Effect of Viscoelastic Properties on 3D Printability of CNF Hydrogels

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TAPPI

Introduction

Safety assessment of chemicals

International restriction of animal examinations

Alternatives

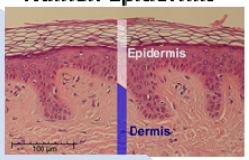
in vitro(test tube) test methods and models based on human cell and tissue cultures

Computer models and simulations

Stem cell and genetic testing methods

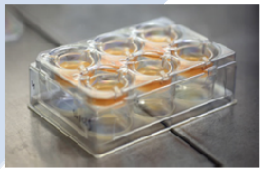
Computerized patient-drug databases and virtual drug trials

Human Epidermis



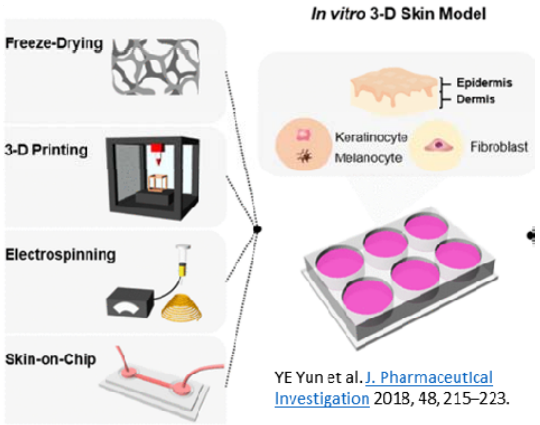
Applications

Skin irritation
Skin corrosion
UV Exposure
DNA Damage
Bacterial adhesion
Omics
Permeability



http://www.episkin.com

Approach



YE Yun et al. J. Pharmaceutical Investigation 2018, 48, 215–223.

3D printing

- Direct fabrication
- Microfluidic chip
- Equivalent systems
- 3D Structure
- Human skin cells

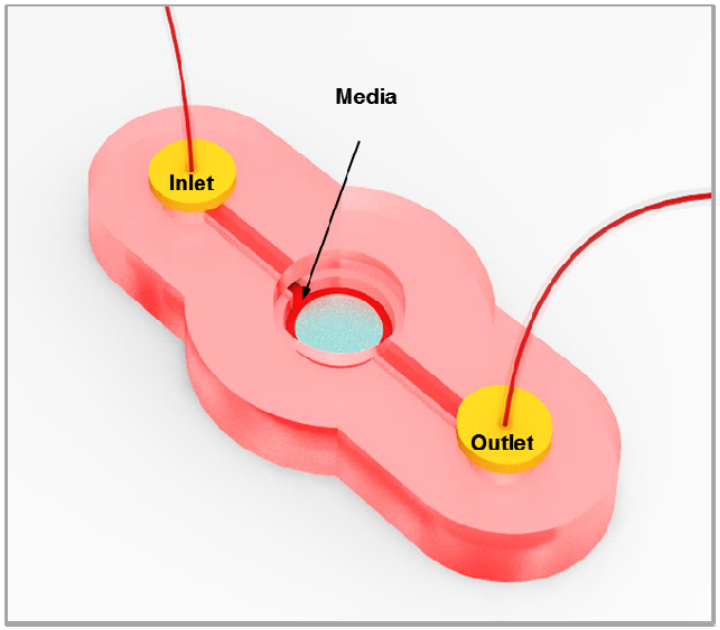
Introduction

3D Bioprinting

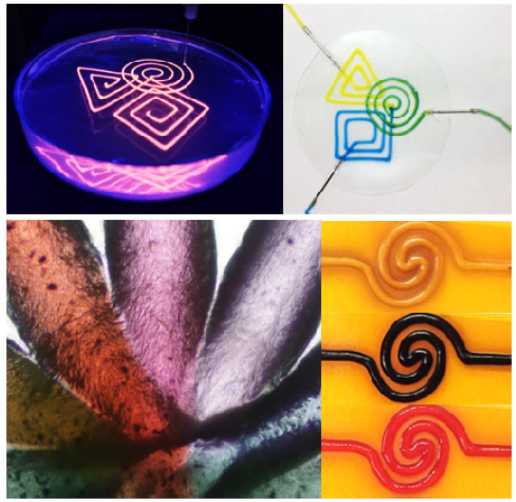
3D cell-laden structures

Tissue engineering
Drug screening
Biosensing

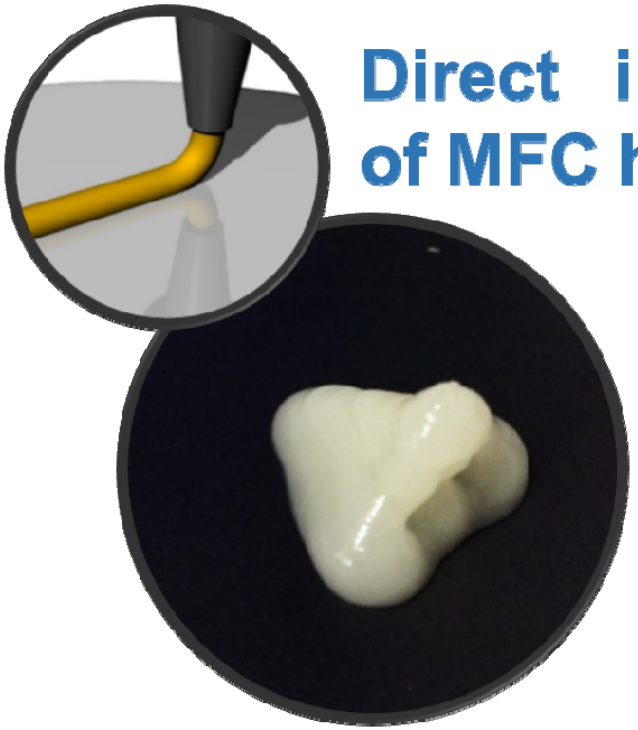
CNF based BioChip



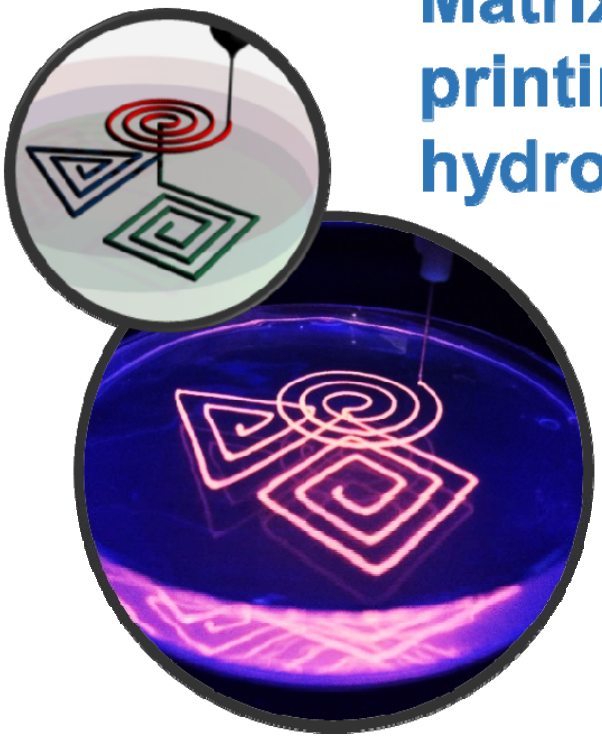
Microfluidic system



Research Interests



Direct ink writing of MFC hydrogel



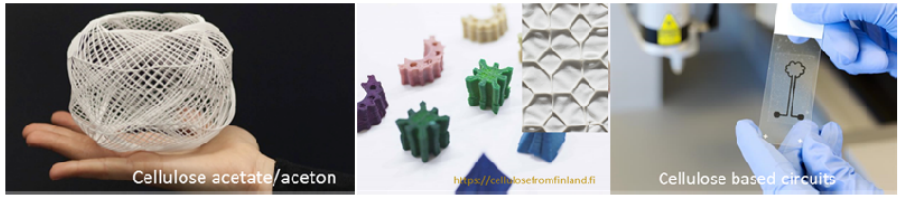
Matrix-assisted 3D printing with CNF hydrogel

