TAIPEI TECH
Dept of Mechanical Engineering
Institute of Mechatronic Engineering

Additive Manufacturing Technology

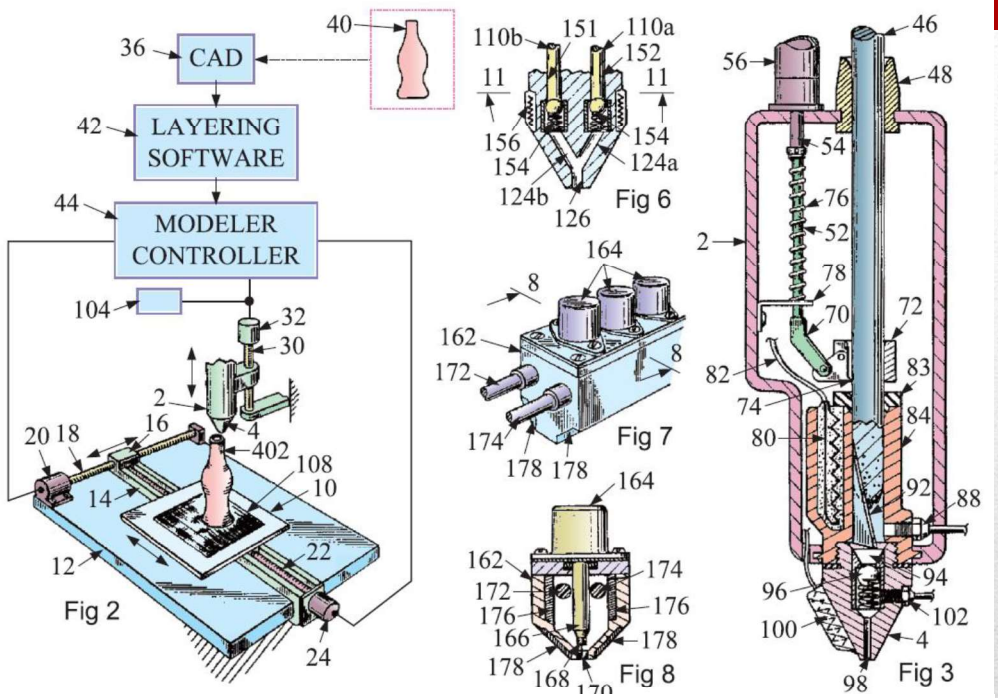
Material Extrusion
材料擠製成型技術

Contents

- The start of the ME technology
- The process principle of the technology
- Different materials
- The development of the systems
- Compare the differences
- Summary

- Material Extrusion is currently the most popular on the market. Whilst there are other techniques for creating the extrusion, heat is normally used to melt bulk material in a small, portable chamber. The material is pushed through by a tractor-feed system, which creates the pressure to extrude.

The technology



1989 applied, US 5121329A
Apparatus and method for creating three-dimensional objects

The begin of material extrusion

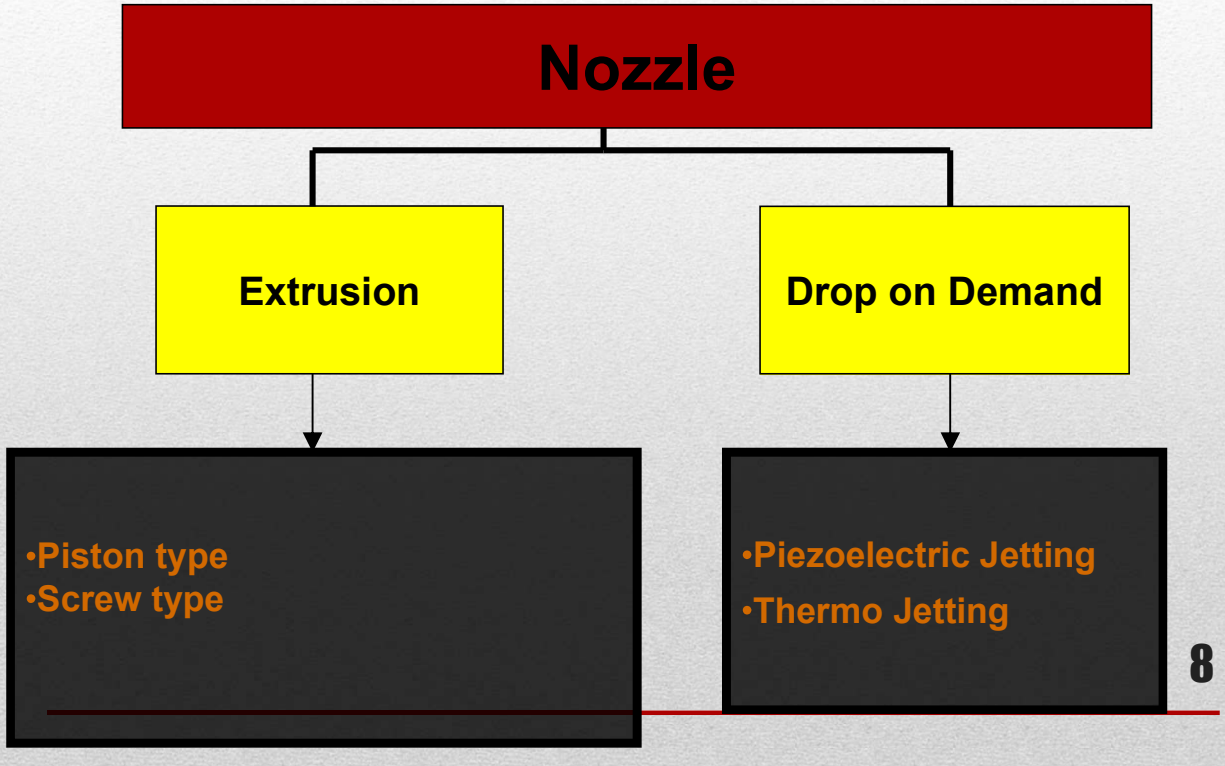
The Principle of ME Manufacturing Process

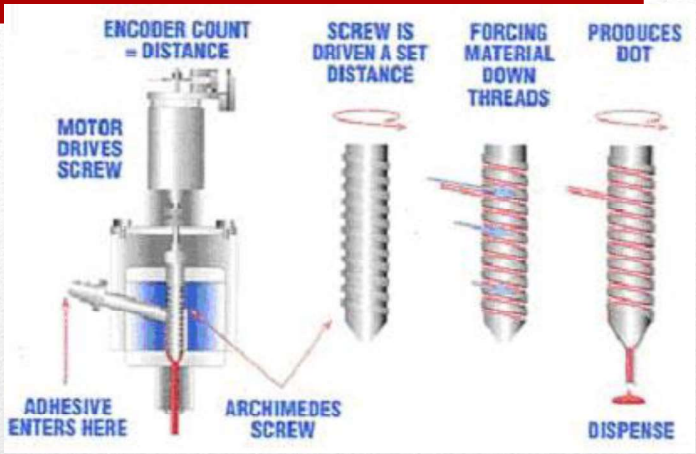
There are a number of key features that are common to any extrusion-based system:

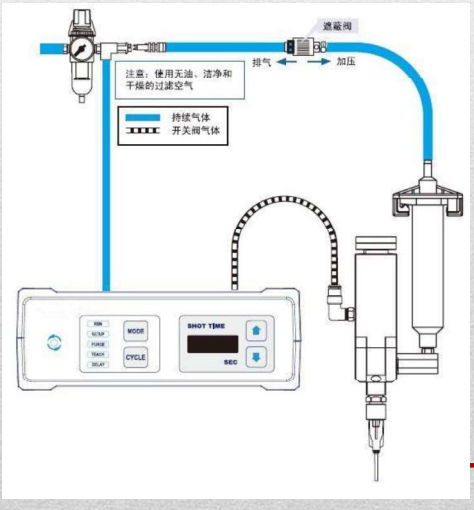
- Loading of material
- Liquification of the material
- Application of pressure to move the material through the nozzle
- Extrusion
- Plotting according to a predefined path and in a controlled manner
- Bonding of the material to itself or secondary build materials to form a coherent solid structure
- Inclusion of support structures to enable complex geometrical features

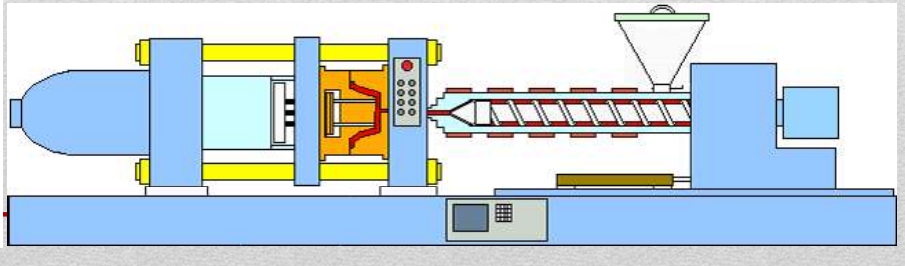
FDM (Fused Deposition Modeling)

