Title: HIGH DEFINITION VERSATILE STEREOLITHIC METHOD AND MATERIAL

Abstract: This invention utilizes a novel application of inkjet technology for the express purpose of depositing precisely imaged and layered strata of rapidly crosslinked polymer thereby providing a new stereolithic (three-dimensional) printing method. It is a stereolithic printing system utilizing x, y, and z axes to plot and deposit successive, additive layers of material up to a resolution of 1/10,000th of an inch in thickness or greater, wherein deposited materials are comprised of a two-part activated monomer or oligomer with an appropriate catalyst, to create fully dimensional objects at various sizes. An x/y/z two dimensional precisely deposited plane of liquid monomer, representing a cross section of the object to be rendered, is deposited from one inkjet reservoir onto a heat controlled platen and inkjet dispenser at the same time as a catalyst is deposited selectively on top of the monomer layer by another inkjet dispensing head. As each layer has hardened imaged areas established, the platen is then lowered upon the z axis and the next successive layer of catalyzed material is likewise deposited atop the first. The catalyst is introduced simultaneously with monomer droplets and not onto a preexisting monomer reservoir. Dissolved metal salts which are caused to precipitate out of solution via drop application of reducing agent creates real metal three dimensional objects. Waste control, removal, and created object support methods are an integral part of this invention. Employing multiple sets of inkjet heads can be used to create strata of various different substrates assembling three-dimensional objects in multiple materials simultaneously in a dynamic form such as gaskets in place on a hard plastic object. In addition employing multiple sets of inkjet heads may include the use of process color tinted or pigmented sets of monomer and catalyst to create objects in full lifelike color, with true photographic detail, in either opaque or transparent substrates. Utilizing either four-color process with resolution control and either opaque or transparent base monomer creates a heretofore unavailable degree of color replication and is completely unique to this invention. Control of the droplet resolution settings provides the opportunity to first create a "rough" or lower resolution "draft" of an item before committing to the higher resolution finished item. Invention also employs a novel business method utilizing the internet for downloadable three dimensional article files for consumer printing. This method, method and materials introduce a new low cost, high definition, high versatility method to create three dimensional objects, making this technology more readily available for the mass consumer as well as industry.
HIGH DEFINITION VERSATILE STEREOLITHIC METHOD AND MATERIAL

BACKGROUND

With the advent of compact computers, especially within the past thirty years as computers have entered private households, the growing use of supporting peripheral stations such as fax and printing machines demonstrates a trend for widespread use of the computer to control precision electromechanical devices. Stereolithography machines (those which create three-dimensional objects) are also a class of machines largely controlled by computer, but the unfortunate fact still remains that the cost and complexity of these devices are usually far too high for the general consumer. Thus stereolithography has been the focus mainly of industry for prototyping machine parts and commodity items, and other purposes, all far out of reach of the general populace.

Most stereolithography machines are dedicated for the express purpose of rapid prototyping, a direct three-dimensional representation of an item to be reproduced as a part of a production line or a decorative item in manufacturing. For reasons of clarity, the existing stereolithography techniques will be divided into either a "selective deposition," wherein an item is successively layered in two dimensional planes, thereby forming a three dimensional object: by thermoplastic powder sintering; layered thermoplastic nozzle deposition; or layered thermoplastic fiber deposition, or layered photo-cured monomer; or "activated polymer separation," wherein an item is successively layered in two dimensional planes thereby forming a three dimensional article by selective activation by ionic bombardment or light activated catalysis forming a solid matrix from within a liquid of adequate crosslinking species such as but not limited to, carboxyl or hydroxyl functional monomer.

Most stereolithography systems, such as US patent 4,996,010 and US patent 5,059,359, are rather large, have expensive optical and/or laser components and as with activated liquid polymer, and are often wasteful. Powder sintering techniques, such as US patent 5,948,342, involve a local heating from a newly leveled powder bed. The area heated will shrink by an amount related to the depth and width of a given region and is slightly variable from one spot to another, often requiring a recalibrated pass from some kind of leveling mechanism and precision is somewhat inherently limited as a result. Selective localized deposition as from a nozzle dispenser such as US patent 6,030,199, US patent 5,301,863, and US patent 6,270,335, also require recalibration mechanisms. By introducing a calibrating mechanism, inherent measuring subsystems must also be
employed, thereby also introducing additional costs and time factors not directly utilized for the fabrication of a three dimensional object.

There are alternate liquid candidates which have been utilized to create three dimensional objects in stereolithography such as heated thermoplastic materials which micro-extrude through nozzles to form serially layerwise deposited three dimensional objects. In addition, in other art photo-curable monomers are deposited and hardened through the use of radiation. Various colored materials using this method are vulnerable to radiation attenuation by absorption mechanisms either in the dye or the pigments or in the case of an opaque white monomer mixture rendered nearly useless for rapid radiation curing.

Stereolithography machines that employ the use of scanning radiation, (such as an excimer UV laser), bear the inherent expense of the lasers attendant power supply and precision optics, to say nothing of the maintenance. The ability to precisely pigment or dye these light curable photopolymers is also extremely limited in this type of system.

The accumulation of diffused activated polymer from boundary layers between liquid and activated solid plastic, usually builds up eventually in the liquid reservoir and also raises viscosity and sensitivity problems for the leftover material, which eventually ends up as waste.

BRIEF DESCRIPTION OF THE DRAWINGS

To further clarify the above and other aspects of the present invention, a more particular description of the invention will be rendered by reference to specific embodiments thereof which are illustrated in the appended drawings. It is appreciated that these drawings depict only typical embodiments of the invention and are therefore not to be considered limiting of its scope. The invention will be described and explained with additional specificity and detail through the use of the accompanying drawings in which:

Figure 1 illustrates a head depositing liquid monomer on a temperature controlled platen.

Figure 2 illustrates an ink jet head nearly simultaneously depositing liquid catalyst to immediately cure the monomer into the desired shape. In addition there is a hard shell being created at the same time as the rest of the object to create a holding bin for the partially cured monomer and catalyst.

Figure 3 illustrates curing of the liquid layers and serial deposition atop the hardened layers, where the layers fuse to create one solid object.
Figure 4 illustrates a finished three dimensional object that has been created and is suspended in a moat of uncured liquid monomer, partially cured liquid monomer, or dry monomer sand in a sealed container created at the same time as the object, which can then be washed away by the alternative embodiment of the washing/flocculating component of the machine and stored in a disposal tank or cartridge, or manually washed away as desired.

Figure 5 illustrates an example of a stereolithography machine.

Figure 6 illustrates an example of a stereolithography machine that includes a mechanism for direct UV illumination of droplets as they are ejected from a head of the machine.

Figure 7 illustrates a drop transit catalysis method.

DESCRIPTION OF SEVERAL EMBODIMENTS

Several embodiments of the present invention utilize a novel application of inkjet technology for the purpose of depositing precisely imaged and layered strata of rapidly catalyzed polymer thereby providing a new stereolithographic (three-dimensional) printing method. Several embodiments include a stereolithic printing system utilizing x, y, and z axes to plot and deposit successive, additive layers of material representing cross sections of the object to be printed up to a resolution of 1/10,000th of an inch in thickness or greater resolution. Deposited materials are comprised of a two-part activated monomer or oligomer with an appropriate alternately deposited liquid catalyst, to create fully dimensional objects at various sizes.

Dispensing specifically tailored liquid monomer and catalyst, or the liquid to solid formation of other liquid reactants, for the purpose of three-dimensional layered rendering, is exploited by this invention in a novel and effective manner. Several embodiments relate to inkjet printing in respect that the embodiments may utilize a head similar to that of a conventional inkjet head for the purposes of depositing reactive layers of monomer and catalyst or solutions of metal ion and reducing agents, both of which depend on the finished reaction byproducts to be of a substantially enhanced solid, taking the shape of a three-dimensional object. U.S. patents 4,962,391, 4,520,374, 4,525,728, and 4,546,362, for example, demonstrate the refinements and characteristics of precise dispensing of micro droplets of ink for the specific purpose of printing onto a two-dimensional substrate such as paper which may find similar applicability to the deposition of three-dimensional objects according to the teachings disclosed herein.
Several embodiments also relate to a need for a more economical, and broader range application of stereolithographic technique. The uses of this type of applied stereolithography technique are not limited to solid modeling, but are also unique because of the large variety of materials to be simultaneously employed, and can be of substantial dynamic modeling use as well. Thus, dispensing specifically tailored liquid monomer and catalyst, or the liquid to solid formation of other liquid reactants, for the purpose of three-dimensional layered rendering, is exploited by this invention in a novel, synergistic, and effective manner.

