International Journal for Research in Engineering Application & Management (IJREAM)
ISSN : 2454-9150 Vol-04, Issue-03, June 2018

A Review on - Materials For Additive Manufacturing

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Abstract: In today's modern technology, additive manufacturing has advanced over the year that usually known as 3D printing. Currently, additive manufacturing applied in various industries such as in particular aerospace, medical, transportation, energy and other consumer products. The most common additive manufacturing technologies such as fused deposition modelling (FDM), poly-jet, inkjet printing, selective laser sintering (SLS), and electron beam melting (EBM) used to fulfil manufacturing industries requirement. In addition, it is important and efficient to look at the materials for the manufacturing process to produce high quality and durable products. The most commonly materials, polymers, metals, ceramics and composites used for additive manufacturing, and mostly available in the form of wire feedstock, powder and liquid. In circumstance, it is essential to have better understanding of available materials, which can be suitable for AM applications; the current review gives the broad ideas on the novel materials with present and future material can be applicable in 3D printing technologies. Emerging pathway of materials from large sizes to Nano sizes in the various forms including larger productivities and high quality performance, with maintaining mechanical performance and geometrical flexibilities scale up the additive manufacturing. The main focus of this article to introduce newly upcoming materials such as graphene, graphite, carbon fiber, and glass, concrete, bioactive drugs, cells, and proteins even food can utilized in 3D printing technologies.

Keywords: 3-D printing, Additive Manufacturing, Novel Materials, Metals, Ceramics, Polymer, Bio ink, Food materials.

I. INTRODUCTION

Additive manufacturing (AM), also known as direct digital manufacturing (DDM) is the collaborative transformation of manufacturing through the exploitation of advances in ICT [1]. The ability to design a part and manufacture it anywhere in the world using 3D printing techniques interpreted as the realization of that has the full potential to revolutionize manufacturing technology [2].The focus of this review to use of high tech-smart-novel materials in manufacturing, In addition plastics, ceramics, metals, and composites most common materials used for manufacturing. Todays need that, it is very critical to select appropriate materials for additive manufacturing (AM) [3]. A better understanding of process parameters and materials behavior facilitates the design of new materials that can meet future requirements [4]. Materials necessities for AM contain the capability to produce the raw material in a form responsive to the specific AM process, appropriate processing of the material by AM, ability to be adequately post-processed to enrich geometry and properties, and appearance of essential performance characteristics in service. As AM has matured, specific classes of material have become related with specific AM practices and applications. Microstructural features affecting AM part properties listed. Service properties of AM parts termed, containing physical, mechanical, optical, thermal and electrical properties [5]. The metal-based materials as 3D printing of metals is mostly challenging due to a build of microstructural alterations that marks, specifically when the metals and alloys are bare to high temperatures. Researchers for diverse types of metals are still discovering mechanism for the dimensional precision and end properties and alloys as the outcomes of some compositional structure cannot shifted to a different compositional structure [6].3D Printing materials for food: Ice cream, magic candy, pasta, molecules for medicine, even human cells. The categories of materials are used in 3D printing matures longer and a lot better exciting by the current scenario. In addition, expanding it is a multibillion-dollar material battle nowadays. As per the recently released 3D-printing market survey, forecasting the technological expansion will drive the 3D-printing market value from its 2017 level of $6.98 billion to $12 billion by the end of 2018. That means a huge requirement of the materials for those machines use. Even that the plastic still most favorable in the 3D-printing materials world. Rendering to a SmarTech Markets report, 3D printing projected to generate $1.4 billion in plastics sales by 2019. This is not just "ordinary" plastic. The industries extensively experimenting with new, novel methods, such as bio-based resins made from corn and soybean oil [7].

 DOI : 10.18231/2454-9150.2018.0433

Additive manufacturing researchers' faces challenges that which materials useable, including high melting points, layer thickness, print speed and production capacity [8].