Nozzle for AM

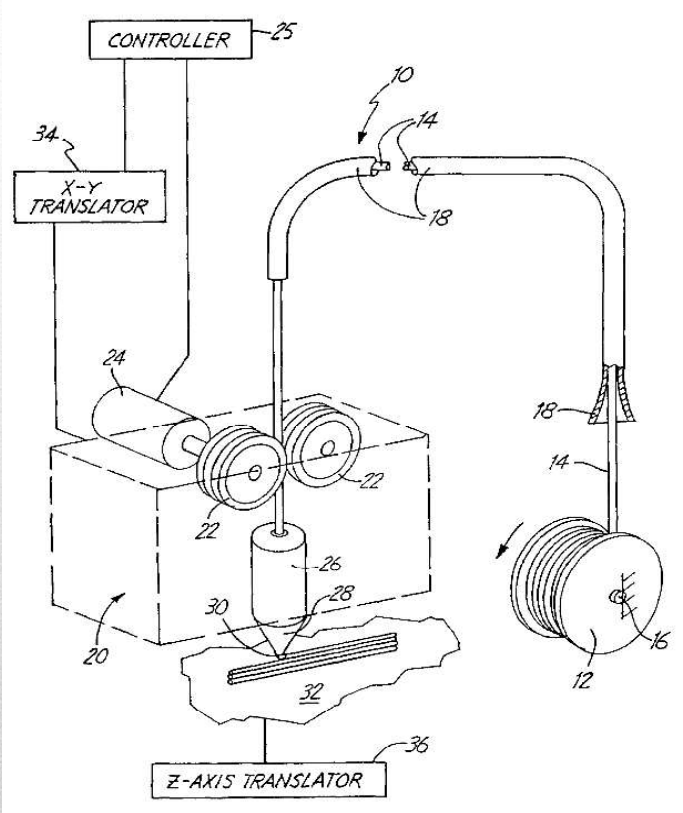




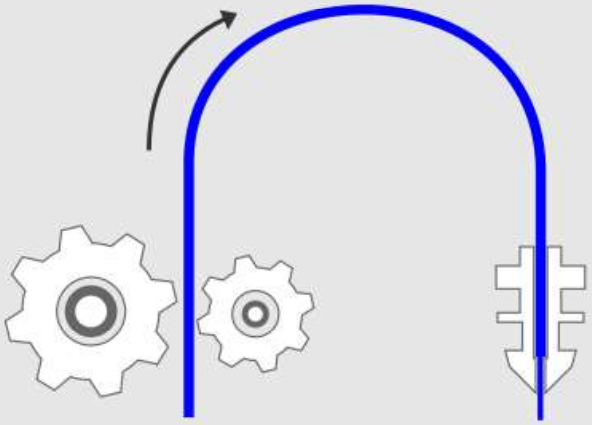




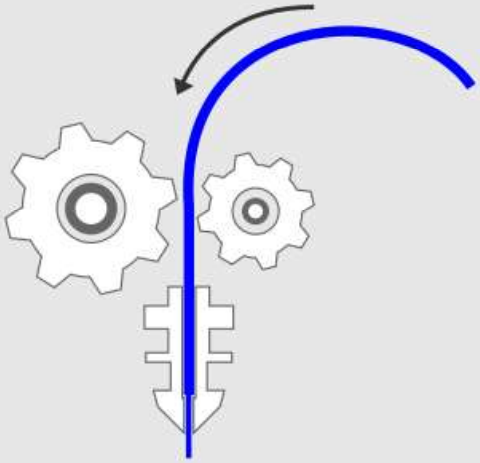
U.S. Patent No.7374712 B2



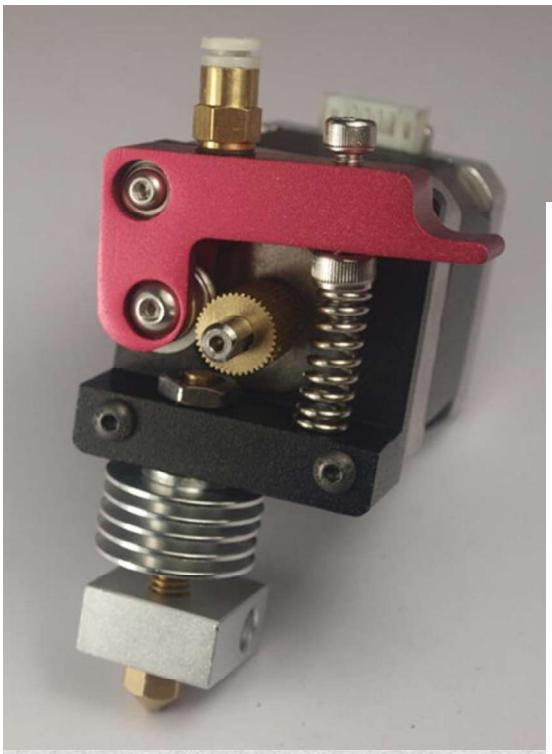
Bowden Extruder



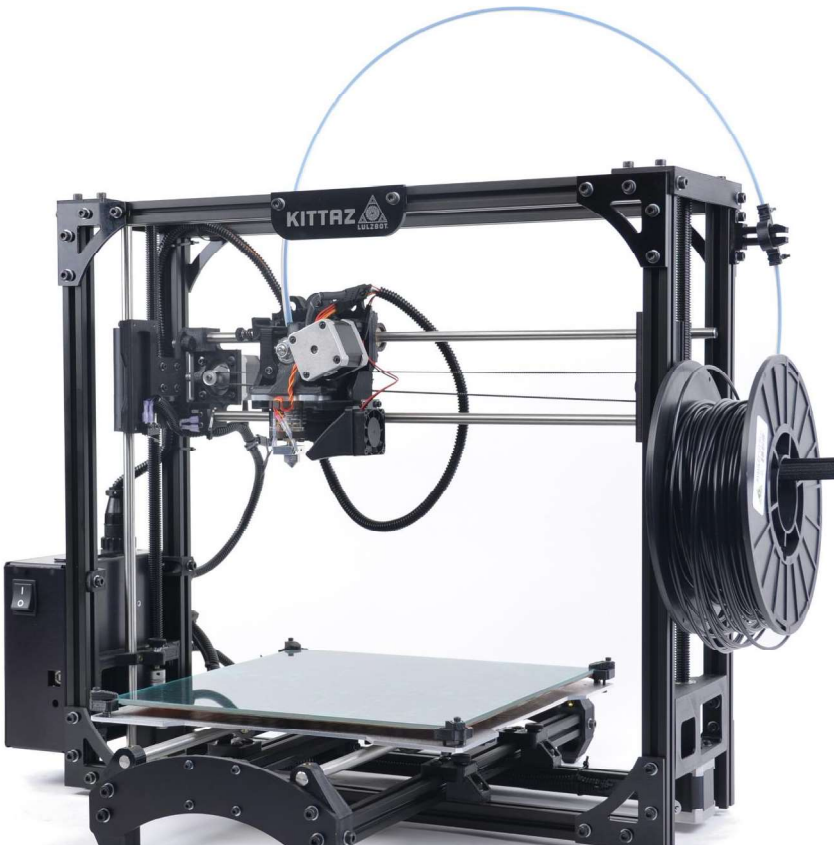
Direct Feed Extruder

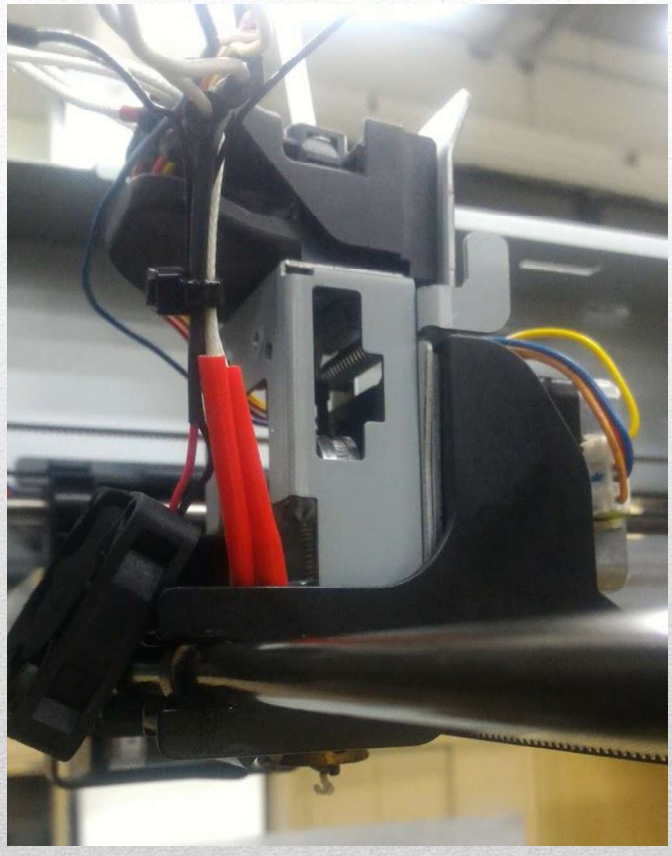


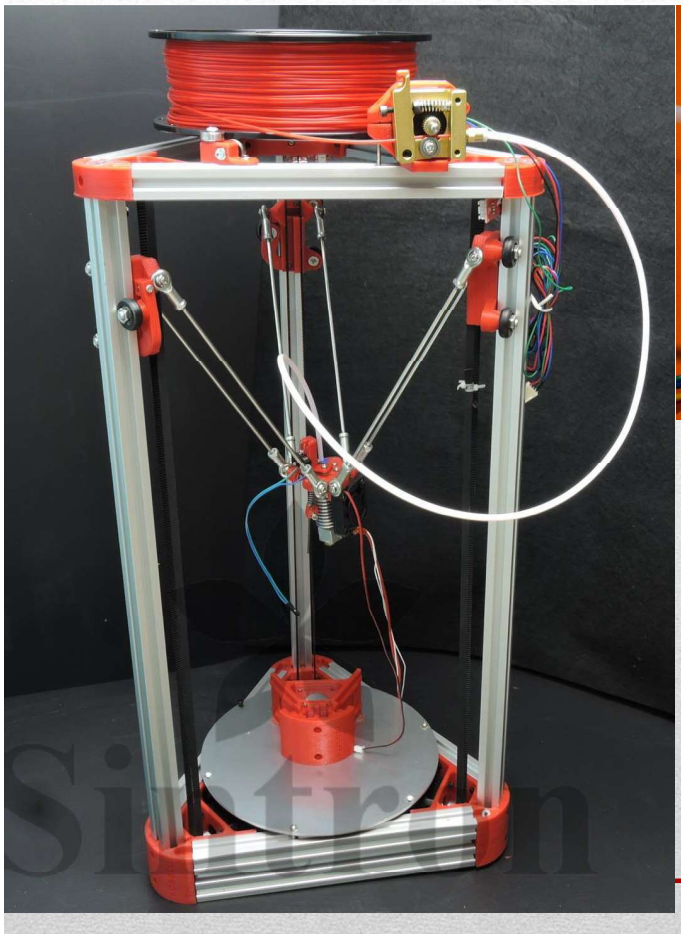
3D PRINTING.COM

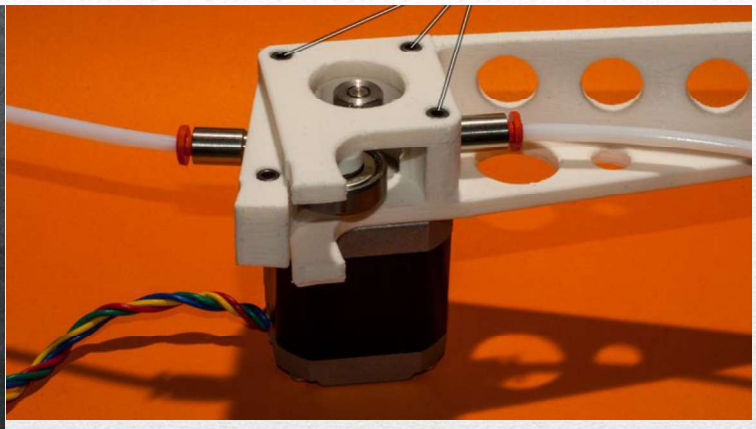