1. Stereolithography Printer Examples

An embodiment of the invention includes a single axis track on which the inkjet head can travel back and forth rapidly with little inertial involvement. Because the inkjet head will move more rapidly than any other motor driven axis, it will not be filled with liquid but rather use liquid-supply catheters from isolated liquid reservoir sources not involved in the motion of the print head, thereby ensuring that the inertial moment of the print head assembly is relatively unhindered by the weight thereof. The inkjet track rests on another carriage assembly capable of moving back and forth in an orthogonal axis relative to the rapidly oscillating inkjet track assembly. This carriage rests on sufficiently stable supports to render precise repetitions of motion and of sufficient height to clear substantial depth of a third axis platform that moves in small incremental steps in the vertical direction.

Catalyst is introduced simultaneously with monomer droplets and not onto a preexisting monomer reservoir. A monomer reservoir represents a greater expense in unused monomer and a medium that transmits vibration induced error. Also, a monomer pool is far harder to control on a layer upon layer basis and is therefore unsuitable for very high tolerances, where as droplet groups have been found to create very precise tolerances and crisply delineated differentiation without bridging between close edges of an image/part.

The embodiments disclosed herein minimize excess waste of monomer wherein the created three-dimensional object is surrounded by a vertical moat concurrently formed of the same solidified material as the object being created. The moat may be filled with uncured liquid monomer, partially cured monomer or a sand-like cured monomer. In this embodiment the vertical moving platform may also have an inlet and outlet micro-tube assembly, which provides for the removal by pumping out of unused liquids, the infusion of washing liquids and their subsequent removal as well.
The entire mechanical assembly is stationed on a leveled platform, the means for which may be provided by screw-adjusted cleats preferably near the perimeter of the bottom chassis or other similar method which will ensure level stability.

Gravity provides for the leveling mechanism necessary for the establishment of uniform layering during the three-dimensional build up of the object. Each liquid layer will remain as a level surface and supporting layer for the solidifying linear infusion of another activating liquid substance that will create the final solid object. The reliance on gravity as the liquid leveling mechanism also eliminates the need for a more expensive and complicated machine element to perform a leveling calibration.

The ink jet head can maintain reasonable control of the thickness of the consecutive layers by simple virtue of its established precision in the printing trade, wherein the resolution of the deposited dots can be controlled via the computer used to activate the printing. Lower resolution items are printed to test or prove a particular design as a draft, and when the draft model is approved the higher resolution full gamut of functions can then be activated.

Several embodiments relate to inkjet printing in that such embodiments utilize a similarly adapted head for the purposes of depositing reactive layers of monomer and catalyst. Knowing that polymerization speeds can be very rapid, it is the purpose of this invention to utilize at least one set of nozzles to deposit a uniform layer of monomer, whereupon a second set of nozzles deposits selective linear/planar tracks or lines of activating catalyst whereby the monomers are prompted to engage in polymerization reactions which render the once liquid monomer into a now solid state. The nozzles and heads may be similar to nozzles and heads used in inkjet printing or may be specialized heads and sets of nozzles.

The head can also include built in alignment and cleaning mechanisms such that alignment of droplets of monomer and catalyst may be accurately controlled and residual monomer and catalyst is removed from the jets of the head.

Solutions of metal ion such as basic solutions of nickel sulfate, nickel chloride and copper sulfate, or metal salts established for electroless deposition such as cupric gluconate, ferrous sulfate and stannous chloride can likewise be deposited in a manner similar as the monomer layers are deposited by the head and reducing agents, such as those which are likewise established for electroless, or otherwise known as autocatalytic use, are deposited by another special set of nozzles similar to the way catalyst is deposited, that is, in selective linear/planar patterns which also correspond to a cross-
sectioned area of a three dimensional object, thereby causing metallic deposition which is precipitated by means of selective reducing chemicals such as palladium chloride, platinum chloride, rhodium chloride, formaldehyde, glucose and many others of the metal plating art of which, depend on the reduced finished reaction byproducts becoming a substantially enhanced multilayered accretion and thus when finished, a homogeneous solid, which takes the shape of a three dimensional object.

In one embodiment of direct electroplating via electrode and cathode, the platform floor of the z stage assembly is the electronegative collector or cathode and an externally applied anode metal bus tipped with carbon, platinum or a conductive plastic membrane and the deposition process is applied selectively thereby in a preformed solidified negative mold of plastic by the same invention by a precursor forming step which forms the mold. Then it is after this mold that metallic deposition with heavier rates of deposition is possible inside the preformed hollow mold with the precursor plastic mold having a microtube assembly both infusing fresh electrolyte and evacuating the exhausted portion of the same. In this manner, greater flux of metal ion are communicated in shorter amounts of time.

The uses of this type of applied stereolithography technique are not limited to solid static modeling, but because of the large variety of materials to be employed, can be of substantial dynamic modeling use as well. Interworking parts such as a working clock can be fabricated in situ without further assembly requirements.

Ceramic investment casting can also be employed by similar process whereby a ceramic suspension is injected into the preformed plastic mold and the water from the suspension is removed by ionic migration from an applied electric field from the same apparatus used for metallic electrodeposition. The same dehydrated (greenware) ceramic core can be fired in a refractory sintering furnace by any kiln established in that art for this purpose and the surrounding hydrocarbon plastic material is also thus pyrolized away.

An embodiment of the invention includes a single axis track on which the inkjet head can travel back and forth rapidly with little inertial involvement. Because the inkjet head will move more rapidly than any other motor driven axis, it can use liquid supply catheters from stationary isolated reservoir sources not involved in the motion of the print head, thereby insuring that the inertial moment of the print head assembly is relatively unhindered by the weight thereof.
The ink jet track rests on another carriage assembly capable of moving back and forth on a Y axis track in an orthogonal axis relative to the rapidly oscillating inkjet track assembly. This carriage rests on sufficiently stable supports to render precise repetitions of motion and of sufficient height to clear substantial depth of a third axis platform that moves in small incremental steps in the vertical direction and is surrounded by a Z axis platform enclosure.

The Z axis platform travels upon three or more vertical screw elevators which are driven by a common drive belt through pulleys on free turning bearings and are powered by a gear reduced stepper motor. The vertical moving platform also has an inlet and outlet micro-tube assembly which provides for the pumping out of unused liquids, the infusion of washing liquids and their removal as well. The single reservoir of washing fluid is maintained by an internal filter and flocculating chemical system which ensures the economical and efficient fresh replenishment of the same.

The entire mechanical assembly can be stationed on a leveled platform, the means of which is provided for by screw adjusted cleats preferably near the perimeter of the bottom chassis. Gravity provides for the leveling mechanism necessary for the establishment of uniform layering during the three-dimensional build up of the object. Each sequential liquid layer remains as a level surface and supporting layer for solidifying linear infusion of another activating liquid substance that will create the final solid object.

The reliance on gravity as the liquid leveling mechanism also eliminates the need for a more expensive and complicated machine element to perform a leveling calibration. The ink jet head can maintain reasonable control of the thickness of the consecutive layers by simple virtue of its established mechanical precision in the printing trade for dispensing discrete droplet volumes and also from software control over the shape and number of droplets or resolution at which they may be dispensed.

Companies such as Epson, Hewlett Packard, Cannon and Buskro Atlas, to name a few, all have interrelated inkjet technologies available for specific printing applications with printing speeds for dot per inch resolutions as high as 4800, that vary from typical values of two - 8 1/2x11 inch sheets of paper per minute up to 500 - 8 1/2x11 inch sheets per minute.

With speeds as high as 1000 deposition layers per minute over a Z platform area of 4 1/4x5 1/2 inches according to the teachings herein, a model of one square mile of Manhattan in 10 minutes can have resolution high enough to discern the wheels and
windows of taxicabs on the streets below the skyscrapers or incorporate workable tolerances for a dynamic model of a V-8 internal combustion engine on the same Z platform area as the Manhattan model with speeds as fast as one minute.

Prior art inkjet-based rapid prototyping systems lack accuracy because they don't make use of the resolution characteristics of inkjet technology. Rather, such conventional embodiments often require milling or skiving operations to achieve the accuracy required for most uses. The net result is that less accuracy is available and a fabricated object will have an inaccurate representation of the intended shape. Thus, improved initial deposition accuracy is a central focus of the embodiments disclosed herein.

Rapid catalysis utilizing a dot monomer to dot catalyst deposition method is not as vulnerable to expansion deformity as large volume structures are. Catalysis may occur as rapidly as a few microseconds or even fifty milliseconds. Heat loss and material stability are controlled in the picoliter range and by the time another layer is deposited in the "z" axis on top of the this layer latent heat of polymerization has already reached equilibrium.

Axes may be plotted through the use of a three dimensional drafting computer software in which a three dimensional rendering is abstracted using the x, y and z axes. Each layer corresponds to a cross section of the finished object.

