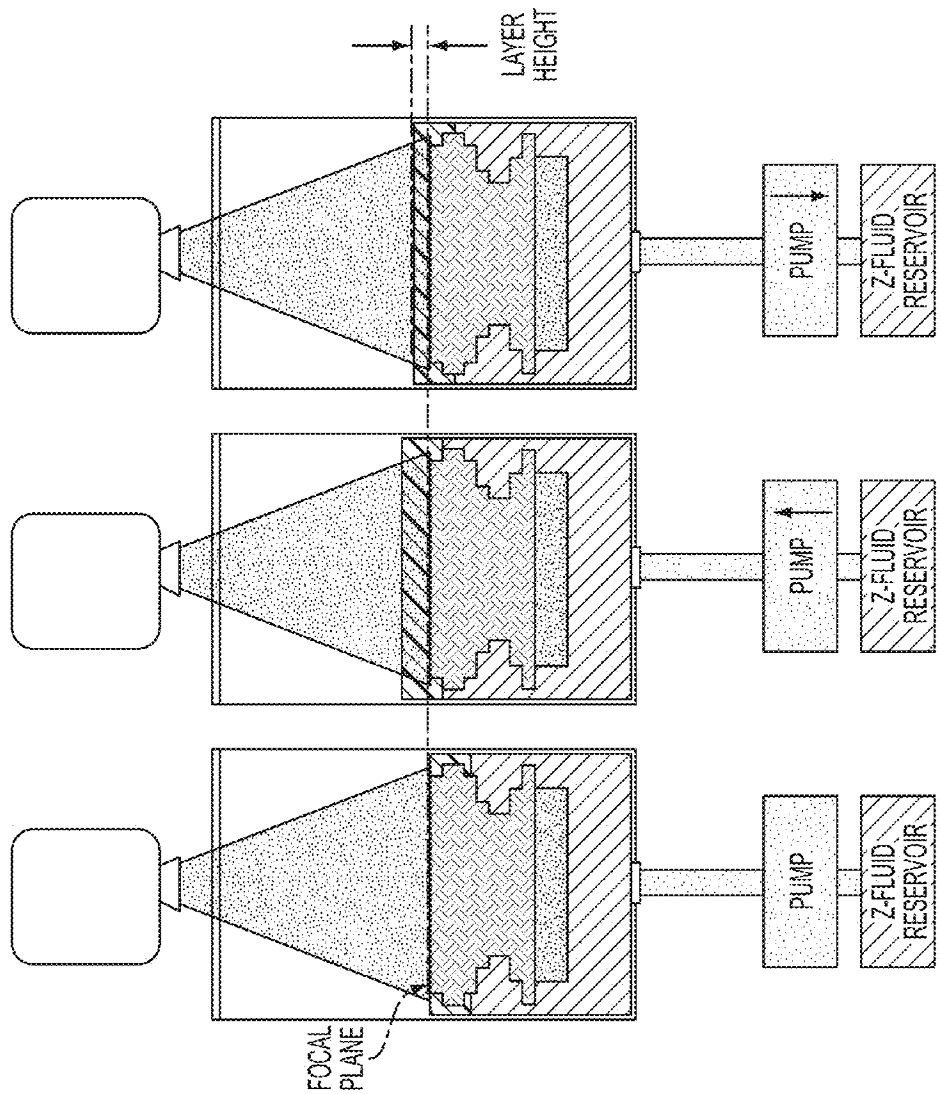


FIG. 5A

FIG. 5B

FIG. 5C

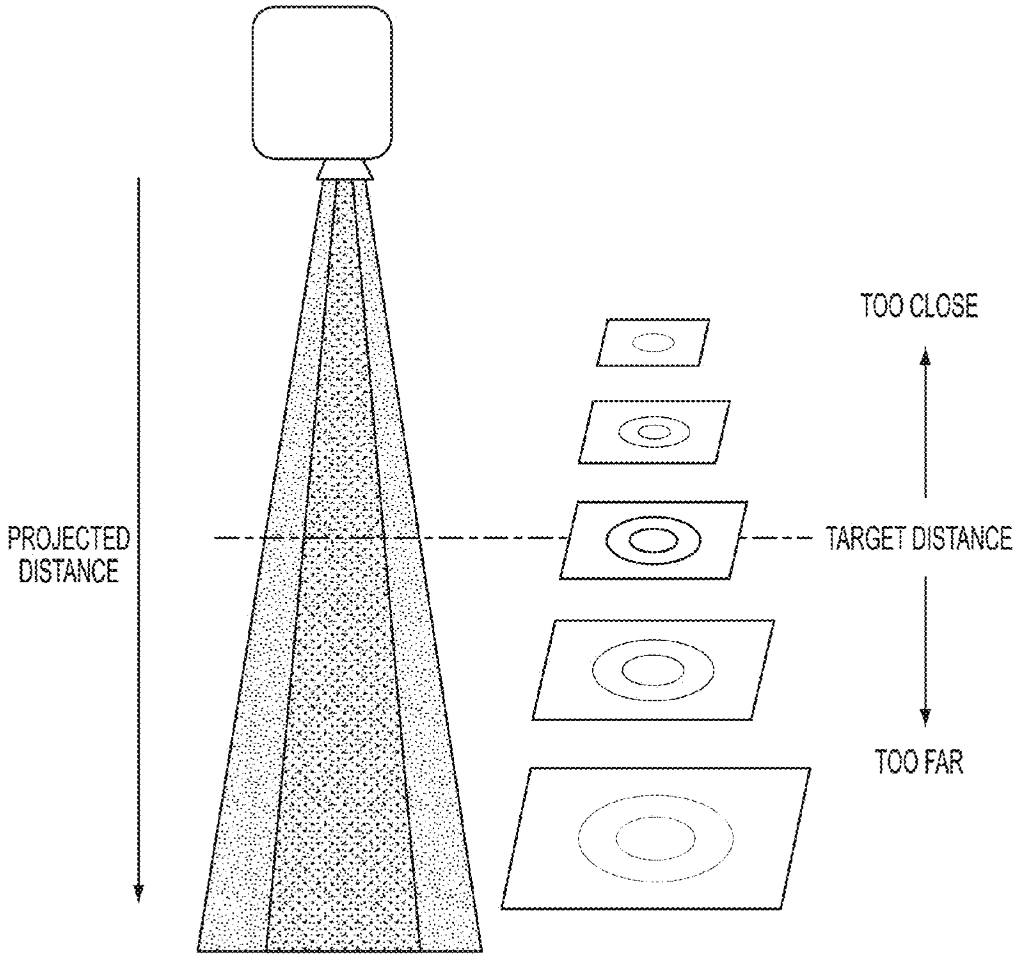


FIG. 6

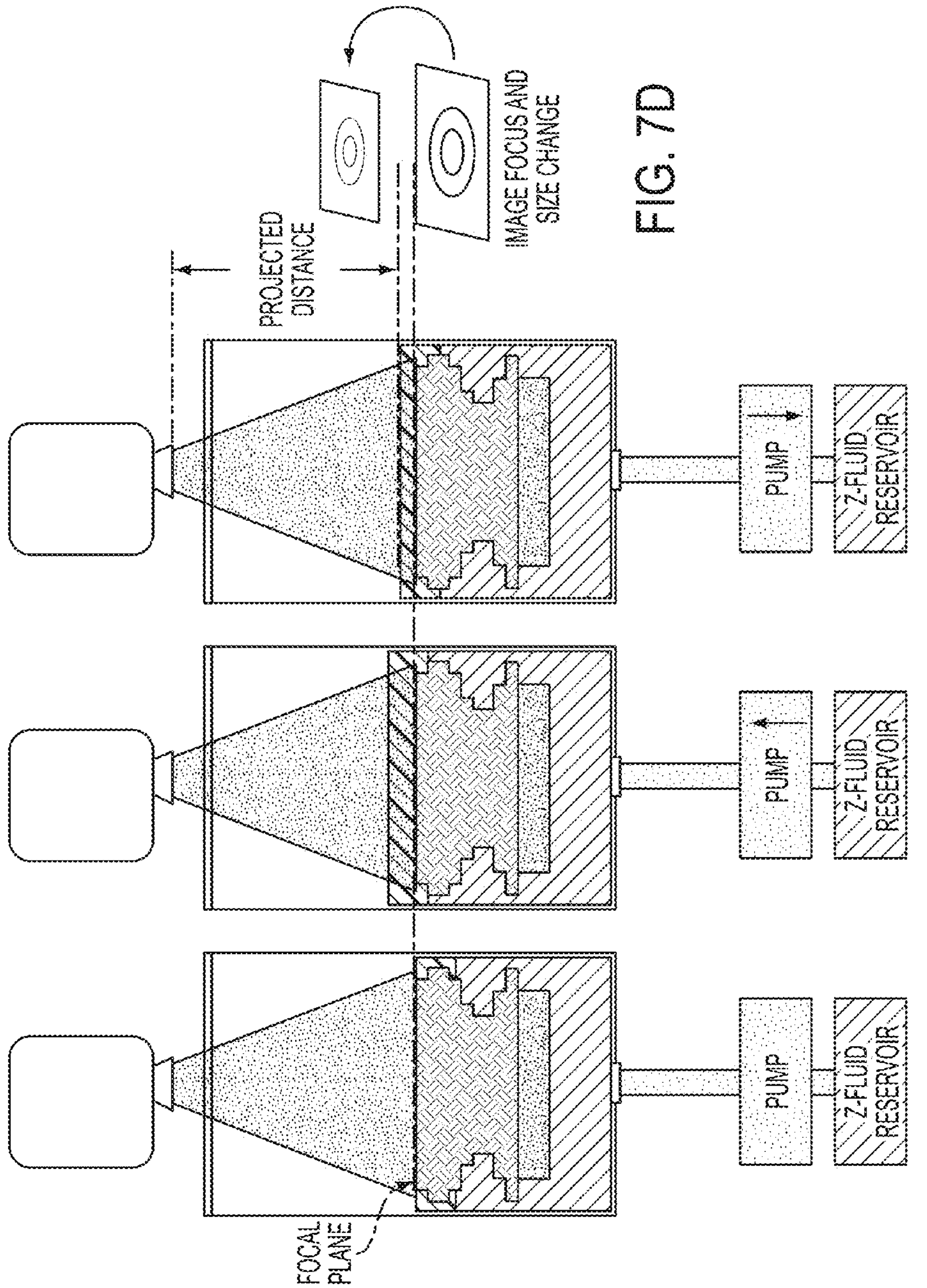


FIG. 7A

FIG. 7B

FIG. 7C

FIG. 7D

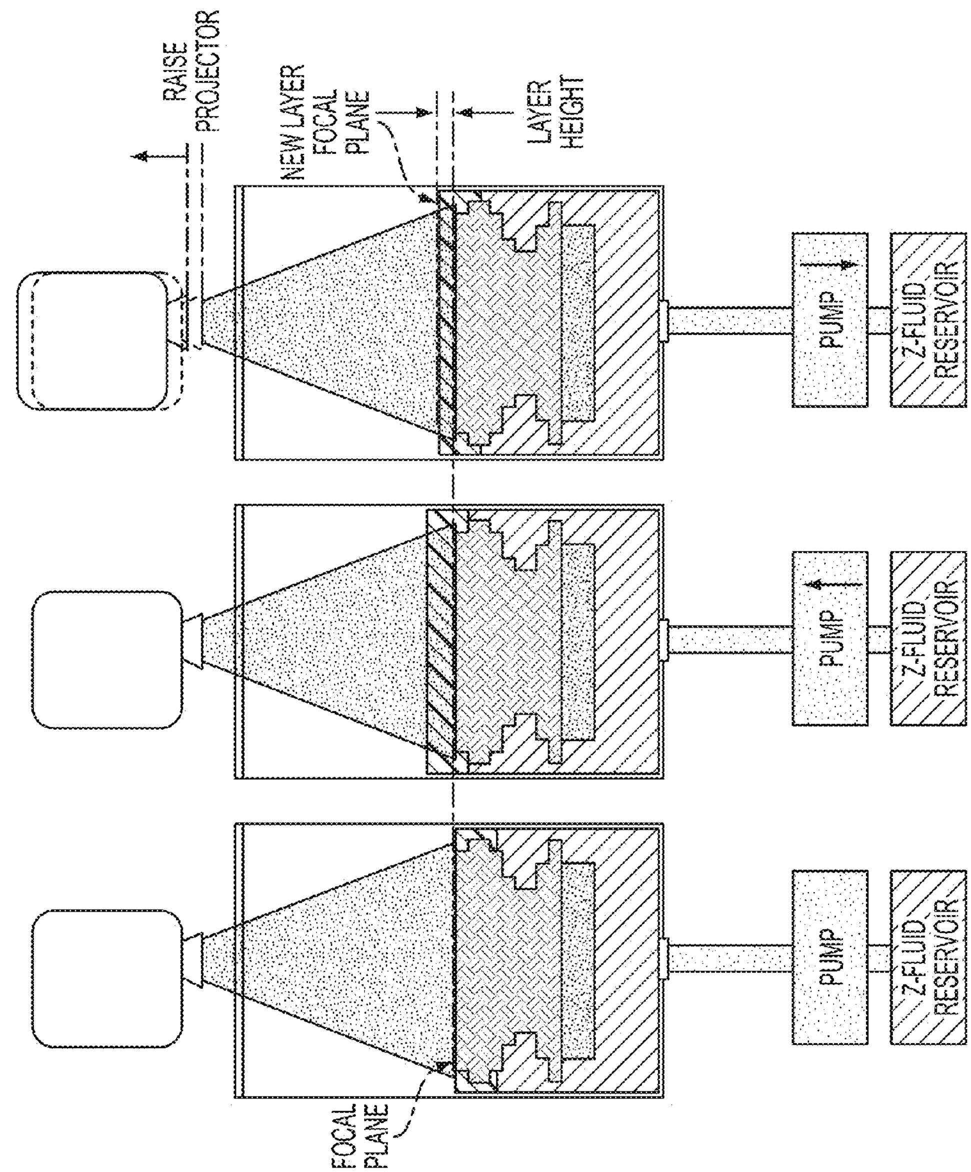


FIG. 8A

FIG. 8B

FIG. 8C

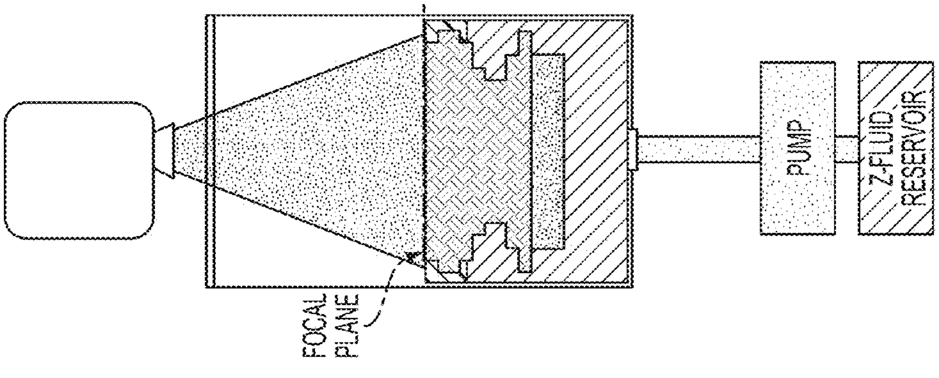


FIG. 9A

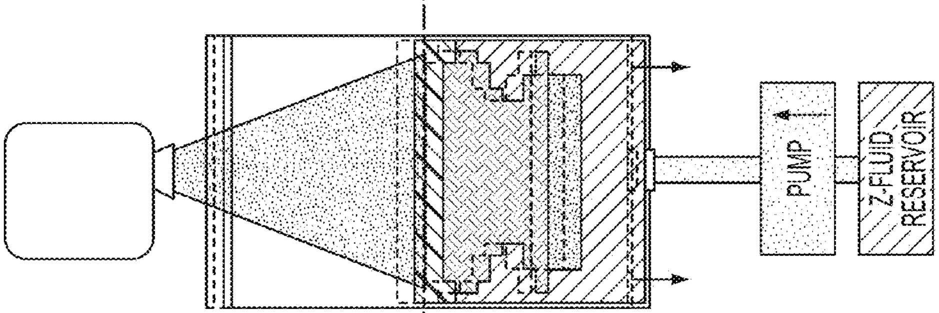


FIG. 9B

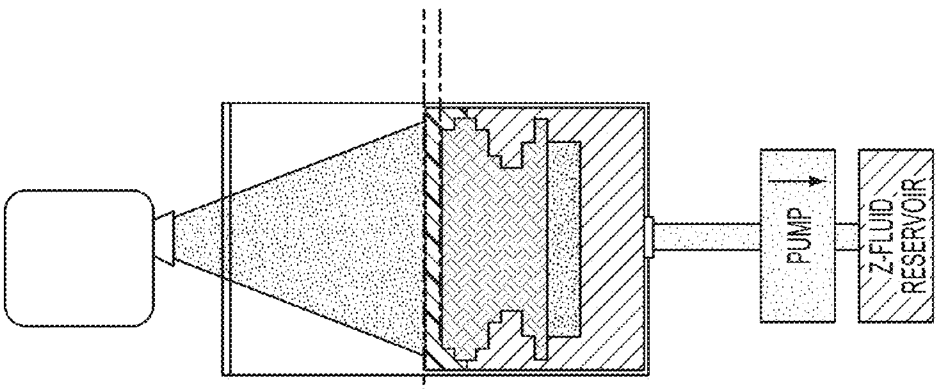


FIG. 9C

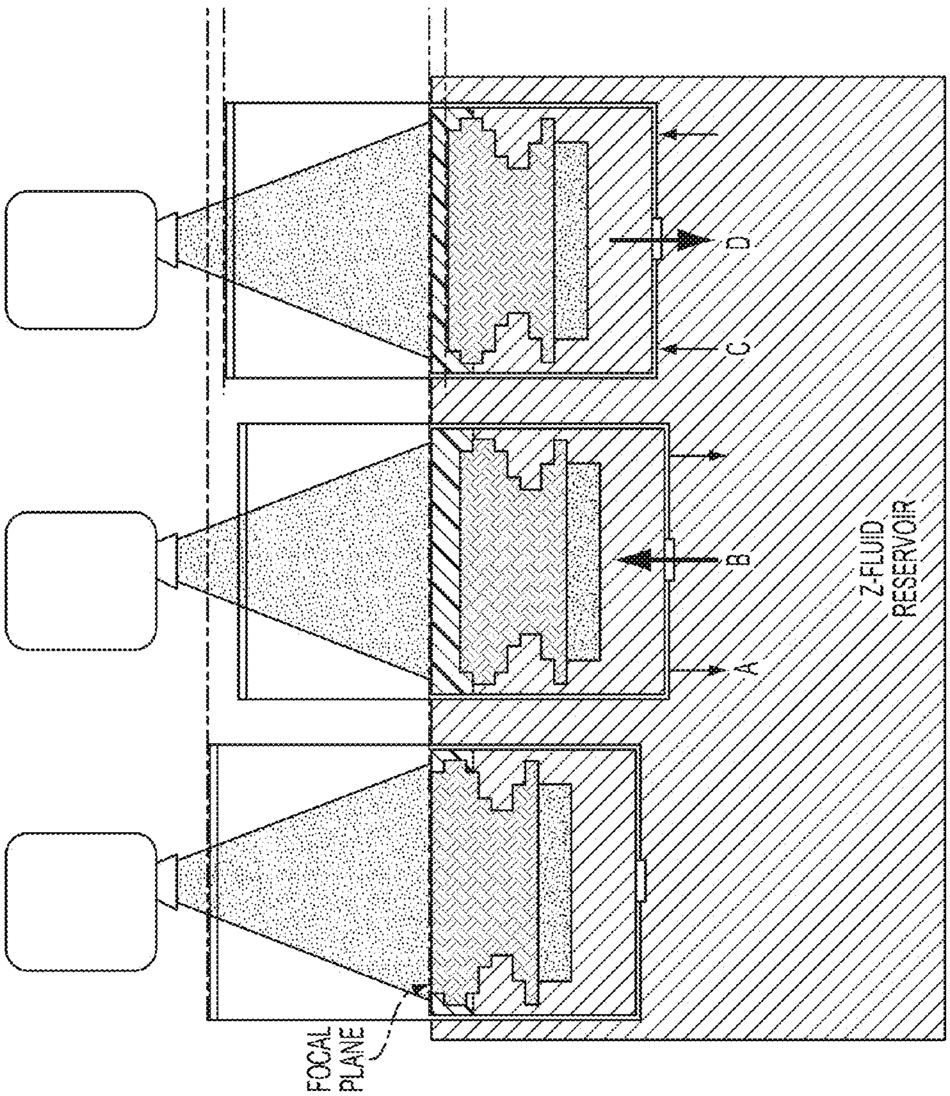


FIG. 10A

FIG. 10B

FIG. 10C

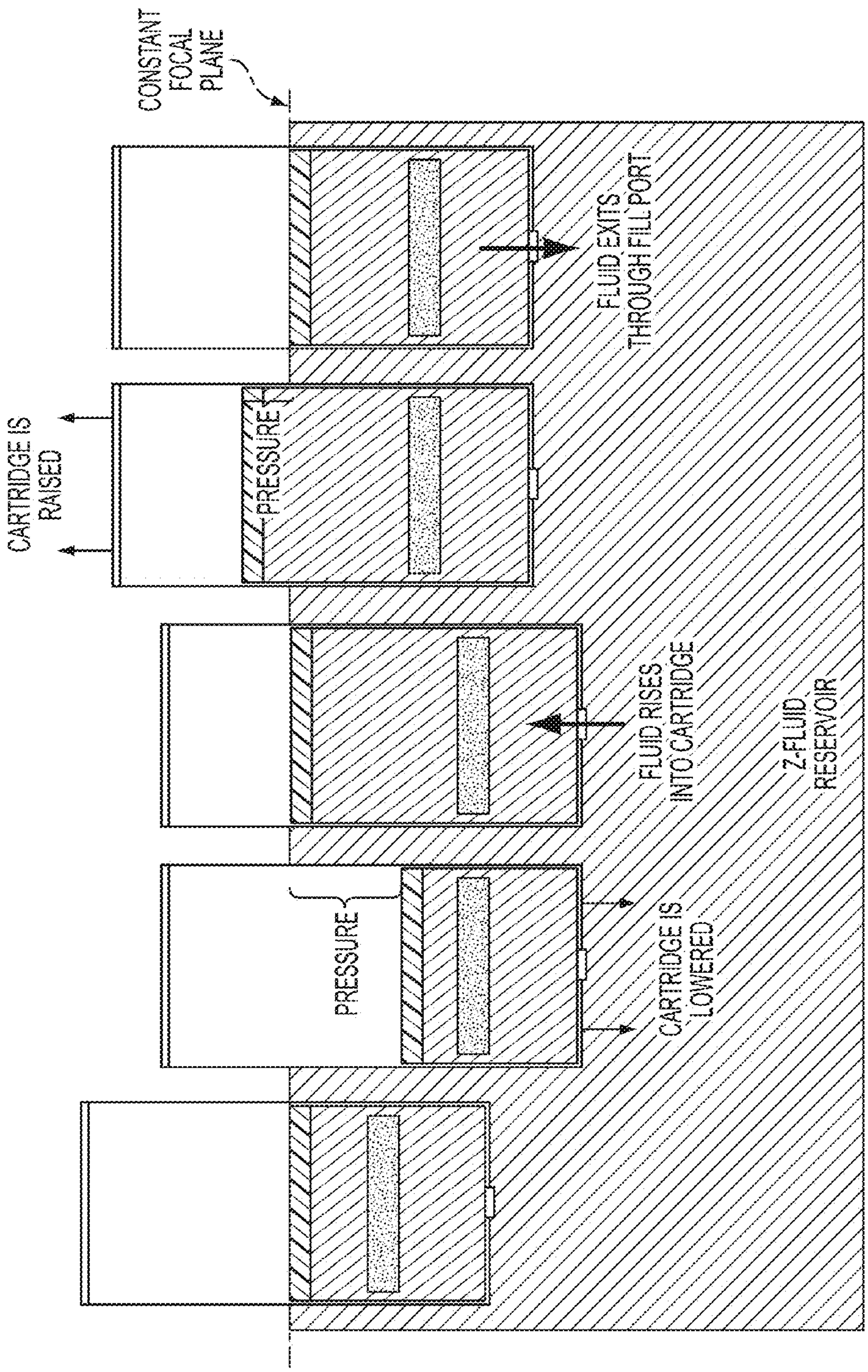


FIG. 11A FIG. 11B FIG. 11C FIG. 11D FIG. 11E

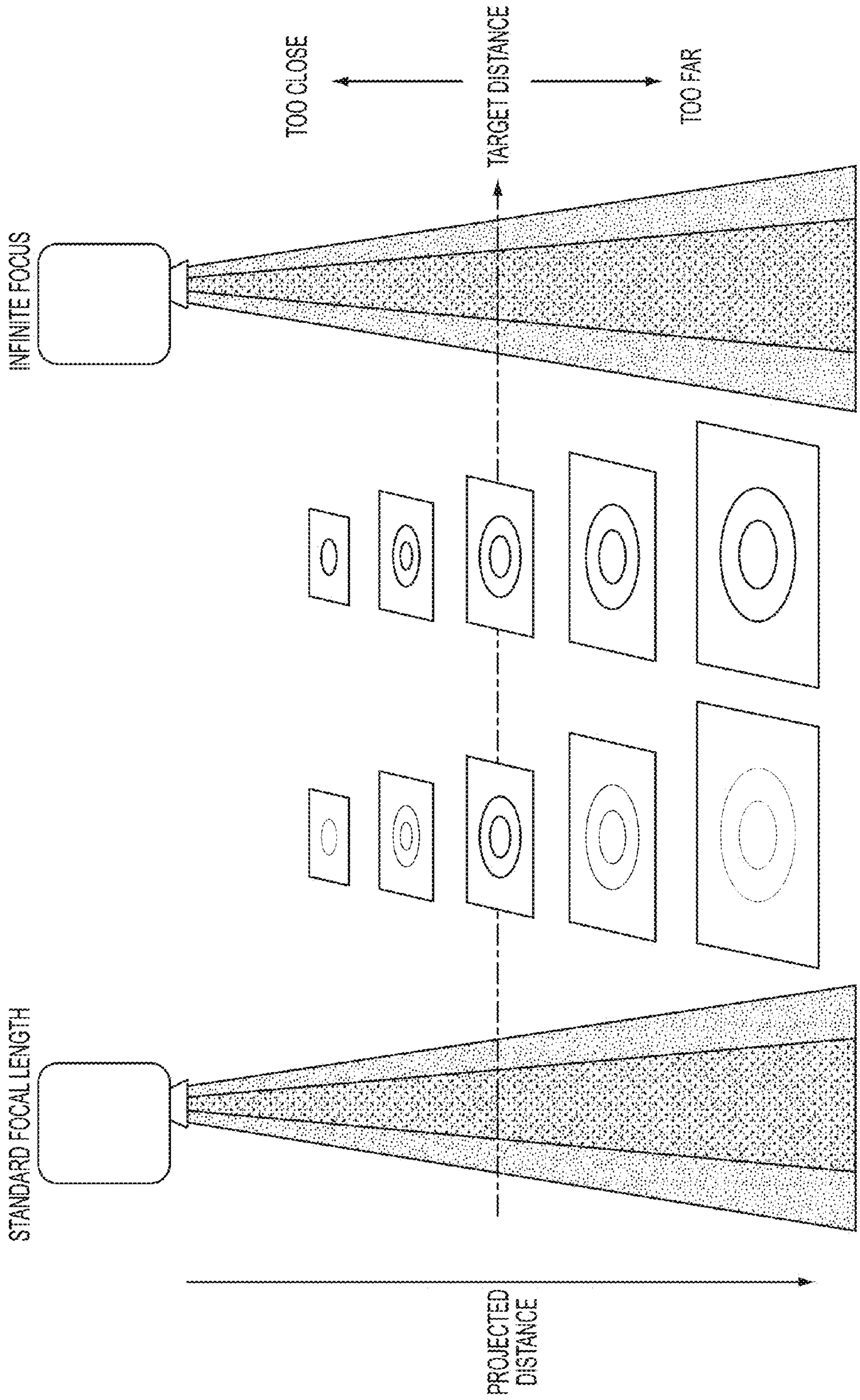


FIG. 12B

FIG. 12A

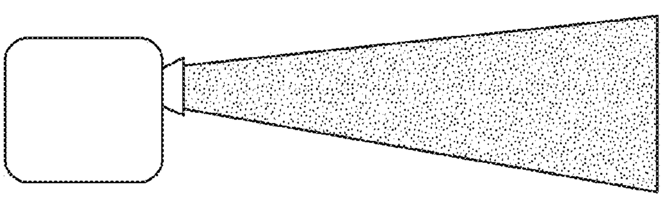


FIG. 13A

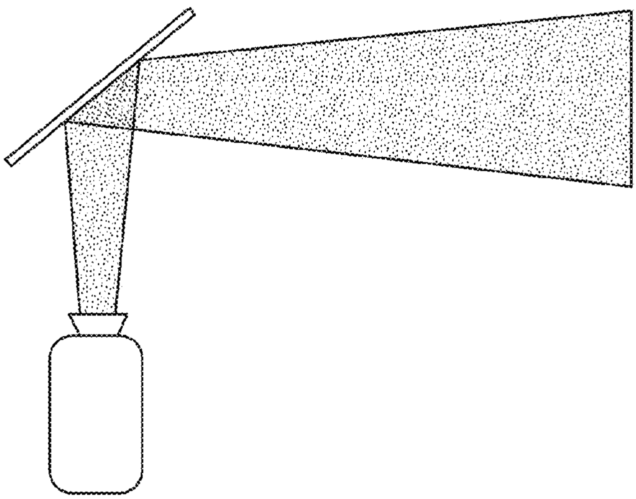


FIG. 13B

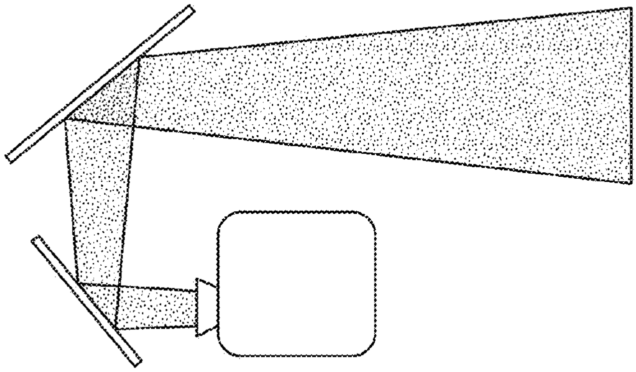


FIG. 13C

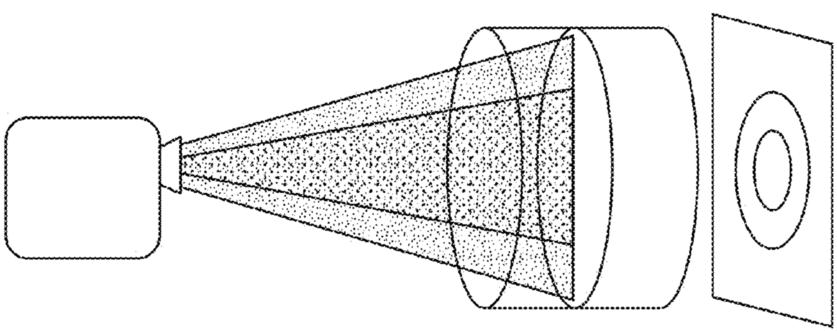


FIG. 14A

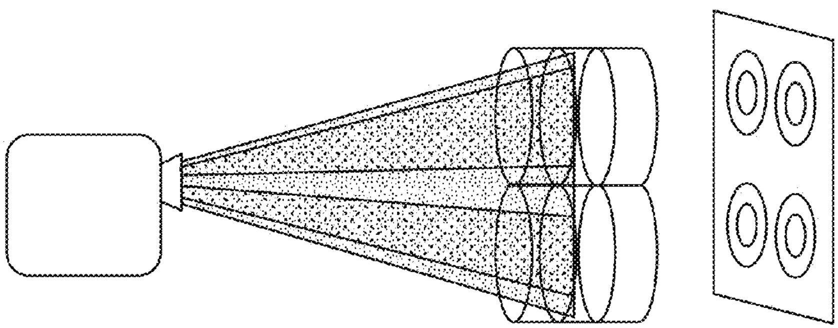


FIG. 14B

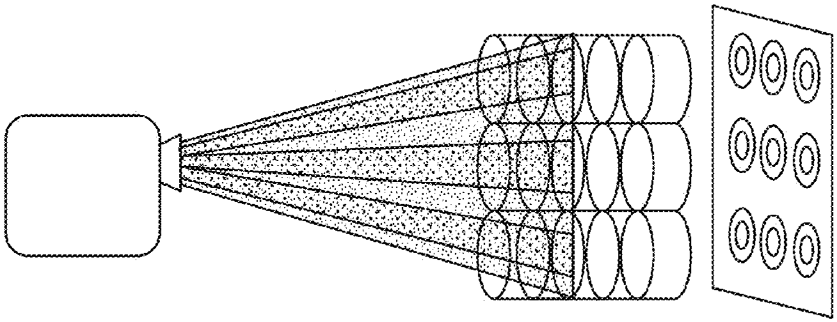


FIG. 14C

CARTRIDGE-BASED 3D PRINTING SYSTEM

CROSS-REFERENCES TO RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. §119(e) of U.S. Provisional Patent Application No. 61/815,603 filed Apr. 24, 2013, and U.S. Provisional Patent Application No. 61/815,607 filed Apr. 24, 2013 which are incorporated herein by reference in its entirety as if fully set forth herein.

FIELD OF THE INVENTION

[0002] Embodiments of the invention are directed to systems, apparatuses and business models for rapidly building custom products out of polymers using 3D printing systems.

