A Novel Method for the Synthesis and Fabrication of 3D-Printed Chitosan-Based Hydrogels

Hoda Gendya, Robert Elkington, Michael Bryant

UNIVERSITY OF LEEDS

Introduction

Chitosan-Based hydrogels:

- 3D networks of hydrophilic chains of polymer
- Polysaccharide-Derived
- Exhibit significant swelling abilities
- Respond to stimuli (pH, Temperature, UV)
- High biocompatibility and biodegradability
- Ideal for drug delivery

3D Printed Hydrogels

are composed of:

1. Photopolymer
   - Chitosan
2. Crosslinker
   - Carboxy Groups
3. Photo-initiator
   - LAP

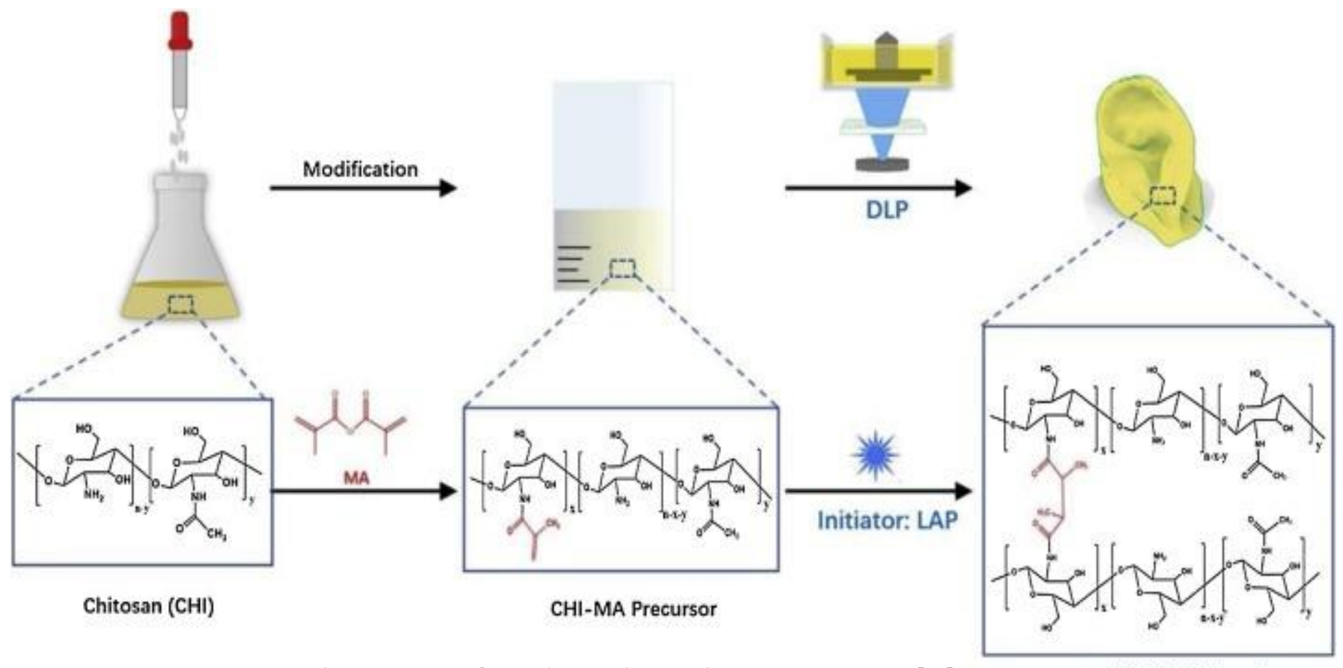

Figure 1: Schematic of Hydrogel synthesis process [1].

The **photo-initiator** reacts to the UV light projected in the Digital Light Processing (DLP) printer, which prints the hydrogels through Layer-by-layer polymerization.

Limitations of this process:

- Lyophilization (Freeze-drying) Machine, which costs £8,000 and requires 72 hours to complete.
- Dialysis Kits, which require 48 hours to complete.

Methodology: Hydrogel Formulation and Print

I. Precursor Synthesis Method Development

A. Different Volumes and weights of the hydrogel components were tested independently to make the ***CHI-MA*** *precursor.*

B. Addition of Polymers

- 1.5 wt% Polyethylene Fibres **(CHI-MA Composite)**
  - Reinforce hydrogel structure
  - Improve mechanical properties
- 1 wt %Photo blocker **(CHI-MA-Tetrazine)**
  - Improve print quality
  - Reduce light scattering