According to the teachings disclosed herein five fundamental problems associated with three dimensional prototyping may be addressed. The first is a local resolution limit established variously by optical refractive parameters, diffusion due to local light scattering or heat as is the problem in many methods heretofore employed. The second is due to speed limitations set forth in powder sintering and many liquid solidification processes, by the need to make every successive layer leveled with a separate non imaging calibration pass. The third is the requirement for massive amounts of liquid monomer, much of which is eventually non-image waste and the gross expense to cure through laser or similar method. Fourth is an inability to simultaneously use a wide variety of structurally versatile materials suitable for dynamic modeling. and fifth is an inability to create fully realistic objects in photographic color in opaque and transparent substrates.

The teachings relate to the resolution limits by experimentally applied use of an ink droplet delivery system with droplet size of monomer and catalyst with secondary heat coordination controlling the shape and uniformity of successive layers. With this type of dual monomer and catalyst droplet application, limited induced local reactivity, has established resolution limits to within one ten thousandths of an inch.
An x/y two dimensional precisely deposited pattern of liquid monomer is deposited from one ink jet reservoir onto a platen by an ink jet dispenser at the same time as a catalyst is deposited selectively on top of the monomer dots by another ink jet dispensing head. As each layer has hardened image areas established, the platen is then lowered upon the z axis and the next successive dot layer of material and catalyst is likewise deposited atop the first. An outside heat source or temperature controller may be employed to accelerate or retard polymerization.

The speed of this process is established mainly by the droplet delivery system which doesn't require time consuming alternate layer calibration, can be amplified by stacked arrays, additional image software support, and electromechanical hardware support.

In the embodiments disclosed herein, the catalyst is introduced simultaneously with monomer droplets and not onto a preexisting monomer reservoir. A monomer reservoir represents a medium that transmits vibration-induced error. Also, a monomer pool is far harder to control on a layer-upon-layer basis and is therefore unsuitable for very high tolerance work, whereas is employed in this new invention, droplet groups have been found to create very precise tolerances and crisply delineated differentiation without bridging between close edges of an image/part due to dendritic branches or other random formations. In addition a monomer pool creates a greater expense in unused monomer.

While there are many patents regarding support systems for created objects undergoing the stereolithographic process, there is presently little addressing of volume of waste or disposal. Waste management and support for the object as it is created can be simultaneously achieved and controlled by the employment of a novel "sand bed technique," whereby supportive material similar to powder sintering layers is deposited by catalyst droplet dithering, which prevents the fusion of adjacent droplets while contributing a solid, fluidized, open-celled sand-like volume by which to support island and negative angled portions of a built up three dimensional image, and also provide a means by which waste monomer is safely evacuated. A moat or otherwise obvious shell like structure is simultaneously built up with the image/part and surrounds the three dimensional image/part thereby limiting also a great deal of excess investment in monomer.

In its preferred embodiment the item created in a clear glass or plastic, sealed chamber of the machine and a washing system is employed. Within this chamber the object has been created on the z platform, and it has been created within its own sealed
catalyzed shell, which had been simultaneously formed with it. The draining of the materials would take place within the sealed newly formed shell. The internal flocculating/washing mechanism in the unit would then be employed to rinse the newly created item and drain away any uncured or partially cured material storing it in a cartridge for easy, non-hazardous disposal along with the fully cured sand-like support material. This is better for both the ease of the user and the environment.

The use of a temperature controlled platen is also preferred, wherein the reaction rates of selected monomer or oligomer, or other unsaturated precursor to a heavier molecular weight of solid plastic and control of catalyst dot size can be embodied.

Also preferred, the platen should be of a conductive material capable of functioning as cathode or electrode which is highly resistant to chemical erosion of strong acids or alkali. The purpose of the electrically conductive platen is for the electrodeposition of metal salt solutions or of dissolved metal solutions into the direct formation of successively layered three dimensional parts. Virtually any metal or alloy may be tailored into the shape under construction with the native material properties of the resulting metal varied according to specification, and herein again, a platen capable of controlling heat in the reaction zone is of great benefit.

The z-axes platen is not preferred to move in either the x or y axes because the precise leveling effect of gravity upon the layers of liquid eliminates the need for a calibrating correction of another mechanical device. Any tangent motion introduced into the z-axes platen stage would contribute perturbed disturbances in the form of micro ripples thereby distorting the desired 3D image. The preferred embodiment will for the same reason have leveling cleats attached to the bottom of the invention and these also, mounted on shock isolation pillows.

The degree of precision with which objects can be created with this invention is basically limited to the precision of the ink jet head. With regard to precision capacity 1200 dpi and greater are readily available in ink jet heads, and finer are available in certain others. Regarding materials used, it has been established by experiment that a dot of reactive catalyst will have its diffusion rate arrested by the surrounding reactive precursor and that the dot gain of the catalyst can be controlled by the limiting speed of the surrounding precursor reactants.

A piezo-delivery system is a more desirable method for the application of monomer in some embodiments. Piezo jet heads are desirable because of droplet delivery, and also because the heating element common to a bubble-jet heads, such as is
employed by Hewlett Packard, can create side reactions and charring with many of the substances and chemical combinations used by the embodiments disclosed herein. Therefore, the use of a peizo-delivery head may have additional advantages when used with the embodiments disclosed herein because of secondary and unexpected effects due to the side reactions and charring associated with inkjet heads.

It is already well known by chemists in polymer science that usable plastic objects such as acrylic or styrene containers have catalyst emissions reduced to near zero amounts because of polymer entrapment. Similarly, inkjet heads containing inhibitors such as hydroquinone can be employed to quench the specific boundaries of reaction zones. Keeping the inhibitor separate rather than in combination with a monomer (which is also possible) is preferable to create the strongest boundary or "safety zone" for reaction control. This method of localized inhibiting imagery can be employed also for the purpose of defining three dimensional objects, for example the quenching agent serves as a masking element to delineate deposited material borders.

An alternative embodiment employing multiple sets of inkjet heads can be used to create strata of various different substrates assembling three dimensional objects in multiple materials simultaneously in a dynamic form, providing the catalysis of one liquid is not unduly inhibited by another so as to prohibit accurate deposition.

Another alternative embodiment employing multiple sets of inkjet heads includes the use of tinted sets of monomer and catalyst to create objects in full lifelike color, with true photographic detail, in either opaque or transparent substrates. Utilizing either four-color process with resolution control and either opaque or transparent base monomer creates a heretofore unavailable degree of color replication and is completely unique to this invention.

Control of the droplet resolution settings provide the opportunity to first create a "rough" or lower resolution "draft" of an item before committing to the higher resolution finished item.

Low resolution or rough draft two dimensional prints are easy because the paper provides the support for more widely spaced drops of ink. In three dimensions, the dots need to be interconnected in three dimensional space. According to an embodiment, droplet size can be increased to create a lower resolution rough draft. In other embodiments, a honeycomb, or other pattern, can create a more open celled structure for "rough" draft objects. Indeed the center of an object can be hollowed thereby conserving monomer. Thus, according to the teachings herein a level of resolution may be selectable
resulting in changes in droplet size, creating selective voids, patterns, and other manner in which the resolution may be reduced and/or monomer may be conserved while still generating an object at a desired lower resolution setting.

Objects can be built in the most economical way possible, including consideration for transparency versus opacity, color, and solid versus detail. Thus, software may be configured to control droplet size, pattern, color, opaqueness, texture, and other aspects of the manner in which the object is generated. These attributes can also be controlled base on other aspect, such as the size of the object generated. For example, where an object is larger, the droplet size can be increased such that the larger object is generated in a shorter amount of time than it would otherwise with a smaller droplet size.

These alternative embodiments can be combined to any degree or at any size to provide complete replication of real objects with remarkable accuracy.

An alternative embodiment employing multiple sets of ink jet heads can be used to create strata of various different substrates assembling three dimensional objects in multiple materials simultaneously in a dynamic form, providing the catalysis of one liquid is not unduly inhibited by another so as to prohibit accurate deposition.

Another alternative embodiment employing multiple sets of ink jet heads includes the use of tinted or pigmented sets of monomer and catalyst to create objects in full lifelike color, with true photographic detail, in either opaque or transparent substrates, all of which are comprised of the appropriate monomer and catalyst additives. In addition glitters and metalized pigments can be used to create the appearance of metal in a polymer base.

According to the teachings herein, multiple catalysis curing cycles may be used. For example, in some embodiments a B-staging catalysis curing cycle may be implemented to provide a first level of polymerization prior to a final catalysis curing cycle wherein a final level of polymerization is achieved. Such embodiments may include multiple mechanisms for enabling each curing cycle. For example, a first curing cycle may include a UV-catalysis cycle accomplished using a UV irradiating mechanism followed by a second isolated heat-accelerated catalysis enabled using a heat conductive mechanism. Each cycle can include any combination of reactive energy introduced to cause catalysis, such as UV irradiation and heat transfer.

The first curing cycle may be implemented to manipulate a first level of polymerization such that droplets of monomer more closely (or substantially) retain a three dimensional spherical shape. However, each droplet of monomer may be only
partially polymerized such that each droplet retains a level of elasticity and the ability to adhere to subsequently applied droplets. Subsequently, a second curing cycle (or multiple subsequent curing cycles) can create a final hardening catalysis of the polymer such that the generated object substantially retains its intended final shape in a fully cured state.

