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CLIP - A STEP TOWARDS ADDITIVE MANUFACTURING

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Abstract - Additive manufacturing processes are time-consuming, layer-by-layer approach where layers are laid down successively to fabricate a complete 3D object. This detainment of the field lead to the characteristic imperfections of layer-by-layer printing explicitly, anisotropic mechanical properties that depend upon print direction, recognizable by the stair-step surface finish effect. CLIP is a photochemical procedure that takes out the constraints with the regular 3D printing by harnessing light and oxygen to rapidly build the objects from the resin pool. Continuous generation of solid polymer parts up to several centimetres in size with goals under 100 micrometres is shown utilizing Continuous liquid interface generation (CLIP).CLIP is practiced with an oxygen-penetrable window underneath the UV projection plane, where it makes a "dead zone" and photo-polymerization is obstructed between this window and polymerizing part. Critical control parameters are identified and complex solid parts are drawn out from the resin pool at rates of several millimetres per hour which promotes the production of objects within the minutes rather than hours. CLIP Production makes the vision possible by combining engineering¬-grade materials with exceptional resolution and surface finish. From the daily products like to industrial components, and highly customizable medical devices, CLIP makes it possible for creators to design the parts and products of the future.

***Keywords*:** Additive Manufacturing, Continuous liquid interface production, Oxygen permeable, Dead Zone

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1. Introduction

Additive manufacturing processes generally referred as rapid prototyping in the industry and commonly identified as 3D printing technologies. Rapid prototyping (RP) is being used in many industries for rapidly creating an assembly or component that resembles the final product before commercialization. It’s an emphasis on a prototype or a basic model in order to create something quick and the output will be obtained from the advanced models and the final product is done. Additive Manufacturing is next step in RP technologies to leverage the speed and ease of creating assemblies or components in the wide range of applications that includes Tissue engineering, Molecular visualization, and less-dense to high-strength materials. Additive manufacturing or 3D printing, is an emerging field with the selective layering of material to build a part directly from CAD data with distinct advantages when compared to increased production. The advantages of additive manufacturing over conventional manufacturing are many which includes an unlimited design, the freedom for the complex geometries and a reducing the by-products wastage The development of a stereo-lithography (SL) device, a platform that uses an exposure of a UV laser to selectively solidify a resin top-down manner during a photo-polymerization process, in 1980 marked the inception of RP technologies. The present RP methods like Selective Laser Sintering (SLS), fused deposition modelling (FDM) and Stereo-Lithography (SLA), are extremely slow because of their layer-by-layer process. An object of several centimetres height takes hours to print and hence are not seen to transform from RP to AM in the industry. To adopt Additive Manufacturing for mass production, printing speeds needs to be increased by at least an order of magnitude while maintaining the part accuracy. If we can grow continuously instead of repetitive layer-on layer processes, we can eliminate the defects or inconsistency in the properties. Furthermore, if we can grow it really faster, we shall be able to start using the materials that are self-curable, with excellent properties. In this direction a company named orange maker has released the first continuous process, in July 2014 commercially available from 2015.Their Additive Manufacturing machine named as Helius 1 Heliolithography utilizes Ultra-violet light directed at ultra-high precision, to polymerize the liquid resin into solid plastic parts, in contrast to SLA, this is a continuous printing process. Later in the same year another kind of continuous AM technology is brought to forefront by Carbon®, which is Continuous Liquid Interface Production (CLIP).

2. Continuous Liquid Interface Production

2.1 Process

CLIP is modification of kinetics of Stereolithography process draws up a support plate, with ~~a~~ growing object anchored to it, from a resin-containing bath, a UV light source continuously projects the cross-sectional images (generated by a Digital Light-Processing imaging unit) of the targeted object through an oxygen-permeable, UV-transparent window from the below of a liquid resin bath that is cured in the resin as the object is steadily built up and drawn out of the bath. The heart of CLIP –is "dead zone", which is a thin uncured resin layer present between the window and printing object whose thickness is no more than 20 microns, but sufficient enough to drive the resin pool as the platform is drawn away from pool. Light pass through dead zone cure the resin above and form solid objects. Resin flows below the curing part as the printing propagates by maintaining the "constant liquid interface". The process is shown in Figure 1.

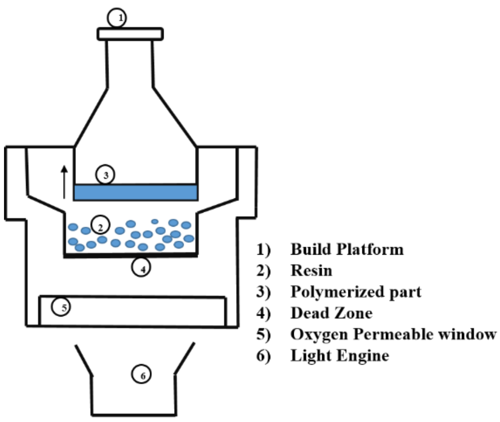

Figure 1: Schematic diagram of CLIP Process

The Oxygen inhibition will lead to the incomplete curing and surface tackiness when photo polymerization is being conducted in the air. A photo initiator (PI) absorbs light and turn into photoexcited photo initiator (PI*), which can either be quenched with oxygen or cleave to form a radical (R*). This radical (R*) reacts with the oxygen and forms peroxide or it can initiate and propagate the polymerization process (i.e. Curing) as indicated in Figure 2.

