Harvard-MIT Division of Health Sciences and Technology
HST.535: Principles and Practice of Tissue Engineering
Instructor:Yongnian Yan

MIT-TH-2005

Scaffold Manufacturing of Tissue Eng. Using Free Forming Fabrication

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2005.9.14

The Center for Laser Rapid Forming

The Center for Bio-Manufacturing

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outline

1. FFF Technologies, FFF~Scaffold Manufacturing
2. Scaffold Manufacturing Technologies
3. Non-degradation Scaffold
4. BONE Tissue Eng. Scaffolds
5. 3-D cell Assembled
6. Laser Directed Guided Writing of cell

What's FFF ?

Free Forming Fabrication

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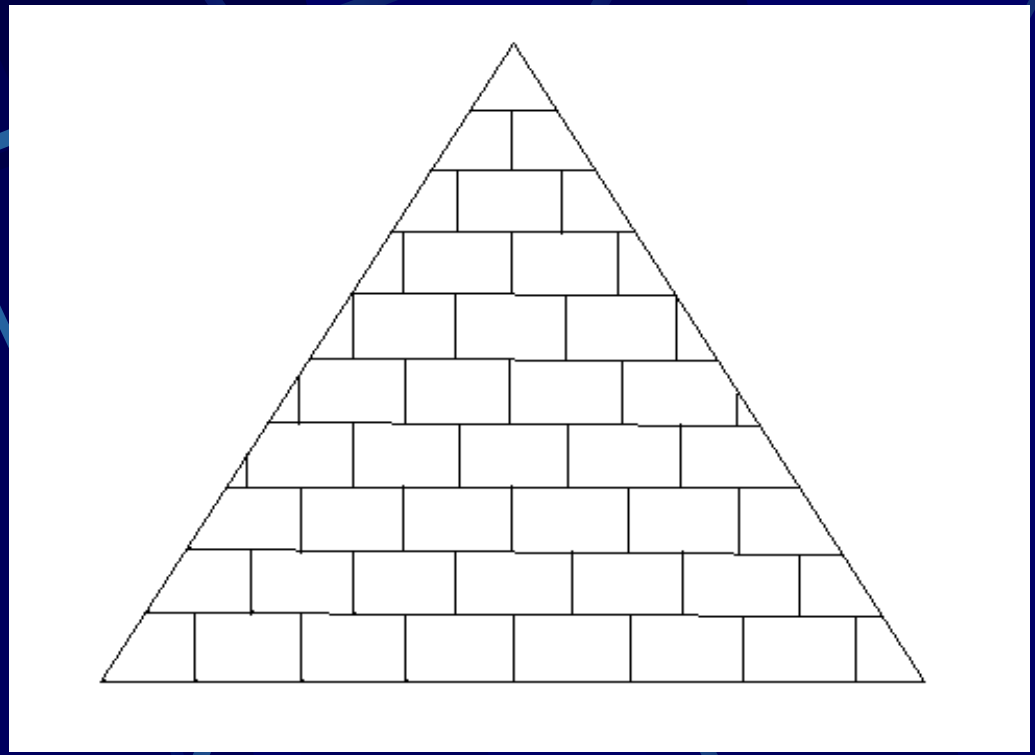
Definition

FFF —— The General name of Making Any Complex Structure using Assembling Elements Driven Directly by CAD Model

Other Names of FFF

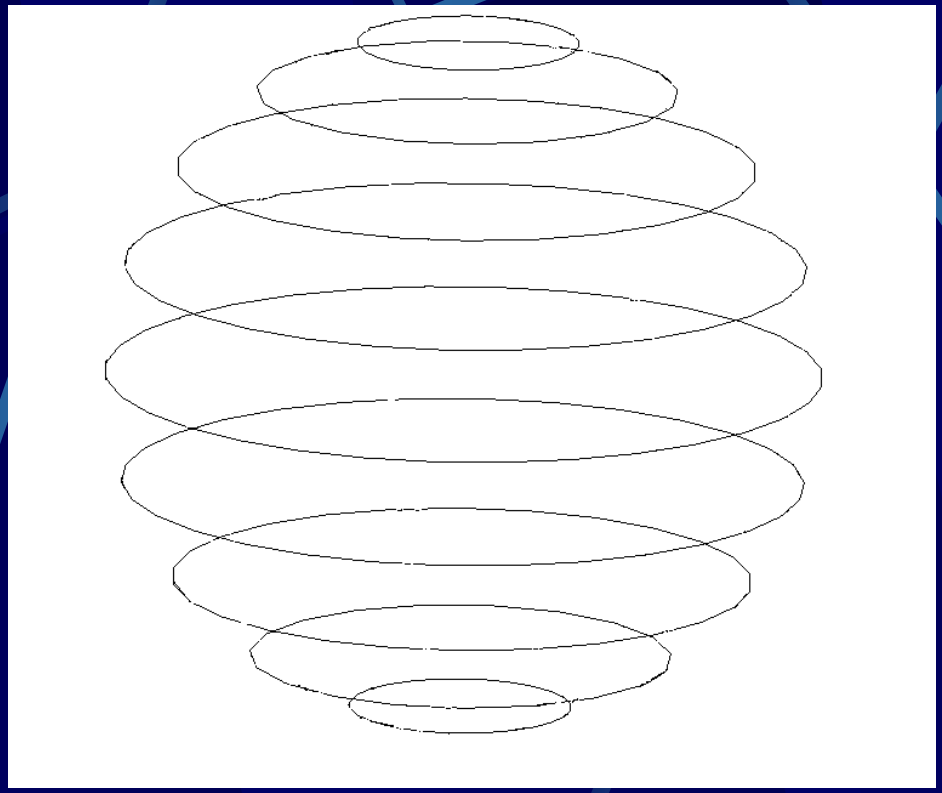
- ***RP*--- Rapid Prototyping**
- ***LM*--- Layered Manufacturing**
- ***MIM*--- Material Increase Manufacturing**
- ***DAM*--- Discretization Accumutation Manufacturing**

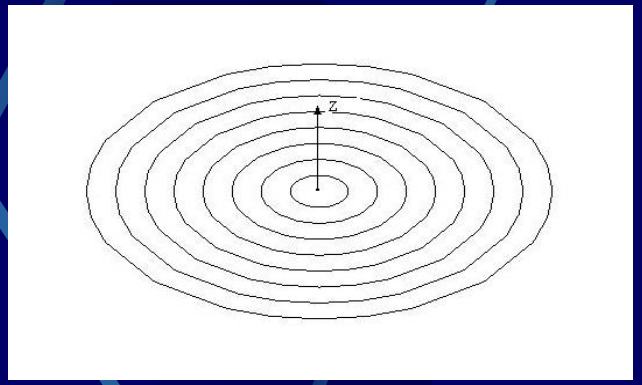
Pyramid

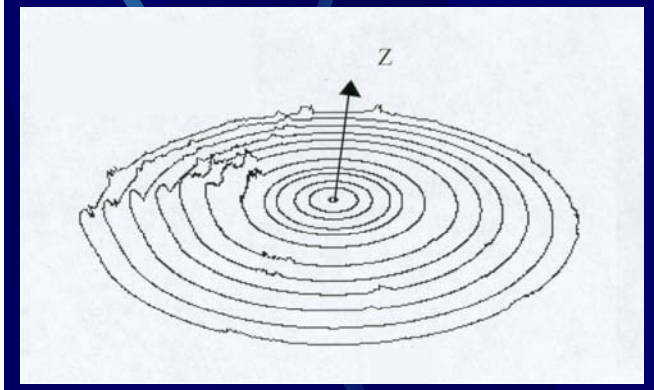


- First: Shape the stones into standard types
- Then: Pile the stones up

The globe







- Slice the globe along the latitude, the cross section will be circular rings or concentric rings

3D-Globe Model

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Design and Building Process

- ***Design***
  - **The number of stones**
  - **The order of pile**

    ------- ***Discretization***

    (Decomposing)
- ***Building***
  - **Pile pyramid by stone elements**

    ------- ***Accumulation***

    (Stacking, pile Assembling)