To allow such multiple catalysis curing cycles, a UV light source may be placed in a location such that a first catalysis curing cycle can be initiated by illumination prior to the reactants being applied to a substrate. For example, referring to Figure 6, a head 600 is shown for application of a prepeg catalyst/monomer/diluent composition 605 as discussed in further detail in section 2 of this application. The droplets 605 are irradiated by a source of light 610 that directs light 610 substantially perpendicular to a flow direction 615 of which the droplets 605 are applied. Thus, the light 610 is irradiated directly upon the droplets 605 and at an intensity to initiate a first stage of catalysis of the droplets 605. Radiation of any electromagnetic radiation of various wavelengths may be used and may be tailored to the particular reactants being ejected from the head 600.

The light source 610 can include a silicon based light source, such as a laser or light emitting diode in combination with a waveguide for directing such light. The light source 610 can be incorporated into the head 600 such that the light source 610 travels in the x-axis and y-axis with the head 600 to deliver the direct irradiation to the airborne droplets 605 prior to application of the droplets 605 to a surface of a heated Z-stage 620. In this embodiment, UV irradiation on the deposited surface 625 may not be desirable as the droplets 605 of the prepeg composition are only catalyzed for the purpose of creating a more localized lobe shaped nucleus for a second droplet of monomer which surrounds the catalyst nucleation lobe and thereby forms its own surrounding polymer material layer in similar shaped fashion. This form of extended catalysis is initiated under the first UV influence cracks a cationic catalyst which can further finish catalysis without the aid of UV light, but controlled very precisely with the addition of application of heat in the deposit zone by the heated Z-stage 620, for example.

The multi-stage catalysis curing cycle can be activated by separate monomer and catalyzed droplets. For example, referring to Figure 7, a view of a drop transit catalysis method is illustrated. UV light 700 irradiates a catalyst droplet 705 at right angles only exposing it before it at the beginning of its path to a substrate 710.

A monomer droplet 715 from another nozzle lands over a nucleus catalyst droplet target 720, coating it where it is held captive for final diffused curing. The catalyst chemical material is composed of a UV activated lewis acid. The lewis acid will continue
a heat accelerated cure cycle even after it is no longer under the influence of UV irradiation. The monomer droplet 715 may be colored by a transparent dye or by opaque micro pigments and will cure readily after combining around the catalyst nucleus 720. The nuclear catalyst droplet 705 can be finely tailored with ingredients that retard curing, disperse catalyst concentration, disperse monomer concentration or any combination thereof. The nuclear catalyst droplet 705 can be hereby designed to acquire just enough gel like properties after UV irradiation, that it does not flatten out upon impact with the substrate 710 and maintains a small highly localized voxel position but is still liquid enough to permit catalyst diffusion into the monomer droplet 715 which lands over the catalyst droplet nucleus 720 as an encapsulant bead. The polymerized encapsulant bead has many times the strength and adds significant volume to the finished voxel. Multiple voxels build up serially in layers to form 3D objects and retarded cure gel voxels can substitute as support media in a way similar to the 'sand bed' theme and also wash away later with the use of detergent/solvent mixtures. Epoxies comprise a very large part of the material benefits available to the monomer chemicals which are available. Cationic curing will cure virtually all of the epoxy monomers and oligomers in the market. Latent heat free radicals can also be employed for such monomers such as acrylics and acrylated urethanes and combined to great advantage with cationic systems. Epoxy, Elastomers, Acrylics, Silicones and many other plastic materials can be used in this type of curing system or in conjunction with others as symbiotic materials.

2. Examples of Reactants and Reactant Products for Use with the Stereolithography Printer

Several candidate materials are viable for implementation of this invention. Among them are several acrylic, epoxy, polyurethane and silicone monomer systems, which are monomer, copolymer, elastomer and oligimer in origin. Virtually any polymerizable material and catalyst can be used. A vast variety of material characteristics have been explored and an even vaster material base of choosing is envisioned.

The selection and formulation of monomers for homopolymer and copolymer formation need to and can have adaptive chemical and environmental compensation for tuning the reaction rates, exothermic accumulation and density modulations. Such chemical manipulation includes a thermostatically controlled conductive core under the Z stage platform that virtually tunes in the peak values needed for rapid polymerization and
also supplies a more even temperature gradient which greatly reduces the exothermic density distortions across the reaction threshold.

Flexibleizing additions such as aliphatic oligomers greatly reduce internal stresses generated from rapidly polymerized plastic masses. The abilities of the state of the art inkjet dispensing mechanisms are matched with monomer formulations that will solidify rapidly enough so as to be cured before the next layer of monomer is applied on top. Viscosity of various monomers can be thinned by heat elements in the catheter members and the inkjet head as well because only fairly thin liquids can be dispensed through an inkjet head (typically less than 200 centipoise).

This invention relies on a head, such as a conventional inkjet printing head or specialized printing head, adapted for the purpose of generating discreet, single or multiple consecutive laminar strata which generate three dimensional representations or models of an object. Such printing heads may be integrated with an appropriate mechanism for generating a geometrical x axis, y axis, and z axis and with a variety of software capable of executing machine codes by computer consistent with real deposition of that corresponding three dimensional representation.

The liquids deposited by a first head are activated by a chemical reaction by another liquid of at least one other head to precipitate from a concentrated solution a metal, or to crosslink an unsaturated species of chemical precursor so that it solidifies thereby, will be comprised of materials such as but not limited to acrylate liquids. The monomer liquids can be comprised of member of the acrylate family, such as the following examples:

- monofunctional acrylates such as methylmethacrylate, polypropylene glycol monomethacrylate, polypropylene glycol monoaacrylate;
- difunctional acrylates such as polyethylene glycol diacrylate, alkoxyalted aliphatic dioldiacrylate, or any difunctional diol of alkoxyalted aliphatic dioldiacrylic;
- trifunctional acrylates such as trimethol propane triacrylate, glyceryl propoxy triacrylate, or any propoxyated group between 3 and 9 of glyceryl triacrylate;
- the highly alkoxylated triacrylates and tetrafunctional acrylates such as di-trimethylol propane tetraacrylate;
- pentafunctional acrylated esters; and
aliphatic urethane acrylates, aliphatic urethane acrylates, urethane methacrylates, aromatic urethane acrylates and epoxy acrylates, silicone acrylates.

The acrylates can be catalyzed by free radical catalysts, wherein the catalysts are comprised of any hydrocarbon based peroxide with pendant peroxide group which are easily liberated such as methylethylketone peroxide, acetone, or peroxide.

Catalyzations can be improved through the use of reactive synergists. The reactive synergists increase the speed and efficiency of reaction such as an amine coinitiator, or vinyl ether. Any other monomer and catalyst combination may mimic the functionality of those herein named so as to have similar acrylate functionality.

Epoxy liquids can be used where the epoxy liquids are comprised of members of the epoxy family. For example, epoxies including Bisphenol A epoxies, Bisphenol F epoxies, epoxy creosol novolacs, epoxy phenol novolacs, cycloaliphatic epoxies, aliphatic epoxies, or any unsaturated hydrocarbon molecule with at least one oxyrain ring that is liquid can be used.

Epoxies can be catalyzed by specific initiators. Examples of such initiators include:

- The family of Lewis Acids, which are initiating homopolymerization through either blocked or unblocked cationic initiators, such as iodonium salts of hexofluoro antimonates, hexafluoro phosphate, or hexacloro phosphate;
- The cycloaliphatic amines family of co-reactive or copolymerization initiators, such as aliphatic amines, cycloaliphatic amines, unsaturated polyamids, aromatic amines, or phenaalkamines;
- The vinyl ether family of co-reactive or copolymerization initiators. The initiators may be from the cyanate ester family of co-reactive or copolymerization initiators;
- The initiators may be from the diisocyanate family of co-reactive or copolymerization initiators;
- The anhydrides family of co-reactive or copolymerization initiators, such as methyl tetrahydrophthalic anhydride, or hexahydrophthalic anhydride; and
• The polyester family of co-reactive or copolymerization initiators having reactive double bonds.

Catalyzations can also be improved through the use of hardeners. The hardeners increase the speed and efficiency of reaction such as an amine coinitiator.

Polyester liquids can be implemented, wherein the liquids are comprised of members of the Polyester family such as polyesters including aliphatic and cycloaliphatic polyesters, or polyester which are viscosity modified by styrene monomer. Polyesters can be catalyzed by specific initiators wherein initiators are can be catalyzed by free radical catalysts. Such catalysts are comprised of any hydrocarbon based peroxide with pendant peroxide group which are easily liberated such as methylethylketone peroxide, acetone, or peroxide.

Catalyzations can also be improved through the use of reactive synergists. The reactive synergists increase the speed and efficiency of reaction such as an amine coinitiator, or vinyl ether.

