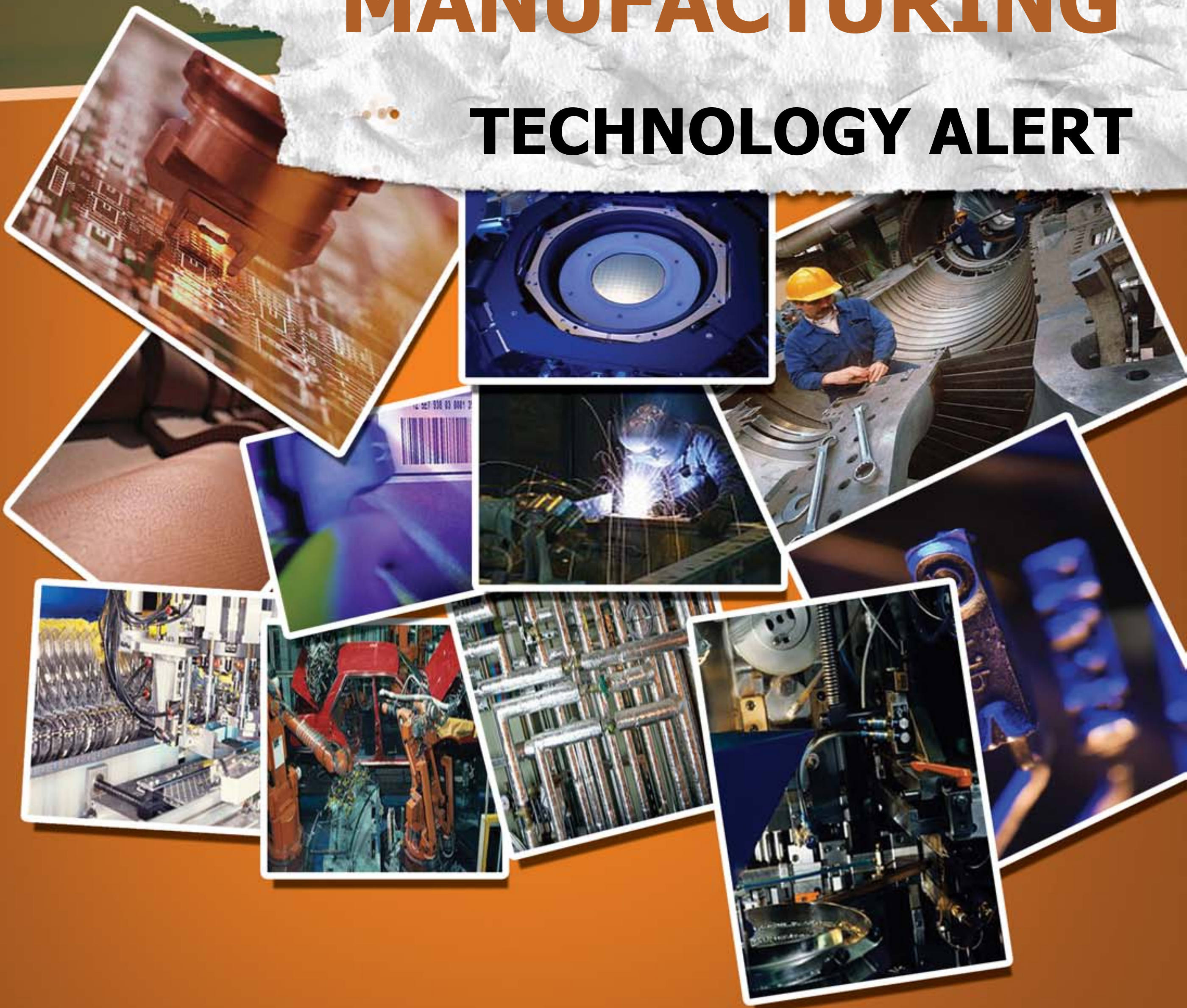
TECHNICAL INSIGHTS

ADVANCED MANUFACTURING

TECHNOLOGY ALERT



25th September 2015

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1. SHAPE MEMORY RESIN FOR 3D PRINTING

Three-dimensional (3D) printing or additive manufacturing has been growing immensely in varied industries. Many research groups are developing and implementing new techniques, methods and materials to optimize and improve the overall efficiency of the process. A key area of interest in 3D printing is the development of materials with improved properties, such as enhanced durability, stability, impact strength, heat resistance.