Discretization/accumulation process diagram

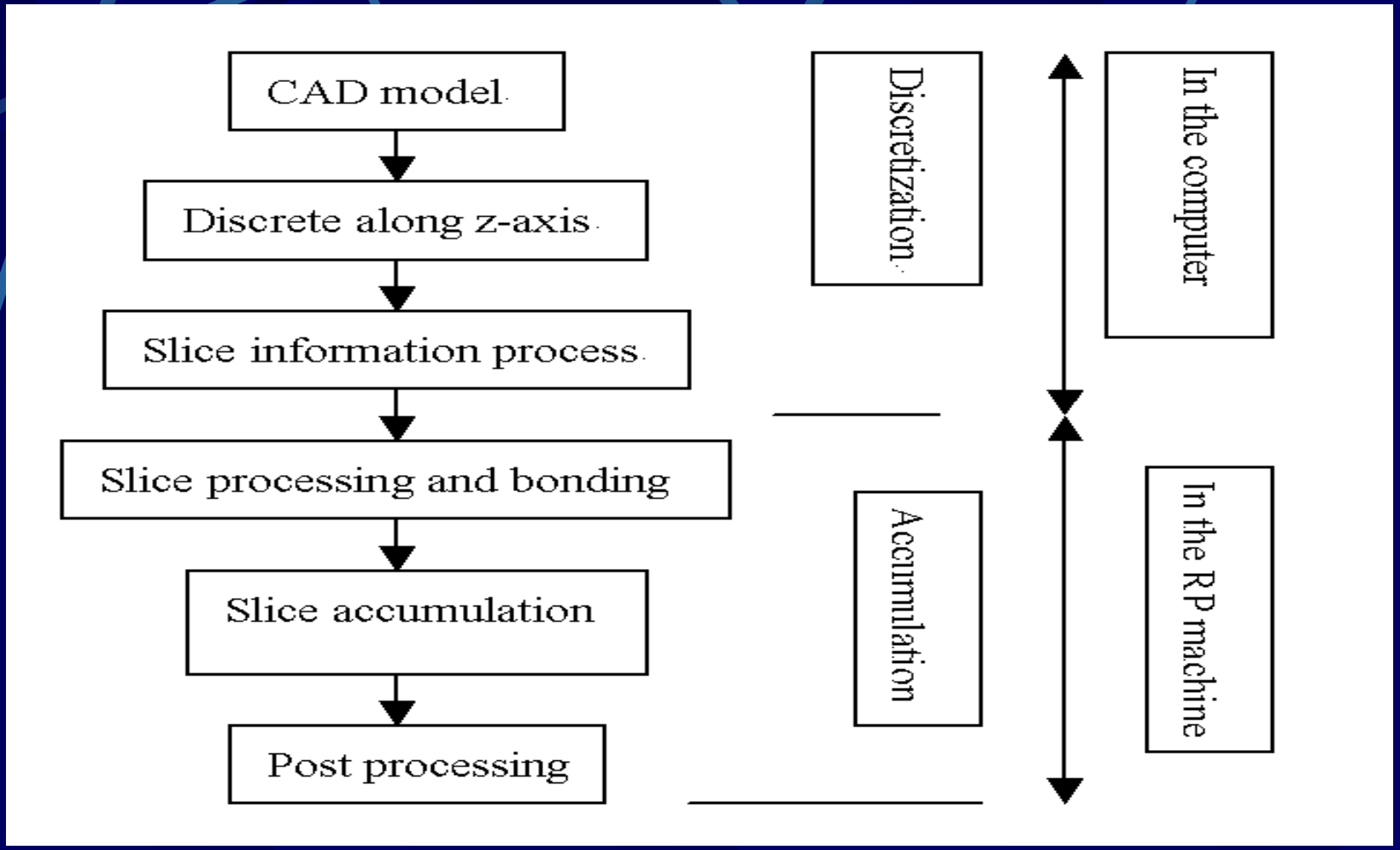

Figure by Tsinghua University, CLRF&CBM

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Advantages

- Any complex shapes
- No need of special tools
- Least manual intervention
- Automatic forming, net manufacturing

FFF Technologies

1. SL – Sterolithography
2. LOM---Lamilated Object Manufacturing
3. FDM Fused Deposition Modeling
4. SLS Selected Laser Sintering
5. 3DP Three-Dimensional Printer

FDM (MEM) and *3DP* are the most important FFF Technologies for Tissue Eng. Scaffold

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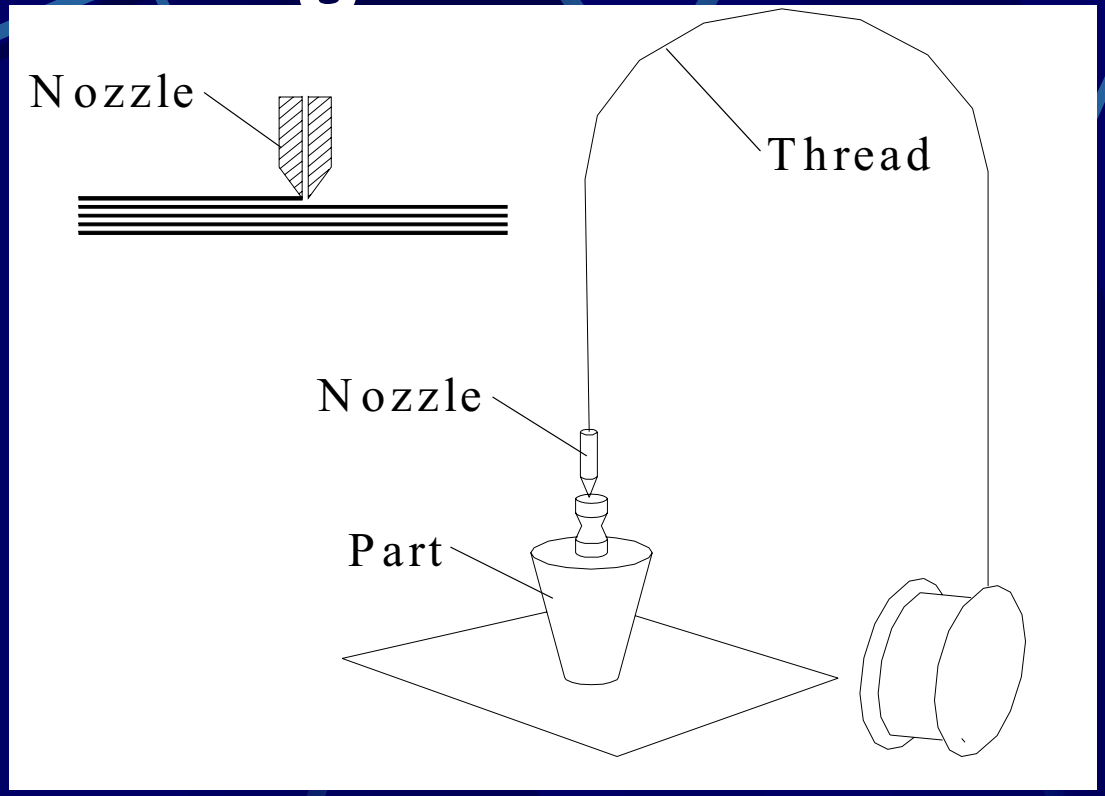
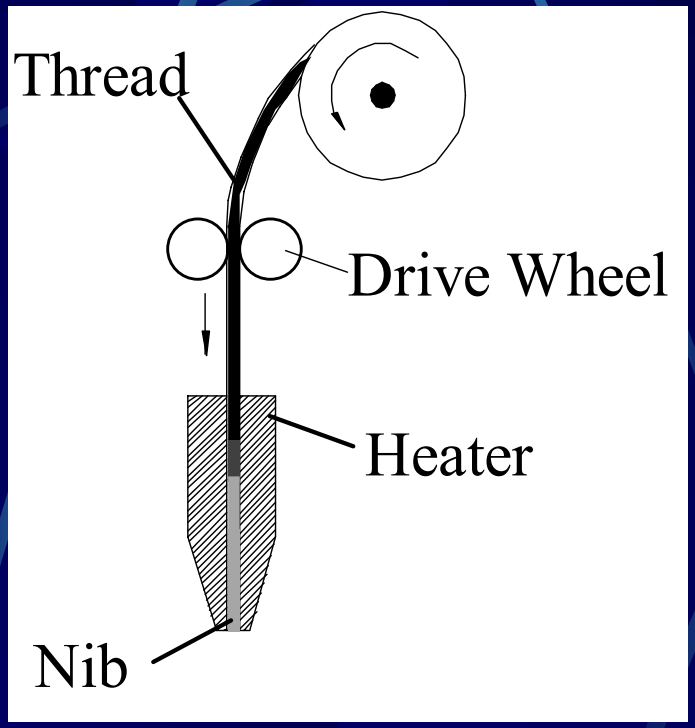
3.FDM Fused Deposition Modeling