II. POLYMERS (THERMOPLASTICS)

Various thermoplastic polymers but can also refer to uncured thermosets, pastes, hydrogels and similar extricable materials used in 3D printing for decades [9]. Filaments well known by their abbreviations (like ABS, PLA and PVA) are essential to the production of an extensive selection of parts helping several industries [8].Possible AM applications using thermoplastics and thermoplastic rubbers are growing as researchers explores methods to strengthen objects along the z axis. Naturally, fused filament production demonstrates superior strength along the x and y axes than the z-axis. Nowadays, study into thermal welding techniques provides all-important "z strength" dynamic in products like load-bearing prosthetics implants [8]. These are some 'conventional' thermoplastics and thermoplastic rubbers have been studied and patented for 3D printing application [9].

A. Photopolymers

Photopolymers are important to vat photo polymerization 3D printing processes such as stereolithography (SLA), digital light processing (DLP) and the latest generation of continual DLP technologies, such as continuous liquid interface production (CLIP) from Carbon— and material jetting processes, specially Multi Jet printing [10].

A photopolymers are thermosets polymer that changes its physical properties-liquid plastic resins that harden when exposed to light source, such as a laser, a lamp, a projector or light-emitting diodes (LEDs). Once the chemical reaction takes place to harden the material, it cannot be re-melted. While they may include a number of ingredients, such as plasticizers and colorants, the key elements necessary for the photo polymerization process are photo initiators, oligomers and/or monomers. When hit with a light source, photo initiators will transform light energy into chemical energy, causing the oligomer (also referred to as "binders") and monomer mixture to form three-dimensional polymer networks. To alter the physical properties of the material, such as the stiffness or viscosity, the chemistry might include a variety of oligomers and monomers, such as epoxies, urethanes and polyesters. Additionally, fillers, pigments and other auxiliary chemistries applied into the mix to change the color of the material or further augment the functionality of the printed part [10].The diverse practical application of these materials are in printing castable models of jewelry or dental crowns to creating biomedical ceramic bone implants [10].

B. Acrylonitrile Butadiene Styrene (ABS)

Acrylonitrile butadiene styrene (ABS) is a tough, sturdy material with superb dimensional accuracy [8]. ABS derived from Acrylonitrile, Butadiene and Styrene polymers, commonly used in personal or household 3D printer. ABS products printed by FDM technique, generally preferred for large part because of great plastic properties [11]. It is lightweight, has good impact strength, abrasion resistant and affordable; ABS polymers bear many chemical formulas. The melting temperature of ABS plastic is 200°C (392°F), The higher melting point of ABS makes for objects that are relatively warp and crack-resistant. This makes ABS a decent superior for producing certain casings and other end-use parts. Due to the strong, sturdy material that widely used for constructing things such as plastic car parts, musical instruments, and the ever-popular Lego building blocks [12]. ABS also applicable in rapid tooling and for forming concept replicas [8].

C. Polylactide (PLA)

Polylactide, or polylactic acid (PLA), filaments contain one of the most popular types of thermoplastic materials. PLA is prepared from organic materials- cornstarch or sugar cane; it is biodegradable and hence eco-friendly. Due to its sugar content, PLA filament gives off a somewhat honeyed smells when heated. It is non-toxic and warp-resistant, even weaker than ABS [8] However, it can achieve a high quality of print feature and is less prone to errors while printing.it is melting point 173°C a far lower than ABS. However, it can achieve a superior level of print detail and is less prone to errors while printing. While storing them in high-temperature locations can result in the part warping, cracking, or melting. Because of great features, it is easy and forgiving to print. The finish detail is usually very neat. It is not prone to stringing or blobbing. Post print finishing is straightforward. It is easy to sand, drill or cut after printing [13]. The polymer used in various applications, including rapid prototyping, candy wraps and eco-friendly sutures [12].

