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Resin Printer Buyer's Guide for Educational 3D laboratories

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Abstract

This report describes history, theory and market situation of resin 3D printers as of Spring 2015. The target audience is 3D labs seeking to buy their first such machine in the near future, with intentions of using it for educational purposes.

Contents

Table 1: First definitions of terms

Term	Definition
Photopolymer resin	A thermosetting plastic in the form of a thick liquid that hardens permanently when exposed to ceirtain kinds of radiation.
Fused Filament Fabrication	A method of 3D printing where the machines melts the tip of a thermoplastic filament with a near constant diameter.

1 Introduction

The company Carbon 3D spurred a new wave of interest in 3D printing, and especially resin 3D printing, when they demonstrated a print at previously unseen speed during a talk published on the popular home page `ted.com`.

This report is written to those who already run a 3D lab using other kinds of printers, but don't currently have any knowledge about the resin 3D printing specifics.

2 Theory

2.1 Glossary

Table 1 contains frequently used terms along with the meaning they carry in this report

2.2 Building material

The process called "hardening permanently" in table 1 is called *curing* in polymer chemistry. What happens on a chemical level is that new covalent bonds, often called cross links, are created between the polymer chains of the material. The effect of many cross links, is that the polymer chains lose their mobility relative to each other, and a gel or a solid is formed.

The density of cross links determines the mechanical properties of the resulting material. Low densities lead to gel-like properties. Intermediate densities lead to (potentially very strong) polymers having both elasticity and viscosity (elastomers). Demonstration videos from Carbon 3D shows a perfect example of such material properties.[1] These materials feels kind of like rubber to touch. High density of cross links leads to “glassy” polymers similar to hardened 2-component epoxy glue or bakelite.

While curing is easily controllable and leads to interesting material properties, it generally leads to materials that are hard or impossible to recycle. The reason for this is that the cross links are hard or impossible to distinguish from the bonds that were already present in the polymer chain. This makes designing a chemical process that selectively removes cross links hard. When cross linked materials are heated, they reach a deteriorate completely or caches fire, instead of melting like thermoplastics do. A famous example of commercial cross linked products that have become an environmental problem are car tires.

There exist one class of polymers that cross links using physical bonds instead of covalent bonds, and is therefore recyclable. They are called thermoplastic elastomers (TPE) and are used by FFF machinses through a filament produced by the company Ninja Flex as well as other compaines. The author as not been able to find any TPE photopolymer resins on the market.

3 History

The idea of producing solid objects by using a computer to control a light beam who selectively cross links a photopolymer is not new. Already in 1956, patent number 2,775,758 was issued in USA, describing a process similar to what we call resin 3D printing today. It was followed by many similar patents, and the idea has been tested commercially by different companies for over 50 years.[1][2] The first company that generalized and successfully commercialized the procedure was 3D Systems Inc. starting around 1986.[3]

4 Carbon 3D’s machine

The invention of Carbon 3D that allows for the high print speed is the use of a UV window between the lamp and the resin that is also oxygen-permeable.[2] The oxygen limits the curing process, creating a layer near the window where the resin stays liquid. This layer is called the *dead zone*, and is on the order of on the order of tens of micrometers thick. Farther from the window, where there is less oxygen, the cure is incomplete (low density of cross links). Still

[1]https://www.youtube.com/watch?v=dXIkRsJLXGs link tested to work 30 − 3 − 2015

[2]The type they use can be bought sepparately here: `http://www.professionalplastics.com/TeflonAF1600_AF2400`[4]