BACKGROUND OF THE INVENTION

[0003] 3D printing or additive manufacturing is a process of making a three-dimensional solid object of virtually any shape from a digital model. 3D printing is achieved using an additive process, where successive layers of material are laid down in different shapes. 3D printing is also considered distinct from traditional machining techniques, which mostly rely on the removal of material by methods such as cutting or drilling (subtractive processes).

[0004] A 3D printer is a limited type of industrial robot that is capable of carrying out an additive process under computer control.

[0005] The 3D printing technology is used for both prototyping and distributed manufacturing with applications in architecture, construction, industrial design, automotive, aerospace, military, engineering, dental and medical industries, biotech (human tissue replacement), fashion, footwear, jewelry, eyewear, education, geographic information systems, food, and many other fields.

[0006] In light of the multiple uses that 3D printing lends itself to, it would be beneficial to use some of the advantages of this technique to build custom product using a variety of materials.

SUMMARY OF THE INVENTION

[0007] An embodiment of the invention is directed to a 3D printing system that directs projected light at tunable wavelengths to cure a polymer resin from monomers or oligomers that is floating on a more dense liquid platform, wherein the curing occurs within a prepackaged vessel that facilitates the printing of specific layers are any given time.

[0008] Embodiments of the claimed invention are directed toward improve existing 3D printed parts by innovating on the interaction between polymerization of the resin and the 3D printer inside of cartridges. For the system described herein, prints occur inside of a cartridge which improves upon a number of issues with existing printers.

[0009] There are two different classes of 3D printers based on cost. There are currently high cost printers, beginning at $10,000 and running into the millions of dollars; and there are hobbyist 3D printers, ranging in price from $100 to $10,000. The latter are usually based on open source kits and have widely varying degrees of accuracy and repeatability. Depending on the market application, the tradeoff among price and various technical properties including material properties, print speed, print resolution, etc. can be important.

[0010] Another way of organizing these printers is by feed stock, of which there are four categories. The first of these is the powdered, sinter-able material used in Selective Laser Sintering (SLS) machines—all of which are currently very high in cost. The second is the thermoplastic filament of fused filament fabrication (FFF) machines. These printers tend to have a fairly proportional cost vs quality curve—e.g. low cost printers tend to be of poor resolution and variable build quality. The third is akin to inkjet printing in which a thin layer of monomer is deposited on a surface and cured by UV, optical light, laser or other sources. The fourth of these are thermoset resin based SLA printers, available at all range of costs.

[0011] One issue with SLA printers in general is that many resins are not safe to handle or are environmentally harmful, thus requiring special handling. To date, this means that only companies with trained professionals or very interested hobbyists are willing to take the risk associated with exposure to the resins. Furthermore, those systems require purge cycling to clean out printer components, such as vats, feed lines, vessels or other such areas which interface with resin between materials changes. This is quite wasteful, and coupled with the generally high cost of resins, this typically precludes the adoption at home of generalized resins. Companies face issues in shelf life of resins, especially after they have been "opened." There does not exist the ability to easily and rapidly change materials between print jobs. There is no simple way to print multiple materials at once on the same printer.

[0012] The system described uses a cartridge-based system to get around these issues. Because the resin is packaged and contained within a pre-sealed cartridge, when used properly, there will be no exposure to uncured resin. The system uses a so-called 'z-fluid' to control height and move the resin relative to the build table inside, allowing clean, efficient prints. This means that the machine will not be exposed to resin and thus never be subject to purge cycles. There are other innovations that readily follow, such as the printing of multiple parts at the same time using different resins. A further advantage is the limited stock required for purchase. Currently, materials are usually sold in large quantities at fairly high prices. This system would enable sale of much smaller amounts of resin in a single batch, also eliminating waste. These lower volumes of stock would also amount to a larger variety of stock.

[0013] Cartridges that are sealed and packaged with the resin can be bought and sold individually following a business models similar to the Keurig K-cup model in which users and customers buy cartridges that fit into a system. The processing occurs in a standardized disposable (or refillable) container in which the contents are variable and chosen by the user. Attachments for the system can allow advanced users self-filling capabilities. This limits cleaning, waste of the resin, purging steps, and allows 24/7 use of the equipment to select rapidly from among different color parts, and parts made from different materials.