D. Nylon

Nylon plastic is polyamide types called White, strong & flexible, Durable plastic [15] very hygroscopic, robust, and stretchy and resilient. It demonstrates excellent material memory. Objects printed from nylon filament reveal good bond between layers [8]. Nylon is moisture-sensitive, that means it readily absorbs water from the air, it is often necessary to print in a vacuum or at high temperatures. Effective 3D printing with nylon requires dry filament [14]. Inventers and manufacturers accomplish tests using functional prototypes printed from nylon. Nylon filaments typically require extruder temperatures near 250 ºC [15], greatly weakens the part. It also ruins the surface finish [8]. Dry nylon prints buttery smooth and has a glossy finish. To dry nylon filament, place it in an oven at 160°F - 180°F for 6 to 8 hours. After drying, store in an airtight container, preferably with desiccant [14]. Nylon is a tough and semi-flexible material that offers high impact and

 DOI : 10.18231/2454-9150.2018.0433

abrasion resistance. Therefore, it is an ideal choice for printing durable parts [16], Low-run, smooth-finish nylon parts used in everything from consumer electronics to adventure sports [8].

E. Polycarbonate (PC)

Polycarbonate also denoted as PC plastics are light and dense, and they possess excellent tensile strength [8]. It is a naturally transparent thermoplastic with high impact resistance and excellent heat resistance than certain acrylics [17]. Materials need temperatures around 260º-300º C. in order to extrude and have proper layer adhesion [8], [17]. Even the PC is naturally transparent, is potential to color PC materials as preferred. Carbon-reinforced PC plastics are strong and heat-resistant enable to print intake manifolds and other parts subject to high temperatures [8]. Some stellar and almost durable RC cars, drones, or anything [17].

F. Polyvinyl Alcohol (PVA)

Polyvinyl alcohol (PVA) is a water-soluble synthetic polymer used to print support structures to achieve complex geometries, such as internal cavities and underneath overhangs. Therefore, once the main object is fully printed, then the PVA purely melted away, frequently by warm water [8]. PVA is nontoxic, neutral and easy to extrude. In 3D printing, PVA generally used in printers with dual-extruders, PVA delivers high tensile strength and flexibility and easily dissolved in water, release the object from the support structure, so, manual post-printing curing, sanding, or grinding not required. At room temperature, the polymer dissolved within 20 minutes in warm water, Contact of water or moisture can dissolve PVA, so it is highly suggested, to keep the filaments dry and sealed. Even mild moisture can ruin an unwrapped reel of filament [18].PVA performs fine together with PLA. PVA extrudes best between 190 and 200°C. Printing at temperatures higher than 200ºC is also possible but is not fine; the material can begin to destroy, leading to jams in the nozzles that are extremely challenging to take out [18].

III. CERAMICS AND GLASS

A. Ceramics

Ceramics an inorganic, nonmetallic, solid material comprising metal, nonmetal or metalloid atoms. It formed from clay sintered in a kiln [19].

Additive manufacturing using silicon carbide (SiC) ceramics deals short-run, economical production, because the inefficient process of making molds eliminated. Geometrically complex ceramic parts provide superior performance with lightweight, properties very striking to jet engine and rocket engine manufactures [8].Commercially feasible production developing using various AM methods, including binder jetting, material extrusion and stereolithography. For instance, finely detailed porcelain objects formed through stereolithography from an extruded aqueous ceramic paste containing of a photopolymer mixed with ceramic powder. Curing, firing and glazing complete the process [8].The method produces ceramic parts with injection-mold excellence, but then again more complicated designs, including delicate cavities and undercuts it reduces costs by eliminates unmolding and other inefficiencies. In over-all, ceramic 3D printing is rapidly developing from the short-run manufacturing of specific objects to the bulk production of customized goods. Finally, the use of additive manufacturing to produce high-performance ceramics may completely alter the manufacturing ways [8]. NYC-based startup: Kwambio’s engineers developed ceramo-one- by creating a new way of binder jetting ceramic powders, which allows to 3D print objects layer by layer.it is a high-precision 3D printer for ceramic objects, Its speed and competitive material cost make an more attractive machine for production [19].