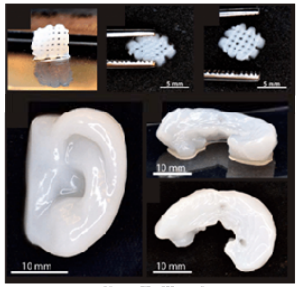
Introduction

Materials vs Technologies

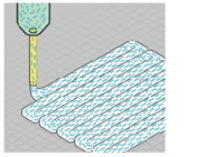
Materials \ Technologies	Polymerization	Bonding agent	Melting	Solvent casting
Ceramic		BJ	LM	
Metal		BJ	LM, EBM	
Powder		BJ		
Plastic	SL, PJ	BJ	FDM, LS	
Wax			MJ	
Colloids	Cellulose Nanofibers			DIW

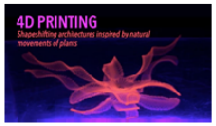
FDM = Fused Deposition Modeling
EBM = Electron Beam Melting
LM = Laser Melting
LS = Laser Sintering
PJ = Photopolymer Jetting
SL = Stereolithography
MJ = Material Jetting
BJ = Binder Jetting
HP = Hybrid Processes
DW = Direct writing /paste extrusion





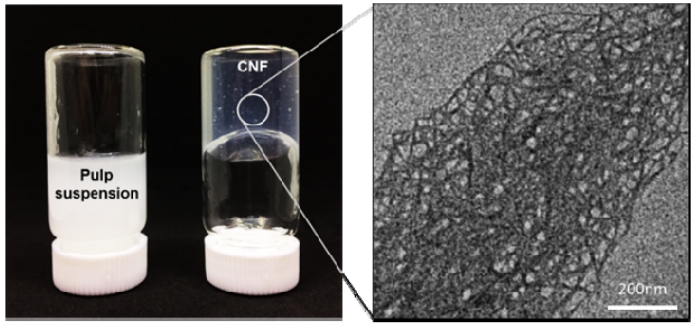
Nanofibrillated cellulose/alginate bioink
Markstedt K et al. Biomacromolecules 16 1489–96





3D printing of cellulose materials, On-demand production of novel applications, VTT webinar series, 7th June, 2018.

Unique properties of CNFs



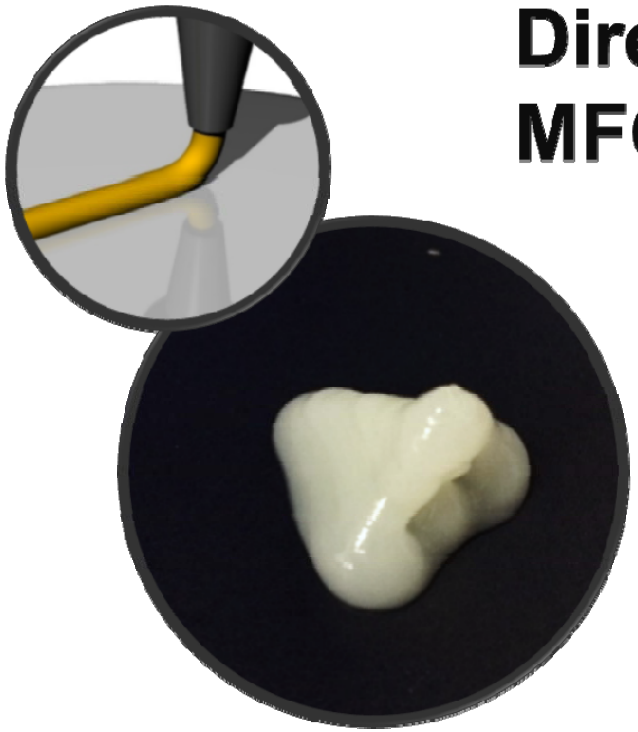
Biomedical
Environmental

Morphology

Rheology

Printability

Water content
High aspect ratio
Hydrogel
Biocompatible
Shear thinning
Viscosity modifying
Gelation



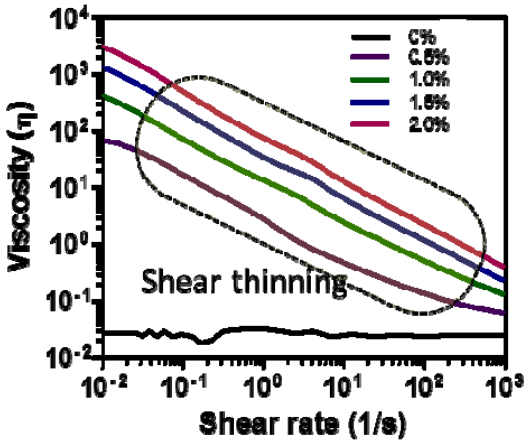
Direct ink writing of MFC hydrogel

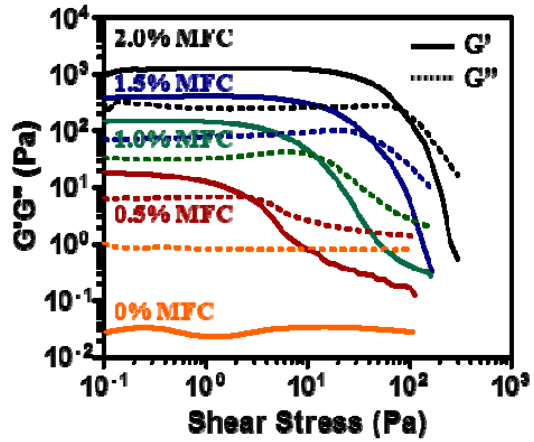
Features of DIW with MFC

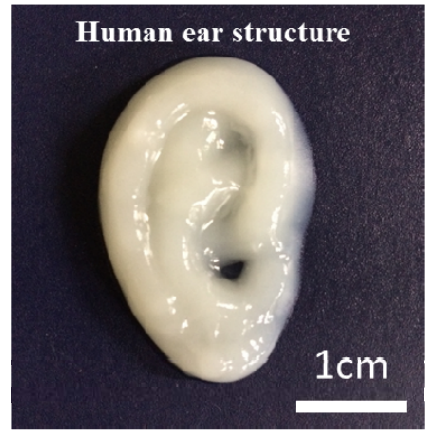
- Simple and biocompatible process
- Cell-laden bioprinting
- Cell culture environment
- Viscosity modifier
- Mechanical reinforcement

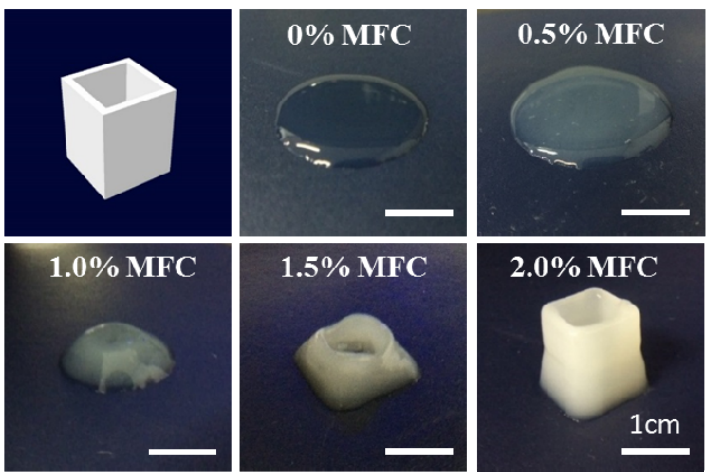
Direct ink writing

Optimization of MFC concentration









with MFC

- Improved printability
- Increase of viscosity
- Shear thinning behavior
- 2% of MFC bio-ink for 3DP