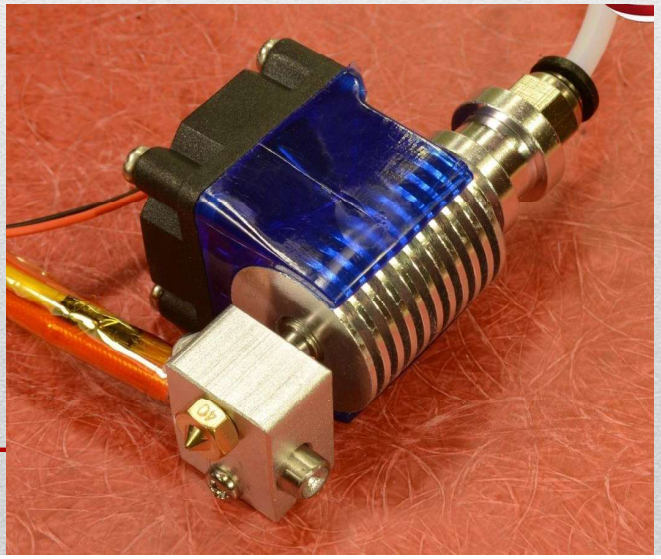
Direct extrusion

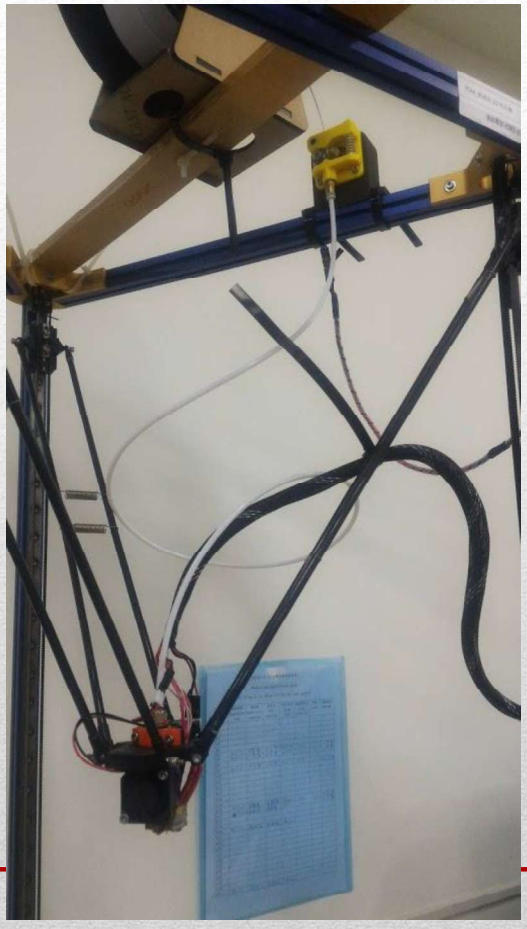


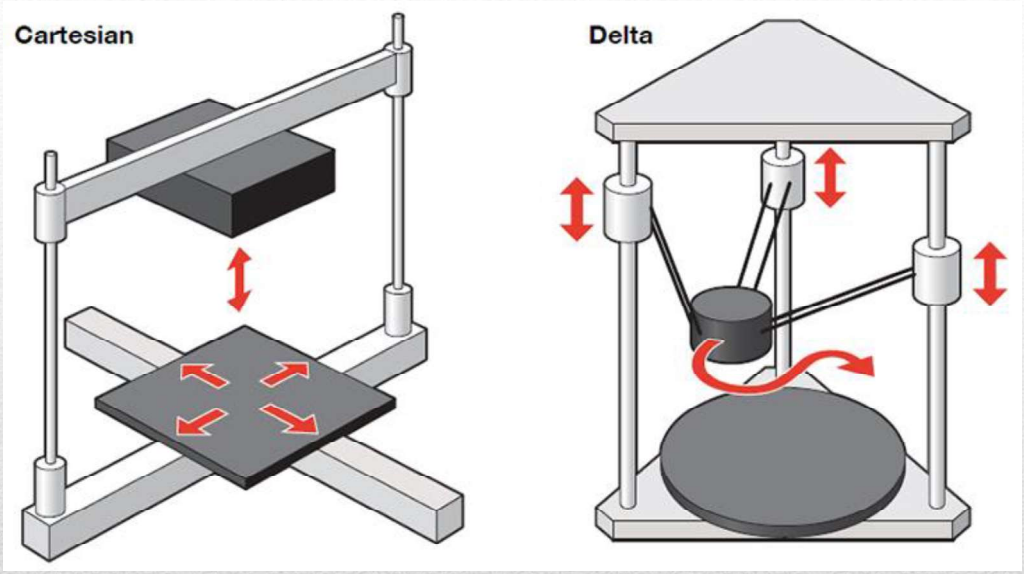


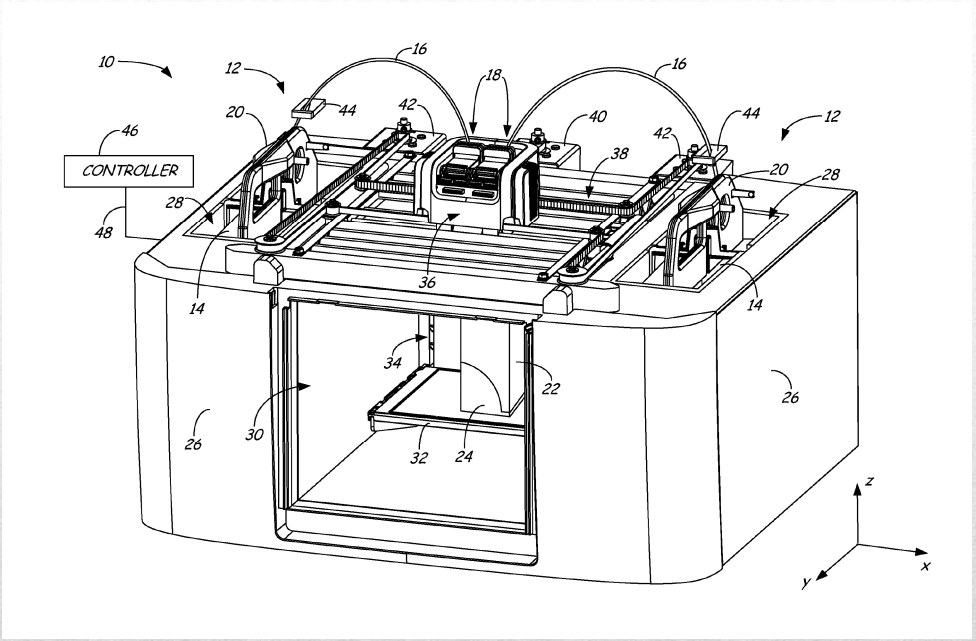


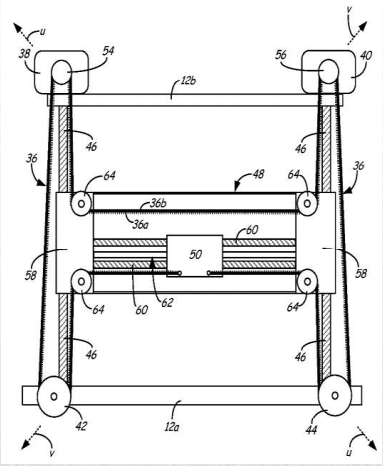




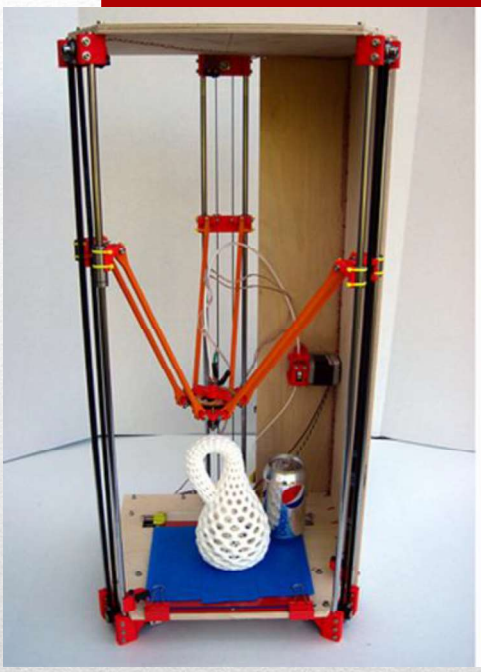



Cartesian
Delta

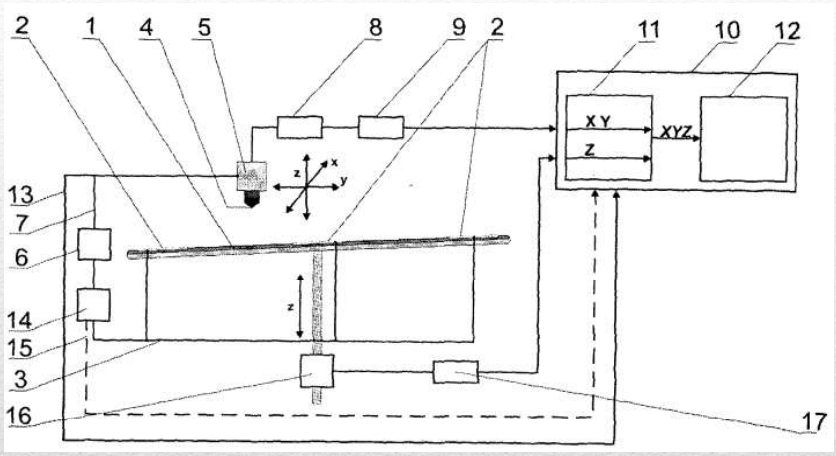


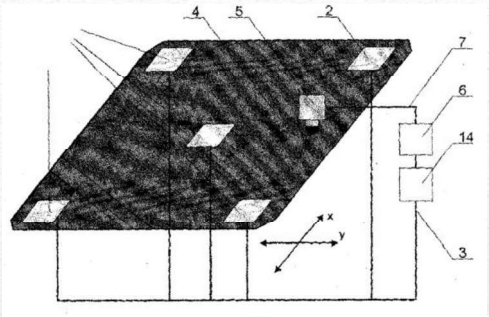


Fortus 900mc結構示意圖



Rostock & Kossel
(Delta type)