Olivier van Herpt developed custom-made clay 3D printer with special extruder system and ceramic filament [20]. Stoneflower3D: ceramic 3D printer from Munich able to print ceramics, porcelain, plaster, experiment with pulp, wax, or even food, make custom jewelry from metal clay, and even automatically deposit paints on canvas or soldering paste on PCBs [19]. Austria-based Lithoz provides a user-friendly online service and ‘plug & play’ network with different glass ceramic material options. In their software to create specific ceramic parts. The patented LCM-Process of Lithoz propose the opportunity to produce 3D printed ceramic products in a fast, more cost-efficient way for Prototypes, small-scale series, and complex geometries. They also offer bone-replacement material tricalcium phosphate for medical purposes [19]. Admatec deliver ceramic printed components, materials consist of alumina- and zirconia-oxide, fused silica, aluminum toughened zirconia and silica based materials for investment casting. Ceramic 3D printing of Hydroxyapatite is currently in development [19].Shapeways or iMaterialise provides online printing service to print a wide variety of ornamental, colorful objects for the home or office. Even, ceramics material used to print the objects is food-safe, recyclable, and watertight. This makes it perfect for cups, saucers, plates, even statues, and figurines [19].

B. Glass

In selective laser sintering (SLS), glass powder moderately liquefied by lasers to build 3D objects suitable in architectural and product design also in the field of optoelectronics. Due to its thermal stability and high transmissivity, fused quartz quality used for optical, communication, electronic and hermetic sealing applications [8].3D-printed optically transparent glass needs high-temperature dispensation of glass powder into a fully toughened product. To create glass objects by additive

 DOI : 10.18231/2454-9150.2018.0433

manufacturing, it is essential to control viscosity, feed rate, layer thickness, flow rate and adhesion [21].

Researches shows the possibility of efficiently manufacturing optically transparent glass using a material extrusion process [8]. For instance, MIT advanced a method for extruded materials to produce optically transparent glass. To create glass objects, material extruding through a ceramic nozzle at temperatures of up to 1640°C. Which extrudes it to cool and harden the resulting stream of molten glass appearances like honey [22]. Researchers predict the opportunities of fiber optics built right into printed glass structure frontages using additive manufacturing [8].

Micron3DP's 3D printing technology is similar to FFF, only much, much hotter, and capable of printing two types of glass materials: soda lime and borosilicate [22].Lawrence Livermore National Laboratory (LLNL) developed a method for 3D printing glass using direct ink writing. Unlike FFF glass 3D printing, high temperatures not required for this form of printing; in fact, the glass could be 3D printed at room temperature, using an ink formulated from concentrated suspensions of silica particles. 3D printing permitted for easier, economical lens fabrication, and enabled composition gradients that are not available on the market [22].German researches produced 3D printed very complex tiny objects using glass- pretzel. The researchers used a "liquid glass" to make complex shapes that are smooth, transparent, and have a very high resolution [23].

IV. METALS

Metal 3D printing has definitely been the hot topic of todays in the Pacific Design & Manufacturing Show by industries [24]. The reason metal 3D printing is so hot because parts can be serially 3D printed for mass production [25]. The technologies involved in metal 3D printing such as Direct Metal Laser Sintering (DMLS), Electron Beam Melting (EBM), laser metal fusion (LMF), Selective Laser Sintering (SLS), Direct Energy Deposition (DED) [25].

Metal powder and wire filament are both materials used in additive manufacturing, depending on the particular method used. Many metals are available in powdered form, including titanium, titanium alloys, steel, stainless steel, aluminum, copper alloys and various super alloys. Precious metals like those that gold, platinum, palladium and silver are also available in powdered form [8].Wire feedstock choices are even more extensive. Because of the availability in the wire feedstock form of metals such as steel and stainless steel alloys even pure metals like titanium, tantalum, tungsten, niobium, molybdenum and aluminum [8].