Any other monomer and catalyst combination may mimic the functionality of those named herein so as to have similar polyester acrylate functionality. Styrene monomers which may be coreacted with the monomer and catalyst combination. Also, polyurethane liquids, polymethyl diisocyanates, organopolysiloxanes, organo butyl polysiloxanes, organosloxane catalyst, tin and platinum catalysts, liquid crystal monomers, pseudo sugars, sterols and others, wherein any other monomer and catalyst combination may has the functionality of those herein named so as to have similar monomer and catalyst functionality with appropriate speed, viscosity and reaction zone properties.

Complete polymerization reactions can vary in speed from several hours such as an epoxy potting formula, to reactions so rapid that they occur in femtosecond flashes of time such as polyacetylene created after pressure autodetonation of acetylene monomer.

The liquids used can be formulated to cure to varying durometers and tints anywhere from materials such as smooth soft rubbery flesh tone, to rigid brightly hued plastic that looks like stained glass or pigmented to look like gold, or even deposited of metal salts to create real metal objects.

A plurality of dyes or micro suspended pigments wherein the chromophore is part of a negative ion such as a sulphonate or contain a chelated metal ion, or the chromophore is a basic positive ion such as an amine salt or ionized imino group, or any of the family
of color precursors originating from keto groups wherein further reduction into the leuco form can be further oxidized to a pigment precipitate, those dispersive dyes, reactive dyes, pigments containing surface deposits of dye on either an organic substrate or on an inorganic substrate or any inorganic metal or oxide thereof which has native finish and color characteristics with visible spectral absorption and emission bands, with small dimensions capable of traversing the narrow apertures of the depositing inkjet head of claim one and which are chemically stable and resistant to molecular fragmentation during at least one type of polymerization reaction, for the purposes of establishing decorative enhancement to the three dimensional object.

As discussed above, multiple curing stages may be implemented. In such embodiments, a 3-part chemical prepeg catalyst material may be used. The 3-part chemical prepeg catalyst material can be specifically formulated with a portion of monomer (for the purpose of starting a partially cured B stage polymer network), a portion of nonreactive diluent (for the purpose of retarding 100% cure of the monomer and compromising the polymers full strength and other material properties), and a photosensitive cationic catalyst of a percentage sufficient to initiate partial polymerization but also of a percentage which is sufficient to remain latent until a final cure of second surrounding monomer material is deposited on it.

Local heat can finish the reaction products in a full polymerization. Cationic catalysts have a property whereby, unlike free-radical curing processes, the cationic released lewis acids will continue to promote polymerization after primary initiation with the UV irradiation. Secondary additional heat is very effective at extending the finished curing process over a longer period of time, thereby allowing exothermic reactions to continue in a more relaxed manner. Polymer surfaces with a slightly more controlled catalysis reaction are also smoother, less reticulated, and generally have better material properties than other method previously used. According to this method, upon microscopic examination, the droplets formed in the former embodiment, have wider less localized pancake-like structures. However, the refined embodiment herein forms smaller, higher resolution polymer dots.

The purposeful multi-staging catalysis method becomes of increased importance in many applications. As disclosed herein, in such applications it is not necessary to maintain local shape integrity to have 100% curing occur in a fraction of a second, droplet upon droplet. As objects become larger and larger, for example, exothermic distortions will predominantly influence structures which require high resolution with resolution-
limiting inclusions and warping. The application of a first activating UV-catalysis coupled with second UV isolated second heat-accelerated catalysis is unique as a single design intent and design function.

3. Examples of Additional Advantages and Applications of the Teachings Disclosed Herein

This invention may surpass the resolution limits of the conventional stereolithographic methods by incorporating a monomer dot to catalyst dot resolution. Using this method, small discreet smooth edged structures of high uniformity and repeatability are rendered. This invention also permits the use of more than one catalyzable material simultaneously with another. Thus, several embodiments permit object formation in full photorealistic color in both transparent and fully opaque materials.

The catalyst is introduced simultaneously with monomer droplets and not onto a preexisting monomer reservoir. In addition, a conventional monomer reservoir as discussed in the background section represents a medium that transmits vibration-induced error. Moreover, a monomer pool is much more difficult to control on a layer-upon-layer basis and is therefore unsuitable for very high tolerance work. Whereas as employed in this invention, droplet groups have been found to create very precise tolerances and crisply delineated differentiation without bridging between close edges of an image/part. In addition, a monomer pool creates a greater expense in unused monomer.

The embodiments disclosed herein reduce the expense and complexity of precision stereolithography by the elimination of previous mechanisms and techniques that produce the highest expense or inhibition of speed, accuracy and/or ease of use. In addition, the embodiments disclosed herein allow for use of more than one material simultaneously forming three dimensional objects and creation of full color, photorealistic three dimensional objects in opaque or transparent materials. When combined with three dimensional modeling, the creation of this economical process for stereolithography enables the general populace to access this technology for engineering, research, artistic and hobby applications via the common personal computer.

Typically CAD, Solid Works or other three dimensional modeling software is used to create objects in the industrial sector however with the advent of three dimensional gaming programs, animation and other software the general populace by means of a simple interface enables a user to utilize the availability of object downloads off of the worldwide web to print out three dimensional objects at home. These would
include items ranging from licensed cartoon figures and other toy, home, and office to apparel accessories made available through joint ventures with the appropriate business. Thus, one aspect of the present invention relates to a point of sale enabling a consumer to remotely purchase and download digital instructions for locally fabricating a product using the stereolithographic printer disclosed herein.

This invention, in its smaller form, will easily serve as a peripheral extension analogous to a desktop printer. In fact, in an alternative embodiment it is created to function as a two- or three-dimensional printer to give the user complete freedom in one unit, with replaceable monomer cartridges.

Such peripheral extensions also enable a new point for licensing 3D art from toy, hobby, restaurant or other theme generated objects of a copyrighted nature that are popular for general consumer use. For example a McDonald's Happy Meal Action Figure, a Disney animated character, a Power Rangers action figure, Mattel Barbie doll accessories, such as shoes or belts, Special Martha Stewart Christmas tree ornaments, rubber stamps, Swarovsky Crystal jewelry items, or any other copyrighted objects for sale may be made utilizing the capacity of the internet to permit consumers to download via an exclusive licensing agreement with revenue generated for both licensor and licensee. Thus the licensing and exclusivity to different manufacturers or owners of commercially viable and popular entertainment or novelty items intellectual property may be enabled at a new point of sale as a result of the convenience offered by the embodiments disclosed herein.

The ability to download such copyrighted, or otherwise proprietary, designs for manufacture by the stereolithographic printer can be enabled by use of a computer connected to both the stereolithographic printer and an internet connection along with software stored on the computer for downloading the data files representing instructions for controlling the stereolithographic printer to construct the three dimensional objects. The computer may also store licenses for later access.

Larger, and or more complex stereolithography units of this invention can also be made to create industrial rapid prototyped items as large as an automobile with several types of materials in place, in color, in a way that heretofore was thought of as impossible, or impossibly expensive.

The invention may improve both the ease and economic viability of stereolithography, as well as increase the capability currently available form existing stereolithography methods. These benefits may extend to both the industrial sector for
quality, speed, cost and versatility, and for the private general consumer who will have a completely new arena for creativity and utility available to them. In addition this invention greatly expands the versatility and variety of materials and provides the ability for users at both professional and consumer levels to create items in photorealistic color in both transparent and opaque versions, metallic objects, and objects comprised of more than one type of material simultaneously deposited.

Advantages of this invention are numerous over current technology. These and other aspects of the present invention will become more fully apparent from the following description and appended claims.

It should be understood that the drawings are diagrammatic and schematic representations of such example embodiments and, accordingly, are not limiting of the scope of the present invention, nor are the drawings necessarily drawn to scale. The present invention may be embodied in other specific forms without departing from its spirit or essential characteristics. The described embodiments are to be considered in all respects only as illustrative and not restrictive. The scope of the invention is, therefore, indicated by the appended claims rather than by the foregoing description. All changes which come within the meaning and range of equivalency of the claims are to be embraced within their scope. Detailed descriptions of apparatus and processing techniques known in the field of the invention to one of ordinary skill in the art have been excluded.
We claim:

1. A machine and method utilizing a plurality of inkjet printing heads adapted for use with at least one specialized molding liquid and one activating liquid which promoted solidification of the molding liquid and which is integrated into an appropriate mechanism for generating a geometrical x axis, y axis, and z axis and with a variety of software capable of executing machine codes by computer, which permits the accurate and immediate dot to dot deposition of one liquid upon the other for the purpose of accurate volume limited catalysis applied for the purpose of generating discreet, single or multiple consecutive laminar strata or cross sections of an object, wherein each layer corresponds to a cross section of the finished object which, as stacked one upon the other generate fully three dimensional representations or models of an object.