[0014] The self-contained nature of this system allows for ease in the supply chain and distribution and facilitated standardized packaging in large scale manufacturing facilities. Due to the scale of this system, extremely low cost cartridge packaging can be amortized over large numbers of cartridges. This allows for the potential to produce the system at a very competitive price point to encourage system use.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] FIG. **1** sets forth the printer terminology in accordance with an embodiment of the invention;

[0016] FIG. **2** depicts a cartridge's life cycle in accordance with an embodiment of the invention;

[0017] FIGS. **3**A to **3**D depicts the structure and design of the cartridge's fill ports in accordance with embodiments of the invention;

[0018] FIG. **4** depicts the specific layer printing steps in accordance with an embodiment of the invention;

[0019] FIGS. **5**A to **5**C shows a top layer refresh in accordance with an embodiment of the invention;

[0020] FIG. **6** shows image size and focus as a function of projected distance in accordance with an embodiment of the claimed invention;

[0021] FIGS. **7**A to **7**C shows the changing of the projected distance with a layer refresh in accordance with an embodiment of the invention;

[0022] FIGS. **8**A to **8**C shows the fixed ("F") cartridge system in accordance with an embodiment of the invention;

[0023] FIGS. **9**A to **9**C shows the Z-cartridge system in accordance with an embodiment of the invention;

[0024] FIGS. **10**A to **10**C shows the sinking ("S") cartridge system in accordance with an embodiment of the invention;

[0025] FIGS. **11**A to **11**E shows a process for passively adjusting build height in accordance with an embodiment of the invention;

[0026] FIGS. **12**A and **12**B shows the image size and focus as a function of projected distance in accordance with an embodiment of the invention;

[0027] FIGS. **13**A to **13**C shows the orientation of projector and light guides in accordance with embodiments of the invention; and

[0028] FIGS. **14**A to **14**C shows the use of a single projector for multiple concurrent prints.

DETAILED DESCRIPTION OF EXEMPLARY EMBODIMENTS

[0029] An embodiment of the claimed invention is directed to a 3D printing system ("system"). The system directs projected light at tunable wavelengths ("light source") to cure a polymer resin from monomers or oligomers ("resin") which is floating on a higher density liquid platform ("Z-fluid") in which the curing ("reaction") occurs within a prepackaged vessel ("cartridge") which facilitates the layer which is printed at any given time. In a further embodiment, the resin can be packaged, sealed and sold within the cartridge. Cartridges of different sizes and dimensions contain different amounts of different colored materials. This allows users to rapidly select from among many combinations when ordering cartridges and easily switch materials, colors, sizes between successive print jobs without a costly system wide resin purge. One or more cartridges are loaded into the system, which allows for quick and convenient Z-fluid manipulation and the printing of the part within the cartridge. To our knowledge, no printer prints parts inside the cartridge which contains the resin. All other systems remove resin from some temporary storage tank and relocate it to a print area. This innovation spawns a host of new business models, new ways to handle resin and new ways to interact with more complex pre-polymers. The system allows for the simultaneous printing of different materials, different parts, different resolutions and different colors. In one embodiment, up to 100 different custom components can be printed at the same time having varying properties such as colors and made from different modulus materials or varying chemical composition.

[0030] In accordance with an embodiment of the invention, the light source can be at a uniform, single wavelength or combinations of wavelengths in the extreme UV range (below about 120 nm), vacuum UV (from about 10 to about 200 nm), UVC (about 200 to about 280 nm, including low pressure mercury lamp sources near 254 nm), UVB (about 280 to about 320 nm), UVA (about 320 to about 400 nm, including high pressure mercury lamps or metal halides near 365 nm), within the visible spectrum (about 400 nm to about 800 nm) or within the IR spectrum and beyond (above 800 nm). The choice of the light source is dependent upon its ability to directly or indirectly lead to curing (reaction). The light source is not limited to, but typically chosen from among one or a combination of light emitting diodes, organic light emitting diodes, lasers (particularly systems which allow for infinite focus projection), excimer lamps, mercury arc lamps, metal halide lamps, fluorescent lights such as black lamps, focused or directed solar radiation, gas-discharge lamps or incandescent lamps. In an embodiment of the claimed invention, the light source is a commercially available home theater projector using Texas Instruments DLP Technology or other forms of digital light projection based photo-curing. In another embodiment, the light source is a commercially available Red, Blue and Green Laser light source.

[0031] In accordance with claimed embodiments of the invention, the resin can be made from a variety of monomers and oligomers including, but not limited to acrylates, urethanes, thiols, alkenes, vinyls, styrenics, acetates, isocyanates, ureas, fluorinated monomers, silicones, and epoxides and combinations of these materials. The resin optionally contains additives including but not limited to a photoinitiator which is dictated by the chosen wavelength of light, light absorbers which limit the depth of cure through the resin, reaction inhibitors which control the kinetics of the reaction, reactive or non-reactive diluents which help control the viscosity of the resin, colorants for aesthetic or functional purposes, antimicrobial particles such as silver micro or nanoparticles, short fiber filler for added toughness, and other fillers to create composite structures from The Resin. In an embodiment, the photoinitiator is bis-acyl phosphine oxide (BAPO). In another embodiment the photoinitiator is 2,2-dimethoxy-2-phenylacetophenone (DMPA). In another embodiment the photoinitiator is diphenyl(2,4,6-trimethylbenzoyl)phosphine oxide (TPO). In another embodiment the photoinitiator is chosen from within the family of Irgacure and Darocure initiators (from BASF).

[0032] In accordance with embodiments of the invention, the Z-fluid refers to a system which is comprised of a base fluid (such as distilled deionized water, tap water, corn syrup, brine, sugar water, liquid metals such as mercury, eutectic gallium indium, various gallium alloys, ferrofluid or other fluid media) and optional additives, such as, but not limited to, sugar, salt, starch, ions, proteins, or combinations thereof, such that the Z-fluid is more dense than the resin. In one embodiment, the Z-fluid can be actively manipulated (through pumping, partial pressures, or mechanical compression) to control the height of the top level of the resin which floats on the Z-fluid within the cartridge. In another embodiment, the cartridge is manipulated (mechanically or otherwise) relative to an external (perhaps secondary) Z-fluid bath. The height of the Z-fluid plus the resin is typically maintained at the focal plane of the projected image or at such as height (in situations of infinite focus laser projections) such that the projected image or trace is of desired size (see FIG. **7**). The Z-fluid height is manipulated up and down in a process called "surface refreshing" such that a controlled thickness of resin is above the growing printed part (see FIG. **6**). Part of the resin is cured into the growing part, which is progressively submerged under the remaining resin and the Z-fluid as successive layers are printed on the top surface (see FIG. **5**). The printed part ends up under the Z-fluid. In an embodiment of the claimed invention that utilizes water and additives such as sugar, the part ends up underwater when the print is completed (see FIG. **4**D). The flow rate of the Z-fluid dictates both the accuracy of the print and the speed of the print. In one embodiment that has been reduced to practice the Z-fluid has been able to be manipulated with greater than 10 micron precision. In one embodiment reduced to practice the Z-fluid has been able to be manipulated at greater than 350 mL/min in a Cartridge with a volume of about 240 cubic centimeters. Larger Cartridges and/or larger, more sophisticated Z-fluid manipulators could increase this flow rate substantially.

[0033] In accordance with embodiments of the claimed invention, the reaction occurs when the projected light stimulates the resin and triggers a polymerization reaction of the portion of the resin upon which the light is projected. The kinetics of the reaction and the amount of the resin that cures in each successive printing step are controlled through choice of light source, light duty cycle, light intensity, pattern of the image on the surface of the resin and the photo-sensitive portion of the resin. The depth of cure of the resin during the reaction is a product of the interaction of these parameters and the height of the surface refreshing step. The viscosity of the resin as it refreshes over the part during Z-fluid manipulation influences the speed with which iterative print steps can be undertaken. In one embodiment, the reaction can progress in a continuous manner as the Z-fluid is manipulated. In other embodiments, the reaction is punctuated by the changing the image and wavelengths of light on the surface of the resin. In one embodiment, the surface refreshing step is sped up to less than six seconds such that the final part print time occurs within 20 minutes. In another embodiment the surface refreshing step occurs at a speedy rate such that the system appears to be printing continuously.

[0034] In accordance with an embodiment, a revolutionary aspect of the claimed invention is the manner in which the cartridge interacts with the 3D printing system.