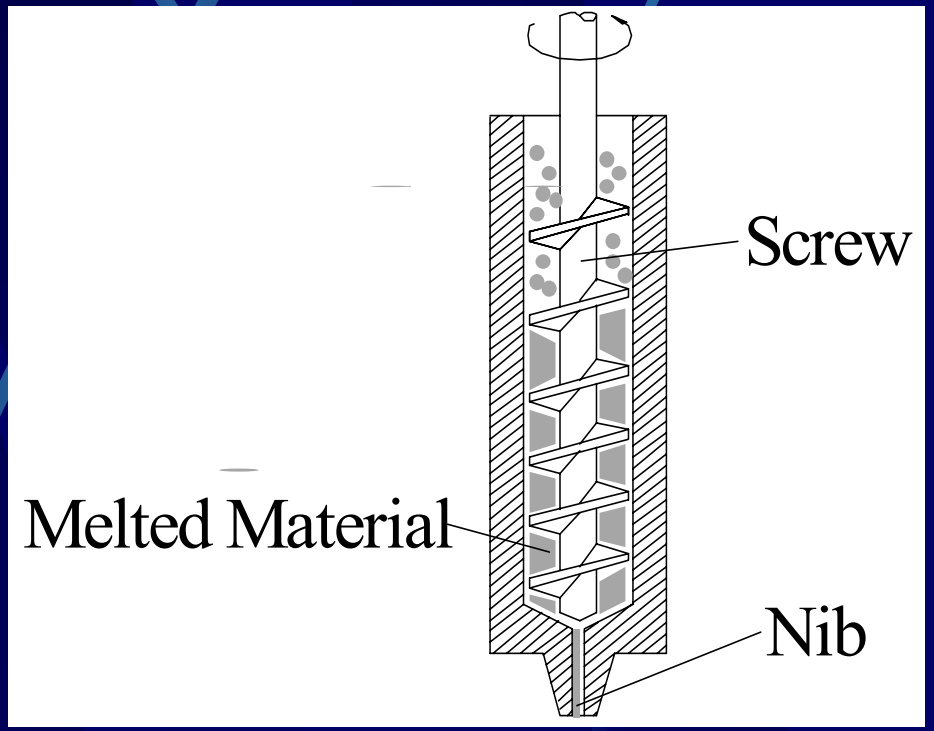


In 1988, *Dr.Scott Crump* proposed FDM process, *Stratasys Co*, developed FDM commercialized systems.

Figure by Tsinghua University, CLRF&CBM

Nozzles:



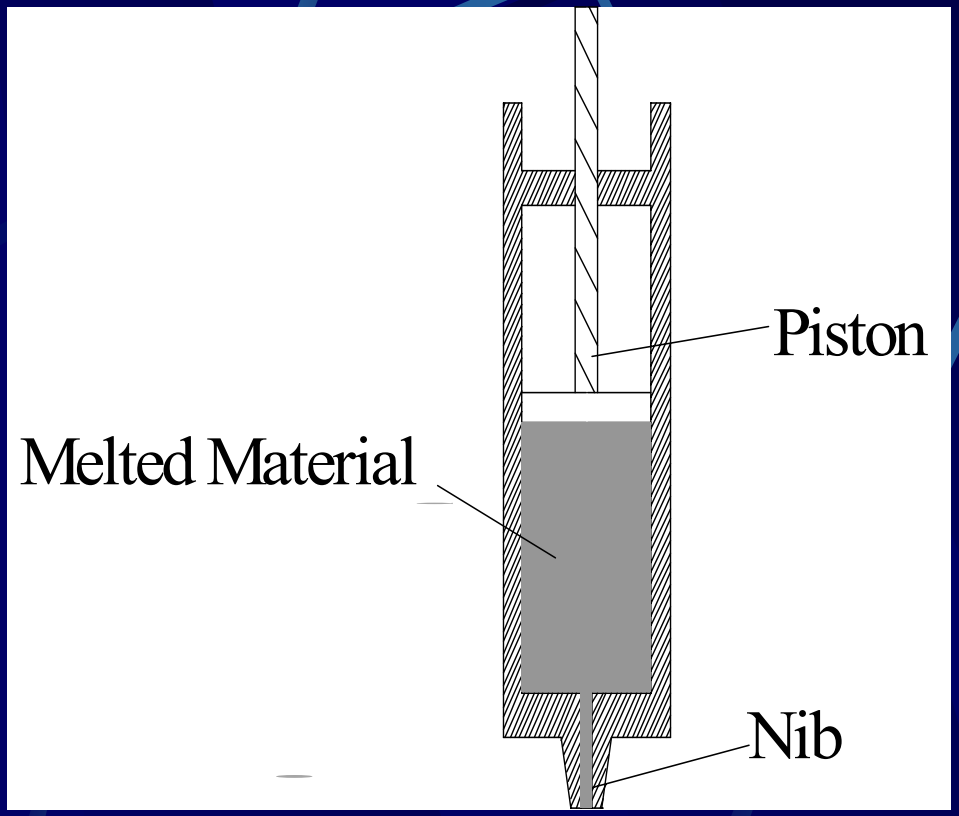


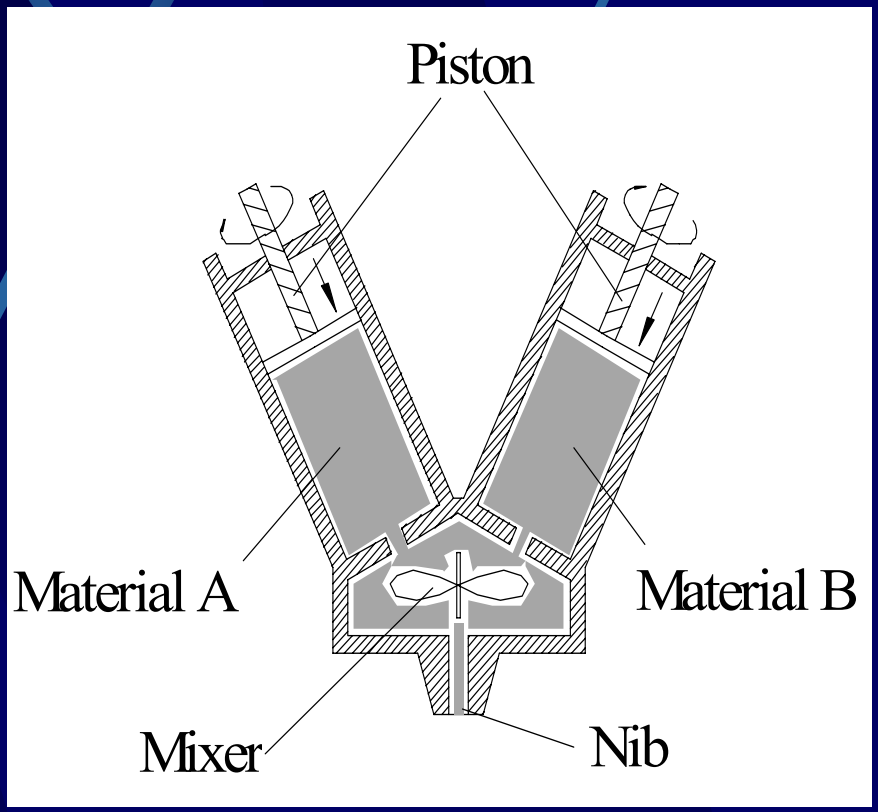
Wheel Drive Nozzle (Filament Material)

Screw Drive Nozzle

Figure by Tsinghua University, CLRF&CBM

Nozzles:



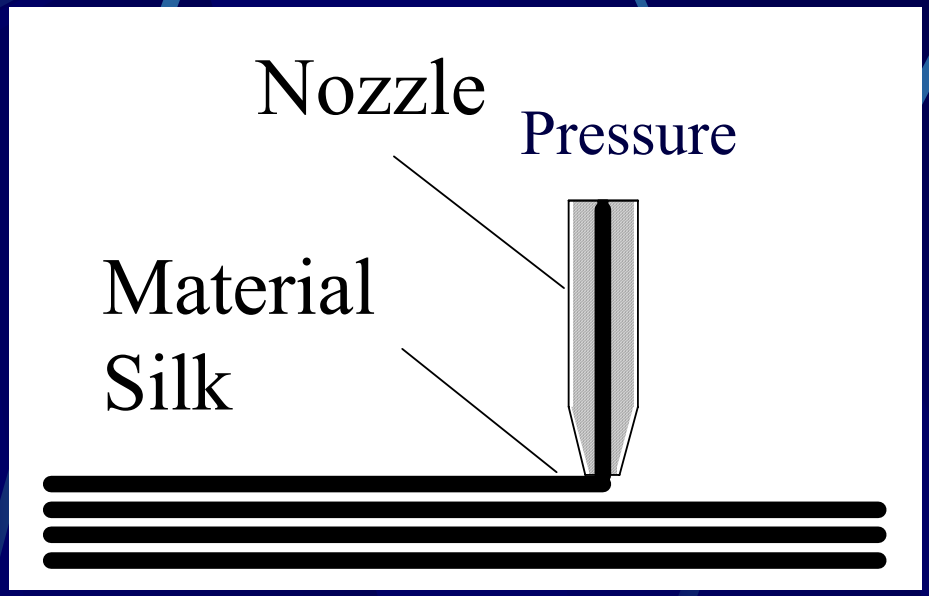


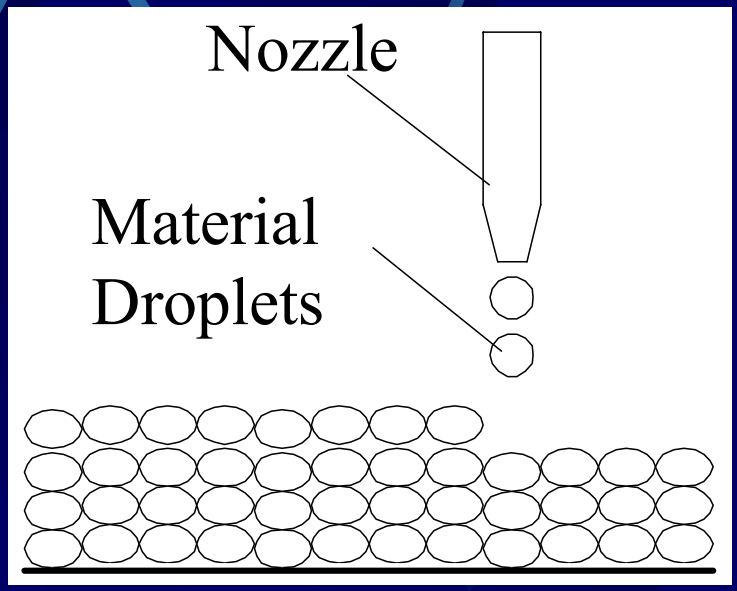
Piston Drive Nozzle **Multi-material Nozzle**

Figure by Tsinghua University, CLRF&CBM

Using FFF, extrusion/jetting nozzles, Make out scaffold

Electro magnetism Piezoelectricity





(a)Extrusion (b)Jetting

Forming process of the scaffolds

Figure by Tsinghua University, CLRF&CBM

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MEM-300-II (Melted Extrusion Manufacturing) System

Developed by Tsinghua University

Figure by Tsinghua University, CLRF&CBM

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2. Scaffold Manuf. Technologies
3. Non-degradation Scaffold
4. BONE Tissue Eng. Scaffolds
5. 3-D cell Assembled
6. Laser Directed Guided Writing(LDGW) of cell

Scaffold has

* Complex structure
* Complex material gradient
* Pore gradient
* Pore rate

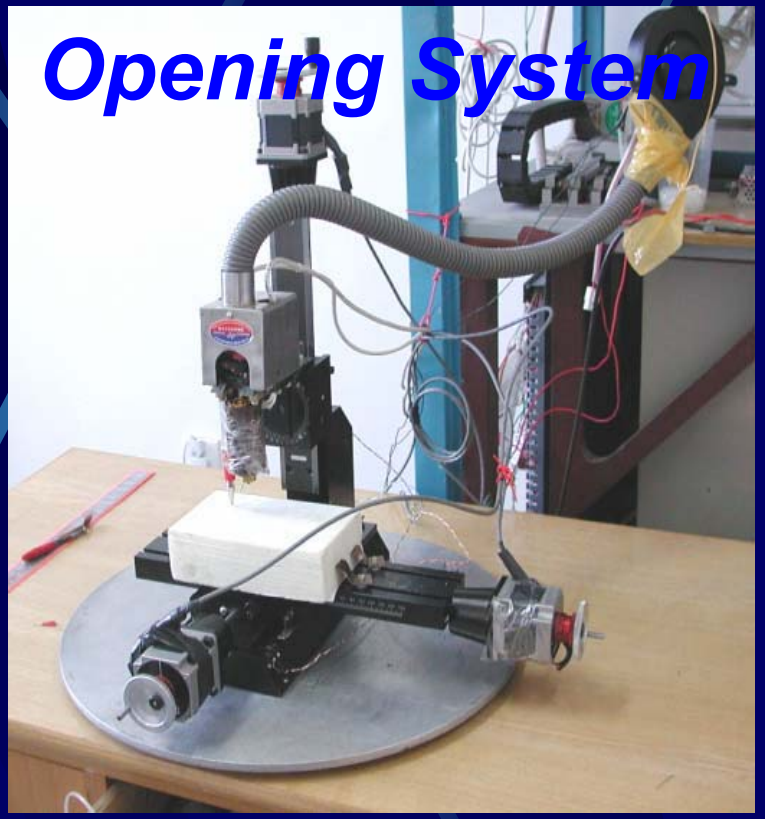
Scaffold characteristics

- Three-dimensional and highly porous with a interconnected pore network for cell growth and flow transport of nutrients and metabolic waste
- Biocompatible and bio absorbable with a controllable degradation and absorption rate to match cell/tissue growth in vitro and /or in vivo

- Suitable surface chemistry for cell attachment, proliferation, and differentiation
- Mechanical properties to match those of the tissues at the site of implantation
- Be easily processed to form a variety of shapes and sizes

Med Form

Opening System



Developed in CLRF, Tsinghua University

Figure by Tsinghua University, CLRF&CBM

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Desk top biomaterial forming Machine

Developed in CLRF, Tsinghua University

Figure by Tsinghua University, CLRF&CBM

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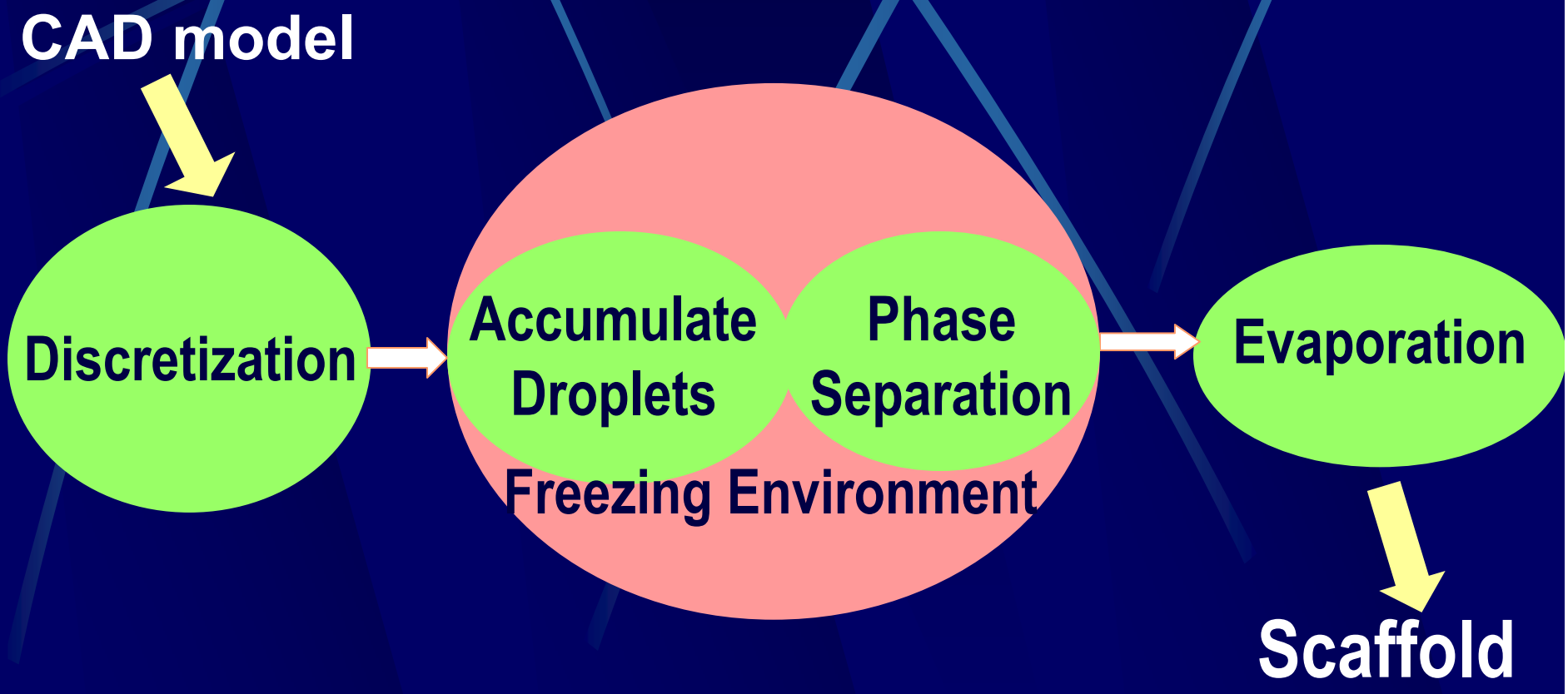
LDM——Low Temperature Deposition Manufacturing