Selective Laser Melting (SLM) and Direct Metal Laser Sintering (DMLS) two metal additive manufacturing processes that belong to the powder bed fusion 3D printing family, both use a laser to scan and selectively fuse (or melt) the metal powder particles, bonding them together and building a part layer-by-layer. In addition, the materials used in both processes are metals that come in a granular form that partially melts many different metals and alloys, yielding objects with a degree of porosity [27].

On the other hand, electron beam melting (EBM) uses very powerful beams of electrons to melt various powdered metals, including titanium, steel and stainless steel. EBM is popular where porosity must be minimized, such as in high-stress, high-temperature aerospace applications [8].

These are some of the more popular metals used in additive manufacturing.

A. Titanium

Pure titanium (Ti64 or TiAl4V) is one of the most commonly used materials in metal 3D printing, because of its versatility, strength, and lightness. It is applicable in both powder bed fusion and binder jetting methods, mostly in the medical industry (to make personalized prosthetics) and the aerospace, automotive, tooling industries (to make parts and prototypes).Due to its highly reactiveness, it can explode in powder form. Then it is required to 3D print in a vacuum or in an argon gas, atmosphere [27].Titanium (TiAl6V4) is a very strong, lightweight, corrosion-resistant material. Which can printed by laser sintering method, 3D-printed titanium (unpolished) appearances matte gray finish with a slightly rougher and less defined surface or a slightly reflective satin finish [28].

EBM use gun, which produces very powerful an electron beam deposits molten metal from titanium wire feedstock, to create parts for a variety of high-performance engineering applications, including jet engines and turbines [8].3D printed titanium parts revolutionize the aviation industry. General Electric (GE) estimates that printed parts could bring down an aircraft's weight by 1,000 pounds. GE is already printing fuel nozzles for its new CFM LEAP engines instead of welding each part from 18 smaller parts, also, Airbus Group and EOS have designed 3D printed nacelle hinges in titanium that save 40% more fuel than their conventionally manufactured counterparts [29].

3D printed titanium parts proved their great success in the medical industry as well. A Chinese farmer's damaged skull reestablished with a 3D printed titanium mesh by the collaboration of Stryker, a medical tech firm and the Xijing hospital. Prosthetic cranial implants 3D printed in Trabecular Titanium successfully implanted in a patient in Argentina. Other applications include custom titanium shoes printed for a horse race in Australia. Hugo Arcier, an artist has created sculptures using 3D printing and displayed them in an exhibition called Dogma. Empire, a bike manufacturer tied up with additive manufacturing firm, Reinshaw to produce a 3D printed titanium bike [29]. Titanium is a hypoallergenic metal which makes it perfect for jewelry if have a metal allergy or sensitive skin. Bugatti produced 3D printed brake -caliper form titanium [28].

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A. Stainless Steel

EBM technology uses powdered stainless steel to produce solid, heavy-duty, water-resistant parts for extreme atmospheres like jet engines, rockets and even nuclear facilities [8]. Also Fusion or laser sintering: DMLS and SLM produces Stainless Steel 3D printing.

316L, a low-carbon alloy of stainless steel also known as 1.4404, is a highly corrosion-resistant material and offers excellent strength. This 3D-printed stainless steel produced via Select Laser Melting (SLM) and has high ductility and good thermal properties. It is applicable for food-safe applications, machine components and production tools [30].

B. High-Performance Alloys

Today's most popular alloys are, Inconel 625, Inconel 713 and Inconel 718 [8], Alloy 625 developed as a nickel-chromium alloy solid solution strengthened by its content of molybdenum and niobium [31]. Such alloys resist thermal creep deformation, and they endure highly acidic environments. These materials particularly used in turbine engines, exhaust systems and fuel systems [31] Because of their rupture-resistant and corrosion-resistant strength widely used in various saltwater marine and naval applications, chemical processing, aerospace and oil and gas industries [8].