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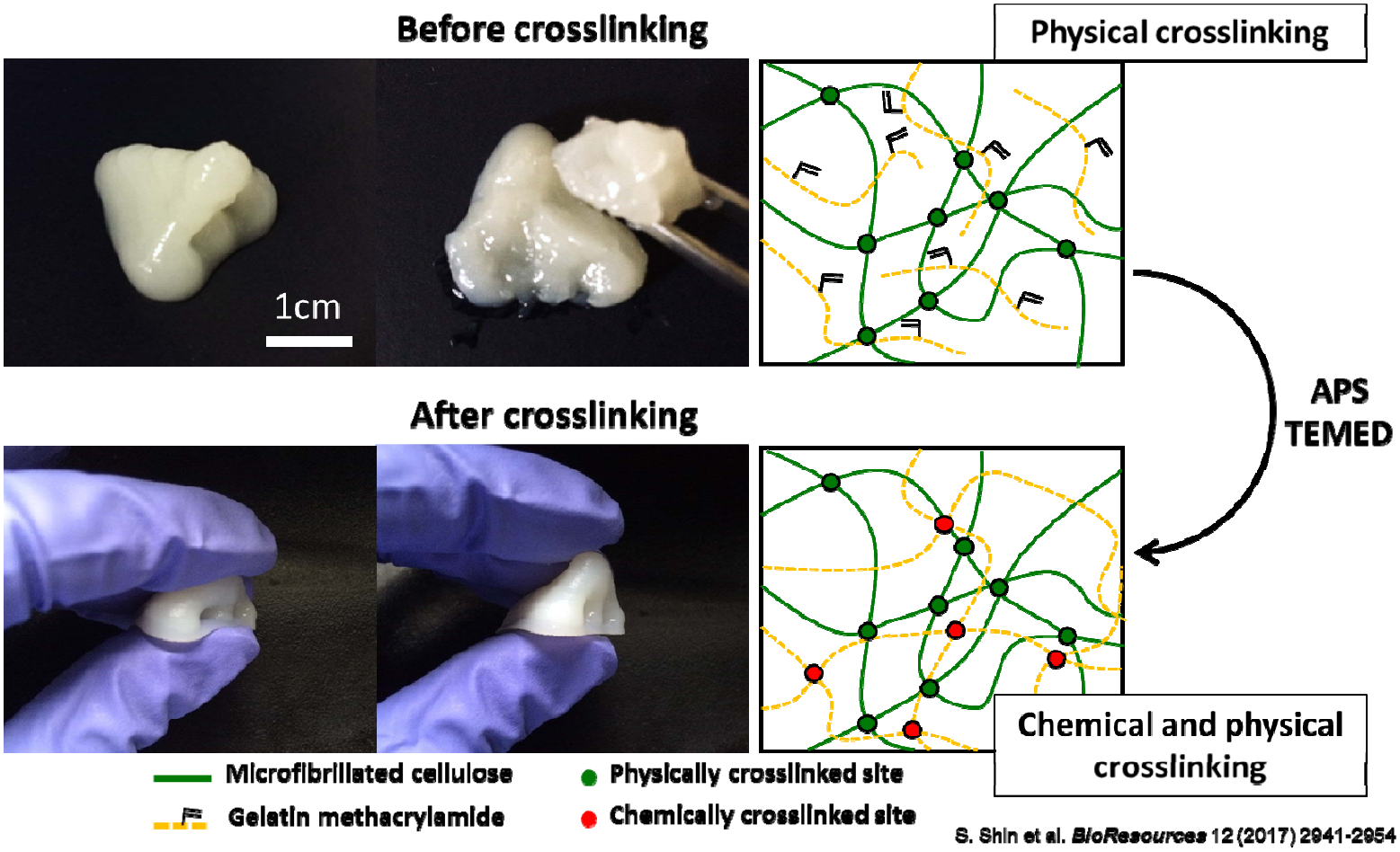
Direct ink writing

Chemical crosslinking of GelMA



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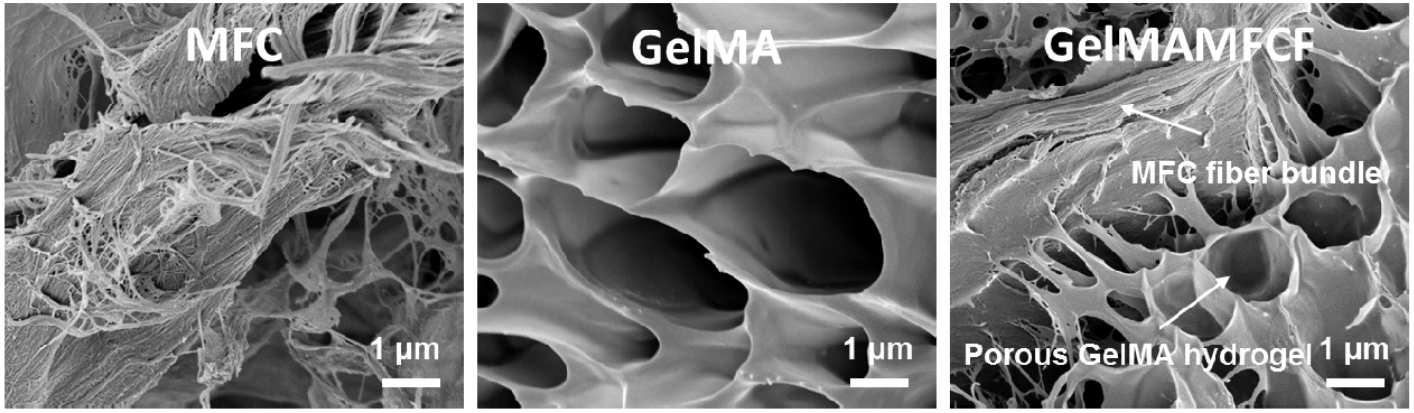
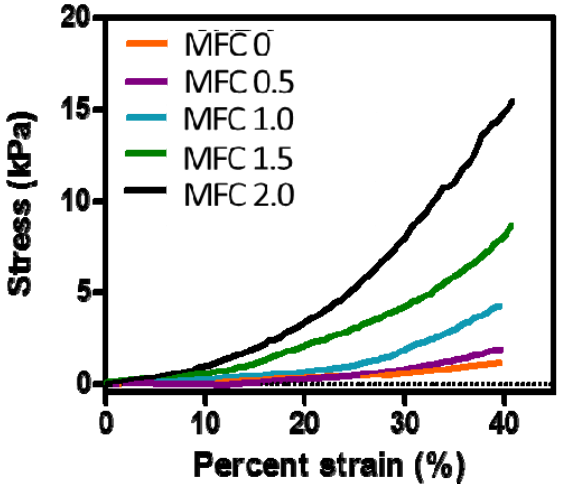
Direct ink writing

Properties of GelMA/MFC composite hydrogel





MFCs were stably bound to GelMA hydrogels.

MFC bundles acted as a structural frame for the GelMA hydrogels.

The mechanical strength of the composite hydrogels was improved.