In tune with the above trend, a German company, 3D-LABS GmbH, a provider of 3D printing services, has been able to develop an innovative new material called LED.W resin. The new material is a 3D printable resin with shape memory characteristics and is, therefore, able to return to its original shape even after an object's form has been changed through heat. Primarily aimed at sterelithography (SLA) 3D printing, LED.W resin offers high processing speed and is a unique 3D printable resin that provides shape retention. Since a shape memory alloy (SMA) is present in the resin, objects printed can be reshaped and changed to their original form multiple times without any change in their materials properties.

It is very easy to change the form of the object printed using LED.W resin. The printed object is subjected to a heat source that softens the material. The object is then reshaped to the desired form and placed in a cold water bath. The cold water bath helps in hardening the material and the object again. This process can be repeated several times without affecting the material properties of the object. The object can be reshaped and reverted back to its original form multiple times without any issues such as breakage or damage.

The material is specially designed for SLA printing machine, which works on Prodways MovingLight® technology. The company is testing the LED.W resin for other applications. It is also working on developing a method to use the material in other SLA machines.

The material can benefit SLA machines by offering higher processing speeds than conventional photosensitive resins; although it has initially been investigated for

3D printers that use France-based Prodways MOVINGLight® technology based on a moving digital light processing head.

Stereolithography 3D printing, the first completely commercial rapid prototyping technology, builds a part model on a platform positioned slightly below the surface in a vat of liquid, photocurable polymer (which is often an epoxy or acrylate resin). A low-power ultraviolet laser, programmed using CAD (computer aided design) data, traces the first ayer of the part with a highly focused UV light beam. The UV laser scans and cures the resin within the boundaries of the outline of the slice until the whole area within the slice cross-section is solidified.

Digital light processing uses a projector to project the image of the cross section of an object into a vat of photopolymer. The light selectively hardens only the area specified in the image.

Due to the shape shifting properties of this newly developed material, it can be used for rapid prototyping of components and parts for the automotive industry. Changes in design can be quickly and easily done without printing new components or wasting printing materials or time. After a prototype made with the material is completely utilized, the same material can be reshaped and used for making other similar components and parts, thereby reducing prototyping material cost.

3D-LABS aims to market the newly developed material in various industries such as automotive, aerospace, and biomedical. Another main market, which the company is focusing on entering, is frame animations, where animators repeatedly change the design and reshape 3D objects for animation purposes. The LED.W resin has potential to begin to impact the 3D printing market by 2016.

A patent nalysis of shape memory resins reveals that countries such as Japan and China followed by Korea have filed the most number of patents in this domain. NEC Corporation (Japan) and NKK Corporation (Japan) have filed the most number of patents involving shape memory resins. Patent WO2015045940 filed by Hitachi Zosen Corporation (Japan) refers to a method for producing a shape memory resin composition. Similarly, patent CN103554838 filed by Dongguan Jieyue Shengshi Sports Goods Co. Ltd. (China), refers to the preparation methods of an epoxy resin with shape memory properties.

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2. 3D PRINTER PRINTS SIX FOOT-TALL OBJECTS QUICKLY

Three-dimensional (3D) printing has been booming with new innovations and techniques. Various industries, such as aerospace, automotive, healthcare, consumer products, increasingly use 3D printing.. Research institutions and companies are constantly working on developing and optimizing new methods, hardware, materials for printing and design software to feed growing opportunities for 3D printing in prototyping as well as emerging production applications. One key area where the there are opportunities for improvements in 3D printing technology entails orienting of large objects.