Cobalt chrome alloys are harder and more temperature-resistant than stainless steel and titanium, so they are also ideal for use in jet engines and turbines [8].Cobalt chrome alloys -Co28Cr6Mo (2.4723) an alloy commonly used for surgical implants as artificial joints including knee and hip joints due to high wear-resistance, biocompatibility, and nickel-free composition [35].

C.Aluminum

Aluminum is 3D printed using the DMLS (Direct Metal Laser Sintering) or SLM process. A very fine metal powder melted with a laser to produce your design layer by layer. Once design is complete, then support structures removed to get finish part. Unused powder can reused for the next model [32].Parts typically have a textured, matte surface, which distinguishes them from traditional milled aluminum parts. Due to its strong, durable services with low weight, cost effectiveness, 3D-printed aluminum used for automotive and racing parts [8].

Aluminum- AlSi10Mg, alloy gives a homogeneous and nearly pore free structure and is impermeable. It offers high hardness values, and good dynamic strength.3D Printed parts of this alloy exposed to shape finishing processes, including heat-treatment, machining, welding, eroding, micro blasting, polishing and coatings [32].

Aluminum: AlSi9Cu3, alloy material gives high thermal conductivity and low density with good strength and high chemical resistance, high-temperature strength, which makes it batter option for engine and gear manufacturing specifically ideal for transmission casings, cylinder heads and engine blocks [32].

Aluminum: AlMgSc (Scalmalloy®RP) specifically designed for aerospace applications. The specific combination of essentials provides better strength. The strength of parts increased with a hardening process. It is mostly suitable for critical design [32].

D.Precious Metals

It is possible to sinter powdered gold, silver, platinum and palladium in DMLS or SLM process machines [33]. Extremely fine metal powder moderately melted to create jewelry [8]. As with the, wax casting process-objects first 3D printed in wax, which used to make a plaster mold, in which the molten metal (precious metals) poured in to cast the result [10]. At the conclusion of the process, the object removed from the remaining metal powder, akin to an archaeological dig [8].Unique and attractive pieces of jewelry feature interlocking or interwoven designs only possible with additive manufacturing [8].

UK based Cookson gold & EON's precious metal additive manufacturing systems utilize a cartridge-based system, rather than powder reservoirs, which delivers the material to the build area with a blade for a 20-micron slice. This process "manages metal really well for accountability" targeted for jewelry [34].

V. BIOPRITNING MATERIALS

Bioprinting is 3D printing techniques to combine cells, growth factors, and biomaterials to construct biomedical parts that excellently replicate natural tissue characteristics. Usually, 3D bioprinting utilizes the layer-by-layer method to deposit materials known as bioinks to create tissue-like structures that used in medical and tissue engineering fields [36]. Bioinks are substances made of living cells that used for 3D printing of complex tissue models. Bioinks are materials that mimic an extracellular matrix environment to support the adhesion, proliferation, and differentiation of living cells [37]. A bioink is a hydrogel biomaterial that extruded through a printing nozzle or needle into filaments that can maintain shape fidelity after deposition [37].

Structural bioink contain alginates, chitosans, collagens, gelatin, hyaluronic acids, decellularized ECMs, and numerous, biggest challenge is to maintain mechanical and degradation properties, construct shape and size, and cell survivability [38]. Sacrificial bioinks are soluble in water, under specific temperatures, or rapidly degrade to allow their removal from the construct. Sacrificial bioinks include non-crosslinked gelatins, pluronics, and other materials that easy remove [38].

Functional bioinks these materials may contain growth factors and other biological cues that stimulate differentiation toward certain tissues. Additionally, release

 DOI : 10.18231/2454-9150.2018.0433

growth factors or other molecules released by the cells to recapitulate the native ECM [38].