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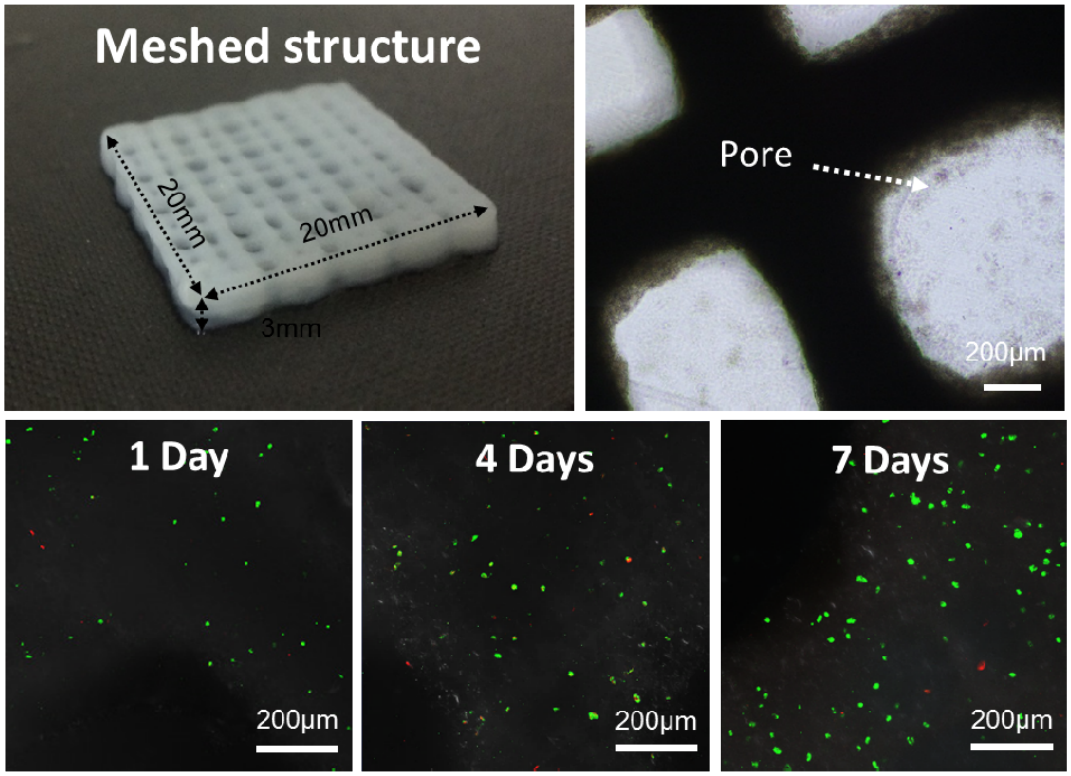
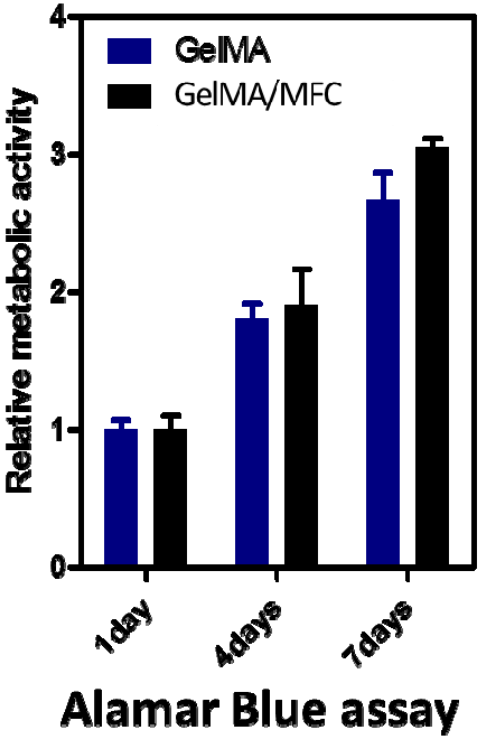
Direct ink writing

Embedment of cells with 3D printed scaffolds





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Matrix-assisted 3D printing with CNF hydrogel

Features of 3D printing in CNF matrix

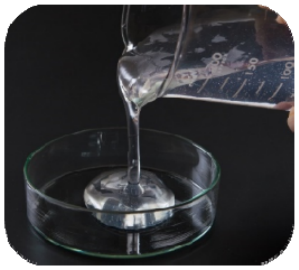
- Simple and rapid process
- Compact design
- Vertical integration of microchannels
- Transparent microfluidic devices

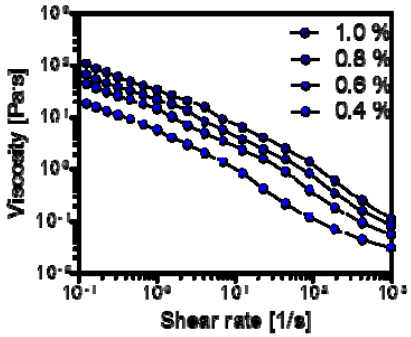
Matrix-assisted 3D printing

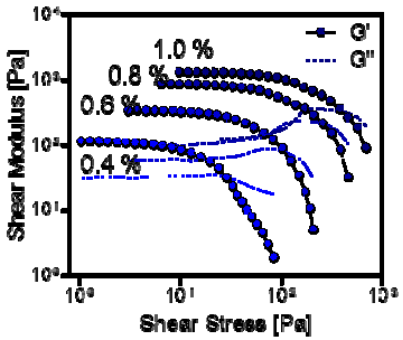
Rheological behavior

- Matrix material : Cellulose nanofiber (CNF)

> - Appropriate viscosity as a 3D printing matrix

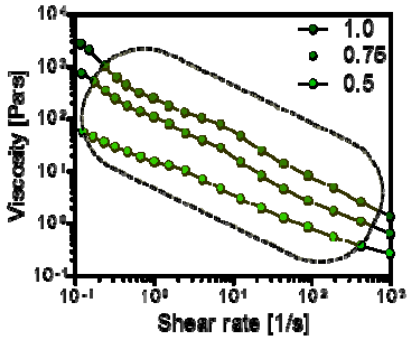


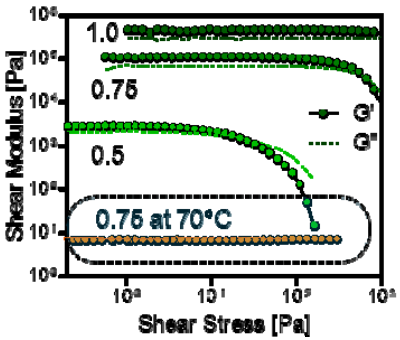




- Ink material : Petroleum jelly (Vaseline)