Addressing the need for rapid, large-format 3D printing, Massivit 3D, based in Israel, introduced the Massivit 1800 3D printer, a unique combination of deposition and UV curing technology, early in 2015. The printer was used to 3D print a full Strati car, and will be used to create large customized signs for events, promotions, or sales.

The printer uses a gel dispensed printing method and is supported by Autodesk's Spark software platform. The company used a special proprietary photosensitive gel, which is cured using UV (ultraviolet) light. The company's proprietary gel-dispensed printing (GDP) technology uses movement similar to that used in fused deposition modeling (FDM) systems, but works with a UV-sensitive gel material that solidifies and becomes a hard polymer when exposed to ultraviolet light. In contrast, traditional thermoplastic materials are cured and hardened as they cool down.

Massivit 3D has been able to fabricate objects at rapid speed and quality because of the specially developed photosensitive gel. The printer had a print volume of three cubic meters and a print speed of 1,000 mm/39 inch per sec in x & y-axis.

At present, the company has upgraded its Massivit 1800 3D printer and its gel-dispensed printing technology to provide greater capabilities. The newly upgraded printer has a capacity to print six-foot tall 3D printed objects within five hours. The upgraded machine has dual processing capacity that allows users to print two different objects in parallel and simultaneously. The printer has a productivity of 35 cm/1 ft. of object per hour, and due to a supportless printing method, the printer also consumes less materials when compared to traditional 3D printers.

The unique material, which the printer uses, is sensitive to specific UV waves, printing engines, and curing engines. Using the gel-dispensed printing technology, the gel gets slowly dispensed and flows though the printing curing engines, where it gets solidified. The printer does not require support structures when printing solid objects such as ceilings and non-vertical walls.

The printer is designed to print huge objects very economically and efficiently without consuming much time and material. This will help various manufacturing industries to print large objects, which has not been very feasible using traditional 3D printers within few hours with high quality and accuracy. By using the Massivit 1800 3D printer, manufacturers can significantly decrease production time of components and parts.

The company is planning to penetrate industries such as automotive, aerospace, construction, and nuclear industries where manufacturers need to produce huge components at a high quality quickly, efficiently, cost-effectively, and is finding early opportunities in communications (such as signage).

Massivit 3D has filed three patents in the domain of additive manufacturing. Patent WO2015125128 pertains to an additive manufacturing device, which uses multiple heads to print different segments of the object simultaneously and quickly. The time taken to complete the printing process is much less when compared to the traditional single head additive manufacturing device. Massivit 3D has also filed a patent (US20150217516) pertaining to a new method and apparatus that reduces the need for support structures and prints large 3D hollow objects or shells, which may consist of thin walls and curved surfaces. The third patent filed by the company, US09011136, also pertains to an additive manufacturing device, which includes, for example, at least two independently driven material dispensing heads that are configured to deposit a material and form at least one material layer of a 3D object.

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3. NOVEL MULTIMATERIAL PRINTHEADS FOR 3D PRINTING

With advancements in 3D printing, researchers are constantly finding new methods and techniques to optimize the printing process for various other applications.3D printing has proven beneficial for printing plastic or metal objects. However, advancements have been required in order to effectively and efficiently 3D print items such as soft robots, light sensors, and wearable electronics.

To achieve printing flexible and wearable devices with electronics, the 3D printer must be capable of making a transition from printing flexible material to rigid material to print the required electronic components. The printer should also be capable of switching between multiple inks of different conductivity and resistivity to print and embed electrical circuitry.

To deal with the above challenges, researchers from Harvard University have designed a new printhead, which can mix and print multilateral concentrated viscoelastic inks. The printheads mix inks and change nozzles according to the design and also have control over the material composition and geometry of the build. The leader of such research is Dr. Jennifer A. Lewis, the Hansjörg Wyss Professor of Biologically Inspired Engineering at the Harvard John A. Paulson School of Engineering and Applied Sciences (SEAS).