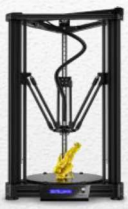




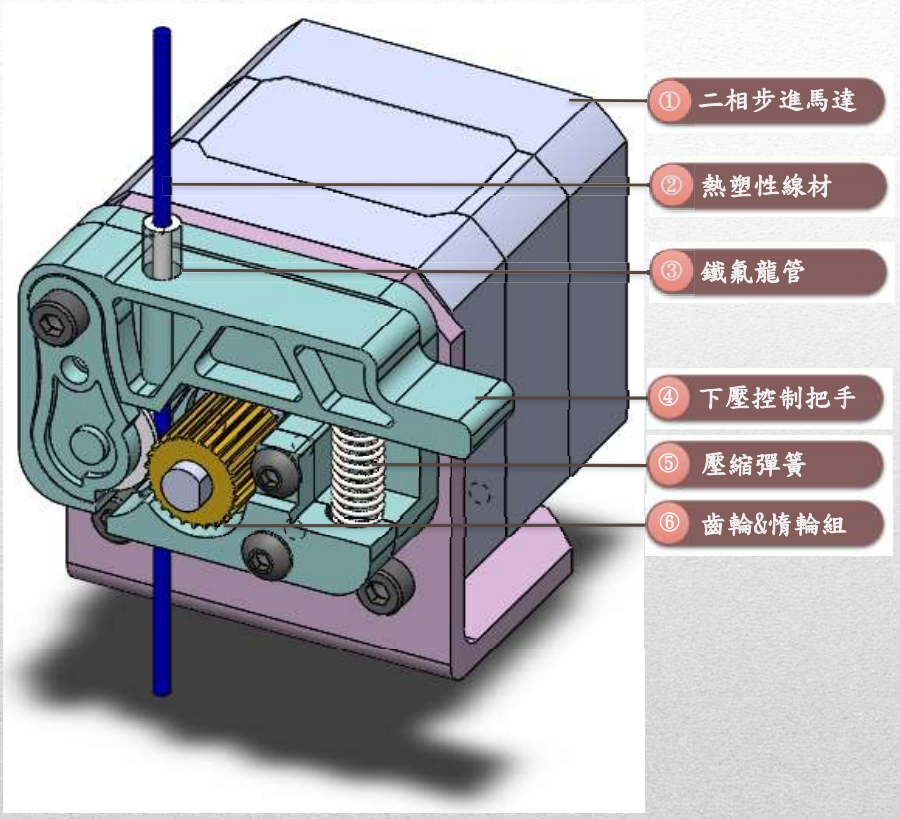
壓力感測器校正示意圖

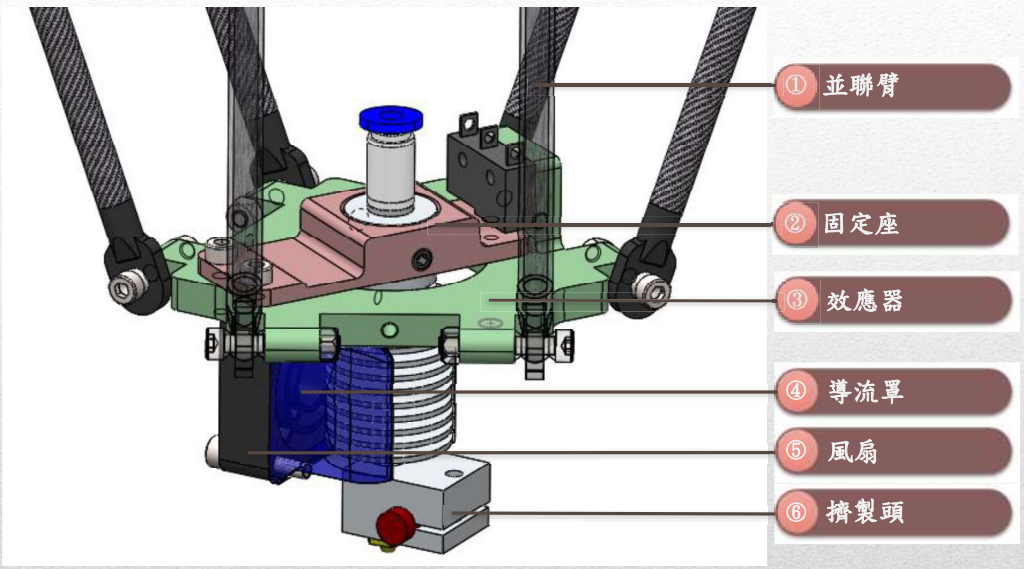
- Cartesian type
- 多採用近端送料
  →進料機構直接架設於擠製頭上方，縮短供料距離，可印製TPU等彈性材

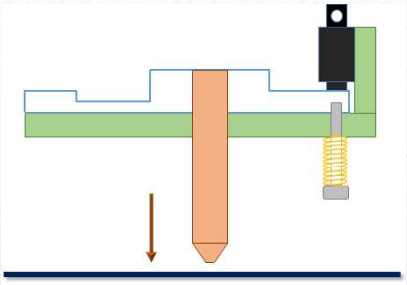
- Delta type
- 成型移動速度較快
  →類似工業機器人設計，負載輕，慣性低，移動較為靈活、快速

廠商	Stratasys©	Stratasys©	Makerbot®	Ultimaker	ALT Deign
型號	uPrint SE Plus	Fortus 900mc	Replicator®	Extended+	ATOM 2.0
機台外觀					
機構設計	Cartesian	Cartesian	Cartesian	Cartesian	Delta
售價(NT)	約60萬元	約750萬元	90000元	88000元	58000元
成型區平整技術	N/A	專利龍門結構	Smart Extruder	手動彈簧調整	限位開關
成型尺寸(cm)	20.3×20.3×15.2	91.4×61×91.4	25.2×19.9×15	22.3×22.3×30.5	22×22×32
最小層厚(μm)	二段式可調	三段式可調	100-200	20-100	50-100
附加功能	WaveWash 55 支撐去除系統	N/A	內建攝影裝置	N/A	雷射模組

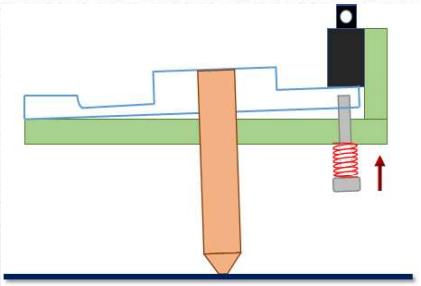
廠商	Stratasys©	Zortrax®	RapRep™	RapRep™	Spark Centre™
型號	Mojo	M200	Rostock	Kossel	Tiko
機台外觀					
機構設計	Cartesian	Cartesian	Delta	Delta	Delta
售價(NT)	約24萬元	79500元	9800元	12999元	N/A
成型區平整技術	N/A	壓力感測器	N/A	限位開關	UNIBODY
成型尺寸(cm)	12.7×12.7×12.7	20×20×18	12×12×15	12×12×15	N/A
最小層厚(μm)	178	50	200-300	200-300	50
附加功能	WaveWash 55 支撐去除系統	Z-SUITE 專用軟體	光軸	線性滑軌	未上市機型