> - Shear thinning behavior
> - Melting temperature at 70℃

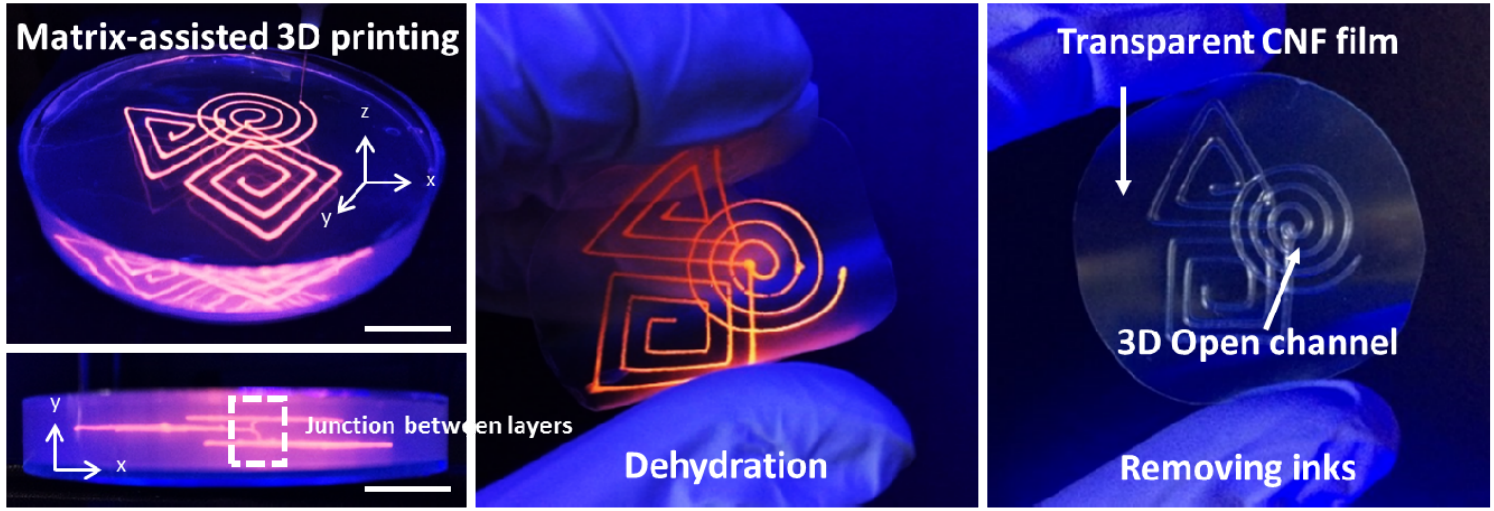


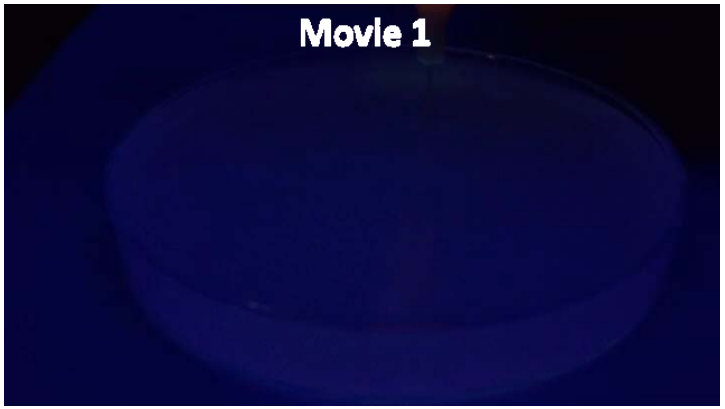


- Immiscibility
- Easy removal

Matrix-assisted 3D printing

Paper-based 3D open channel microfluidic device





Fabrication of a flexible microfluidic thin film with multilayered channels by matrix-assisted 3D printing in the CNF hydrogel.

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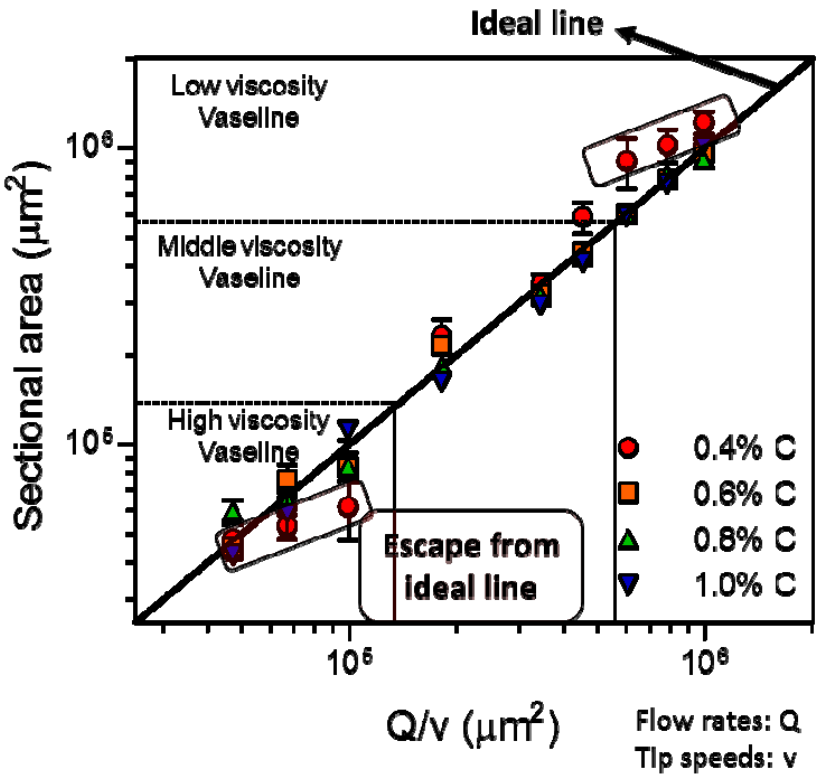
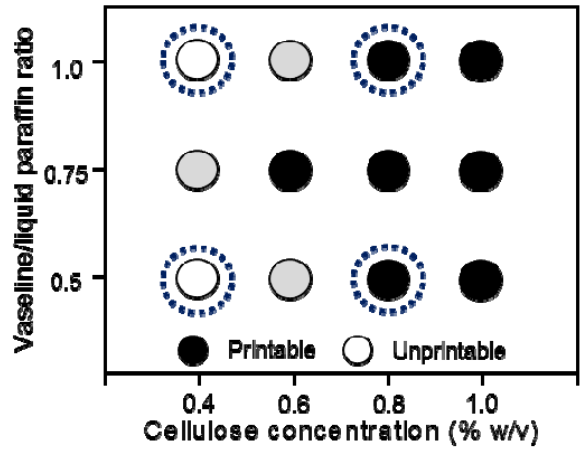
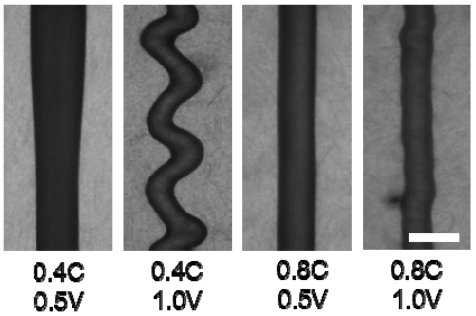
Matrix-assisted 3D printing

Printing performance vs Combination of CNF and ink concentrations







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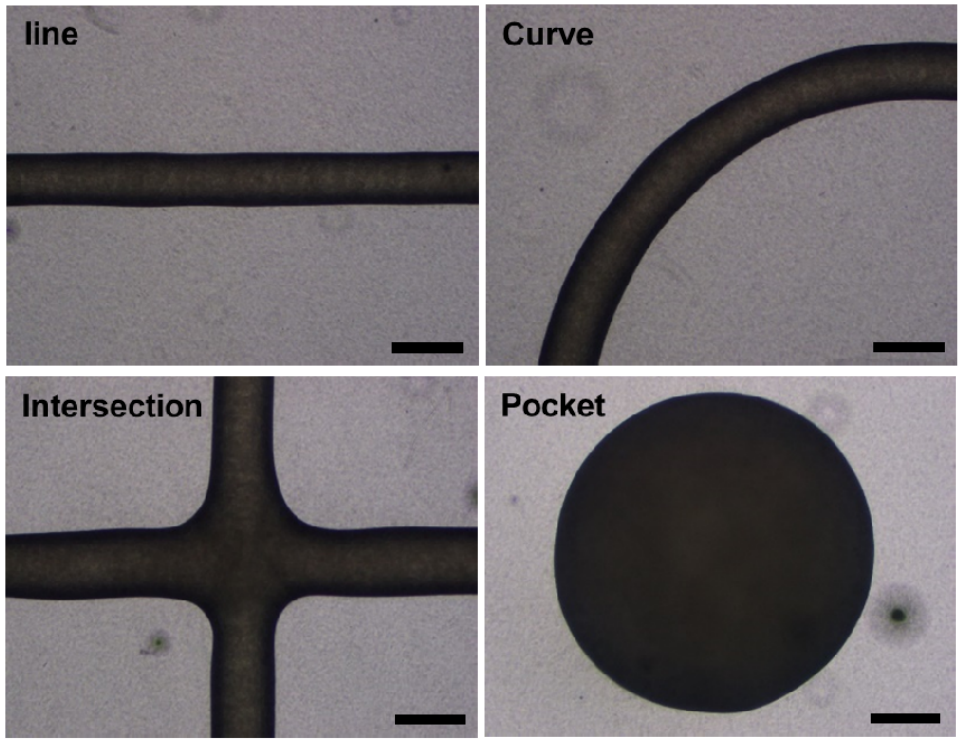
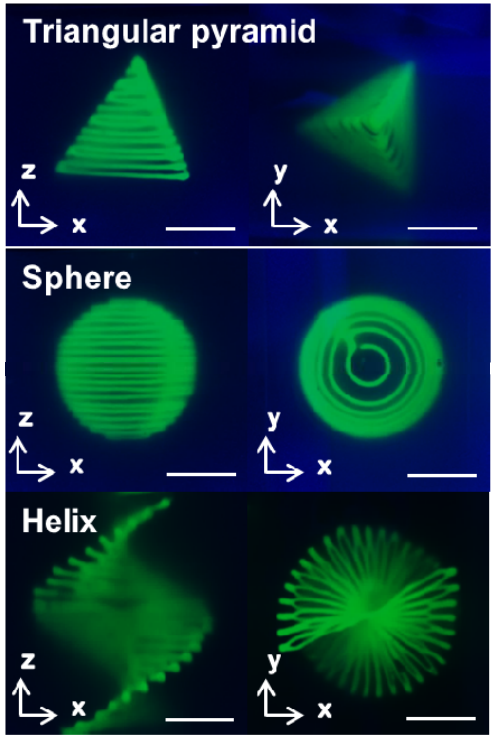
Matrix-assisted 3D printing