[0035] In an embodiment, the resin can be packaged, sealed and sold within the cartridge. Cartridges of different sizes and dimensions contain different amounts of different colored different materials. This allows users to rapidly select from among different combinations when ordering the cartridges and easily switch materials, colors, sizes between successive print jobs without a costly system wide resin purge.

[0036] In an embodiment, the cartridge can interact with the 3D printing system in a way that allows the cartridge to be shaken, twisted, spun, or vibrated in an effort to help control resin settling at increasing small layer thicknesses. For example, this could use piezoelectric or ultrasonic methods to controllably agitate the cartridge. Many designs can be envisioned toward this end and would be obvious extensions of the claimed invention to one skilled in the art.

[0037] In certain embodiments, one or more cartridges are loaded into the system, which allows for quick and convenient Z-fluid manipulation and the printing of the part within the cartridge(s). The system would allow for the simultaneous printing of different materials, different parts, different resolutions and different colors. In an embodiment, it is possible to print up to 100 different custom earpieces at the same time in different colors and made from slightly different modulus materials using this system (see FIG. **2**).

[0038] In an embodiment, the cartridge is comprised of "the casing," "the lid," "the build table," "the fill port(s)" and optionally other interfaces for post processing steps.

[0039] In an embodiment, the cartridge also serves as the final packing material for the sale of a part. For example, a user could enter a brick and mortar store, have a scan made of their ear canal, choose a material stiffness and aesthetics (color, sparkles, texture, etc.). The part would print in real time in front of the user inside the cartridge, which could optionally also serve as the labeled packaging for the produced good.

[0040] In an embodiment, the cartridge contains interfaces such as inlets for compressed air, supercritical carbon dioxide or other methods to control the porosity or density of either the resin of the polymer as it cures. This can be very useful for the printing of foam-like structures or structures with pseudo-random porosity below or above the print resolution.

[0041] In an embodiment, the cartridge may contain a predetermined structure within the cartridge suspended above the resin and well encapsulated. For example a computer chip, an electronics housing necessary to drive speakers, a preassembled earphone, hearing aid, Bluetooth device or other audio component could be preassembled, packaged into the cartridge and packaged with a specific resin composition. Users or businesses could use these pre-fabricated units and print custom earpieces for users on the spot after which a functional post-processing step could enable sophisticated functionality. Other such models in which components are pre-packaged within the cartridge can be likewise envisioned and audio products merely serve as one example and not an exhaustive list of pre-packaged applications.

[0042] In an embodiment, the light source can project images at non-active wavelengths (in the visible spectrum) superimposed on the print surface such that targeted commercial advertising occurs on the surface as the print is taking place. Since watching these prints is a novelty (for now at least), there is a captive audience and target eyeballs and prime real estate for branding high tech products and technologies. Alternatively, an episodic series of short perhaps funny or clever skits or animations could help incentivize and reward use.

[0043] The composition of the cartridge can be made out of materials such that the resin can be easily removed from it. Potential materials include fluorinated plastics (teflon/ptfe), polypropylene, polyethylene, polyoxymethylene, texin, and a variety of others. The cartridge may be injection molded, blow molded, vacuum-assisted resin transfer molded, extruded and shaped, otherwise thermoplastically processed or assembled from individual sheets with adhesive or welding techniques. The cartridge may optionally be fabricated partially or wholly from composite materials, thermoset materials, metals or in rare cases ceramics.

[0044] The composition of the cartridge can be made of materials such that the cartridge is recyclable, within a single or multiple recycling streams. The cartridge may be partially or wholly made out of materials that dissolve or degrade upon exposure to specific stimuli, such as but not limited to heat above a certain temperature, exposure to acids or bases, exposure to solvents or exposure to radiation in the form of the energetic photons.

[0045] In an embodiment, the cartridge is an injection molded part that is filled with the resin and vacuum sealed during manufacturing. The vacuum sealing process occurs such that the sealing material is a film transparent to the light source and resistant to the resin over the specified shelf life of the cartridge.

[0046] There are several different mechanisms as to how z-fluid can be introduced into the cartridge and manipulated while within the cartridge. In all cases, it is important to prevent resin from exiting the cartridge during the print job. In one embodiment, the cartridge is screwed into place, and this action reveals holes in the bottom of the cartridge through which z-fluid can rise. In another embodiment, the cartridge snaps into place, and syringe needles perforate a foil seal. In this embodiment, the bevel on the needles matches in length to the wall thickness of the cartridge. In another embodiment, the cartridge is divided such that the two sides of the cartridge are separated only via a small hole located in the bottom; fluid is introduced in a side without resin to prevent resin from escaping.

[0047] Fluid may be introduced actively or passively. In active systems, Z-fluid is pushed with a pump, usually a syringe or peristaltic pump, but also optionally one of a variety of other types of pumps (see FIG. **8**). Additionally, raising or lowering fluid pressure may be accomplished by manipulating partial pressure or air or another fluid, either pulling vacuum where it is intended to rise, or raising pressure where it is intended to fall. Moreover, in a passive system, the cartridge itself would rise or fall and fluid would flow into or out of that cartridge.

[0048] The cartridge system also opens the possibility for interesting business models. In many, a focus on sustainability is made possible. In one such embodiment, the cartridges are preloaded into a vending machine for a specific customized product. The machine is able to print and remove the part, then any extra resin remains in the cartridge and the cartridge remains in the machine. The used cartridges can then be picked up for proper recycling and reuse. This scenario is in opposition to a system wherein a part is printed in a machine and remaining resin must be flushed or polymerized in order to change colors.

[0049] In another embodiment, the cartridges are prefilled with specific masses of resin, so that a part printed within such the cartridge does not leave residual resin. In a similar embodiment, a facility could be set up where the cartridges are filled to order. This allows end users to select from a wider variety of sizes, materials, and colors, while the inventory is stored in more discretized units.

[0050] There are several different mechanisms by which the print is anchored within the cartridge.

[0051] Two issues that can arise from the distance between the light source and the height of the resin within the cartridge are (i) the focus of the projected light and (ii) the size of the image. The focus of the light can be adjusted or accounted for in several ways including, but not limited to using an infinite focus laser projector, moving the projector to match the height change of the resin when the cartridge is stationary or moving the cartridge to keep the top surface of the resin within the focal plane of the light source. Alternatively in designs of the cartridge in which the cartridge is porous and interacts with an external z-fluid, the light source and the cartridge could move in tandem relative to the z-fluid as the part is printed.

[0052] Embodiments of the claimed invention are directed to several distinct types of cartridges. A cartridge may be picked depending upon the proposed use. The claimed invention allows for variable actuation mechanisms which describe how the distance between the top of the resin and the light source are manipulated.

[0053] F-cartridges: In one embodiment, fixed cartridges called “f-cartridges” are used in which the cartridge is actively filled. The light source moves on the z-axis. The Z-fluid is actively pumped or otherwise manipulated in the z-direction. The cartridge remains fixed on the z-axis. The f-cartridge based system is depicted in FIG. **9**.

[0054] Z-cartridges: In another embodiment, z-axis mobile cartridges called “Z-cartridges” are used in which the cartridge is also actively filled. The cartridge moves along the z-axis to compensate for fluid being pumped or otherwise manipulated. The light source is fixed. A z-cartridge based system is depicted in FIG. **10**.

[0055] S-cartridges: In yet another embodiment, sinking cartridges called “s-cartridges” are used in which the cartridge is porous upon “cartridge activation” such that z-fluid can flow in and out of the cartridge while the resin remains within the cartridges. For example, this is a porous cartridge in which the cartridge moves within the z-fluid while the distance of the light source to top surface of the resin remains unchanged. Specific examples would be printing something in a fixed basin, in a kitchen sink, in a bathtub, in a swimming pool in a pond, in a lake or in an ocean. The z-axis motor or hydraulic pump or other means of cartridge manipulation allows the cartridge to be submerged into the z-fluid during the print process. An embodiment of the S-cartridge system is depicted in FIG. **11**.