① 二相步進馬達
② 熱塑性線材
③ 鐵氟龍管
④ 下壓控制把手
⑤ 壓縮彈簧
⑥ 齒輪&惰輪組

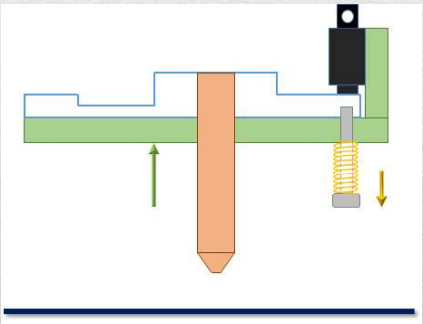

① 並聯臂
② 固定座
③ 效應器
④ 導流罩
⑤ 風扇
⑥ 擠製頭



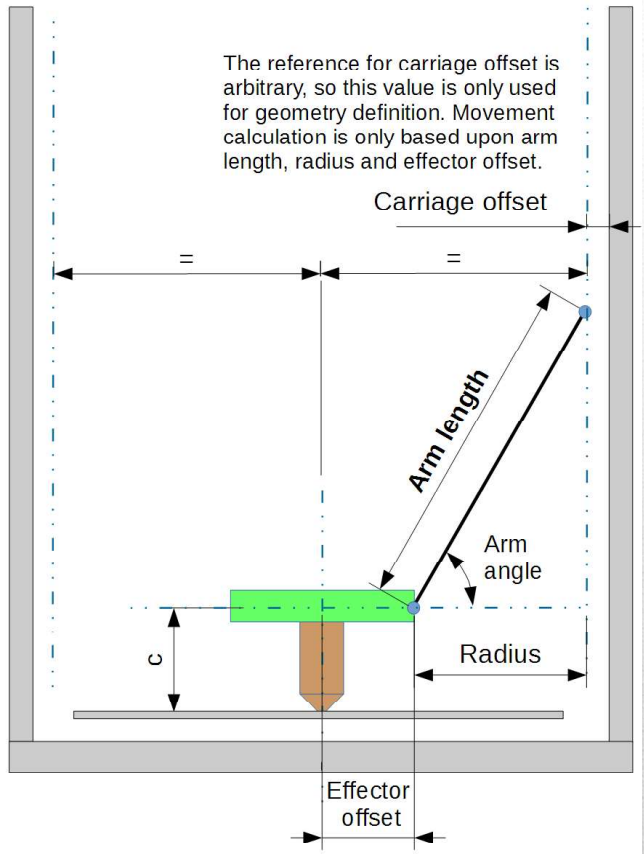
(a) 校正機構初始狀態

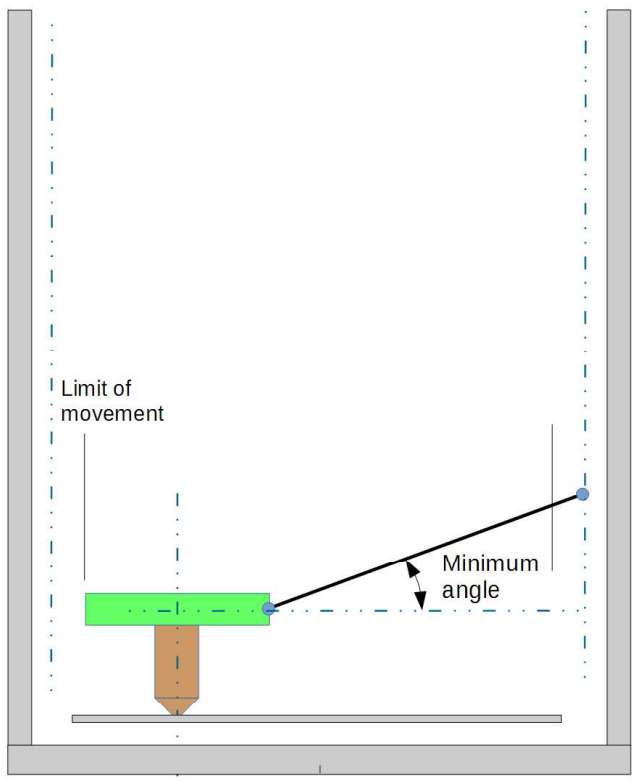


(b) 限位開關觸發

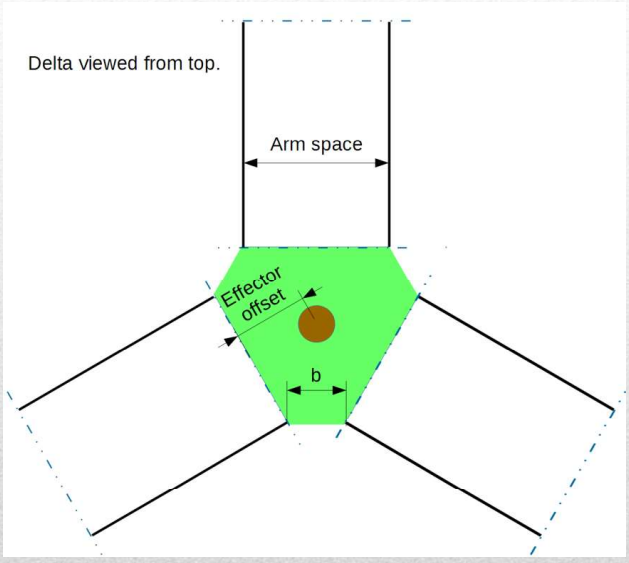


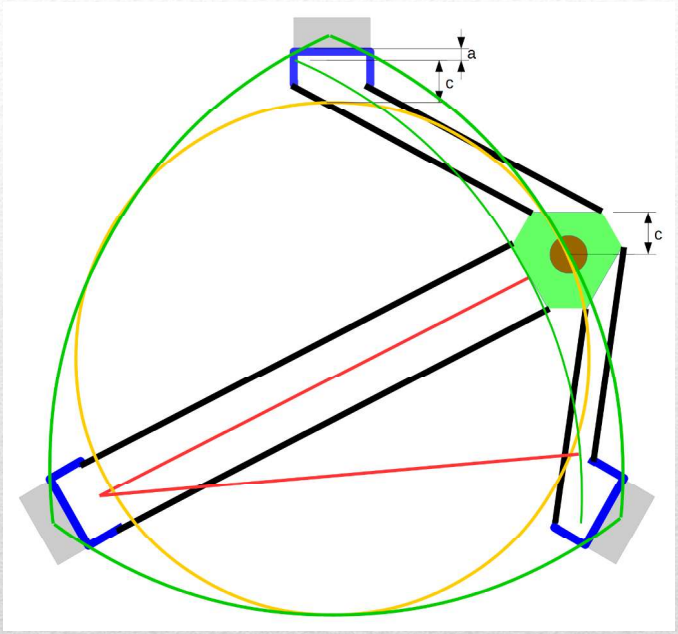
(c) 連續26個座標點探測





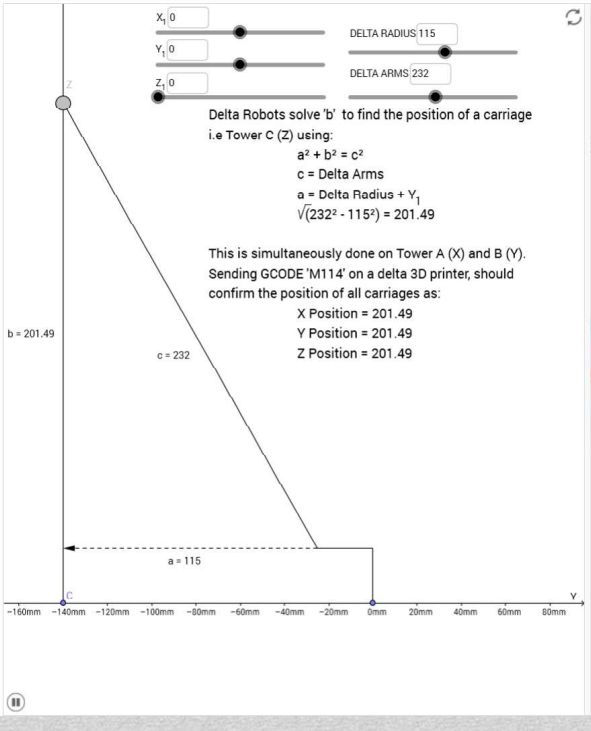
https://reprap.org/wiki/Delta_geometry

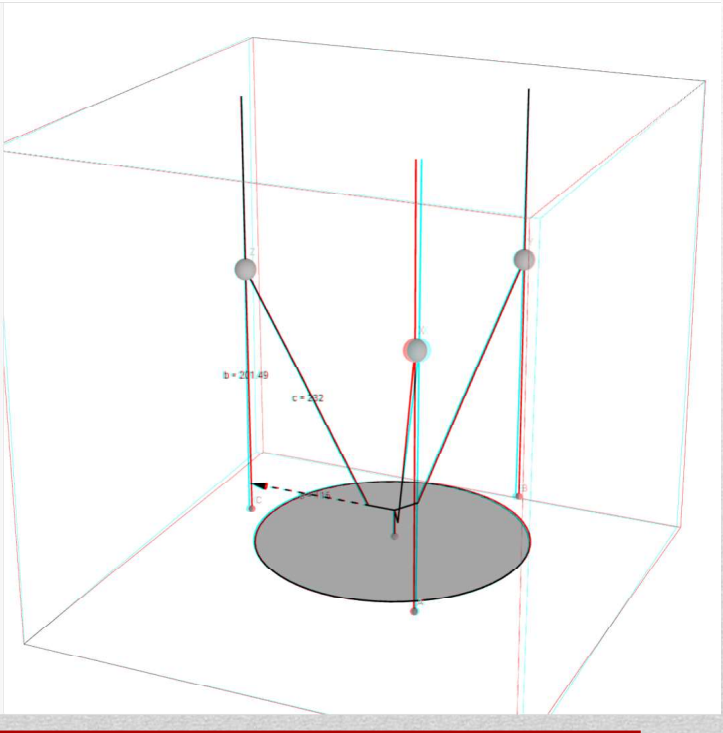




dSim Graphic Simulator

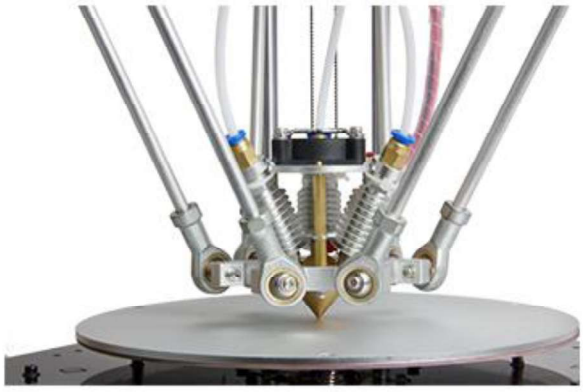
dSim Graphic Simulator





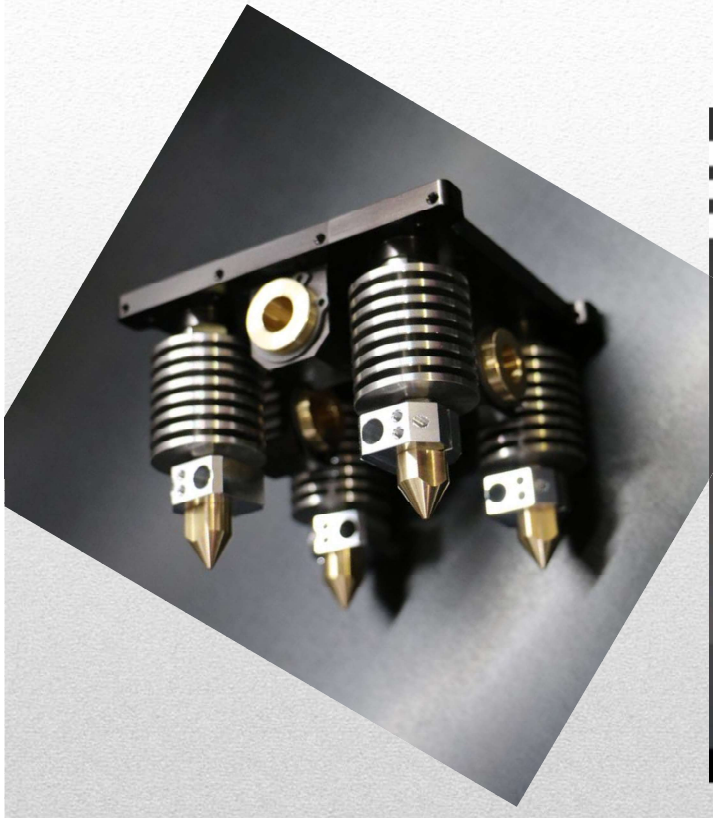
3-IN-1-OUT MIX COLOR
3D PRINTING HOTEND

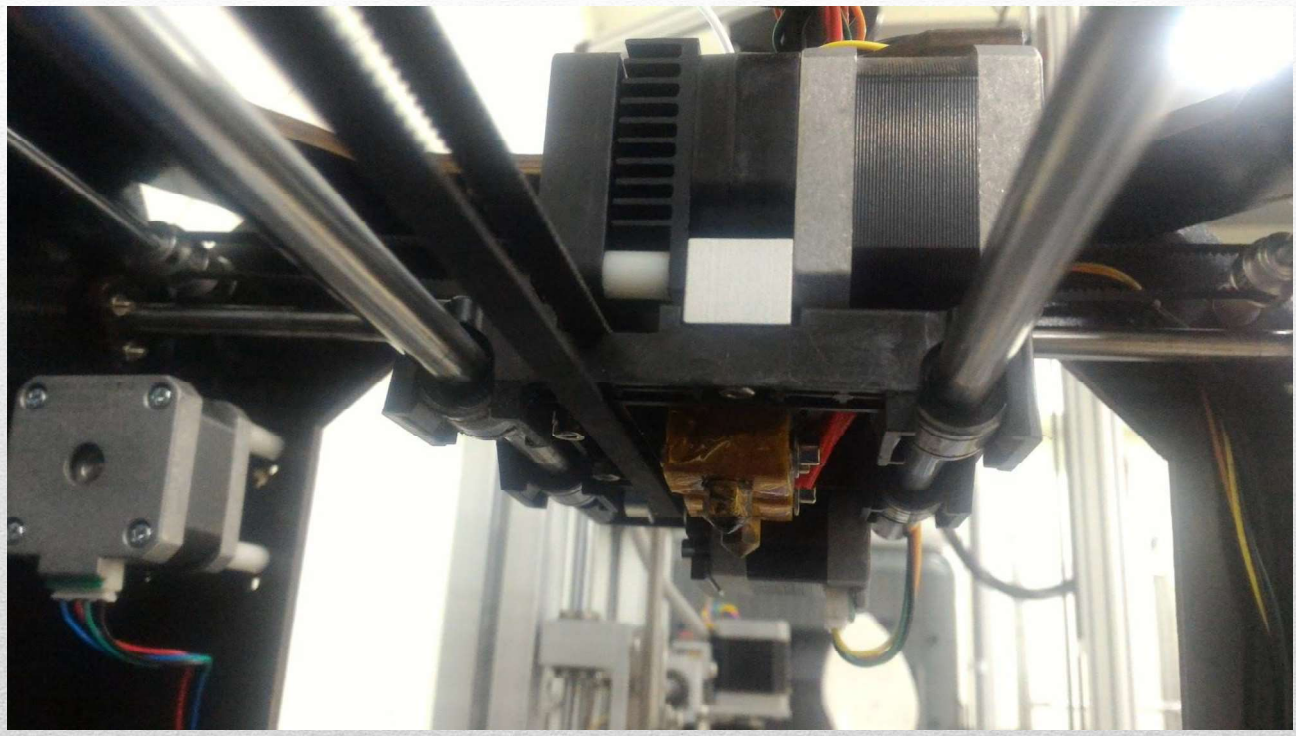
The 3-in-1-out mix color 3D printing hotend is a single nozzle hotend for printing in multiple colors that requires a minimum of calibration.