Flexibility in 3D structure design





Sufficiently stable during printing and long-term storage

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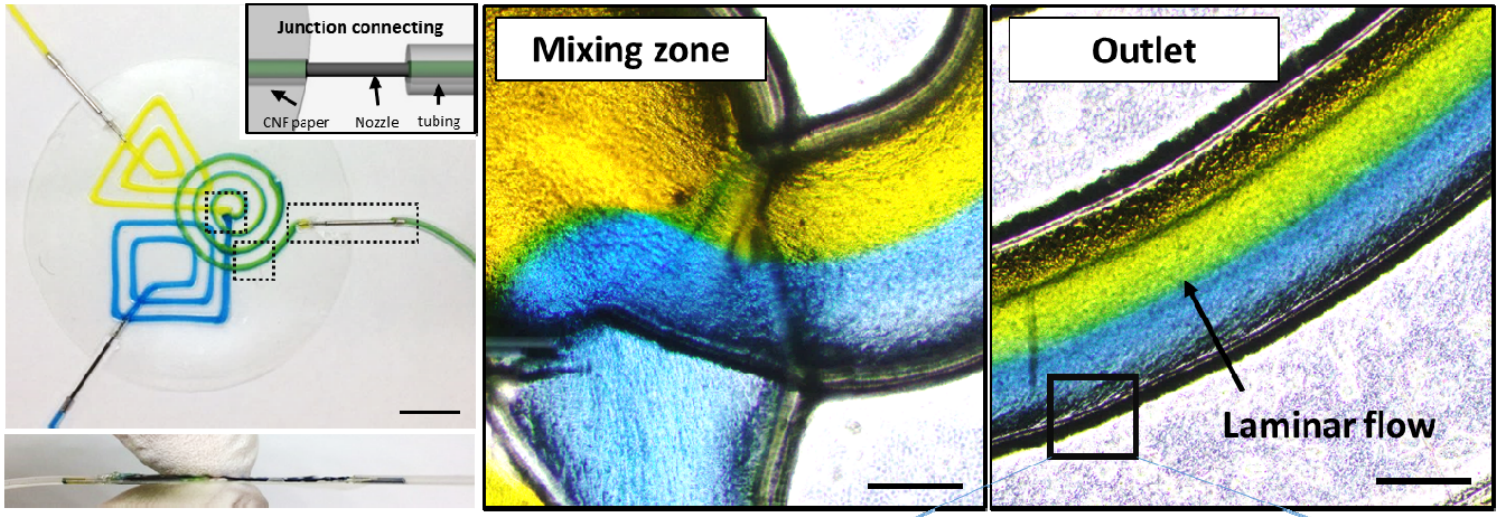
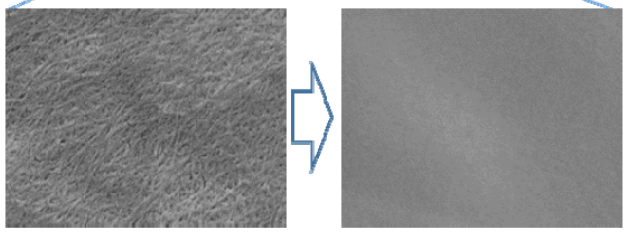
Matrix-assisted 3D printing

Transparent microfluidic devices



Transmittance : > 75 % (visible)
Direct, real time observation

Increase of detection efficiency
In colorimetric analysis



PDMS coating

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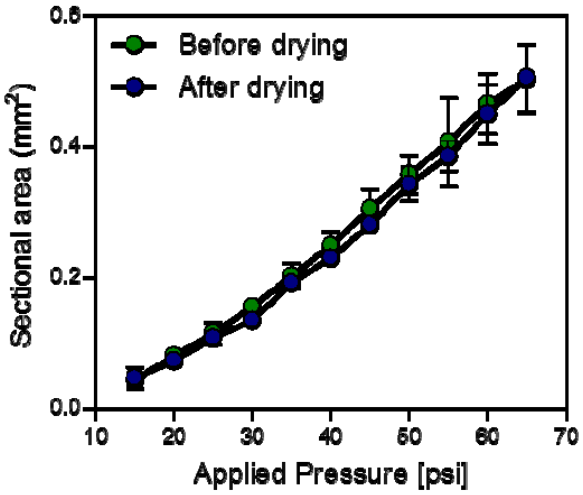
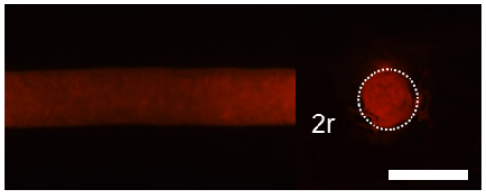
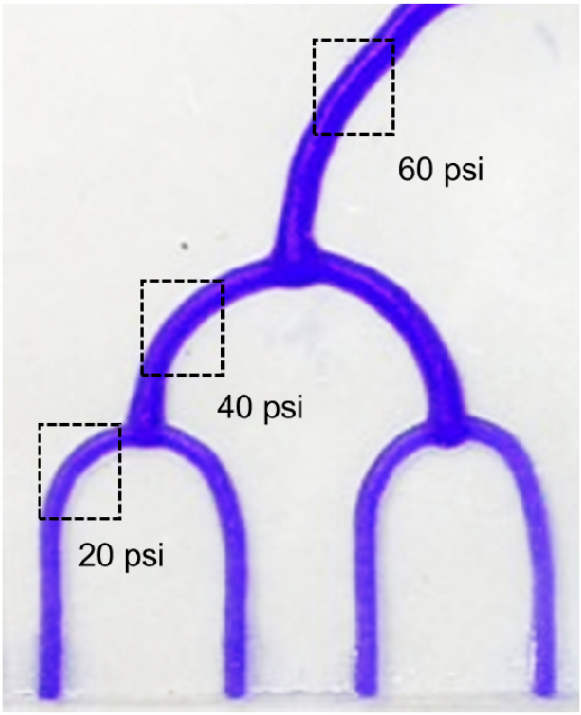
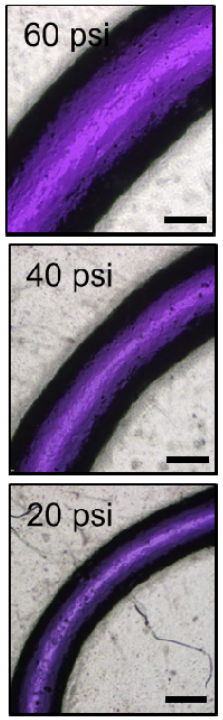
Matrix-assisted 3D printing

