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NRC «Kurchatov Institute» - IREA

NRC «Kurchatov Institute» Laboratory of luminescent and detector materials

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Towards new production technologies: 3D printing of scintillators

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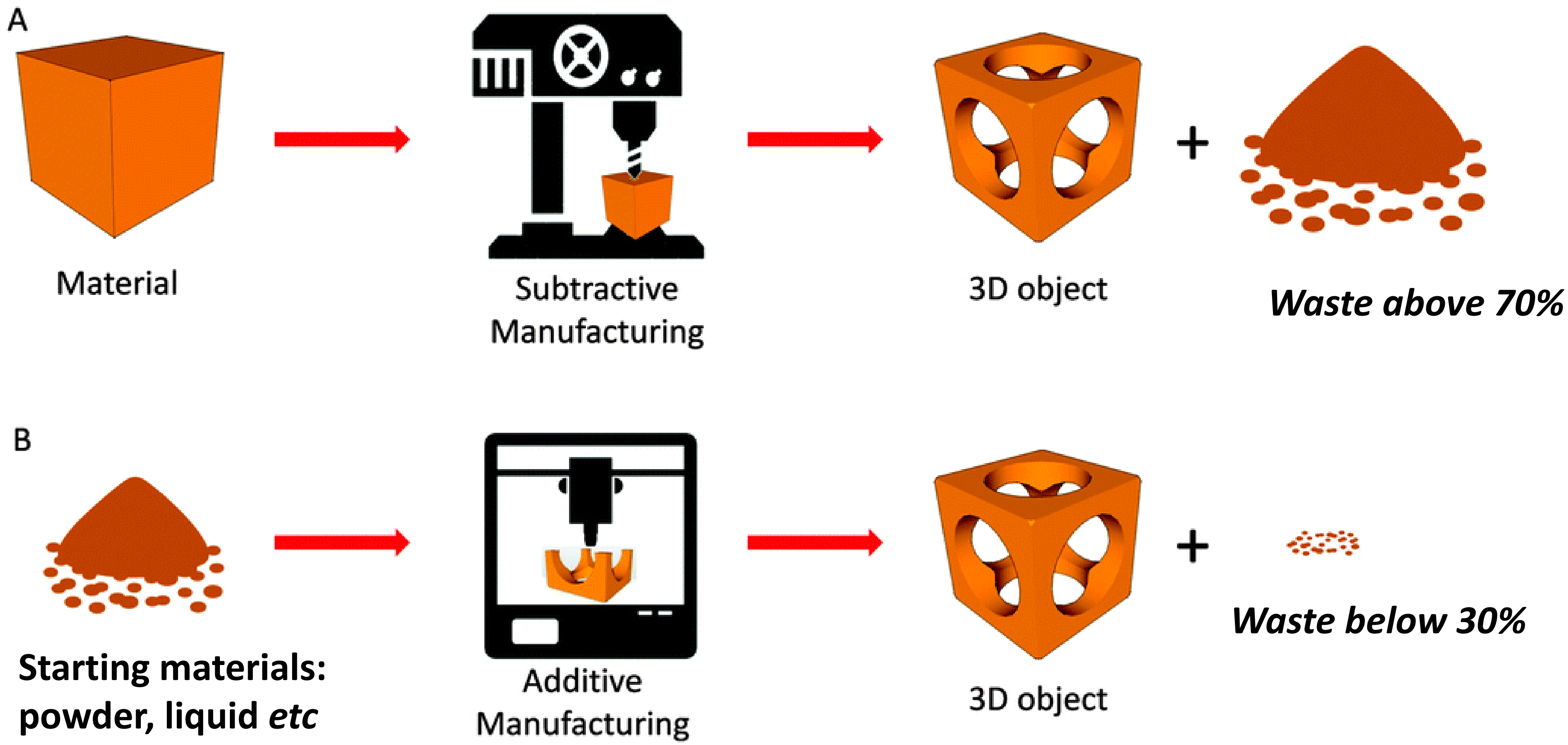
Inroduction. Traditional manufacturing *versus* 3D printing



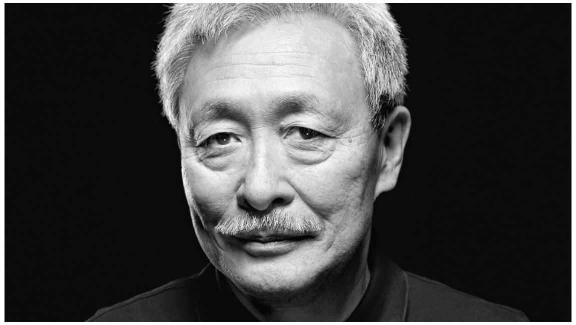
A. Ambrosi, M. Pumera, *Chem. Soc. Rev.*, 2016, **45**, 2740-2755.