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Bio-material Forming Platform

Developed in CLRF, Tsinghua University

Figure by Tsinghua University, CLRF&CBM

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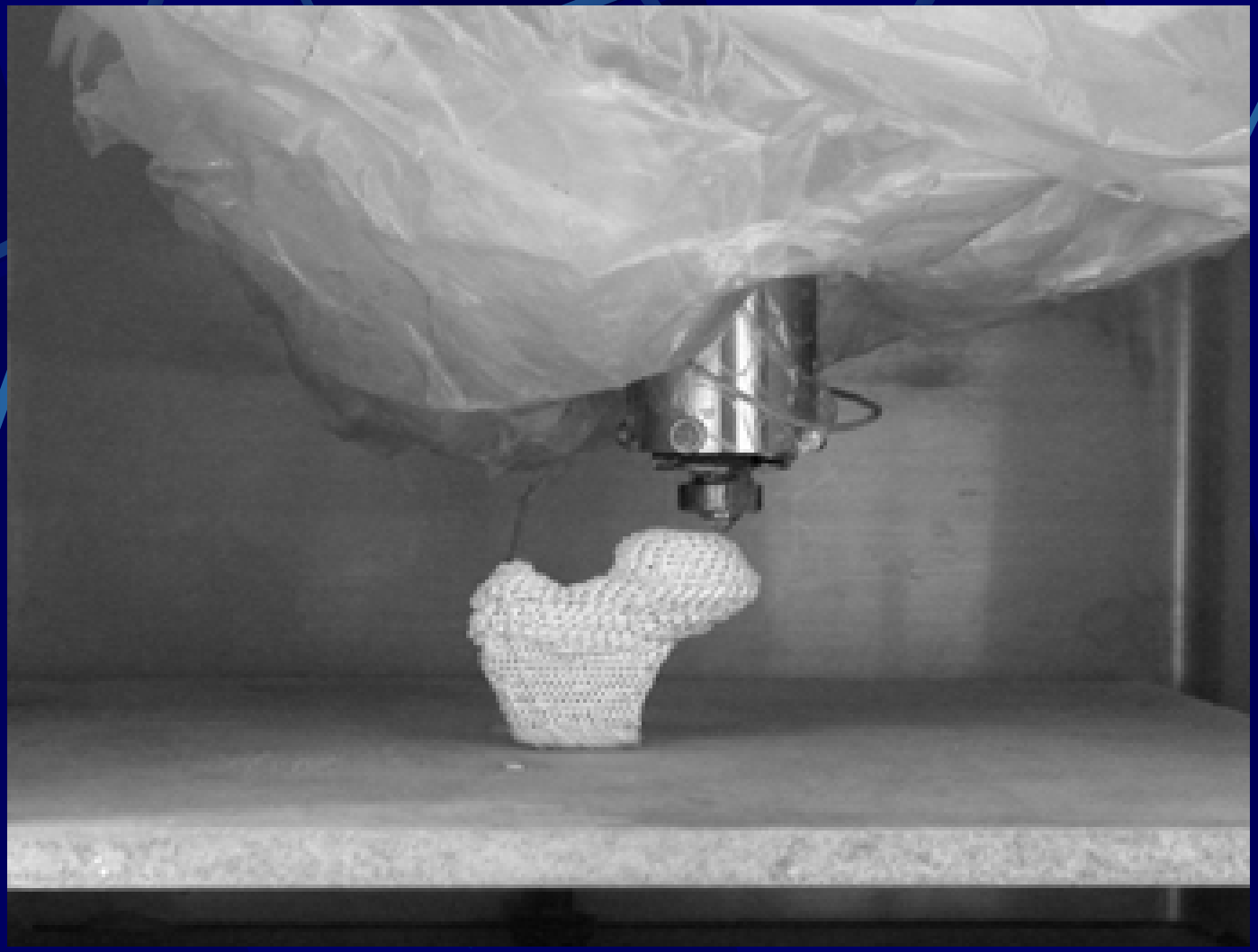

Developed in CLRF, Tsinghua University

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Multi-Nozzleo system of Scaffold form Machine

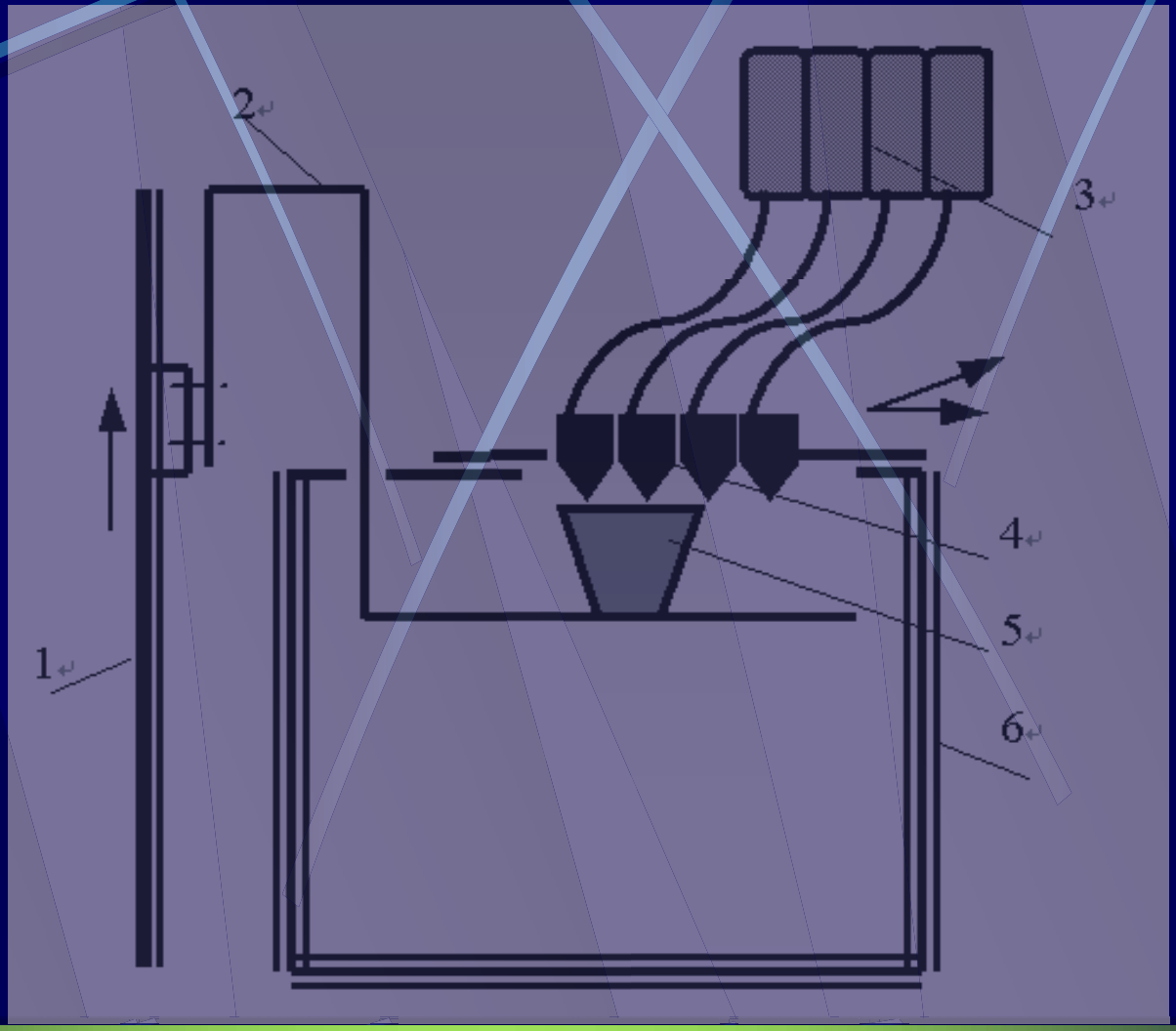

Figure by Tsinghua University, CLRF&CBM

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name	TissForm		
Forming material	Biocompatible materials		
Number and type of nozzles	Screw pump	Electro magnetism valve	Piezoelectricity crystal
	2	1	1
NC card	American Del ton company Pmac NC card		
Environment	-30℃—30℃		
Forming space	200*200*200 mm^3		
Scan speed	70 mm/s		