2. Adapted inkjet head as in Claim 1 for the purposes of depositing reactive layers of monomer and catalyst or solutions of metal ion and reducing agents, both of which depend on the finished reaction byproducts to be of a substantially enhanced solid, taking the shape of a three dimensional object; adapted for use with specialized molding liquids and integrated into an appropriate mechanism for generating a geometrical x axis, y axis, and z axis for the purpose of generating discreet, single or multiple consecutive laminar strata or cross sections of an object, wherein each layer corresponds to a cross section of the finished object which, as stacked one upon the other generate fully three dimensional representations or models of an object.

3. In the machine of Claim 1 the ink jet track rests on another carriage assembly capable of moving back and forth on a Y axis track in an orthogonal axis relative to the rapidly oscillating inkjet track assembly. This carriage rests on sufficiently stable supports to render precise repetitions of motion and of sufficient height to clear substantial depth of a third axis platform that moves in small incremental steps in the vertical direction and is surrounded by a Z axis platform enclosure.

4. In the machine of Claim 1 the Z axis platform travels upon three or more vertical screw elevators which are driven by a common drive belt through pulleys on free turning bearings and are powered by a gear reduced stepper motor. The vertical moving platform also has an inlet and outlet micro-tube assembly which provides for the pumping out of unused liquids, the infusion of washing liquids and their removal as well. The single reservoir of washing fluid is maintained by an internal filter and
5. The machine in Claim 1 wherein the z-axes platen does not move in either the x or y axes with leveling cleats attached to the bottom of the invention, mounted on shock isolation pillows or similar leveling mechanism.

6. The mechanism or system in Claim 1 utilizing x, y, and z axes to plot and deposit successive, additive layers of liquid material up to a resolution of 1/10,000th of an inch in thickness or greater, wherein deposited materials are comprised of a two-part activated monomer or oligomer with an appropriate catalyst, wherein these liquids are catalyzed to harden and bond with the previous layer, thereby creating seamless fully dimensional objects at various sizes.

7. Wherein the liquid as in Claim 1, particularly wherein at least one inkjet depositing head distributes a liquid which is activated by a chemical reaction by another liquid of at least one other inkjet depositing head to precipitate from a concentrated solution a metal, or to crosslink an unsaturated species of chemical precursor so that it solidifies thereby, utilizing a plurality of materials including but not limited to:

Acrylate liquids wherein monomer liquids are comprised of member of the acrylate family

- monofunctional acrylates such as methylmethacrylate, polypropylene glycol monomethacrylate, polypropylene glycol monoacrylate;
- difunctional acrylates such as polyethylene glycol diacrylate, alkoxylated aliphatic dioldiacrylate, or any difunctional diol of alkoxylated aliphatic dioldiacrylic;
- trifunctional acrylates such as trimethol propane triacrylate, glyceryl propoxy triacrylate, or any propoxylated group between 3 and 9 of glyceryl triacrylate;
- the highly alkoxylated triacrylates and tetrafunctional acrylates such as di-trimethylol propane tetraacrylate;
- pentafunctional acrylated esters;
- aliphatic urethane acrylates, aliphatic urethane acrylates, urethane methacrylates, aromatic urethane acrylates and epoxy acrylates, silicone acrylates;
- which acrylates can be catalyzed by free radical catalysts,
- wherein catalysts are comprised of any hydrocarbon based peroxide with pendant peroxide group which are easily liberated such as methylethylketone peroxide, acetone, or peroxide;
- for which catalizations can be improved through the use of reactive synergists,
- wherein the reactive synergists increases the speed and efficiency of reaction such as an amine coinitiator, or vinyl ether;
wherein any other monomer and catalyst combination may mimic the 
functionality of those herein named so as to have similar acrylate functionality;
epoxy liquids wherein the liquids are comprised of members of the epoxy family 
such as epoxies including Bisphenol A epoxies, Bisphenol F epoxies, epoxy creosol 
 novolacs, epoxy phenol novolacs, cycloaliphatic epoxies, aliphatic epoxies, butylated 
epoxies; or any unsaturated hydrocarbon molecule with at least one oxyrin ring that is 
liquid;
epoxies which can be catalyzed by specific initiators wherein initiators are from 
the family of Lewis Acids, which are initiating homopolymerization through either 
blocked or unblocked cationic initiators such as iodonium salts of hexofluoro antimonates, 
hexafluoro phosphate, or hexacloro phosphate;
from the cycloaliphatic amines family of co-reactive or copolymerization initiators, such as aliphatic amines, cycloaliphatic amines, unsaturated polyamids, aromatic amines, or phenalkamines;
from the vinyl ether family of co-reactive or copolymerization initiators;
from the cyanate ester family of co-reactive or copolymerization initiators;
from the diisocyanate family of co-reactive or copolymerization initiators;
from the anhydrides family of co-reactive or copolymerization initiators, such as methyl tetrahydrophthalic anhydride, or hexahydrophthalic anhydride;
from the polyester family of co-reactive or copolymerization initiators having 
reactive double bonds;
for which catalizations can be improved through the use of hardeners, wherein the 
hardeners increase the speed and efficiency of reaction such as an amine coinitiator;
polyester liquids wherein the liquids are comprised of members of the polyester 
family such as polyesters including but not limited to aliphatic and cycloaliphatic 
polyesters or polyesters which are viscosity modified by styrene monomer;
polyesters which can be catalyzed by specific initiators wherein initiators can be 
catalyzed by free radical catalysts
wherein catalysts are comprised of any hydrocarbon based peroxide with pendant 
peroxide groups which are easily liberated such as m ethylethylketone peroxide, acetone, 
or peroxide;
free radical generators wherein catalysts are comprised of any belonging to the 
azide family being preferably soluble in light molecular weight reactive monomers such 
as those in the acrylic, polyester, polyurethane, or any copolymers of the same.
for which catalyzations can be improved through the use of reactive synergists,
wherein the reactive synergists increases the speed and efficiency of reaction such
as an amine coinitiator, or vinyl ether;
wherein any other monomer and catalyst combination may mimic the
functionality of those herein named so as to have similar polyester acrylate functionality;
and styrene monomers which may be coreacted with them, also polyurethane liquids,
polymethyl diisocyanates, organopolysiloxanes, organo butyl polysiloxanes,
organosiloxane catalyst, tin and platinum catalysts, liquid crystal monomers, pseudo
sugars, stearols and others, wherein any other monomer and catalyst combination may
have the functionality of those herein named so as to have similar monomer and catalyst
functionality with appropriate speed, viscosity and reaction zone properties.
8. Wherein the liquid as in Claim 7, particularly wherein at least one inkjet
depositing head distributes a liquid which is activated by a chemical reaction by another
liquid of at least one other inkjet depositing head to precipitate from a concentrated
solution a metal in a precursor mold so that it solidifies thereby, utilizing a plurality of
materials including but not limited to solutions of metal ion such as basic solutions of
nickel sulfate, nickel chloride and copper sulfate, or metal salts established for electroless
deposition such as cupric gluconate, ferrous sulfate and stannous chloride can likewise be
deposited in a manner similar as the monomer layers are deposited by the inkjet head and
reducing agents, such as those which are likewise established for electroless, or otherwise
known as autocatalytic use, are deposited by another special set of inkjet nozzles similar
to the way catalyst is deposited, that is, in selective linear/planar patterns which also
correspond to a cross-sectioned area of a three dimensional object, thereby causing
metallic deposition which is precipitated by means of selective reducing chemicals such
as palladium chloride, platinum chloride, rhodium chloride, formaldehyde, glucose and
many others of the metal plating art of which, depend on the reduced finished reaction
byproducts becoming a substantially enhanced multilayered accretion and thus when
finished, a homogeneous solid, which takes the shape of a three dimensional object.
9. An embodiment of this invention of direct electroplating via electrode and
cathode, the platform floor of the z stage assembly, would be the electronegative collector
or cathode and an externally applied anode metal bus tipped with carbon, platinum or
even a conductive plastic membrane and the deposition process would be applied
selectively thereby in a pre formed solidified negative mold of plastic by the same
invention by a precursor forming step which forms the mold and then it is after this mode
that metallic deposition with heavier rates of deposition would be possible inside the preformed hollow mold with the precursor plastic mold having a microtube assembly both infusing fresh electrolyte and evacuating the exhausted portion of the same, greater flux of metal ion are communicated in shorter amounts of time.

10. The machine in Claim 1 wherein an x/y two dimensional precisely deposited plane of a set of dots of liquid as in Claim 7 is deposited from one ink jet reservoir onto a platen by and ink jet dispenser at the same time as a catalyst is deposited selectively on top of the monomer dot layer by another ink jet dispensing head and as each layer has hardened imaged areas established, the platen lowered upon the z axis and the next successive layer of catalyzed material likewise deposited atop the previous

11. The liquid as in Claim 7 wherein dual monomer and catalyst droplet application, limited induced local reactivity, has established resolution limits to within one ten thousandths of an inch.