NOTE: Casting is not AM, because use some tools and patterns!

Introduction. A brief historical review

1980s

The Birth of 3D printing and rapid prototyping as conception (makes three-dimensional parts layer by layer). First patens.



Hideo Kodama **SLA**

Chuck W. Hull **SLA**

Carl R. Deckard **SLS**

Scott S. Crump **FDM**

1990s

The first SLA (stereolithographic apparatus), SLS (selective laser sintering) and FDM (Fused Deposition Modelling) machines. The production of a some **plastic, wax or even metal** objects.

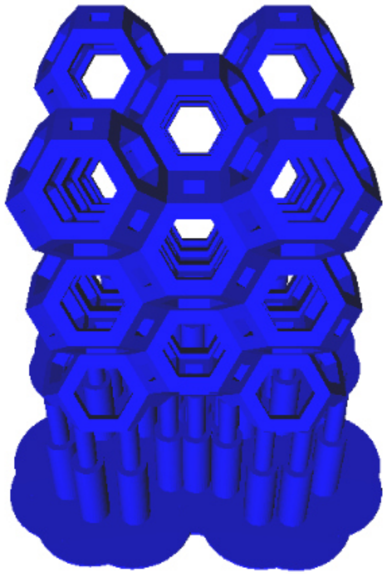
2000s

Open-source and open-ware movement. Democratization and cheapening. Expanding the range of available materials.

2010s

Lapse of key «hystorical» patents. Mass scale of inventive activities and common availability of <u>desktop</u> 3D printers. A lot of small start-up companies found funding through crowdfunding platforms (KickStarter *etc*).

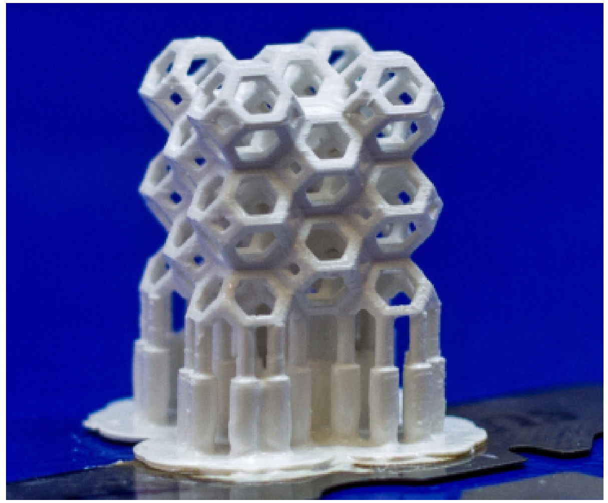
Classification of 3D printing techniques. Basic steps



Using materials

3D Printer

Formation method



6 Physical body after 3d priting (SLA)

1 Digical 3D (CAD) model, ussally STL-format file

2. Slicing the model into many layers and generate computer code

3 Print first 2D slice and supports

4 Increment height and print next layer

5 Post process treatment (if needed)

Classification of main techniques in 3D printing

Vat polymerisation (VP)
- Stereolithography (SLA)
- Digital Light Processing (DLP)

Continuous Liquid Interface Production (CLIP)

Two-Photon Polymerization (2PP)

Liquid monomers (oligomers), light-activated resin .

Material Extrusion
- Robocasting
- Fused Deposition Modeling (FDM)

Glass 3D Printing (G3DP)

Paste, Slurry, Clay, Food, Composite, Polymers (ABS, PLA)

Powder Bed Fusion
- Electron-Beam Melting (EBM)
- Selective Laser sintering (SLS)