Tiss-Form Machine

Developed in CLRF, Tsinghua University

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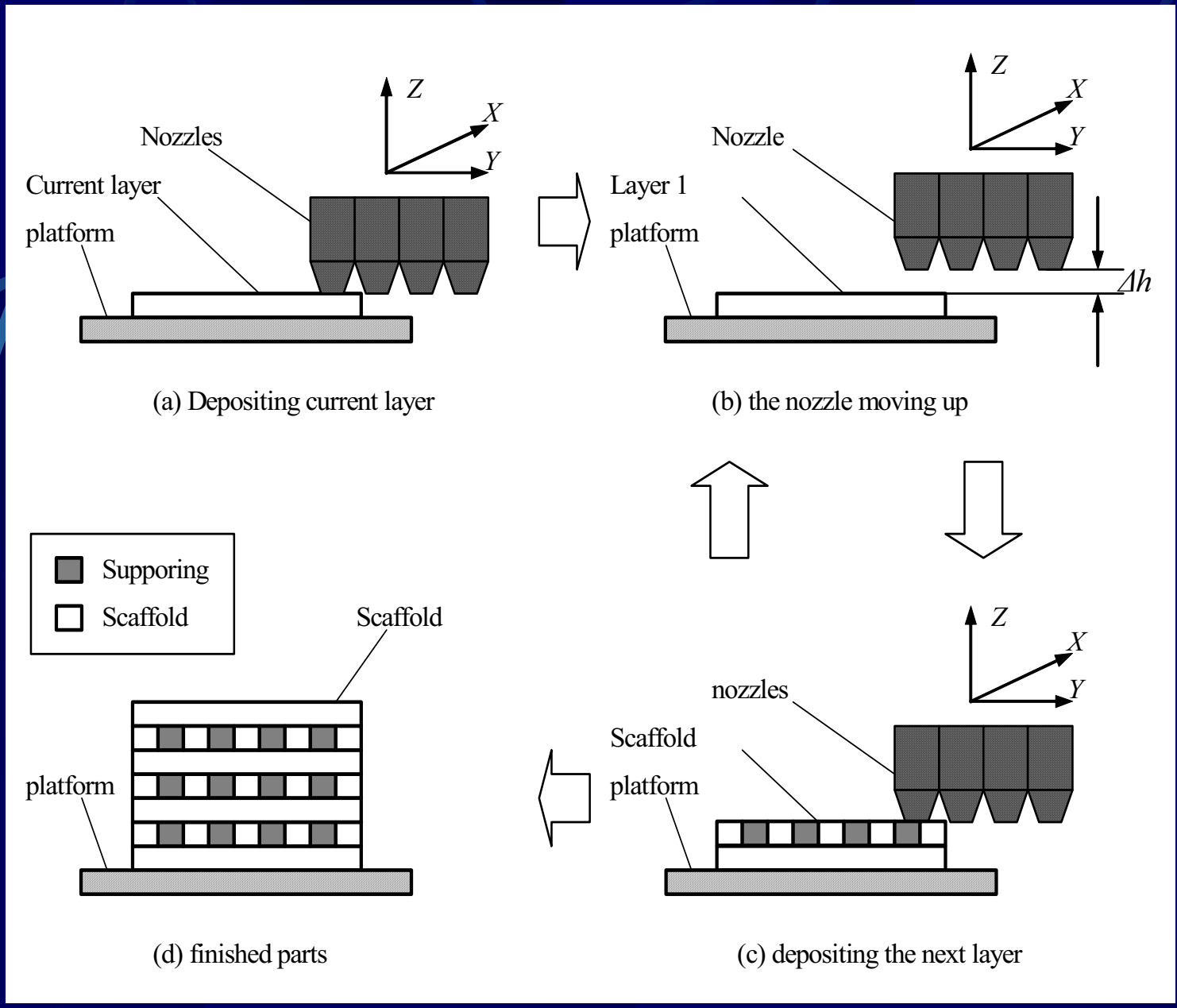
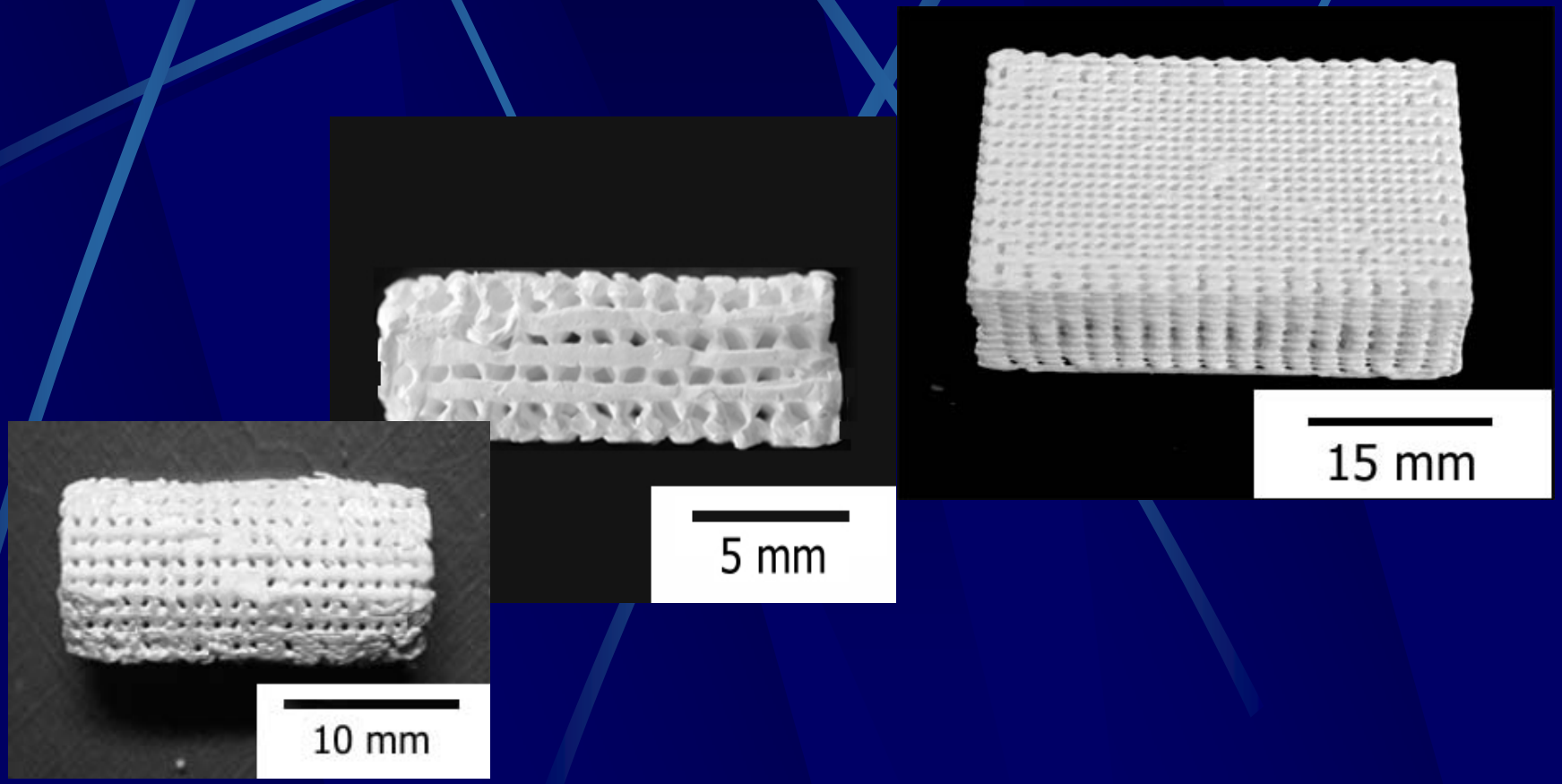