Control of the channel dimension : Pressure









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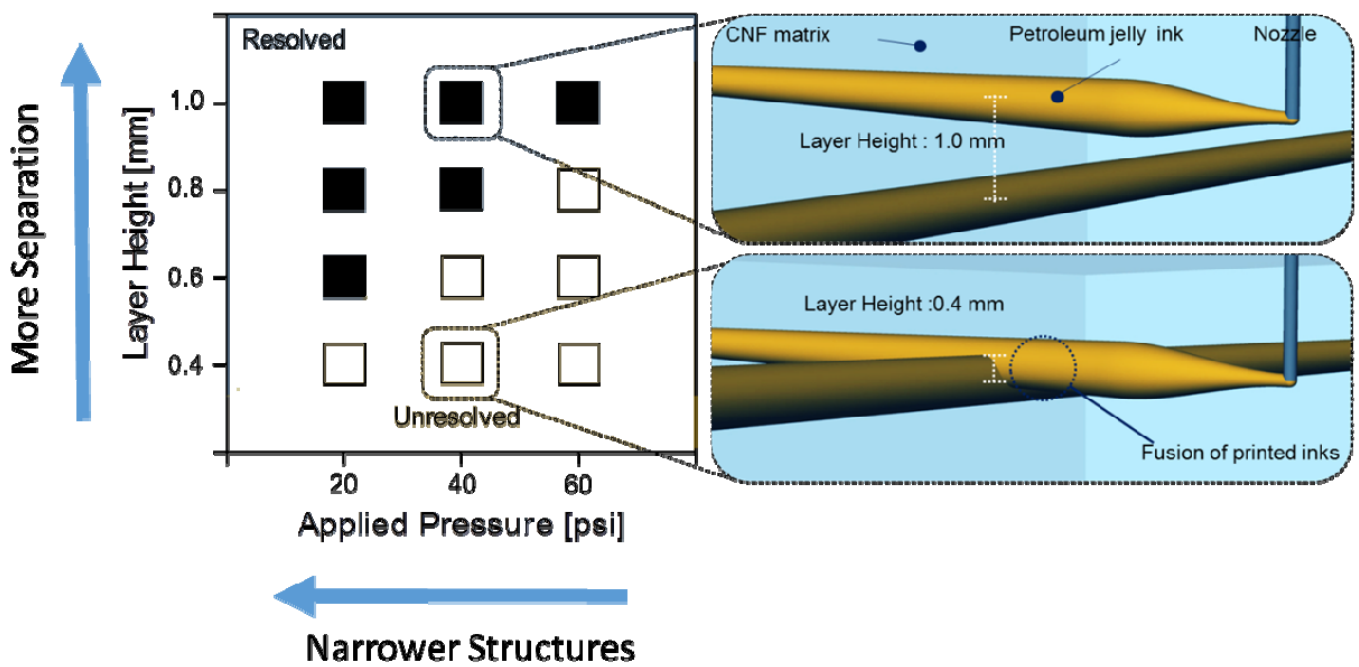
Matrix-assisted 3D printing

Printing resolution :
Layer spacing and Applied pressure



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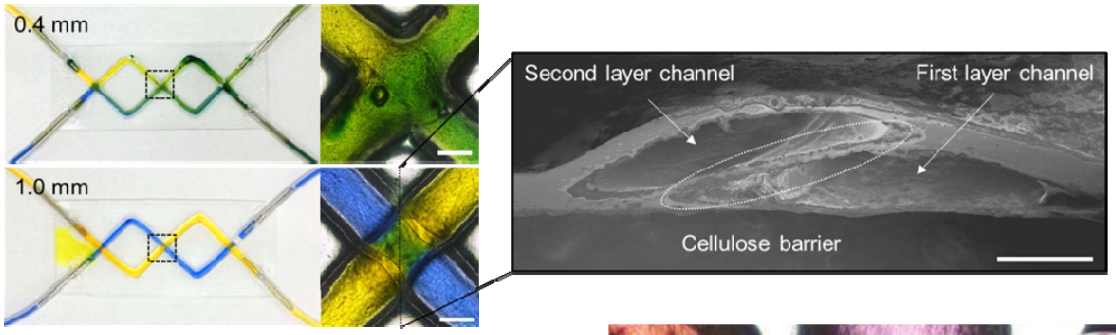
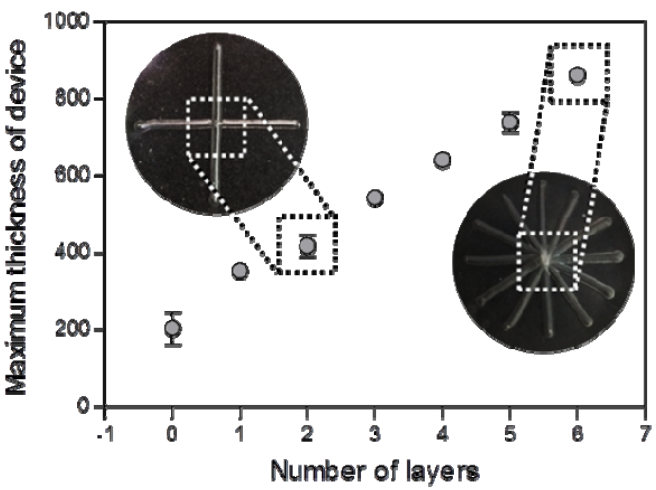
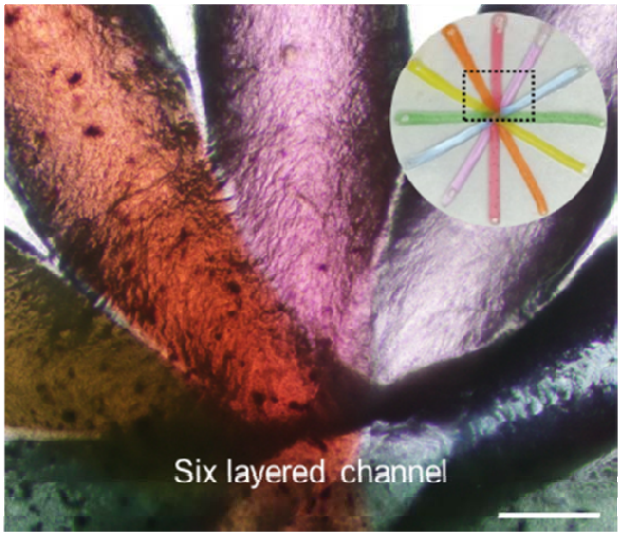
Matrix-assisted 3D printing