12. The liquid as in Claim 7 wherein the diffusion rate of a dot of reactive catalyst is arrested by the surrounding reactive precursor and that the dot gain of the catalyst can be controlled by the limiting speed of the surrounding precursor reactants.

13. The liquid as in Claim 7 wherein the liquids have catalyst emissions reduced to near zero amounts because of polymer entrapment.

14. The liquid as in Claim 7 wherein the liquids have catalyst emissions reduced to near zero amounts because of polymer entrapment using inkjet heads containing inhibitors such as hydroquinone employed to quench the specific boundaries of reaction zones.

15. The machine in Claim 1 droplet delivery system which needs no alternate layer calibration, can be amplified by stacked arrays, additional image software support, and electromechanical hardware support.

16. The machine in Claim 1 droplet delivery system with droplet size of monomer and catalyst and with secondary heat coordination for the purpose of controlling the shape and uniformity of successive layers.

17. The machine in Claim 1 wherein an electrical temperature control element utilized with the machine in Claim 1, such as a resistance heater or a Peltier junction which can alternately heat or cool, preferably one which is embedded within the supporting z axes structure base whereupon the generated objects are created, of Claim 1, which is temperature controlled by thermostat feedback, wherein the reaction rates of selected monomer or oligomer, or other unsaturated precursor to a heavier molecular
weight of solid plastic and control of catalyst dot size can be embodied for the purpose of moderating the rates of chemical reactions involved in stereolithic object generation.

18. A heating element as in Claim 17 which is also capable of conducting an electrical current, conductive material capable of functioning as cathode or electrode which is highly resistant to chemical erosion of strong acids or alkali, for the purpose of electroplating or accelerating a metallic precipitation either through direct current or through an alternating current of various voltages, which is embedded within the supporting z axes structure base whereupon the generated objects are created for the purpose of electrodeposition of metal salt solutions or of dissolved metal solutions into the direct formation of successively layered three dimensional parts.

19. Machine in Claim 1 preferred embodiment of the invention includes a single axis track on which the inkjet head can travel back and forth rapidly with little inertial involvement and not be filled with liquid but rather use liquid-supply catheters from isolated liquid reservoir sources not involved in the motion of the print head, thereby ensuring that the inertial moment of the print head assembly is relatively unhindered by the weight thereof.

20. Machine in Claim 1 uses gravity which provides for the leveling mechanism necessary for the establishment of uniform layering during the three-dimensional build up of the object, with each liquid layer remaining as a level surface and supporting layer for the solidifying linear infusion of another activating liquid substance that will create the final solid object, with reliance on gravity as the liquid leveling mechanism.

21. Machine in Claim 1 uses waste control method by the employment of a novel "sand bed technique", whereby supportive material similar to powder sintering layers is created by the process of depositing widely dithered of catalyst droplets, creating grains of cured monomer, the liquid monomer between which prevents the fusion of adjacent droplets.

22. A method of minimizing excess waste of monomer wherein the created three dimensional object is surrounded by a vertical moat concurrently formed of the same solidified material as the object being created forming a shell in which excess monomer or "sand bed" can be accumulated.

23. Machine in Claim 1 uses method of support by the creation of a solid fluidized area by which to support island and negative angled portions of a built up image using the "sand bed" method of Claim 22.
24. Machine in Claim 1 uses method of deposition wherein a moat or otherwise obvious shell like structure is programmed to be simultaneously built up with the image/part and surround the three dimensional image/part thereby holding and limiting the amount of excess monomer and creating space for "sand bed" support area of Claim 22.

25. The machine in Claim 1 wherein a washing system, a chamber within which the object has been created on the z platform, and it has been created within its own sealed shell, which had been simultaneously formed with it, and the draining of the materials take place within, utilizing an internal flocculating / washing mechanism to rinse the newly created item and drain away any uncured or partially cured "sand bed" material of Claim 22.

26. The machine in Claim 1 wherein a washing system on the vertical moving platform may also have an inlet and outlet micro-tube assembly, which provides for the removal by pumping out of unused liquids, the infusion of washing liquids and their subsequent removal

27. The washing system wherein a wherein the flocculating / washing mechanism from Claim 26 drains away any uncured or partially cured material and stores it in a removable cartridge for easy, non-hazardous disposal.

28. A method of direct electroplating via electrode and cathode, the platform floor of the z stage assembly as in Claim 18 the electronegative collector or cathode and an externally applied anode metal bus tipped with carbon, platinum or even a conductive plastic membrane and the deposition process applied selectively thereby in a pre formed solidified negative mold of plastic by the same invention by a precursor forming step which forms the mold and then it is after this mode that metallic deposition with heavier rates of deposition would be possible inside the preformed hollow mold with the precursor plastic mold and having a microtube assembly as in Claim 17 being used to both infuse fresh electrolyte and evacuate the exhausted portion of the same with greater flux of metal ion communicated in short amounts of time.

29. The machine in Claim 1 constructed in an alternative embodiment with multiple carriages employing multiple sets of ink jet heads used to create strata of various different substrates assembling three dimensional objects in multiple materials simultaneously wherein sets of monomer and catalyst are programmed to deposit layers of various materials in position, generating models in a dynamic form.
30. Machine in Claim 1 constructed in an alternative embodiment of the invention with multiple axis tracks on which the inkjet heads can travel back and forth rapidly with little inertial involvement and not be filled with liquid but rather use liquid-supply catheters from isolated liquid reservoir sources not involved in the motion of the print head, thereby ensuring that the inertial moment of the print head assembly is relatively unhindered by the weight thereof.

31. Alternative embodiment of the machine in Claim 1 employing multiple sets of inkjet heads and liquids with tinted sets of monomer and process color catalyst to create objects in full lifelike, photorealistic color, with true photographic detail in transparent substrates.

32. Alternative embodiment of the machine in Claim 1 employing multiple sets of inkjet heads and liquids with tinted sets of monomer and process color catalyst to create objects in full lifelike, photorealistic color, with true photographic detail in opaque substrates.

33. Alternative embodiment of the machine in Claim 1 employing multiple sets of inkjet heads and liquids with tinted sets of monomer and catalyst to create objects in a range of selected colors and finishes in transparent substrates.

34. Alternative embodiment of the machine in Claim 1 employing multiple sets of inkjet heads and liquids with tinted sets of monomer and catalyst to create objects in a range of selected colors and finishes in opaque substrates.

35. A plurality of dyes or micro suspended pigments wherein the chromophore is part of a negative ion such as a sulphonate or contain a chelated metal ion, or the chromophore is a basic positive ion such as an amine salt or ionized imino group, or any of the family of color precursors originating from keto groups wherein further reduction into the leuco form can be further oxidized to a pigment precipitate, those dispersive dyes, reactive dyes, pigments containing surface deposits of dye on either an organic substrate or on an inorganic substrate or any inorganic metal or oxide thereof which has native finish and color characteristics with visible spectral absorption and emission bands, with small dimensions capable of traversing the narrow apertures of the depositing inkjet head of claim one and which are chemically stable and resistant to molecular fragmentation during at least one type of polymerization reaction, for the purposes of establishing decorative enhancement to the three dimensional object in Claims 31, 32, 33, 34.

36. A plurality of solutions of metal ion such as basic solutions of nickel sulfate, nickel chloride and copper sulfate, or metal salts established for electroless
deposition such as cupric gluconate, ferrous sulfate and stannous chloride can likewise be deposited in a manner similar as the monomer layers are deposited by the inkjet head and reducing agents, such as those which are likewise established for electroless, or otherwise known as autocatalytic use, are deposited by another special set of inkjet nozzles similar to the way catalyst is deposited, that is, in selective linear/planar patterns which also correspond to a cross-sectioned area of a three dimensional object, thereby causing metallic deposition which is precipitated by means of selective reducing chemicals such as palladium chloride, platinum chloride, rhodium chloride, formaldehyde, glucose and many others of the metal plating art of which, depend on the reduced finished reaction byproducts becoming a substantially enhanced multilayered accretion and thus when finished, a homogeneous solid, which takes the shape of a three dimensional object in Claims 17, 28.

37. The machine in Claim 1 wherein there is control of the droplet settings to first provide the opportunity to create a "rough" or lower resolution "draft" of an item before committing to the higher resolution finished item.

38. The machine in Claim 1 wherein the entire mechanical assembly will be stationed on a leveled platform, the means for which is provided by screw-adjusted cleats preferably near the perimeter of the bottom chassis or other similar method which will ensure level stability.

39. A method for ceramic investment casting employed whereby a ceramic suspension is injected into the preformed plastic mold and the water from the suspension removed by ionic migration from an applied electric field from the same apparatus used for metallic electrodeposition and same dehydrated (greenware) ceramic core can be fired in a refractory sintering furnace by any kiln established in that art for this purpose and the surrounding hydrocarbon plastic material is thus pyrolyzed away.