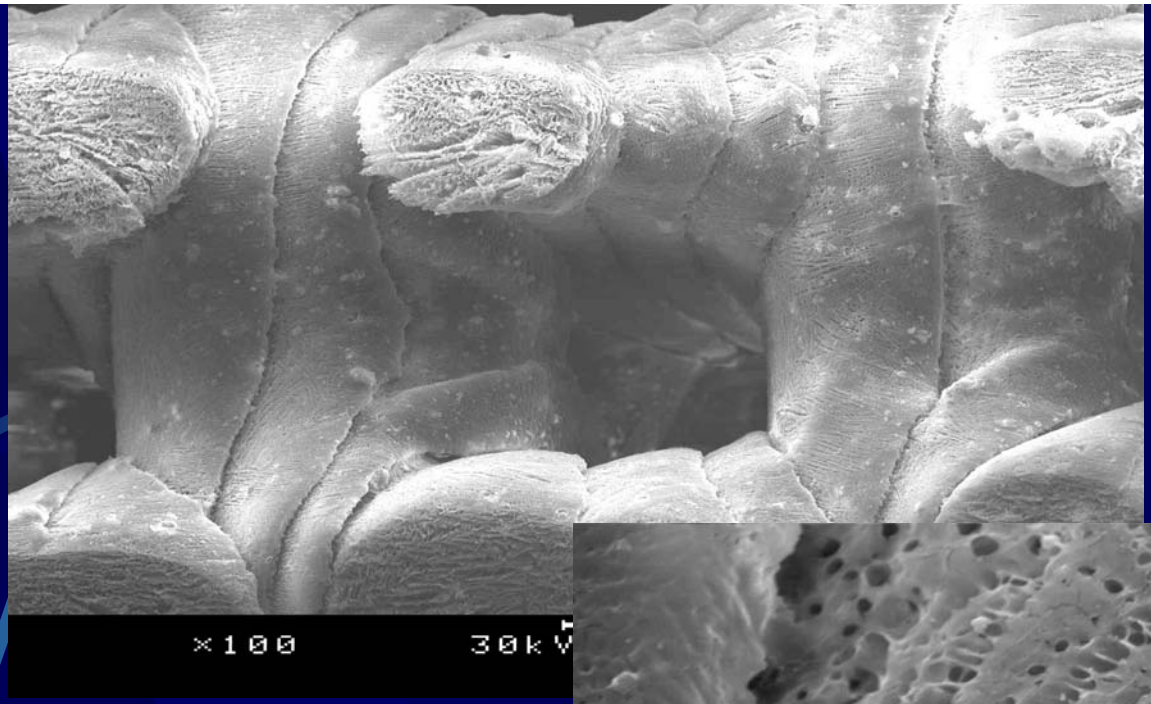
Figure by Tsinghua University, CLRF&CBM

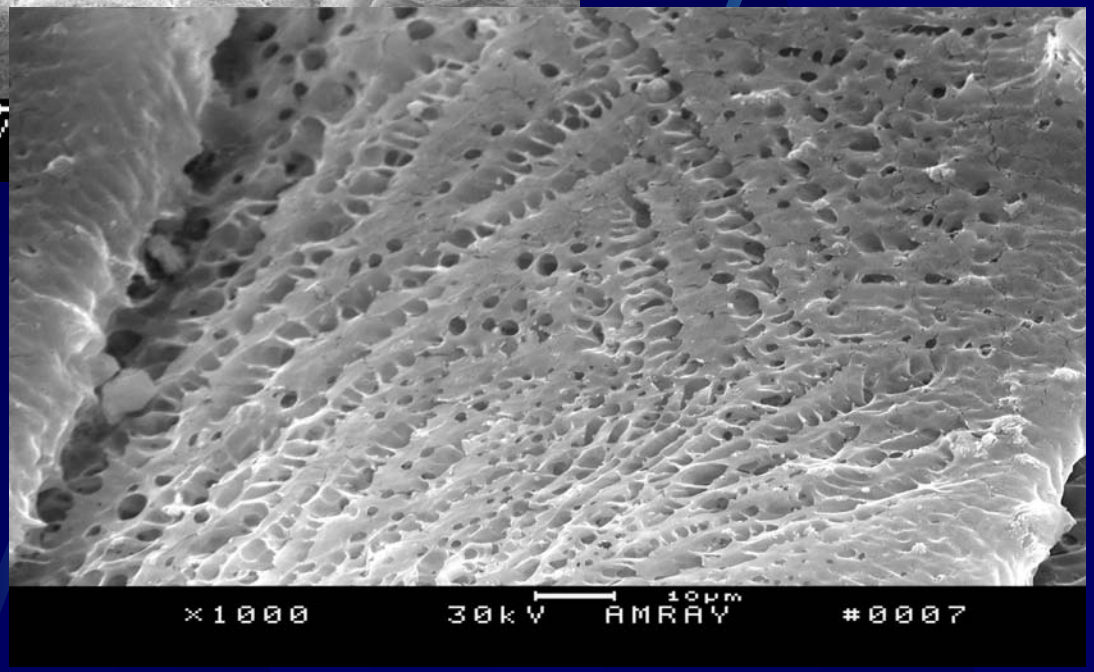
Scaffold poly (L-lactic acid)
Tricalcium Phosphate