The traditional method of diffusive mixing for complex fluids is only effective for low-viscosity fluids, but is ineffective for fluids with a high viscosity, especially when the fluids are mixed in low volumes over a short time frame. To deal with this challenge, the researchers designed the multi-material printhead with active microfluidic mixers. The active microfluidic mixers in the print heads consist of rotating impellers inside a microscale nozzle, which mixes a wide range of complex fluids with high- and low-viscosity very efficiently. The printhead is capable of mixing resistive and conductive inks to print and embed electrical circuitry to the object being printed.

While a printhead switches material at the start-and-stop of a process when printing an object, most of the time the printed object has structural defects due to improper switching of the ink. Lewis Labs has also designed another printhead, which can change between multiple inks within a single nozzle very rapidly and efficiently. The printhead eliminates the chances of structural defects in the objects being 3D printed. The newly developed printheads use only one nozzle thereby eliminating the need for multiple nozzles and also allow users to stop and top the ink flow as per the application. This system allows the user to control material flow and efficiency of the build.

The newly designed printheads also enable users to easily print flexible and wearable devices with electrical circuitry embedded in them. This innovative method can be used for rapid prototyping of electronic components with different materials and circuitry for the automotive, aerospace, and biomedical sectors. The printheads are user friendly and cost-effective, since the material wastage is much less when compared to traditional methods of 3D printing.

The printheads also provide control over the material flow, which gives freedom to automotive component manufacturers to 3D print components and parts with different high and low viscosity fluids. Due to the rapid active mixing technology in the printheads, the process flow time for printing a component is much less. The research team is currently working on optimizing the printheads for enhanced efficiency and improving the design for large scale manufacturing.

From a patent analysis conducted on printheads for 3D printing, it is evident that countries such as the United States and Japan followed by Korea and China have filed the most number of patents in this domain. Companies such as Samsung Electronics (Korea) and Epson Electronics Company (Japan) have filed the most number of patents. Patent WO2015135434 filled by Print-Rite Unicorn Image Products Co. Ltd. (China), refers to a printhead for a 3D printer, which also consists of a long cylindrical printing nozzle, a heater, and a shut-off valve. The same company has filed another patent (WO2015131833), which relates to a printhead consisting of a heater, a feeding device, and a printing nozzle. The printhead is used for rapid molding and prototyping using fused deposition modeling process.

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4. 3D NODE TECHNOLOGY FOR MANUFACTURING VEHICLES

Automobile manufacturers are constantly researching and implementing new methods and techniques for manufacturing cleaner and greener vehicles. Even though there are efficient options for manufacturing powertrains using alternative energy sources such as fuel cells and batteries, a cleaner and greener method or technique has not been implemented for manufacturing the body frame, chassis, and other large components of a vehicle. There is a need for such a technique.

Toward addressing this need, a California-based company, Divergent Microfactories, is focused on creating a more efficient and cleaner manufacturing paradigm using 3D printing and a newly developed Node technology.

The Node technology is used for making car chassis using pieces of carbon fiber tubing, which are connected to 3D-printed aluminum joints. One of the major advantages of using Node technology to make chassis is that the space and time for cutting and assembling the chassis are much less, since the process uses 3D printing to build the chassis. The chassis are 90% lighter in weight and at the same time more durable and stronger when compared to the traditional chassis of a conventional vehicle.

Divergent Microfactories uses laser-based printing systems, which melt aluminum powder to form the node. Structural carbon fiber tubes are used to connect the nodes making it easier to build the chassis. The nodes and tubes take very minimal time to get printed and are also lightweight.