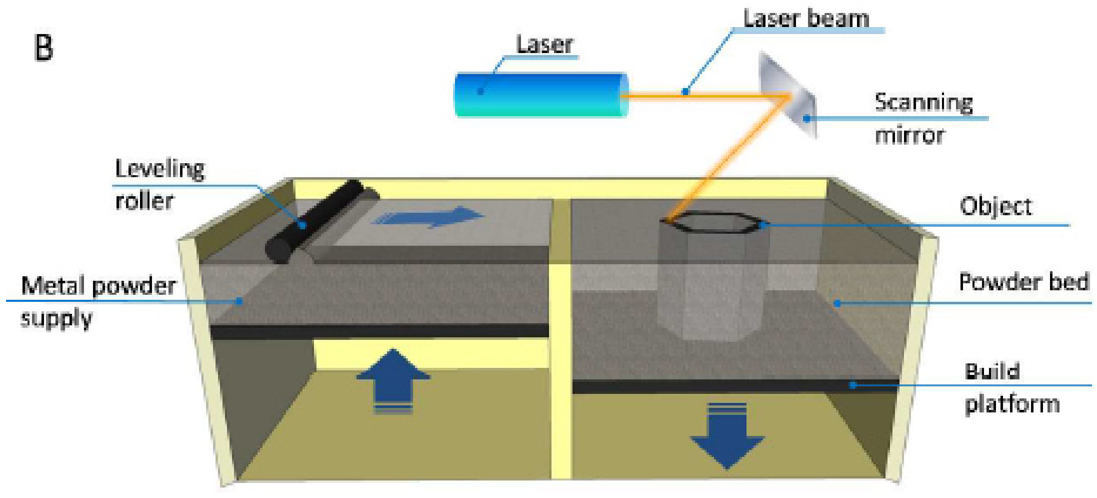
Selective Laser melting (SLM)

Powder: typically metals, nylon/polyamide, some ceramics, some glasses

Binder/Material Jetting

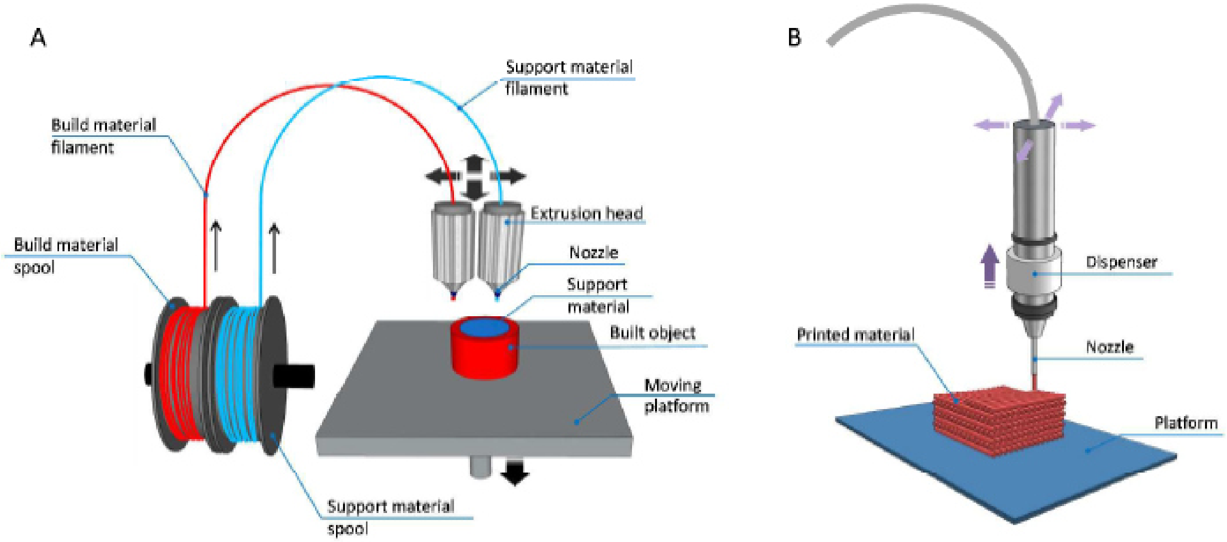
Directed Energy Deposition

SLS & SLM - Selective laser sintering (melting)



Core principle	Advantages	Disadvantages
Layer formation occurs as a result of local sintering of polymer or metal powders	High mechanical characteristics; there is no need for supporting structures; manufacturing of metal products; the minimum element size is 30–100 µm	High temperatures upon sintering; high roughness of the surface; high cost; need to use powders with narrow particle size distribution; need to use protective atmosphere; need the post-treatment; need large amount of powder to work

FDM - Fused deposition modeling



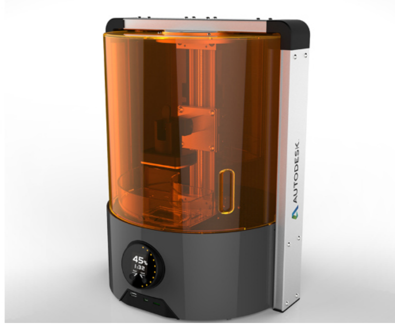
Core principle	Advantages	Disadvantages
Forming a material layer by a filament obtained by extrusion of a thermoplastic polymers (composites) through a nozzle	Simple; Versatile; Low cost of the materials; minimal amount of wastes; possibility of obtaining composite structures	Quite low print resolution (the minimum element size is limited by the diameter of the extruder opening and is 150–700 µm; layer thickness is 20–370 µm); anisotropy of mechanical properties; using a supporting structure is necessary