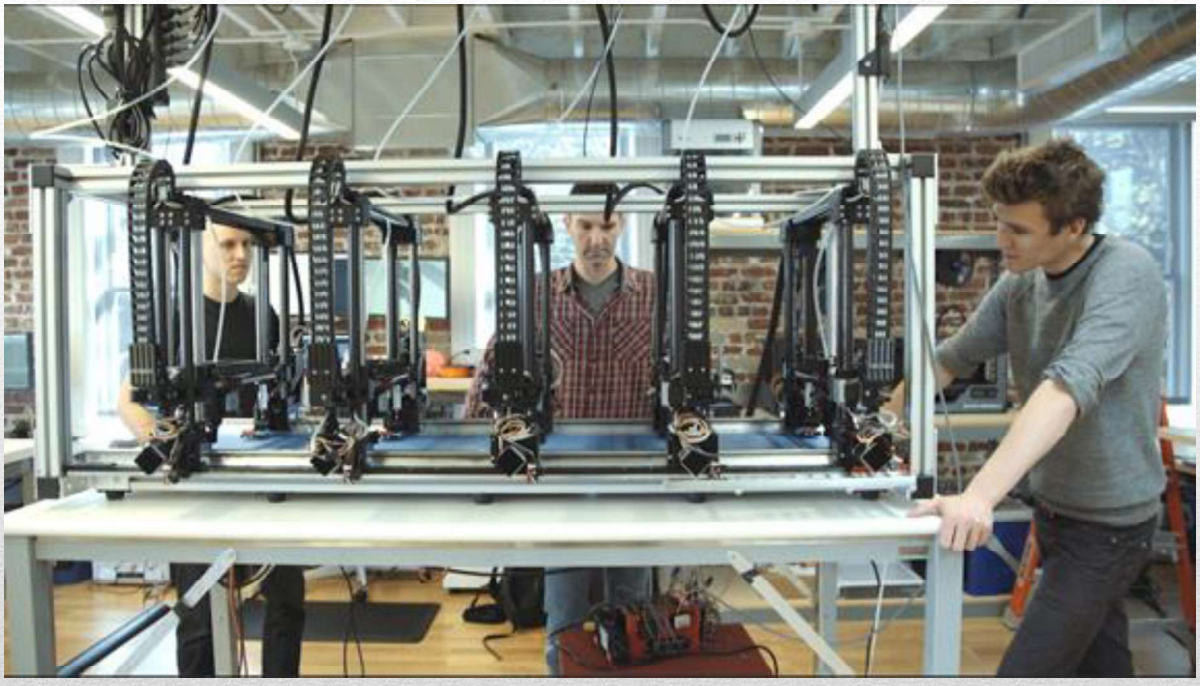


The 3-in-1-out mix color 3D printing hotend allows you to feed three filaments through three independent feed-in channels and be extruded out through one nozzle which provides a faster, easier and more precise method of 3D printing and this can be a new frontier of 3D printing.

EASIER CALIBRATION







Autodesk Project Escher Aims to Speed Up Additive Manufacturing with Multiple Nozzles

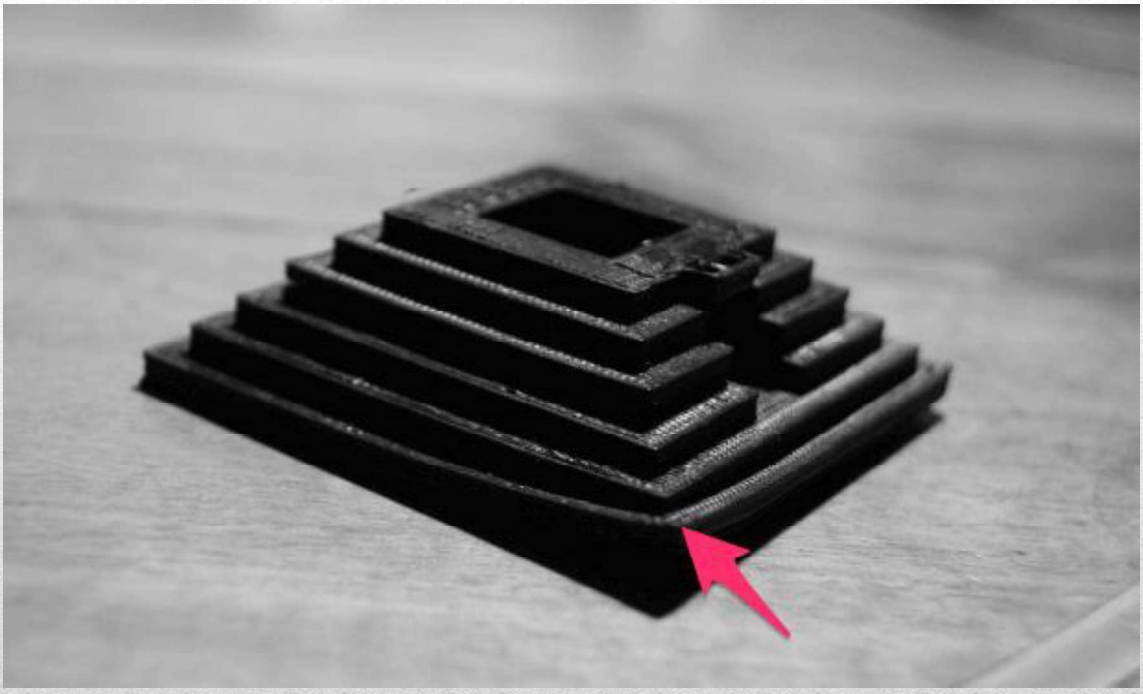
The development of the material

FDM 材料各種 ABS 材料的性質變化 (根據 Stratasys 公司的數據表編譯)

特性	ABS	ABSi	ABSplus	ABS/PC
抗拉強度	22 MPa	37 MPa	36 MPa	34.8 MPa
拉伸模量	1627 MPa	1915 MPa	2265 MPa	1827 MPa
延伸率	6%	3.1%	4%	4.3%
抗彎強度	41 MPa	61 MPa	52 MPa	50 MPa
彎曲模量	1834 MPa	1820 MPa	2198 MPa	1863 MPa
沖擊試驗	106.78 J/m^2	101.4 J/m^2	96 J/m^2	123 J/m^2
熱變形 @66 磅	90°C	87°C	96°C	110°C
熱變形 @264 磅	76°C	73°C	82°C	96°C
熱膨脹	5.60E-05in/in/F	6.7E-6in/in/F	4.90E-05in/in/F	4.10E-5 in/inF
比重	1.05	1.08	1.04	1.2

Thermal properties	PLA	ABS
Melt volume index (MVI)	10.3 cm³/10min	9.7cm³/10min
Glass transition temperature	60-65°C	105°C
Slumping temperature	70-80°C	110-125°C
Melting temperature	160-190°C	210-240°C
Printing temperature	190-220°C	230-250°C
Recommended printbed temperature	50-70°C (heated bed not mandatory)	80-120°C (heated bed required)

The **melt volume index** (or melt flow index) is a measure of the ease of flow of the melt of the polymer. It is measured as the amount of material flowing in 10 minutes through a capillary of a defined diameter and length.
The **glass transition temperature** (or glass point) is the point at which a hard and brittle (glassy) material transitions into a molten or rubber-like state when the temperature is increased. This value matters when you print something you plan to pour hot water or beverages in: When you print a coffee mug using PLA, the bottom sags when you pour in coffee that is hotter than 60ºC. Why ABS is no good idea either: See the "Recommended fields of application" section below.
The **slumping temperature** indicates the heat resistance limit: At temperatures above this value, the object will be distorted. When your printer has a heated bed, the heated bed temperature must be below the slumping temperature; otherwise, the object will deform.
The **melting temperature** (or melting point) is – obviously – the temperature at which the material starts melting.
The **3D printing temperature** is usually higher than the melting point as you want the filament to be molten (and not just starting to melt) when pressing it through the printer nozzle.



ABS is more prone to warping than PLA.

PLA vs ABS Filament: **Recommended fields of application**

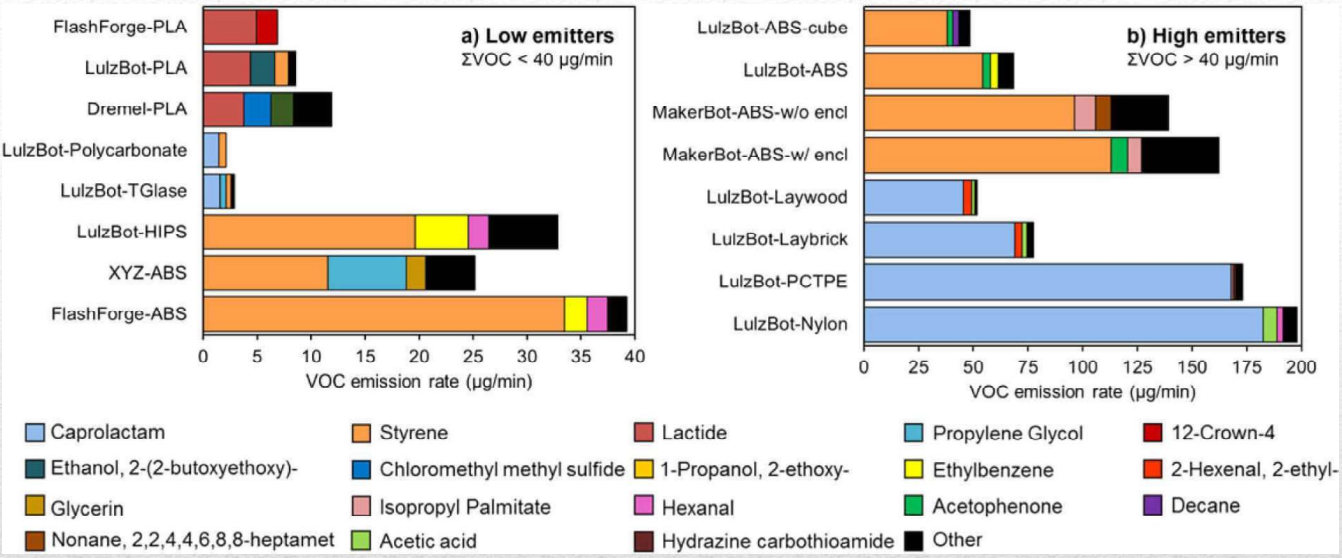
PLA is widely used in 3D printing, e.g. for household items, gadgets, and toys. It is better suited when flexibility is not your major requirement as it is more prone than ABS to break under pressure. On the other hand, it is biocompatible with the human body and can be used for objects that are worn on the skin.