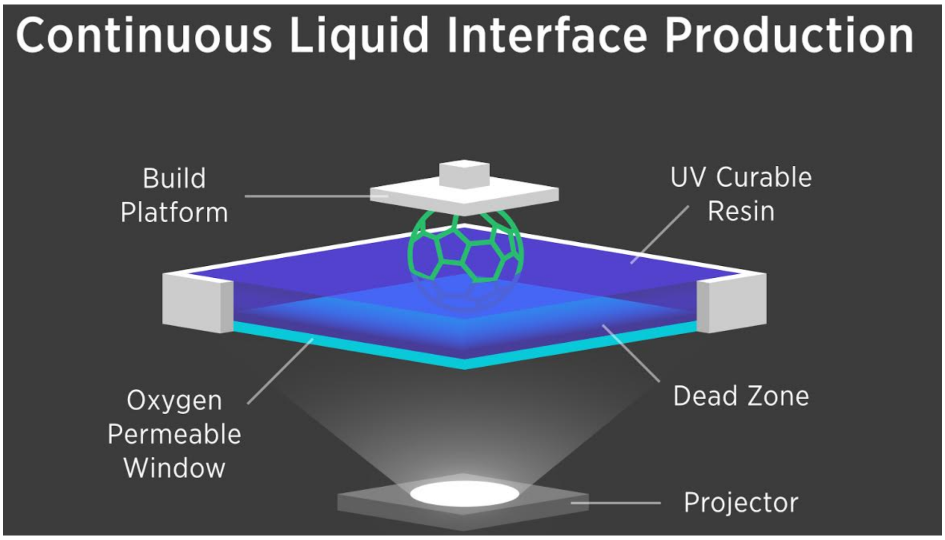

Figure 1: A schematic showing key properties of Carbon 3D's machine. Image courtesy of Carbon 3D.

farther from the window, at distances where UV light still shines through, the cure is completed. A schematic of the mechanism is shown in Figure 1.

The dead zone and its contiously increasing curability makes it possible to control the curing process by projecting quick sequences of UV-images through the window, making layers indistinguishable. Being able to flash entire images on the resin at once, in stead of curing with a laser point, and doing it without pauses is what gives Carbon 3D's machine higher print speeds than other 3d printers.

Carbon 3D has unquestionably made an invention, but it is not one that is hard to either understand or reproduce. Therefore competition will catch up very quickly if consumers show interest. The first test of that (after toda, 30 – 3 – 2015) will maybe be the Kickstarter project of a smiliar machine scheduled this coming September.[7]

5 The Open Source Movement's Desings

In table 2 you find a (far from exhaustive) list of open source resin based 3D printer designs. All of those uses UV lasers to cure the resin, hence print speeds are slow. Prices are very competitive.

The RepRap movement, who spurred the revolution in cheap 3D printers, has not yet taken any resin 3D printer to their chest. One reason for this is

Table 2: Some open source resin printers

printer	price pre-assembled	price kit	website
mUVe	$ 1500	$ 1000	`muve3d.net`
Peachy Printer	$ 400	$ 100	`peachyprinter.com`
LittleRP	$ 1000	$ 500	`littlerp.com`

that the project's self replication goal is hard to reach with parts like lasers and projectors.

6 Health

This section describes Methacrylate Photopolymer Resin (MPR), which is used in many desktop printers. Other resins exist, many advertising themselves as "low irritation".

MPH irritates skin, and eyes if it gets in contact. It is also suspected to irritate respiratory tract if inhalated, especially at higher temperatures. If swallowed, MPH causes a range of symptoms, from headache to central nervous system effects.[5]

Gloves are needed when removing prints from the print bed, a procedure that can be difficult without spilling resin. With risk of spilling resin around the machine, having food, cups of coffee and clothes close to the printer is not advised. Also, the printer must run in an adequatly ventilated area.

Most resin 3D printers (including Formlabs' and Carbon 3D's printers) use UV lamps.

7 Price

7.1 Material

The cost of 1 kg of resin currently ranges from ≈ 60 € to ≈ 200 €.[6] This is roughly three times more expensive than material for FFF printers.

Cost is also very much affected by amount of spill and amount of material needed to make solid figures strong.

8 Printing Process

The print will come out wet, and needs to be removed from the building platform using gloves. Before the printed figure can be handled normally, it needs to be bathed in UV-lights to complete curing, preferrably in an UV chamber.

8.1 Possible Complications

8.1.1 Daylight

As resins curation is driven by UV light, a bed of resin left in daylight over a day turns into an expensive and un recycable plastic brick. The resin must hence be stored in a dark place, and the printer must be cleaned after a finished print (or permanently shielded against UV light).

8.1.2 Dust and Bubbles

To get the maximum precision out of a resin printer, the resin itself must be clean. Small particles like dust or small bubbles of gas will cause bumps and bubbles on the surface.

9 Conclusions

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A Appendices