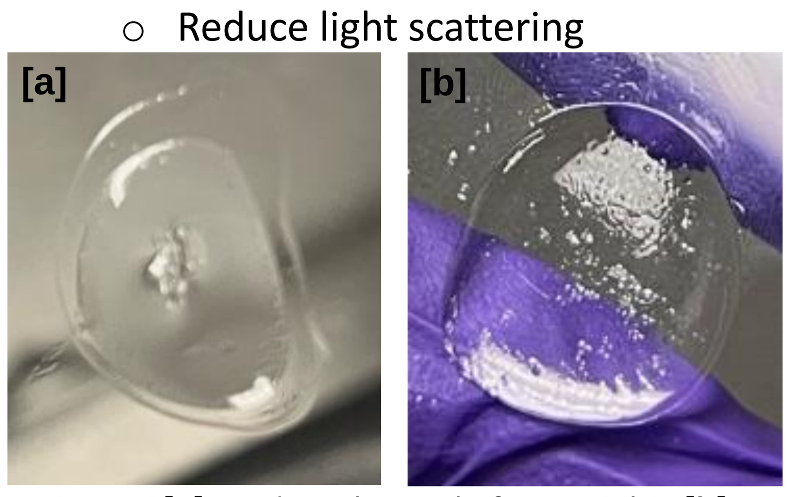

Figure 3[a]: Hydrogel sample from Trial 3. **[b]:** Hydrogel Sample from Trial 11

II. Print Parameter Optimisation

Parameters tested:

1. Normal Exposure time
   - Affecting the interlayer adhesion
2. Bottom Layer exposure time
   - Affecting hydrogel adhesion to print plate

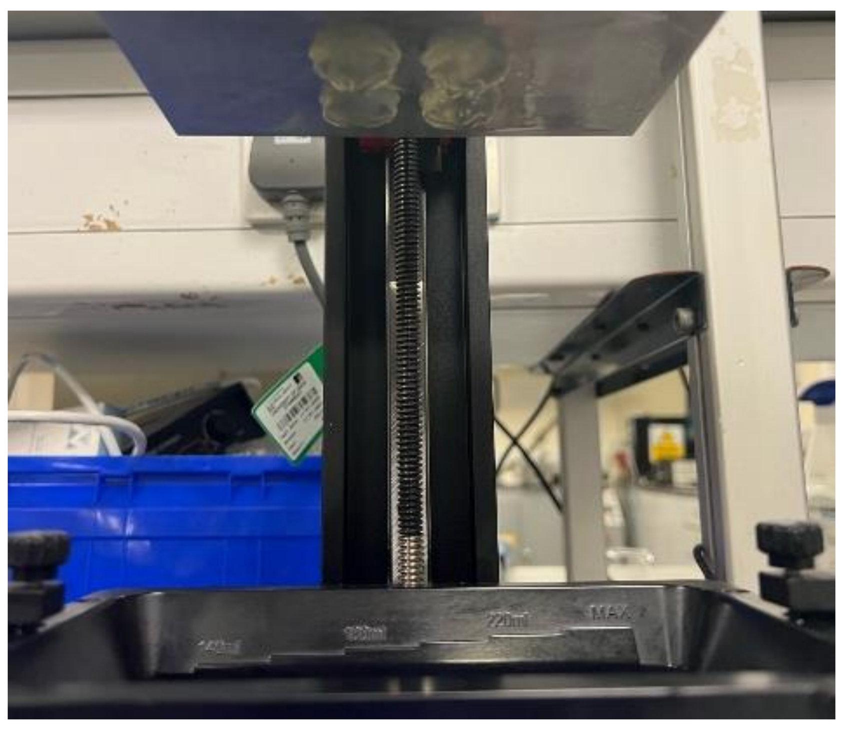

Figure 2: The printed hydrogels seen adhered to the print platform

Methodology: Testing

Swelling Testing

- Triplicate samples of each hydrogel type were obtained.
- Swelling tests were performed:
- Submersion of samples in deionized water for 24 hours.
- Weight before and after submersion was recorded.