Due to its relatively low glass point, PLA is unsuitable for objects that are subject to heat: When exposed to 60°C or more for some time, it loses its shape. You wouldn't use PLA for objects that are exposed to direct sunlight for a prolonged time or that are placed in a car. It is also not suitable for kitchen equipment that is put into the dishwasher (at least not for dishwasher programs at 60°C or more).

ABS is better suited for objects that need to withstand rough usage, hot environments, that need to be weather-proof, that may be dropped or have to be bendable. It can be used for parts that are subject to mechanical stress, for interlocking parts or pin-joints.

ABS is not considered to be a food-safe material: Especially when the material gets in contact with hot liquids or warm food, chemicals from the plastic will leach out into the liquid or food over time. To seal the surface, you need to post-process it using solvent polishing or painting that is food-save.

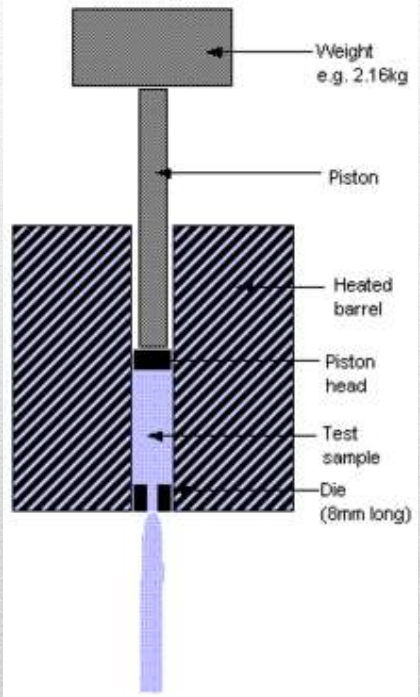
塑膠名稱	優　　點	缺　　點	用　　途
聚乙烯(PE)	易加工.可撓曲.耐衝擊. 化學鈍性佳.	軟.易有割痕. 限低溫使用.	包裝膜.容器.管子. 電絕緣材料.玩具等
聚丙烯(PP)	具有剛性.抗磨蝕性好. 不產生應力龜裂. 電氣阻抗性佳.	染色困難. 不能採用熱封. 易受氧化.	類似PE用途. 保險桿.纖維. 汽車儀表板等
聚酸醛(POM)	磨擦係數低.耐衝擊. 潛變性好.耐疲勞.	不宜戶外用途. 須尺寸穩定要共聚合	齒輪.機械元件. 打火機零件等
耐龍(Nylon)	磨擦係數低.化學鈍性. 耐衝擊.	吸水.帶靜電.	可織纖維.襯套. 軸承等
聚氯乙烯(PVC)	透明性佳.耐候性優. 可塑化成具.	褪色.熱安定性差. 受限於環保問題.	唱片.地板.雨衣. 軟管.皮包.鞋子等
聚苯乙烯(PS)	亮麗的外觀. 硬且透明性優(非晶質)	脆.褪色.易受侵蝕.	原子筆. 透明的廚房用具等
聚碳酸酯(PC)	耐高熱.耐衝擊. 透明度佳.	吸水.上色困難	透鏡.葉輪.安全帽. 窗的玻璃等
ABS	可保持光滑.收縮率小. 可做成平板.	戶外使用會褪色. 不易上色.	電視機.收音機.時鐘. 吸塵器.燈罩.樂器等



People usually refer to ABS by the acronym, so you might not know what it stands for: acrylonitrile butadiene styrene. Why is that important? Styrene is one of those hazardous volatile compounds — it's toxic and maybe cancer-causing. While the Environmental Protection Agency (EPA) in the United States doesn't have protections against it, the Department of Heath and Human Services calls styrene "reasonably anticipated to be a human carcinogen."
Fortunately, PLA (polylactic acid) breaks down into lactic acid — the same chemical that makes you sore after working out — so there's no threat there.

Toxic Emissions are Worse than We Thought

The **melt flow index** (**MFI**) is a measure of the ease of flow of the melt of a thermoplastic polymer.



Home > Plastics > Generics > Polylactic Acid (PLA)

Polylactic Acid (PLA) Typical Properties

Polylactic Acid (PLA) - Manufacturers - Materials - Classification

Product Description

This data represents t

This information is pro

General

Material Status

Availability

Physical

Specific Gravity

--

73°F

Melt Mass-Flow Rate

210°C/2.16 kg

190°C/2.16 kg

Molding Shrinkage

Flow : 73°F

73°F

Mechanical

Tensile Modulus

73°F

73°F

Tensile Strength

Yield, 73°F

Yield, 73°F

Home > Plastics > Generics > Acrylonitrile Butadiene Styrene (ABS)

Acrylonitrile Butadiene Styrene (ABS) Typical Properties

Acrylonitrile Butadiene Styrene (ABS) - Manufacturers - Materials - Classification

Generic ABS
Generic ABS - Carbon Fiber
Generic ABS - Carbon Fiber, Nickel-Coated
Generic ABS - Glass Bead
Generic ABS - Glass Fiber
Generic ABS - Stainless Steel Fiber

Product Description

This data represents typical values that have been calculated from all products classified as: Generic ABS

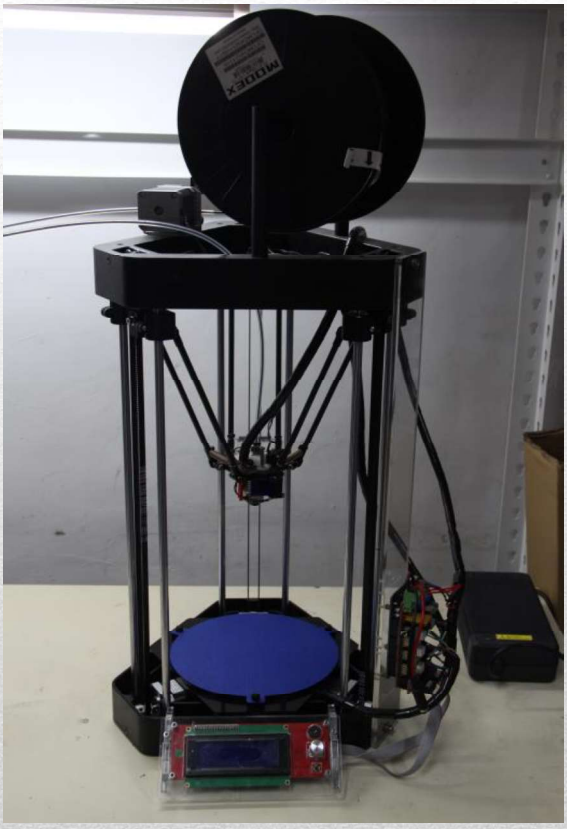
This information is provided for comparative purposes only.

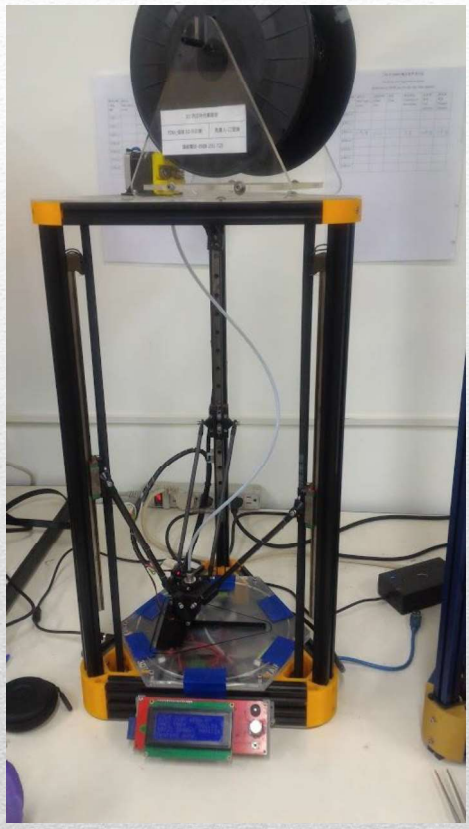
General

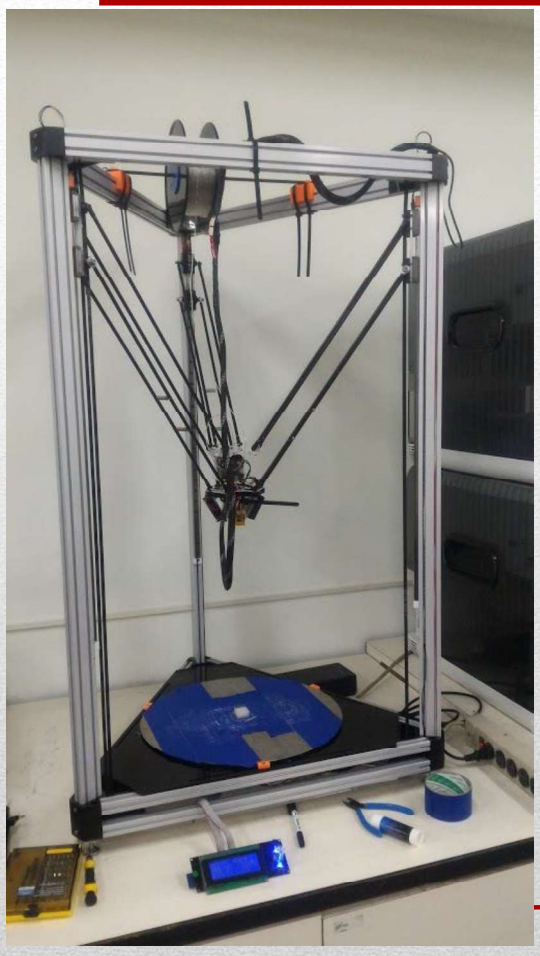
Material Status	• Commercial: Active	
Availability	• Africa & Middle East	• Europe
	• Asia Pacific	• Latin America