Protective lattices made-up from ingredients such as PCL, PLGA, printed around softer bioprinted builds for applications in cartridge and bone to survive forces while growth occurs. Moreover, these supportive bioinks act as structural supports that offer rigid structure to complex and complex builds that contain intricate shapes, overhangs, and vessel networks, etc. until growth progressions enough to support their own weight [38].

VI. FOOD: 3D PRINTING MATERIALS

3D food printers is much more complicated, combining nozzles, powdery material, lasers, and robotic arms to make sugar sculptures, patterned chocolate, and latticed pastry [43].ChefJets's 3D printer crystalizes thin layers of fine-grain sugar into a variety of geometric configurations [44]. Choc Edge, Barcelona-based Natural Foods, dispenses chocolate from syringes in beautifully melty patterns [45].

Foodini's cutting-edge printers can tackle even more. That uses fresh ingredients loaded into stainless steel capsules to make foods like pizza, stuffed pasta, quiche, and brownies [43].Barilla's pasta maker machines prints noodles with water and semolina flour,In additions Hod Lipson's prototype, fabricates nutrition bars and simple pastries [44].

Smoothfoods made of mashed carrots, peas, and broccoli, which 3D printers congealed with an edible glue.Dutch food designer Chloé Rutzerveld documented the creation of cracker-like yeast structures containing seeds and spores that sprout over time, and thinks the snack he synthesized and those like it natural, transportable products printed efficiently [43].

VII. FUTURE MATERIALS

A. Multimaterial Shape Memory Polymer (4D printing)

MIT engineers and Singapore University researchers (SUTD) published their work in the journal Nature, about Multimaterial 4D Printing with Tailorable Shape Memory Polymers, their research on a heat-responsive polymer. The SMP (Shape Memory Polymers) has ability to shape differently, after bend or exposed to extreme pressure, and successively recover its original shape upon environmental stimuli: heat [39].

B. 3D Printing Molecules

Chemists of the University of Illinois have been working in 3D printing molecules, Led by a medical doctor, Martin D. Burke, the team have created a machine capable of automatically synthesizing new small organic molecules by welding together pre-made building blocks that can be able to put together in any configuration. Two hundred such building blocks already exist. As a result, the machine has the ability to 3D print billions of different small organic compounds that possibly tested as new drugs or for other uses. This printer currently developed by REVOLUTION Medicines, Inc. [39].

C.3D Printing Conductive Materials

Viginia Tech's team built, using microstereolithography, millimeter-sized 3D objects from a conductive polymer made using an ionic liquid. Indeed, this technique could allow engineers to print conductive components or even tissue scaffolds and human cells [39].

D.3D Carbon Nanotubes

By FDM, process carbon nanotubes used to reinforce plastic objects to 3D print. The process involves coating the plastic filament with carbon nanotube ink and then subjecting it to microwaves, much stronger object produced by this technique [40].

F.3D Printing Graphene

Haydale Graphene Industries, a UK based graphene and nanomaterials manufacturer, has announced a launch of its new line of graphene-enhanced PLA filaments with improved strength and stiffness or better performance. Others also introduced 3D printed graphene aerogel. It is 7.5 times lighter than air, and a cubic meter of the stuff weighs just 160 grams [41].

E. 3D Printing Cemented Carbide

Fraunhofer IKTS have developed a method to 3D print cemented carbide with the binder jetting 3D printing technology, producing extremely hard objects. In fact, these objects can withstand enormous forces present in production machines like mills or drills. Furthermore, complex objects are possible, such as helical shapes or cooling tunnels inside components [39].

H. 3D printing of Cellulose

VTT Technical Research Centre of Finland with other universities has started project in which textile applications like 3D printing of cellulose are being developed and the application of cellulose-based materials in the built environment is being studied [42].

I. 4D Bio-inks.

4-Dimensional Bioinks are the next frontier for bioink development. These bioinks build on 4D biomaterials that defined by their sensitivity to external stimuli [38].4D bioprinted constructs have robust shape-changing capabilities will change the future of medical,4D printing flourish the next decade [37].