SLA - Stereolithography. Plastics

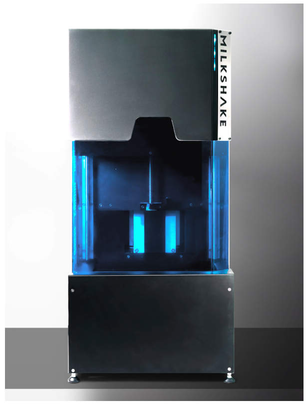
Core principle	Advantages	Disadvantages
Polymerization of liquid monomers upon light irradiation.	High resolution (the layer thickness is 20–100 μm; the minimum element size it is 50–100 μm); high speed; possibility of using a large amount of material as a photopolymer filler (up to >50% of ceramic powder); possibility of using experience on formation of phase composition and microstructure accumulated in the ceramic technology.	Restricted number of photopolymers in use; Single material; high cost; using a supporting structure is necessary; light scattering on ceramic particles; high suspension viscosity;

FormLab Form 1 & 2
desktop SLA printer
high-resolution 3D printer
for professional.
Funding about **3 000 000 $**
via kickstarter.com on 2014.
Current price ~ 10 000 $

Ember Autodesk



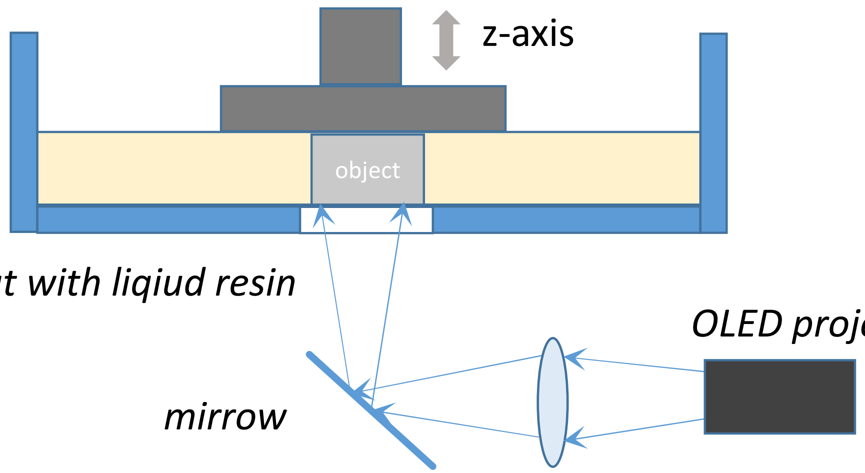
price ~ 8000 $



milkshake3d

price < 3000 $

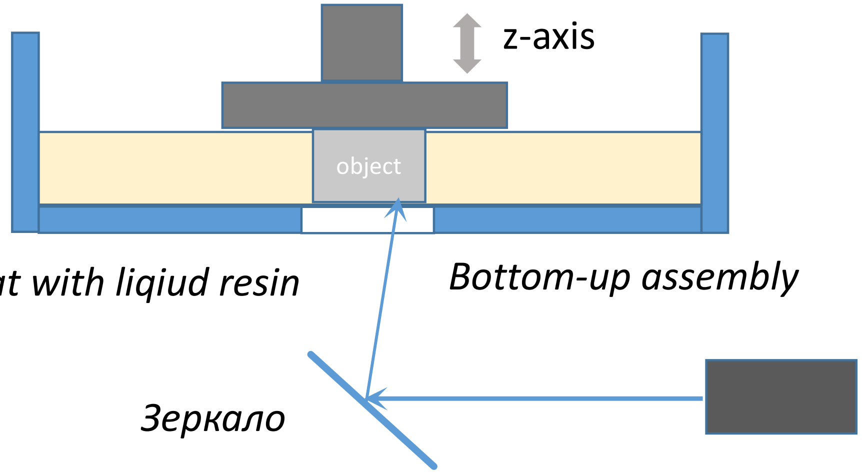
SLA - Stereolithography. Plastics



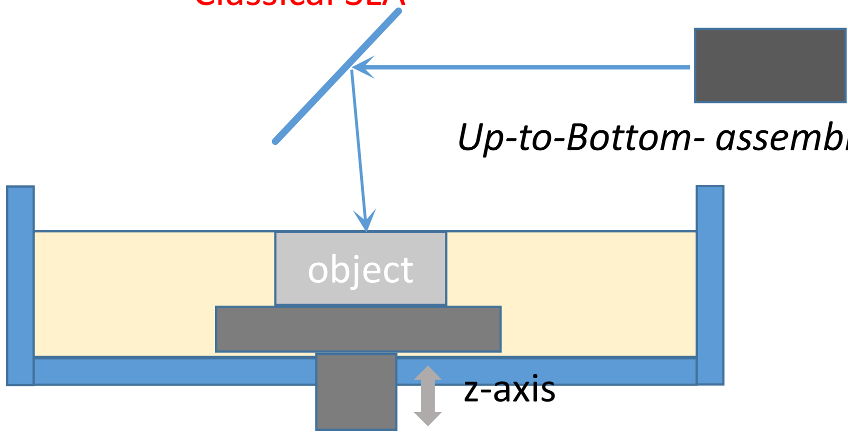
DLP = “digital light processing”

Bottom-up assembly

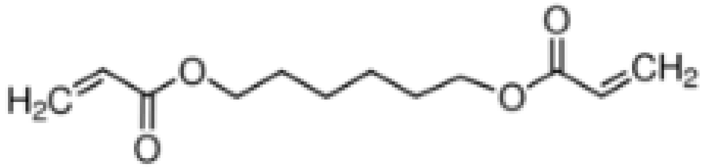
Инвертированный SLA = “stereolithography”