Developed in CLRF, Tsinghua University

Figure by Tsinghua University, CLRF&CBM





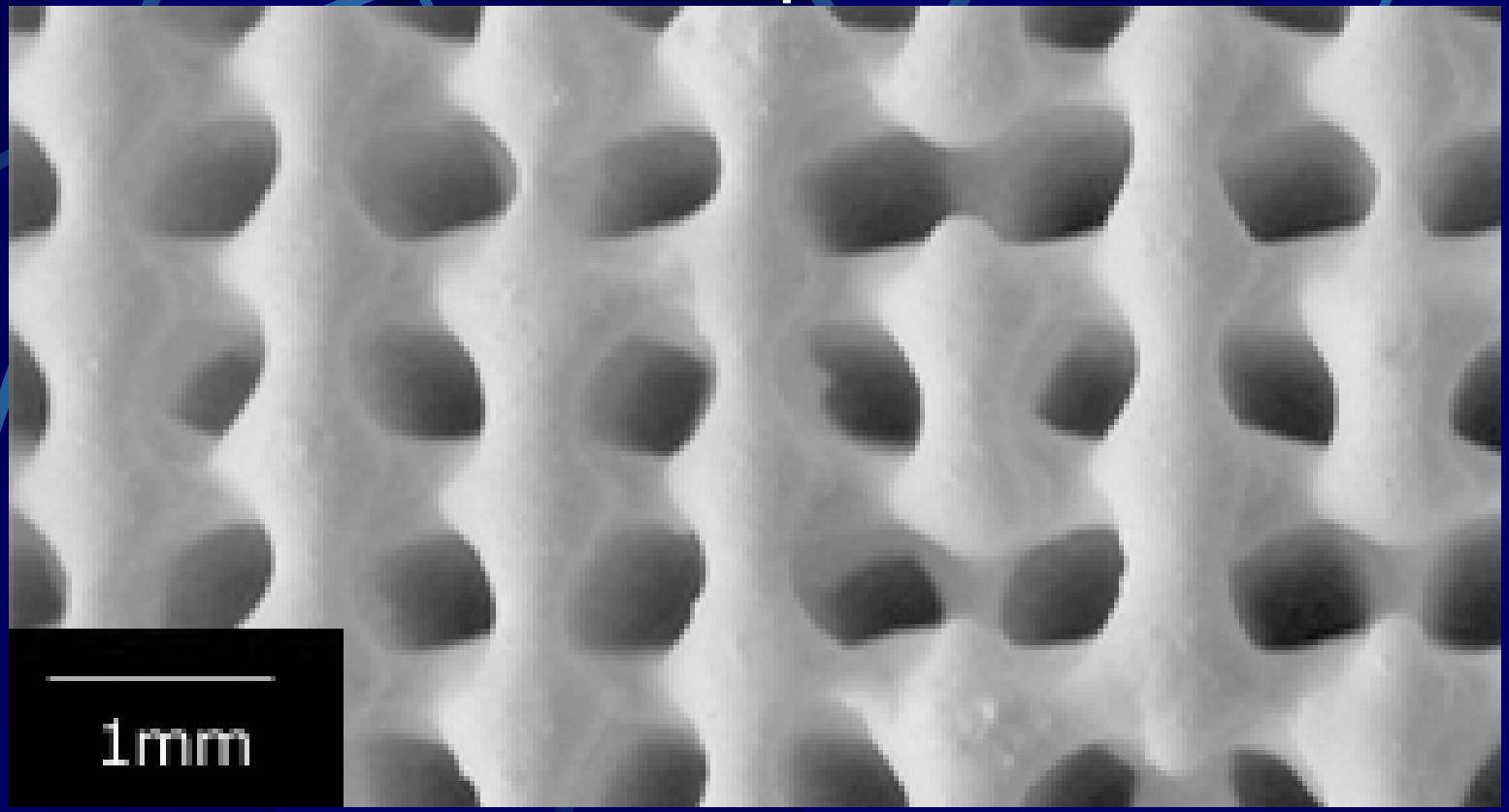
Porosity

85~90%

Developed in CLRF, Tsinghua University

Figure by Tsinghua University, CLRF&CBM

Scaffold poly (L-lactic acid)
Tricalcium Phosphate

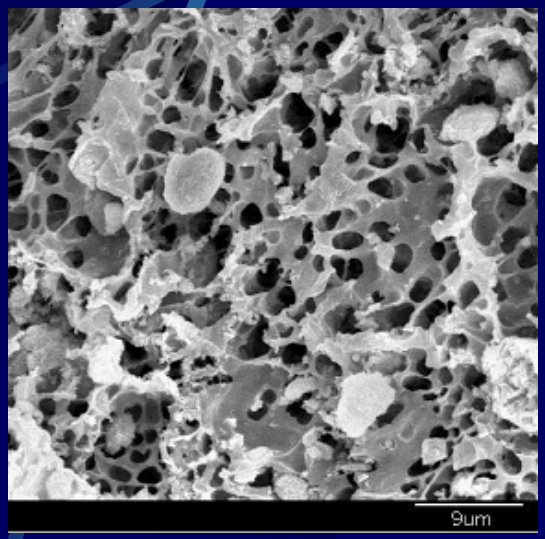


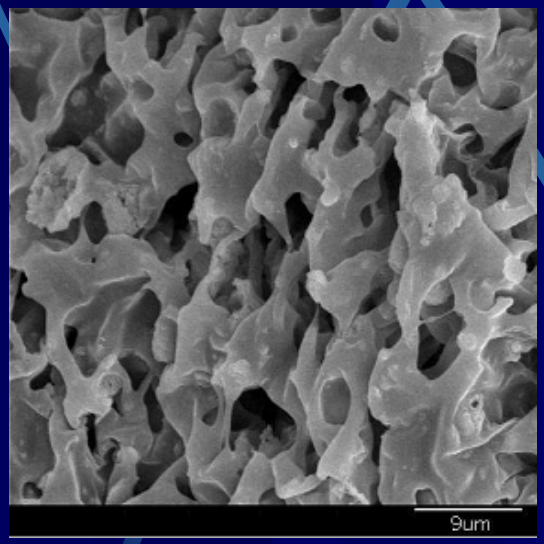
Macro pores structure of PLGA/TCP
From Solid-Liquid phase separation

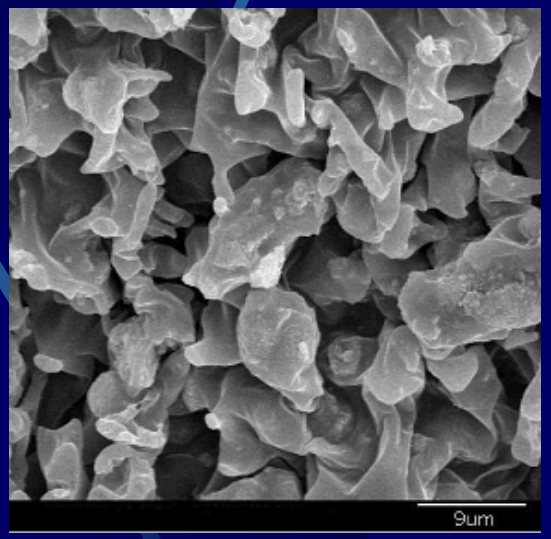
Figure by Tsinghua University, CLRF&CBM

To ensure the desired porosity, it needs to adjust the temperatures of the nozzles and the environment.

Material(1)







(a) PLLA/TCP **(b) PDLLA/TCP** **(c) PLGA/TCP**

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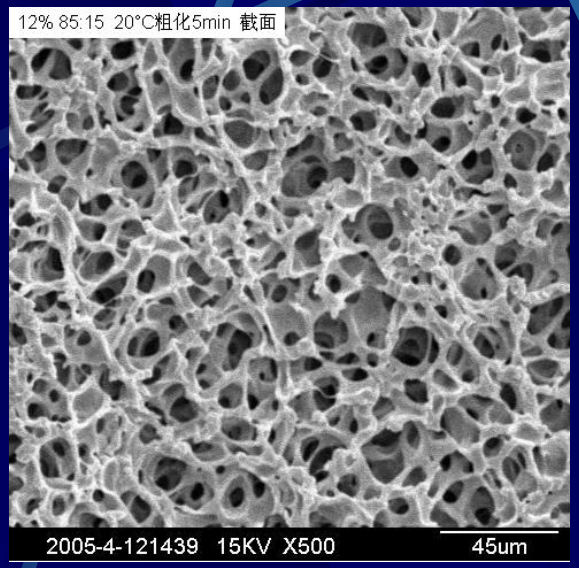
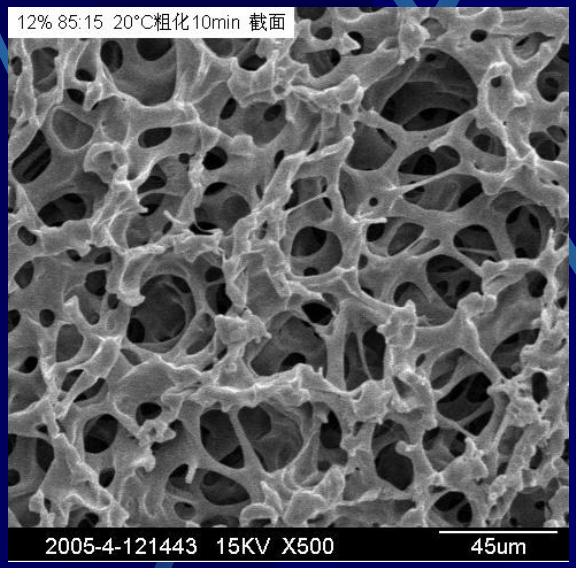
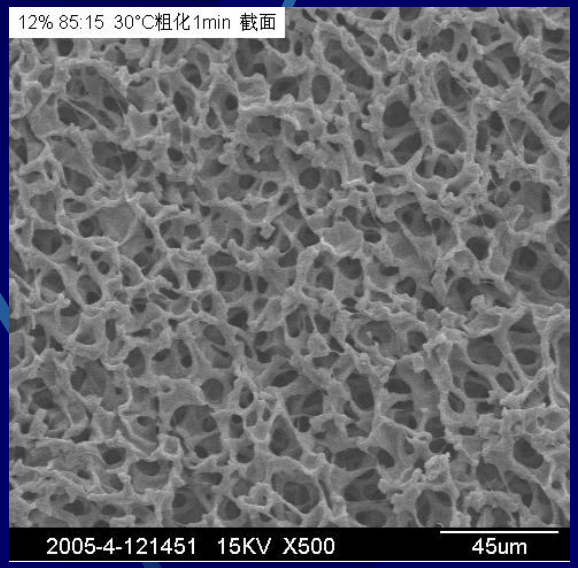
Material (2)







(a) PLGA/Dioxane/water aging for 5 min at 20℃
(b) PLGA/Dioxane/water aging for 10min at 20℃
(c) PLGA/Dioxane/water aging for 5min at 30℃

Figure by Tsinghua University, CLRF&CBM

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Scaffold for Rehabilitating of Microtia

(Undegradable)

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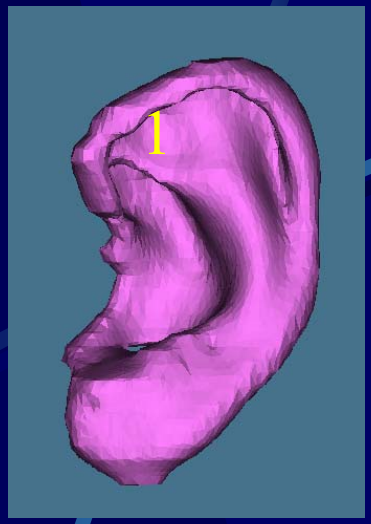

(1)CAD Modle

(2) Artificial ear

(3) Healthiness ear

(4) Rehabilitated ear

Cooperated with Peking Plastic Surgery Hospital

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