DOI : 10.18231/2454-9150.2018.0433

VIII. MATERIALS EVOLUTION IN 3D PRINTING.

A. The Infancy Stage: 1981 to 1999

In 1981, Dr. Hideo Kodama published his findings of a fully functional rapid prototyping (RP) system. The material used for the process was thermoset polymer-also called a thermosetting plastic; that irreversibly cured from a soft solid or viscous liquid, prepolymer or resin [46]. In 1984, Chuck Hull filed his own patent for steriolithigraphy, in which layers added by curing photopolymers-light activated resins with ultraviolet resin. In 1988, FDM- a special application of plastic extrusion, developed by S. Scott Crump-commercialized by his company Stratasys [47].

In 1993, MIT, developed powder bed and inkjet-based 3D printing in which materials used ceramics starch and gypsum, plaster fill the powder bed, and liquid "binder" -water used to activate the plaster. In 1994 to 1998, various industries used titanium alloyed powder material and some of used wax materials in inkjet print head method [46], [47].

B. The Adolescence Stage: 1999 to 2010

The adolescent history runs from 1999 through to 2010. This was the decade where we saw the first ever, 3D printed organ means biggest breakthrough of materials. It was a human bladder. The Scientists at Wake Forest Institute for Regenerative Medicine, they 3D printed the synthetic scaffolds of the organ. After that, they coated it with actual cells taken from real patients [49]. Surgeons were able to implant the newly formed tissue into patients; it is so revolutionary because the patient's own immune system would not reject an implant made of their own body cells. Even today, it sounds incredible, but it happened, and improved things continue to happen.

As far as medicine goes, this was the decade for 3D printing technologies. As research continued, advanced medical uses emerged. Here are just three others that are hard to believe [49] [50]:

i. The first fabricated, functional miniature kidney

ii. The first prosthetic leg - complex components

iii. The first bio-printed blood vessels using human cells

C. The Adult Stage: 2011 to the present day

If thought, 3D printing had reached its peak, think again. It is as though there are no boundaries going forward. The swiftness in which the technology has picked up in recent times is nothing short of spectacular. Charles Hull knew, he was onto something big, but he could never have envisioned just how big it would all get. Today, anyone can print with materials other than plastics. There are options to print with metals, glass, paper and wood among others [49].

Now days it is possible to print musical instruments, jewelry, household items, and clothing accessories. The Future potential looks at 3D printed homes, drones, vehicles, foods, and other human body parts. There seems to be no limitations. It is going to change because of the types of things will be able to print in 3D in all kinds of different materials, which keeps the industry alive and thrilling [49].

The future of 3D printing: Nano electronics such as small cameras, Nano fluidic filters inside channels that are only a micrometer wide. Printable electronics: the future, 3D printing flexible screens or flexible batteries, thin like rolled up and fit in a pocket!, The future materials for 3d nanomaterials, living cells, lithium iron, carbon nanotube, and Graphene [51].There is still plenty of future history around 3D printing, which shows strongly inspired to develop new materials for the future application of 3D printing.

IX. CONCLUSION

This review takes an in-depth look into established material classes' polymer, metal and ceramic materials, compatible with all main 3D printing technologies, ranging from thermoplastics and metals to concrete, chocolate and even living cells with its different form Powders, Filaments, and liquids. In future, all of these materials will developed for more strong industrial applications, so that AM can fit in to the bigger manufacturing supply chain as a production technology. At the same time, more competitors into the market, a drop in price to the machines and new methods for material processing will reduce the price of the materials, increasing AM use even further. As AM is included into the larger manufacturing supply chain, more exceptional, novel and functional materials will be developed, such as the graphene inks, cellulose, 4D Bioink. This will eventually make it possible to 3D print fully functional objects, possibly supporting the visions of completely automated factories that some businesses may just be dreaming about future of AM technologies.

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