[0056] In an embodiment, the printer is compatible with a multi-cartridge system is compatible with all three types of cartridges, f, z and s series. For simplicity this system is shown in the z series in the attached figures, but can be readily made with multiple cartridges in each system.

[0057] In embodiments of the claimed invention, the light source can be stationary or mobile. In embodiments of the invention, multiple cartridges can be included. The number of cartridges can be but are not limited to 4, 16, 25 and 100 cartridges. Most often, multi-cartridge prints are useful when a standard part or several parts needs to be printed in different colors out of different materials. The simultaneous nature of a multi-cartridge system allows this scenario in rapid time.

[0058] In embodiments of the claimed invention, the z-fluid can globally fill all cartridges at one uniform rate or individually fill cartridges at different rates.

[0059] In yet another embodiment of the claimed invention, the z-fluid can be a series of macro, micro or nanoparticles or objects that can be filled into the cartridge to displace resin and manipulate the height of the resin. While this may seem impractical in many but a few specialty cases, this method of manipulating resin height through filling and removing of solid particles can be necessary to limit interaction with certain resins with other fluids. In one specific embodiment, small BB pellets can be fed into a cartridge to alter the build height.

[0060] In yet other embodiments, solid objects could be added into a system that is partially filled with other z-fluid which can limit the size of the pump and z-fluid reservoir needed for larger or more complex prints.

[0061] The accompanying drawings illustrate several aspects of the claimed invention. FIG. **1** depicts (A) the projector, (B) the maximum area ("build envelope") of the projected image, (C) an example projected image where resin cure will actually take place, (D) the resin, (E) the printed part, (F) the Z-fluid, (G) the build table, (H) the cartridge casing, (I) the cartridge lid, and (J) a typical fill port

[0062] FIG. **2** depicts (A) the cartridge as manufactured without lid attached ready to be filled, (B) the cartridge ready for sale and use, filled with a pre-selected amount of resin, (C) the cartridge after loading into the machine, filled with a small amount of Z-fluid, just enough to raise the top surface of the resin to the height for the first printing layer, (D) the cartridge at the end of printing, containing a printed part completely covered by z-fluid with a minimal amount of residual resin on the top surface, (E) the cartridge as removed from the printer, containing no Z-fluid and only a printed part and thin cured layer of resin at the top

[0063] FIG. **3** depicts various arrangements of fill ports and compatible build table designs. When fluid is actively pumped directly into the cartridge, it must be done through a port and is thus practically limited. When fluid is not pumped directly into the cartridge, many more apertures, or even a mesh, can be used. This also applies when the cartridge is moved as in the S-Cartridge system.

[0064] FIG. **4** depicts the sequence of printing steps, comprising (A) the previous layer complete, (B) the Z-fluid added to the cartridge in a sufficient quantity that the resin completely flows over the top surface of the part, (C) the z-fluid removed from the cartridge such that the resin has settled to exactly one print level thick, (D) the active curing image projected onto the part, selectively curing the layer, (E) the layer has cured and bonded to the rest of the printed part and the curing image is no longer displayed

[0065] FIG. **5** shows the top layer refresh consists of the z-fluid rising enough that resin completely covers the printed part, then the z-fluid falling to a level where the resin will settle exactly one layer-thickness above the printed part.

[0066] FIG. **6** illustrates a target distance, at which the image is in focus and of the correct size, as well as closer and further from that target distance such that the image is out of focus (blurry) and either undersized (too close) or oversized (too far from the projector).

[0067] FIG. **7** illustrates that as the printing proceeds, each printed layer is at a different distance from the projector, and thus some active mechanism is needed in order to counter that and keep the image the correct size and in focus.

[0068] FIG. **8** shows that in the fixed cartridge system, as z-fluid is pumped into a fixed cartridge to raise the print level, the projector is raised to keep the focal plane at the resin surface.

[0069] FIG. **9** shows that in the z-cartridge system, as z-fluid is pumped into the cartridge to raise the print level, the cartridge is lowered to keep the focal plane at the resin surface.

[0070] FIG. **10** shows that in the sinking cartridge system, the cartridge is lowered into a bath of z-fluid to raise the print level and there is no change in the distance between the projector and the surface of the resin.

[0071] FIG. **11** shows one of the passive aspects of the system which is the use of relative pressure to manipulate the level of resin without actively pumping z-fluid.

[0072] FIG. **12** shows that in a standard projector, there exists a focal plane outside of which the image is blurred. In an infinite focus projector, however, the image is always in focus. In both cases, the size of the image varies with distance and so must be accounted for.

[0073] FIG. **13** shows that the projector may be positioned in a variety of orientations and the image manipulated using mirrors. In this way, the size of the system is variable.

[0074] FIG. **14** shows that a single projector can print multiple parts using only a section of the available area for each part. At the very least, this allows multiple materials to be printed using separate vats. Ideally, each vat would be independently controlled and parts can be started at different times. In such a system, the position of the cartridge would need to be actively controlled.

[0075] While particular embodiments of the present disclosure have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the disclosure. It is therefore intended to cover in the appended claims all such changes and modifications that are with the scope of this disclosure.

What is claimed is:

1. A 3D printing system comprising:

a light source;

at least one cartridge casing, wherein the casing comprises a fill port; and

a resin that floats on a liquid platform.

2. The system of claim **1**, wherein the resin is located within the cartridge casing.

3. The system of claim **1**, wherein the resin is cured by projecting the light source on the resin inside of one or more cartridge casings.

4. The system of claim **1**, wherein the light source can be of a single wavelength, tuned to different wavelengths, or be a spectrum of wavelengths.

5. The system of claim **1**, wherein the light source has one or more wavelengths ranging from 10 nm to 800 nm.

6. The system of claim **1**, wherein the light source is selected from one or a combination of light emitting diodes, organic light emitting diodes, lasers, excimer lamps, mercury arc lamps, metal halide lamps, fluorescent lights, focused or directed solar radiation, gas-discharge lamps or incandescent lamps.

7. The system of claim **1**, wherein the light source is focused, redirected or positioned through digital mirror displays or shadow masks to control the image that is projected onto the resin.

8. The system of claim **1**, wherein the resin can be made from a variety of monomers and oligomers including, but not limited to acrylates, urethanes, thiols, alkenes, vinyls, styrenics, acetates, fluorinated monomers, isocyanates, ureas, silicones, and epoxides and combinations of these materials.

9. The system of claim **8**, wherein the resin comprises additives such as a photoinitiator, reaction inhibitors, reactive or non-reactive diluents, colorants for aesthetic or functional purposes, antimicrobial particles such as silver micro or nanoparticles, short fiber filler for added toughness, UV absorbers, UV blockers, radical scavengers, or other fillers.

10. The system of claim **1**, wherein the liquid platform is comprised of a base fluid and optional additives, such as, but not limited to, sugar, salt, starch, ions, proteins, or combinations thereof, such that the Z-fluid is more dense than the resin.

11. The system of claim **1**, wherein the system comprises more than one cartridge casing.

12. A process of 3D printing using the system of claim **1**, the process comprising the steps of:

introducing the liquid platform into the cartridge casing through the fill port;

allowing the resin the flow over a printed part or build table;

manipulating the liquid platform from the cartridge casing to allow the resin to settle over the printed part or build table; and

curing the resin by projecting the light source on the resin.

13. The process of claim **12**, wherein the liquid platform and/or resin are agitated, shaken, vibrated or otherwise moved through piezoelectric, ultrasonic or other mechanical means.

14. The process of claim **12**, wherein the height of the liquid platform is controlled vertically in order to control the thickness of the resin.

15. The process of claim **12**, wherein the curing occurs when the projected light stimulates the resin and triggers a polymerization reaction of the portion of the resin upon which the light is projected.

16. The process of claim **12**, wherein the resin is packaged within the cartridge casing and optionally pre-packaged with functional components such as but not limited to electronic chips, audio drivers, structural supports, tubes, hoses, wires or other components which the resin will ultimately be printed on, in or around.

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