Classical SLA

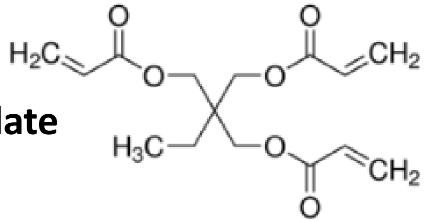


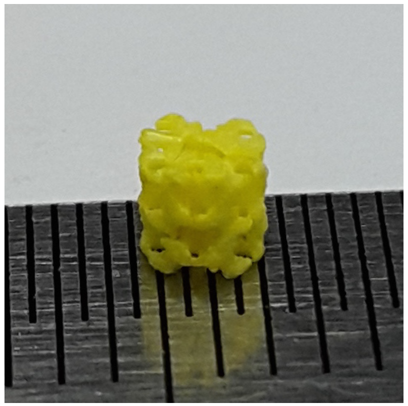
SLA - Stereolithography. Ceramics (YAG & ZrO_2)

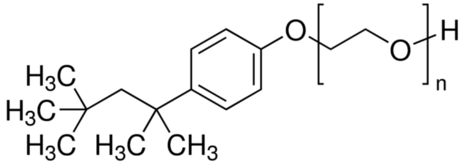


1,6 Hexanediol diacrylate

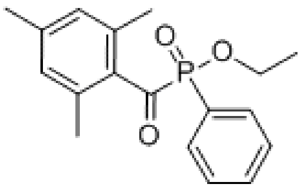
Trimethylolpropane triacrylate



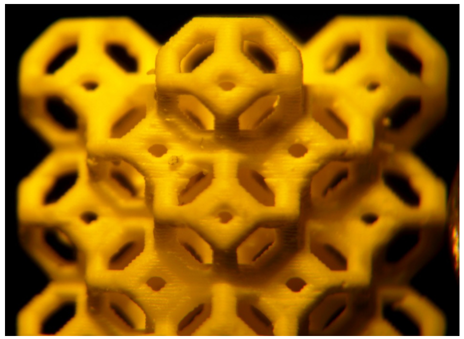


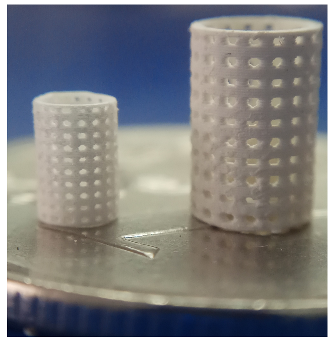


Triton X-100



+ Inert diluent
+ Dye
+ Light absorber
+ Inhibitor of polymerisation
+ ***Very fine ceramic powder***





Photoinitiator - Ethyl (2,4,6-trimethylbenzoyl) phenylphosphinate

3D printing of scintillators

Inorganic polycrystalline oxide materials with complex shape - **YES**

Some plastics and inorganic glasses - **VERY POSSIBLE**

Single crystal - **NO**

+

Not direct application of new approaches:

may be create some tooling, tooling inserts *etc.*

Conclusions

- 3D printing is a high-tech toy with a good perspective, which allow to create the complex shape parts (details) from many materials
- 3D printing allow to complement a traditional opportunities
- 3D printing allow small lab (or just for one researcher!) to make some complex part(s) with outstanding properties

Thank you for your kind attention. Questions?