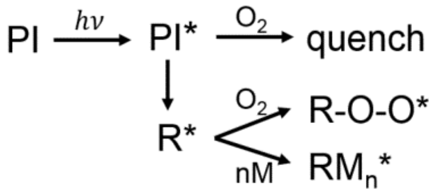

Figure 2: Role of O_2

2.2 Stereolithography Vs CLIP

The process of 3D printing which takes the advantage of an oxygen-inhibited dead zone is shown in Fig.-1. The thin layer of oxygen-enriched resin above the window creates a liquid "dead zone" (in which solidification cannot occur) below the growing part. As the cured part is drawn out continuously from resin pool, the suction forces will be created which renew the reactive liquid resin. This CLIP technique differs from the traditional bottom-up stereolithography, where, "UV light exposure, resin renewal, and object movement is conducted layer upon layer". For the inverted top-down approach in which object is successively lowered in a resin bath while printing and the photo-polymerization takes place at the air-resin interface. The steps are to be conducted sequentially for each layer to form final object. In contrast the printing speeds for the CLIP is limited by curing rate of resin and its viscosity but not by stepwise layer formation. Traditional 3D printed materials exhibits variable strength and mechanical properties which depend on their print direction. CLIP parts have consistency in all the directions. The gentleness and resolution of this process makes it possible to adopt a wide range of materials having surface finish which is needed for end use parts. Once the CLIP part gets printed it must be baked in a forced-circulation oven where the heat setting off takes place which cause the materials to strengthen. The Green Young's modulus of parts range between 250-280Mpa while the cured part has young's modulus of 3800-4000Mpa.

2.3 Materials & Applications

The material options available for Digital Light Synthesis technology leveraging the CLIP process, cover a wide range of material properties to satisfy the needs of various industries. Some of the broad types of material option available with applications successfully deploying these material capabilities are given in Table 1.

Table 1: Materials & Applications

Material	**Variants**	**Properties**	**Applications**
Medical PolyUrethane (MPU)	MPU 100	1. Bio-compatibility 2. Sterilizability 3. Durability 4. Abrasion Resistance 5. Chemical Resistance	1. One time surgical instruments 2. Surgical Tool Handles 3. Ligating Clip Holders 4. Prosthetics 5. Drug Contact Devices
Elastomeric PolyUrethane (EPU)	1. EPU 40 2. EPU 41	1. Tear Strength 2. Resilience 3. Elasticity 4. Impact absorption	1. Lattice structures 2. Gaskets 3. Seals
Silicone (SIL)	SIL 30	1. Bio Compatibility 2. Low hardness 3. Tear resistance	1. Bike Handles 2. Headphone pads 3. Watch Wrist bands
Rigid PolyUrethane (RPU)	1. RPU 60 2. RPU 61 3. RPU 70	1. Stiffness 2. Ductility 3. Toughness 4. Rigidity	1. Charger Housing 2. Motor Mounts
Flexible PolyUrethane (FPU)	FPU 50	1. Impact strength	1. Action Camera Mounts 2. Re-closable fasteners 3. Snap Fit parts
Cyanate Ester (CE)	1. CE 220 2. CE 221	1. Stiffness 2. Thermal Stability	1. Cooling Modules 2. Fluid Manifolds 3. Drive Gears 4. Pipette Cleaners
Epoxy (EPX)	EPX 82	1. Thermal Stability	1. Connector housings 2. Pedal levers 3. Brackets
Urethane Methacrylate (UMA)	UMA 90		

3. Scales of Additive Manufacturing

AM is not only about simplication/part consolidation and speeding of the process of product development, but also the financial gains in this process. The comparison of the Carbon's Digital

Life Synthesis to that of conventional methods like of injection moulding of various part present the inherent advantages of such technologies apart from existing advantages

3.1 Oracle Case Study:

In 2015, Oracle was working on a demanding design needed to be incorporated in micro servers to a larger network, Carbon partnered with oracle in this arduous.

3.2 Riddell Case Study:

In 2018, Riddell's player protection helmets were used by select players in NFL teams demonstrates how Carbon's Digital light synthesis was deployed for mass manufacturing of custom equipment to football players. Each of this Helmet is made up of 140000 individual struts which are custom fit a players' physical dimensions. This demonstrates us the capabilities of CLIP technology, into most demanding applications like athletes protective equipment.

4. Conclusions

3D printing foundational patents expired recently and enabled worldwide open-source community to innovate and accelerate progress in the much demanded area i.e., adopt Rapid Prototyping to Additive Manufacturing technologies around the world. Case-studies from Ford's Automotive components; Adidas's Athletic Footwear; Carbon's machinery mounts; Oracle Server mounts; New England Orthodontic Laboratory's Thermoforming Models; Becton, Dickinson and Company's haemocytometer adapter on single-cell genomic analysis system; Derby Dental Laboratory Smile shapers® parts; Wilson Tool Quick Tap ™ Tapping tools prove that CLIP enabled Digital Light Synthesis is a technology disrupting manufacturing industries with the introduction of digital manufacturing platform and a closely collaborated development in various areas of a product life cycle.

References

1. J. R. Tumbleston, D. Shirvanyants, N. Ermoshkin, R. Janusziewicz, A. R. Johnson, D. Kelly, K. Chen, R. Pinschmidt, J. P. Rolland, A. Ermoshkin, E. T. Samulski, J. M. DeSimone. "**Continuous liquid interface production of 3D objects**" *Science*, 2015; DOI: 10.1126/science.aaa2397
2. Vanek, J., Galicia, J. A. G. and Benes, B. (2014), "**Clever Support: Efficient Support Structure Generation for Digital Fabrication**". Computer Graphics Forum, 33: 117–125. DOI: 10.1111/cgf.12437
3. Vanek, J., Galicia, J. A. G., Benes, B., Měch, R., Carr, N., Stava, O. and Miller, G. S. (2014), "**PackMerger: A 3D Print Volume Optimizer**". Computer Graphics Forum, 33: 322–332. DOI: 10.1111/cgf.12353