Even though companies have 3D printed cars such as the Strati, Urbee, Shelby Cobra replica, C16 German electric vehicle, they are relatively small in size and had limited-power electric drives. Divergent Microfactories has used its node technology and 3D printing methods to build a unique 3D printed supercar, called "Blade." The car weighs around 1,400 pounds and is equipped with a 700-horsepower bi-fuel engine. The overall chassis, built for the Blade using the nodes only weighs 46 kg.The engine can use both gasoline or compressed natural gas and can reach 0 to 96.5 km/hour speed in two seconds. The overall result of this new novel technology is that it reduces the use of resources, man-power and decreases pollution, which is generated while manufacturing vehicles. The car has more power, but also has a better fuel economy rate and reduced wear and tear on roads.

Divergent Microfactories is planning to spread this new manufacturing platform with small entrepreneurial teams around the world and then slowly move to larger vehicle manufacturers. The company is expecting and encouraging small and large entrepreneurial teams to design and build their own large complex structures and new vehicle designs using node technology.

Divergent's technology has potential to eventually lead to a profound industry shift, enabling, automotive manufacturers to to produce inexpensive and efficient vehicles using 3D printed node technology. To achieve this utopian shift, the company needs to ensure that its chassis construction method can meet automotive safety standards.

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5. PATENT ANALYSIS ON FUSED DECOMPOSITION MODELING

Fused decomposition modeling (FDM) is an additive manufacturing technology used for rapid prototyping and modeling of parts and components using 3D printing techniques. The FDM process builds 3D shapes or objects by driving filaments of thermoplastic polymer materials into a heated liquefier to be extruded through a small diameter nozzle onto a build platform. FDM typically relies on melting and selectively depositing a thin filament of thermoplastic polymer (such as acrylonitrile butadiene styrene or ABS, plastic, polycarbonate and investment casting wax) in a cross-hatching mode to form each layer of a part. Other materials, such as metals (for example, stainless steel), may be used in specialized FDM applications.

The FDM process can produce parts or objects at a relatively fast rate with high accuracy, and may not require post-processing or post-curing, since molds are not used. This technique can economically produce durable and large parts, does not require expensive lasers, and can use less expensive materials and systems compared to laser sintering or electron beam melting technologies. However, the process and is rather slow while printing large and dense objects, and can result in lower mechanical properties in the Z axis.

The most number of patents for FDM are filed in the UK followed by the United Sates, and the European Patent Office. From the patent analysis for FDM, it is evident that most of the patents filed are based on 3D printers, materials and methods used to achieve FDM. A patent (CN 103895228) filed by an inventor Wang Limin from China, pertains to colored 3D printing equipment using based on fused deposition modeling. The University of Jinan (China) has filed a patent (CN103862676) pertaining to a new FDM 3D printer with a simple, compact structure, small size, low manufacturing cost. This FDM printer consists of a system for movement in X-axis, Y-axis, and Z-axis; a base; a rack; and a printing device. Patent WO 2015037574, assigned to Toray Industries, Inc., pertains to a material for FDM in which a warp-free modeled object is obtained without devising a modeling shape or installing a special apparatus as a 3D printer device. A modeled article providing flexibility and excellent surface polishing properties is obtained.

Title	Publication Date/ Publication Number	Assignee	Inventor	Abstract
Methods of using thermoplastic polyurethanes in fused deposition modeling and systems and articles thereof	July 23, 2015/ WO 2015109141	LUbrizol Advanced Materials, Inc.	Cox, John M.	The present invention relates to systems and methods for solid freeform fabrication, especially fused deposition modeling, as well as various articles made using the same, where the systems and methods utilize certain thermoplastic polyurethanes which are particularly suited for such processing. The useful thermoplastic polyurethanes are derived from (a) a polyisocyanate component, (b) a polyol component, and (c) an optional chain extender component where the resulting thermoplastic polyurethane has a crystallization temperature above 80°C and retains more than 20% of its shear storage modulus at 100°C relative to its shear storage modulus at 20°