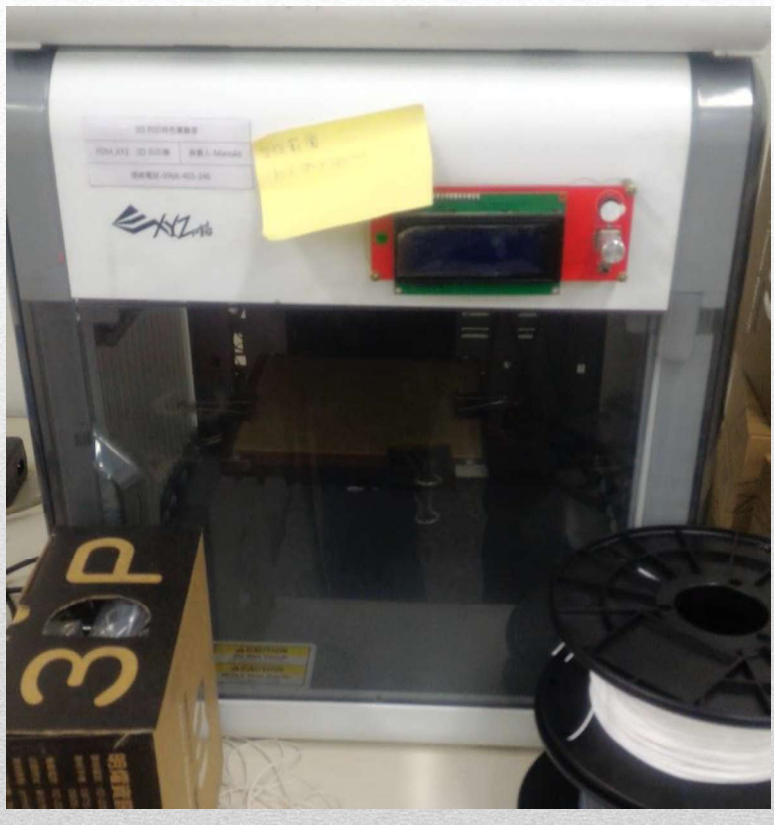
Physical	Nominal Value
Specific Gravity	
--	1,03 to 1,11
73°F	1,04 to 1,11
--	0,0379
--	1,01 to 1,10
Apparent (Bulk) Density	0,25 to 0,36
Melt Mass-Flow Rate (MFR)	
220°C/10.0 kg	1,0 to 36
220°C/10.0 kg	0,49 to 36
Melt Volume-Flow Rate (MVR)	
220°C/10.0 kg	0,0793 to 2,52
--	1,36
	2250 to 10400 psi

Additive Manufacturing in NTUT 3D Technology Lab



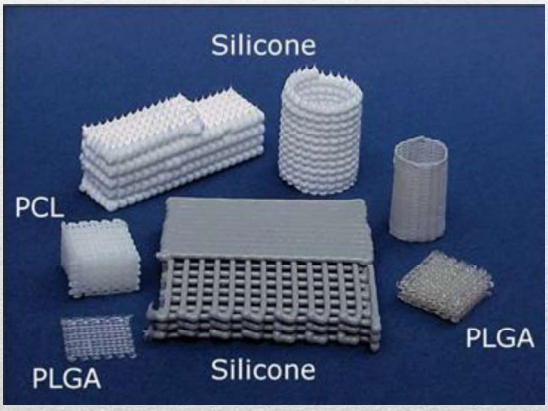




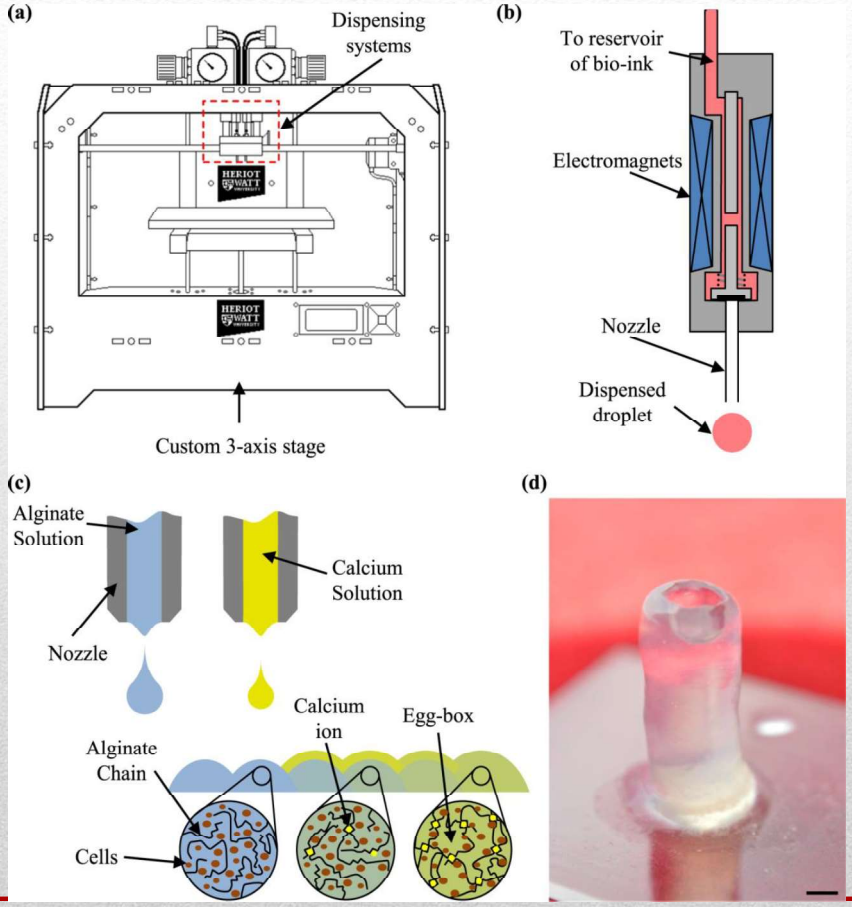


BIOPRINTING

Bioprinting can be used to print tissues and organs.
A framework or structural element that holds cells or tissues together can be printed.



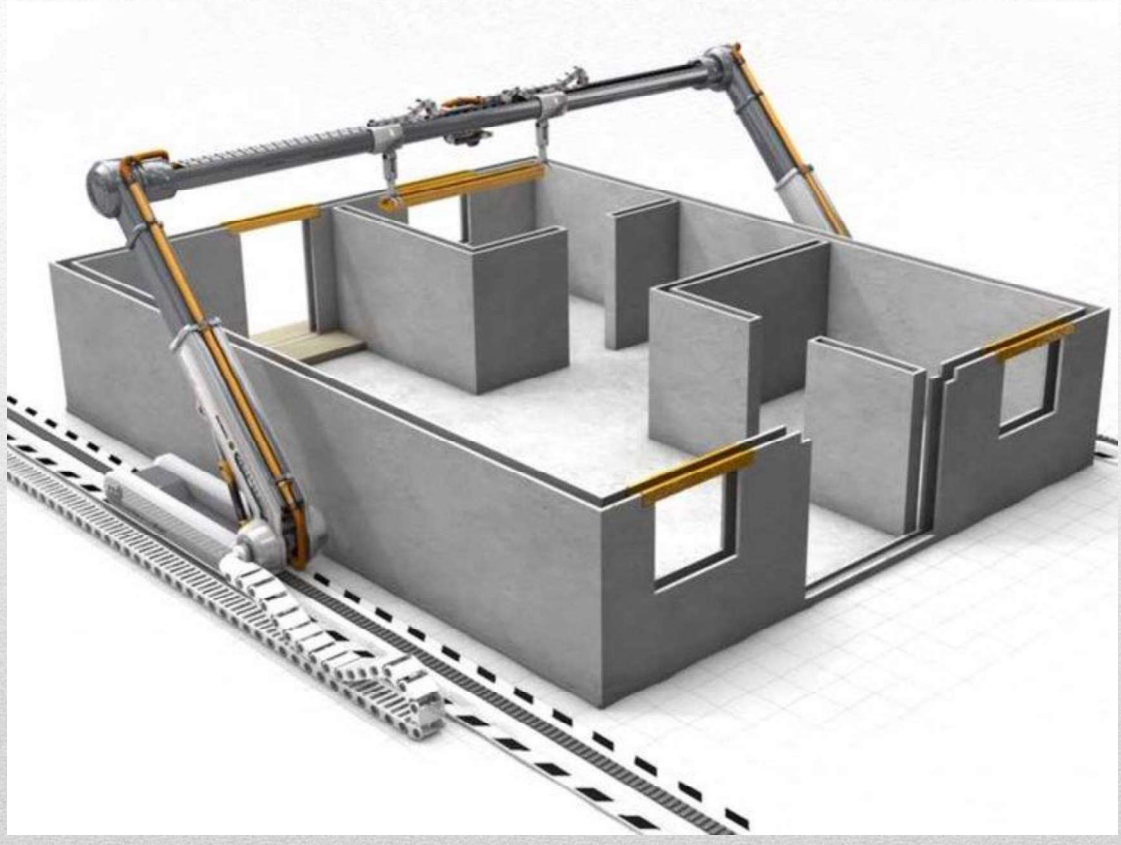
Making scaffold



https://www.euronews.com/2019/04/16/world-s-first-3d-printed-heart-with-human-tissue-revealed

https://www.youtube.com/watch?v=Y7JbJzorfYU

HOUSE PRINTING



https://www.businessinsider.com/3d-printer-builds-house-in-24-hours-2014-1

http://fortune.com/2018/04/22/3d-printed-homes/

http://www.homecrux.com/gaia-is-the-worlds-first-3d-printed-mud-house/110107/

Larger for Industry

THE MXT

Speed & Precision

BigRep's second-generation Metering Extruder Technology (MXT) delivers exceptional speed and precision for industrial projects, forming one of the defining features of the EDGE. A higher travel speed makes the premium model machine ideal for high-speed print completion.

THE BUILD CHAMBER

Controlled Environment

A heated build chamber provides a controlled, high-temperature environment for engineering-grade materials of up to 200°C in the chamber and 220 °C on the print bed. The EDGE's ventilation system, compatible with standard factory environments, ensures an even chamber temperature and user safety from fumes.

THE BUILD VOLUME

Enormous Print Bed

The largest of its kind with a controlled heated environment, BigRep's EDGE offers enormous volume for maximum flexibility and large-scale industrial print capacity. The EDGE has a build size (1500 x 800 x 600 mm) and an advanced pull-out print bed ensures large, heavy prints are easy to remove.

https://bigrep.com/

Build volume	**x 1500 y 800 z 600 (mm)**
Layer height resolution	**0.1 mm - 1.6 mm***
Acceleration	**Up to 10 m/s²**
Extruder	**Two MXT extruders**
Printing technology	**FFF – Fused-Filament-Fabrication (Material Extrusion)**
Certified Bigrep materials	**Engineering Plastics, High-Performance Plastics** More engineering materials in development
Support materials	**Soluble Plastics**
Print bed temperature	**Max. 220 °C**
Chamber temperature	**Max. 200 °C**
Printer weight	**Approx. 3500 kg**
Size	**x 3100 y 1600 z 2220 (mm)**
Power	**240 V – 360 V, 3 x 32 A, 50/60 Hz**
Safety certifications	**CE machinery/ UL/ FCC/ Korean Certification**