Multi-layered channels







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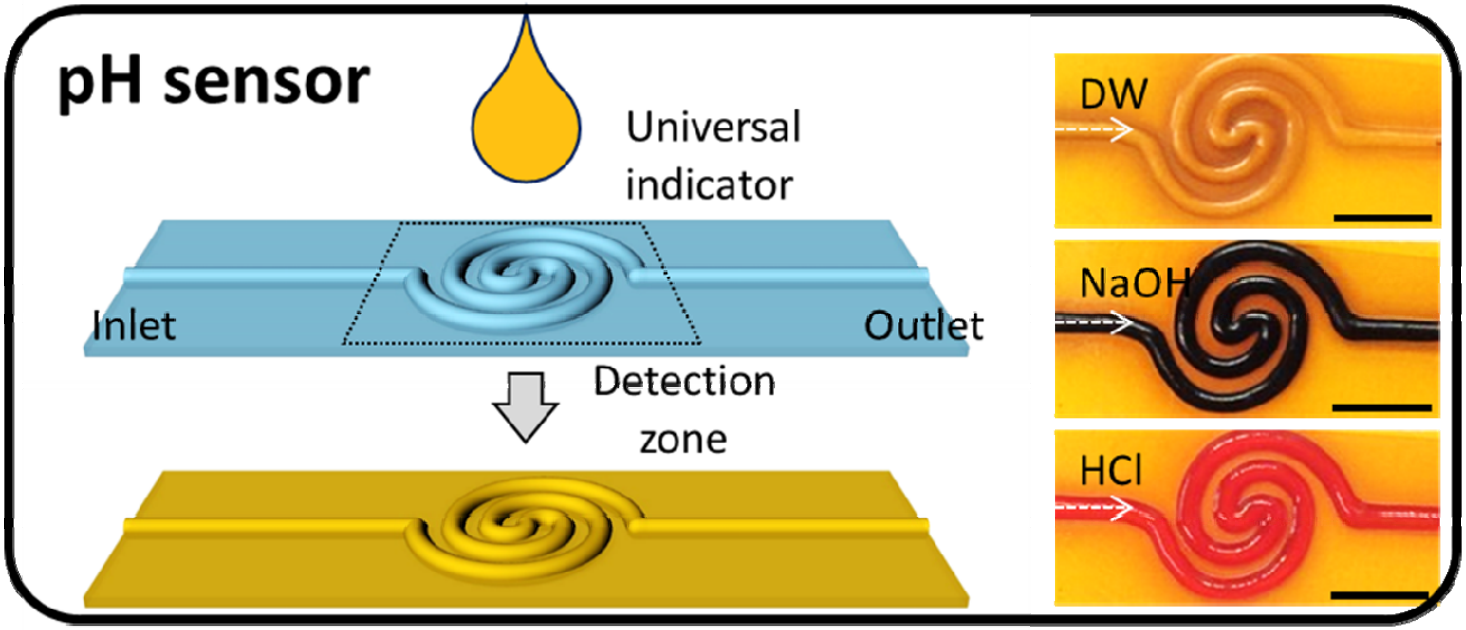
Microfluidics application

Colorimetric analysis : pH sensor



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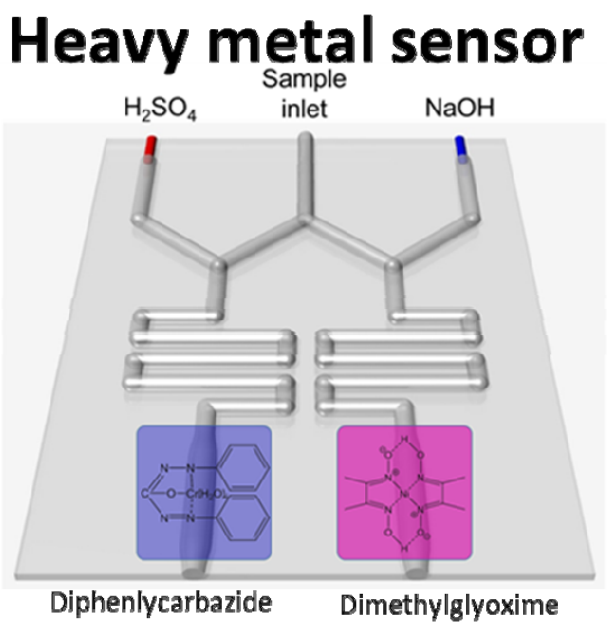
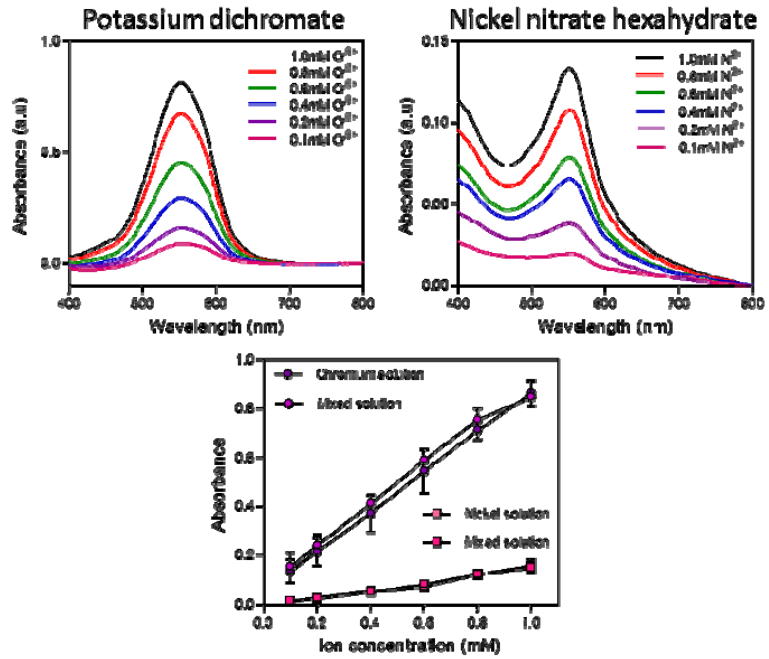
Microfluidics application

Colorimetric analysis : Heavy metal sensor



Cr^{6+} Ni^{2+}

pH-dependent reactions



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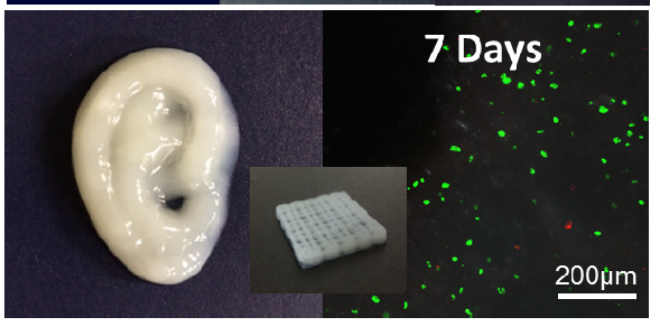
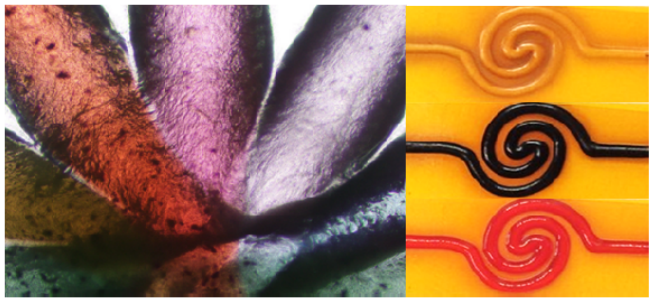
Conclusions

Direct Ink Writing:
Natural viscosity modifier



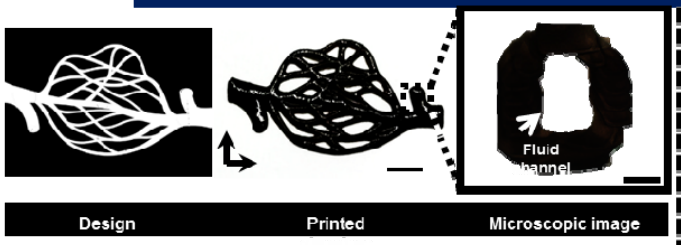
Matrix assisted 3D printing
Microfluidic channel design



On-going research
Novelty and originality

Digital Light Processing 3D printing

High resolution organ-printing



Acknowledgment

Sungchul Shin (CNF, 3DP)
Donghyuk Shin (3DP Tool)
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Dr. Minsung Park (BC composite)
Dajung Lee (Conductive CNF)
Hwaryun Lee (CNF)
Jonghyun Shin (CNF)
Dr. Suboem Park (BC composite)
Dr. Jie Cheng (TOBC smart gel)
Dr. Jaeyoo Choi (BC composite)
Prof. Hye Jung Youn (Pulp/CNF)
Prof. Changseok Ki (Rheology)

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IPET
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Thank you

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