Material for fused-deposition-type three-dimensional modeling, and filament for fused-deposition-type 3D printing device	March 19,2015/ WO 2015037574	Toray Industries, Inc.	Naito, Yoshiyasu	[Problem] To provide a material for fused-deposition-type three-dimensional modeling whereby a warp-free modeled object is obtained without devising a modeling shape and without installing a special apparatus as a 3D printer device, and whereby a modeled article having flexibility as well as excellent surface polishing properties is obtained. [Solution] A material for fused-deposition-type three-dimensional modeling, obtained by blending 10-900 parts by weight of a styrene-based resin (B1) obtained by copolymerization of an aromatic vinyl-monomer (b1) and a cyanated vinyl-monomer (b2), and/or 5-400 parts by weight of a thermoplastic resin (B2) having a glass transition temperature of 20°C or lower and/or 5-30 parts by weight of a plasticizer (B3), with respect to 100 parts by weight of a polylactic resin (A).
Improvements relating to fused deposition modelling	March 05, 2015/ WO 2015028809	The University of Warwick	Purssell, Christopher	A fused deposition modelling apparatus for forming a build using at least two different materials. The apparatus comprises an extrusion head (8) arranged to receive a first material comprising a feedstock material for extrusion from the extrusion head (5), and to also receive an elongate object (6) comprising a second material different to the first material. The extrusion head comprises an outlet (18) for extrusion of first material and is arranged to deliver at least part of the elongate object (6) through said outlet (18).
Closed-loop control fused deposition modeling high-speed 3D printer and closed-loop control method	Feb 05, 2015/ WO 2015014290	Panowin Technologies Co., Ltd.	Liu, Haichuan	The present invention relates to a closed-loop control fused deposition modeling high-speed 3D printer and a closed-loop control method, which belong to the technical field of 3D printing. Since a 3D printer is provided with a grating module, a grating scale therein is fixed on a machine frame, and a grating reader moves with a running gear, the accurate mechanical displacement information about an extrusion spray head can be obtained. In a crisscross printing running gear, the accurate motion compensation of the running gear is achieved by the compensation of the closed-loop control, so as to improve the accuracy of the position of the extrusion spray head, thereby improving the 3D printing accuracy significantly and being able to satisfy the technical requirements of high-accuracy printing. The closed-loop control fused deposition modeling high-speed 3D printer of the present invention has a relatively simple structure and low costs. The control method of the present invention is easy to achieve and has a relatively wide application range.
FDM (fused deposition modeling) 3 D (three dimensional) printing cold plate molding resin membrane	Sept 03, 2014/ CN 104015357	Tian Ye	Tian Ye	The invention discloses a FDM (fused deposition modeling) 3 D (three dimensional) printing cold plate molding resin membrane which has a thickness of 50-250mum, and comprises a hot melt layer, a base layer and a non-setting adhesive layer, the thickness ratio of hot melt layer to base layer to non-setting adhesive layer is 17-23:17-23:9-11; the hot melt layer is ethylene-vinyl acetate copolymer; the base layer contains high density polyethylene (75-85wt%), linear low density polyethylene (5-15wt%) and calcium carbonate (1-10wt%); the non-setting adhesive layer is an oily non-setting adhesive. The FDM (fused deposition modeling) 3 D (three dimensional) printing cold plate molding resin membrane has the advantages of low cost, when in use, a baseplate with a smooth and flat surface is required, and special requirements on the texture are not required. The problem of high cost of traditional 3D printing baseplates and adhesive films can be solved, and the problems of low safety and large machine loss caused by heating of the baseplates can be solved. In addition, the FDM (fused deposition modeling) 3 D (three dimensional) printing cold plate molding resin membrane is not only suitable for printing small-