40. Entire chemical set add colorants and opaque versus transparent Any dye soluble in monomer or catalyst serves to create desired color including photorealistic through same color theory utilized in industry standard CMYK or RGB color differentiation software. White opaque monomer with colored catalyst. Any sub micron white pigment with good light scattering characteristics such as but not limited to zinc oxide, titanium dioxide, aluminum oxide, organic multi layered refractive or possessing a high refractive differential.

41. An interface of software and hardware that permits the downloading off the internet of three dimensional object files which can then be executed at home or office
or any other remote location, for example: licensed action figures, cartoon figures, gaming figures from video games, licensed cartoon figures, accessories for home and office.

42. An online implemented point of sale method, comprising:
   purchasing a digital model of a product;
   downloading the digital model;
   fabricating the product using the digital model to control a stereolithographic printer.

43. An online implemented point of sale method according to claim 42, wherein the act of purchasing a digital model of the produce further includes simultaneously purchasing a license to fabricate the product.

44. An online method according to claim 42, wherein the stereolithographic printer includes a plurality of inkjet printing heads adapted for use with at least one specialized molding liquid and one activating liquid which promoted solidification of the molding liquid and which is integrated into an appropriate mechanism for generating a geometrical x axis, y axis, and z axis and with a variety of software capable of executing machine codes by computer, which permits the accurate and immediate dot to dot deposition of one liquid upon the other for the purpose of accurate volume limited catalysis applied for the purpose of generating discreet, single or multiple consecutive laminar strata or cross sections of an object, wherein each layer corresponds to a cross section of the finished object which, as stacked one upon the other generate fully three dimensional representations or models of an object.

45. A removable reservoir for use with a stereolithographic printer, the removable reservoir comprising:
   a reactant;
   a chamber for carrying the reactant; and
   an end configured to allow access by the stereolithographic printer to the reactant, wherein the reactant includes one or more of the following:
   acrylate liquids wherein monomer liquids are comprised of member of the acrylate family monofunctional acrylates such as methylmethacrylate, polypropylene glycol monomethacrylate, polypropylene glycol monoacrylate; difunctional acrylates such as polyethylene glycol diacrylate, alkoxylated aliphatic dioldiacrylate, or any difunctional diol of alkoxylated aliphatic dioldiacrylic; trifunctional
acrylates such as trimethol propane triacrylate, glyceryl propoxy triacrylate, or any propoxylated group between 3 and 9 of glyceryl triacrylate; the highly alkoxylated triacrylates and tetrafunctional acrylates such as di-trimethylol propane tetraacrylate; pentafunctional acrylated esters; aliphatic urethane acrylates, aliphatic urethane acrylates, urethane methacrylates, aromatic urethane acrylates and epoxy acrylates, silicone acrylates; which acrylates can be catalyzed by free radical catalysts, wherein catalysts are comprised of any hydrocarbon based peroxide with pendant peroxide group which are easily liberated such as methylethylketone peroxide, acetone, or peroxide; for which catalizations can be improved through the use of reactive synergists, wherein the reactive synergists increases the speed and efficiency of reaction such as an amine cointiator, or vinyl ether;

wherein any other monomer and catalyst combination may mimic the functionality of those herein named so as to have similar acrylate functionality;

epoxy liquids wherein the liquids are comprised of members of the epoxy family such as epoxies including Bisphenol A epoxies, Bisphenol F epoxies, epoxy creosol novolacs, epoxy phenol novolacs, cycloaliphatic epoxies, aliphatic epoxies, butylated epoxies; or any unsaturated hydrocarbon molecule with at least one oxyain ring that is liquid; epoxies which can be catalyzed by specific initiators wherein initiators are from the family of Lewis Acids, which are initiating homopolymerization through either blocked or unblocked cationic initiators such as iodonium salts of hexofluoro antimonates, hexafluoro phosphate, or hexacloro phosphate; from the cycloaliphatic amines family of co-reactive or copolymerization initiators, such as aliphatic amines, cycloaliphatic amines, unsaturated polyamids, aromatic amines, or phenaalkamines; from the vinyl ether family of co-reactive or copolymerization initiators; from the cyanate ester family of co-reactive or copolymerization initiators; from the diisocyanate family of co-reactive or copolymerization initiators; from the anhydrides family of co-reactive or copolymerization initiators, such as methyl tetrahydrophthalic anhydride, or hexahydrophthalic anhydride; from the polyester family of co-reactive or copolymerization initiators having
reactive double bonds; for which catalizations can be improved through
the use of hardeners, wherein the hardeners increase the speed and
efficiency of reaction such as an amine coinitiator; polyester liquids
wherein the liquids are comprised of members of the POLYESTER family
such as polyesters including but not limited to aliphatic and cycloaliphatic
polyesters or polyesters which are viscosity modified by styrene monomer;
polyesters which can be catalyzed by specific initiators wherein initiators
can be catalyzed by free radical catalysts wherein catalysts are comprised
of any hydrocarbon based peroxide with pendant peroxide groups which
are easily liberated such as methylethylketone peroxide, acetone, or
peroxide; free radical generators wherein catalysts are comprised of any
belonging to the azide family being preferably soluble in light molecular
weight reactive monomers such as those in the acrylic, polyester,
polyurethane, or any copolymers of the same; and/or

for which catalizations can be improved through the use of
reactive synergists, wherein the reactive synergists increases the speed and
efficiency of reaction such as an amine coinitiator, or vinyl ether; wherein
any other monomer and catalyst combination may mimic the functionality
of those herein named so as to have similar polyester acrylate
functionality; and styrene monomers which may be coreacted with them,
also polyurethane liquids, polymethyl diisocyanates, organopolysiloxanes,
organo butyl polysiloxanes, organosiloxane catalyst, tin and platinum
catalysts, liquid crystal monomers, pseudo sugars, stearols and others,
wherein any other monomer and catalyst combination may has the
functionality of those herein named so as to have similar monomer and
catalyst functionality with appropriate speed, viscosity and reaction zone
properties.

46. A machine according to claim 1, wherein the plurality of inkjet printing
heads include a piezo jet head.

47. A method for generating a three dimensional object comprising:

performing a first curing cycle prior to deposition of a droplet of monomer
on a substrate, the droplet of monomer forming a portion of the three dimensional
object; and
performing a second curing cycle after deposition of the droplet of monomer on the substrate.

48. A method according to claim 47, wherein the first curing cycle includes directly irradiating the droplet with UV radiation as the droplet of monomer is ejected from one of the inkjet printing heads but prior to the droplet of monomer being disposed upon the substrate.

49. A method according to claim 48 wherein the droplet of monomer is irradiated by a light source disposed in close proximity to the ink jet printing head from which the monomer is ejected.

50. A method according to claim 48, wherein the droplet of monomer is irradiated by a UV source carried by the inkjet printing head.

51. A method according to claim 48, wherein the second curing cycle includes the transfer of heat to the droplet after deposition of the droplet of monomer on the substrate.

52. A method according to claim 51, wherein the second curing cycle further includes UV irradiation of the droplet of monomer on the substrate.

53. A method according to claim 47, wherein the method is performed using the machine of claim 1.

54. An inkjet head comprising a jet configured to eject monomer and a light source for irradiating the monomer as it is ejected from the jet.

55. A prepeg composition comprising:

   a catalyst;

   monomer; and

   a diluent

56. A prepeg composition according to claim 55, wherein the monomer is configured to start a partially cured B-stage polymer network, the diulent is configured to retard a 100% cure of the monomer, and the catalyst is a photosensitive cationic catalyst of a percentage sufficient to initiate partial polymerization but also of a percentage which is sufficient to remain latent until a final cure of a second surrounding monomer material is deposited.

57. A reservoir comprising a housing containing the prepeg composition of claim 55.

58. A method of generating a three dimensional rough draft object, comprising:
selecting a droplet size for the machine of claim 1 based on a desired
resolution of the three dimensional rough draft object; and
manufacturing the three dimensional rough draft object using the machine
of claim 1 and the selected droplet size.

59. A method of generating a three dimensional rough draft object,
comprising:

determining a three dimensional pattern of droplets for generation by the
machine of claim 1 for the three dimensional rough draft object; and
manufacturing the three dimensional rough draft object using the machine
of claim 1 and the determined pattern such that the amount of monomer used to
manufacture the three dimension rough draft is minimized due to the pattern
generated.
Figure 3
Partially or Uncatalyzed Liquid Monomer Inside 3D Shell

Hardened Polymerized Toy Soldier 3D Figure

Hardened Polymerized 3D Shell Forming Moat for Uncatalyzed Monomer

Figure 4
Figure 6
Transit Catalysis Illustration

UV Absorbing Surface

UV Lamp

UV Reflector

UV Light Beam 70°

UV activated First Stage Catalysed Droplet

Monomer Droplet 715

Monomer Droplet Captured Around First Stage Catalyst Droplet nucleus Heat finished Catalysis

Substrate 720

Figure 3