				sized items, but also suitable for printing large-sized items (with the length, width and height up to 500mm), and edge warping problem may not be produced when in printing of the large-sized items.
Fused deposition modeling device and method	Aug 06, 2014/ CN 103963301	Inventec Appliances (Shanghai) Co., Ltd.	Zhang Zefeng	The invention provides a fused deposition modeling device and method. The method comprises the steps as follows: a material feeding monitoring device monitors whether a forming material is in normal working or not and sends material state signals to a control device; the control device controls the modeling device to continuously work or stop according to the material state signals. The fused deposition modeling device can automatically stop printing after the forming material is not in normal working, and automatically and continuously print after the faults of the forming material are eliminated, so as to avoid material shortage idling and material clamping, and save time and materials.
Colored 3D (Three Dimensional) printing equipment using fused deposition modeling method	July 02,2014/ CN 103895228	Wang Limin	Wang Limin	The invention provides colored 3D (Three Dimensional) printing equipment using a fused deposition modeling method. The colored 3D printing equipment comprises three sets of feeding mechanisms for filamentary raw materials with red, yellow and blue base colors, a material mixing heater (4), a static/dynamic pipeline material mixer (5), a replaceable type printing nozzle (6), a three-dimensional motion molding platform (7) with a heating function and an equipment control system, wherein the feeding mechanisms are composed of a discharging scroll (1), a stepping type motor feeding machine (2) and a feeding guide pipe (3). The colored 3D printing equipment is characterized in that a three-primary-color principle is utilized, namely the red, yellow and blue colors are mixed according to a proper ratio to obtain nearly all colors in the natural world; thermoplastic raw material fused wires or powder with the red, yellow and blue colors can be heated and mixed according to different ratios to form different colored printing materials, and then the fused deposition modeling (FDM) method is used for carrying out 3D printing to obtain a colored product. The colored 3D printing equipment has the beneficial effects that the disadvantage that a current colored 3D printing equipment using the fused deposition modeling method only can be used for printing a single-color or double-color product is overcome; the post-period coloring and processing time of the product is shortened, the working efficiency is improved and a 3D printing application is enriched.
FDM (fused deposition modeling) technology-based 3D (three-dimensional) printer	June 18, 2014/ CN 103862676	University of Jinan	Wei Demin	The invention discloses an FDM (fused deposition modeling) technology-based 3D (three-dimensional) printer. The FDM technology-based 3D printer comprises a rack, a base, an X-axis movement system, a Y-axis movement system, a Z-axis movement system and a printing device, wherein the rack comprises a left upright column, a right upright column and a lower connecting plate; the printing device is connected with the X-axis movement system; the X-axis movement system is connected with the Z-axis movement system; the Z-axis movement system comprises a left screw rod and a right screw rod; screw rod nuts are arranged on the left screw rod and the right screw rod; a power supply and a controller are arranged at the bottom of the base; the controller is connected with the X-axis movement system and the printing device; the X-axis movement system comprises a first numerical control motor, X-axis movement guide rails and a first limiting switch; the X-axis movement guide rails are respectively connected with Z-axis fixed seats and are connected

				with supporting arms of the printing device; the first limiting switch is connected with the lower parts of the Z-axis fixed seats, is matched with a left supporting arm of the printing device and is connected with the controller. The FDM technology-based 3D printer is simple and compact in structure, small in size and low in manufacturing cost
MULTICOLOURED FUSED DEPOSITION MODELLING PRINT	Mar 27,2014/ US 20140088751	Pridoehl Markus	Pridoehl Markus	The invention relates to a modified fused deposition modeling process for production of multicolored three-dimensional objects. More particularly, the invention relates to a 3D printing process with which 3D objects with particularly good color appearance compared to the prior art can be produced. The process according to the invention is based on surface coloring or additive coating of the polymer strand used for production of the actual object or of the melt which results therefrom in the nozzle.
Multicoloured fused deposition modelling print	Mar 19, 2014/ EP 2707198	Evonik Roehm GmbH	Pridoehl Markus	A fused deposition modelling method for producing multicoloured three-dimensional objects, in particular a 3D printing method with which 3D objects can be produced with a particularly good colour image in comparison with the prior art. The method is based on the concept that the polymer strand (2), or the resultant melt, that is used for producing the actual object is superficially coloured or coated with additives in the nozzle (1).

Exhibit 1 lists some key patents related to fused decomposition modeling.

Picture Credit: Frost & Sullivan, WIPO

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