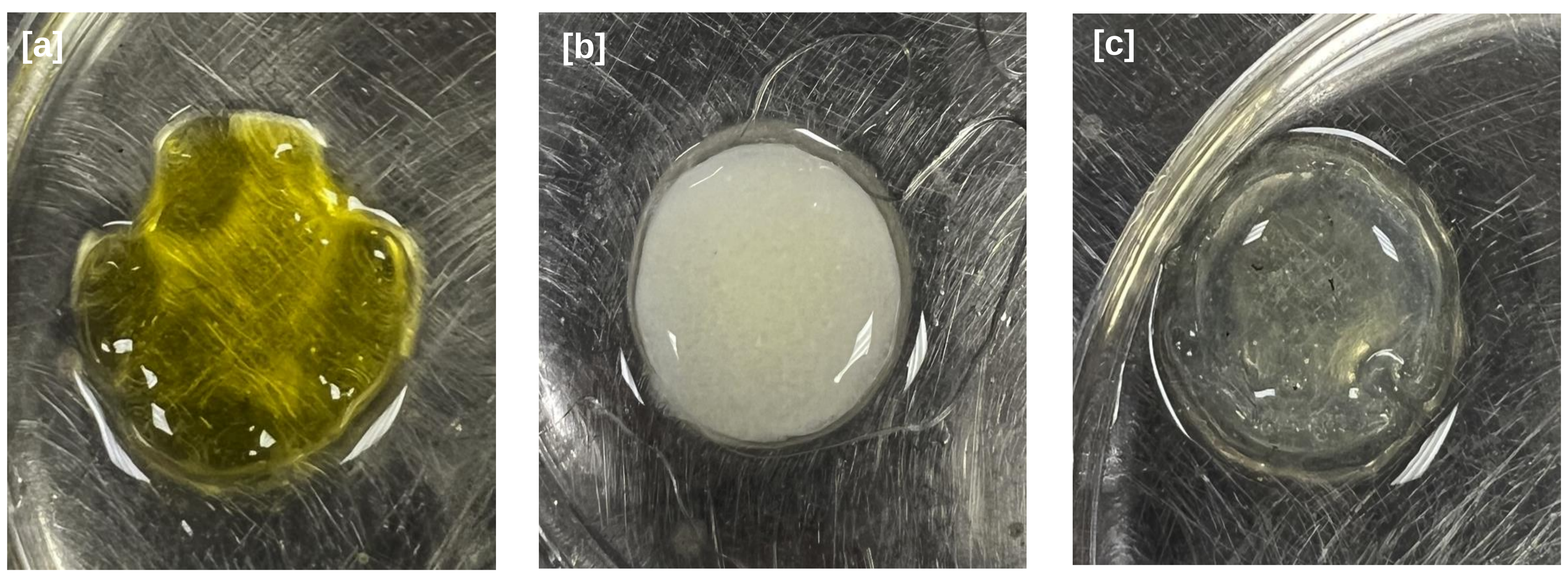

Figure 4[a]: CHI-MA-Tetrazine Swelling test sample. **[b]:** CHI-MA Composite Swelling test sample. **[c]:** CHI-MA Swelling test sample

Compression Testing

- Triplicate samples of each hydrogel type were obtained.
- Test parameters for the UMT TriboLab:
  - 0.5 N contact load
  - 5 N linear loading for (CHI-MA & CHI-MA Composite)
  - 7 N linear loading for (CHI-MA Tetrazine)

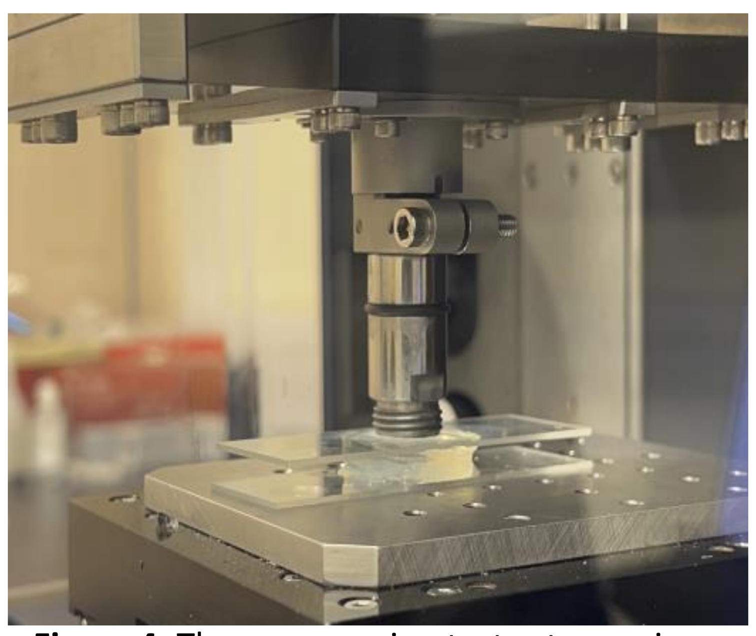

Figure 4: The compression test set-up using glass slides.

Results & Discussion

I. Swelling Test Results

Swelling reporting in literature:

- 110% to 150% [2-5].

The Composite behaved as expected due to:

- Increased surface roughness
- High-density networks

CHI-MA-Tetrazine:

- No prior literature.

Table 3: 24 h swelling test results for the three hydrogel categories fabricated

Hydrogel Type	Sample	Wd (g)	Wt (g)	Swelling Ratio (%)
CHI-MA	1	1.413	2.6875	90.19815994
	2	1.334	2.386	78.86056972
	3	1.2685	2.8887	127.7256602
	4	1.0733	2.7696	158.0452809
			Average	**113.7074177**
CHI-MA Composite	1	1.7898	3.0251	69.01888479
	2	1.8276	3.344	82.97220398
	3	1.8989	3.2673	72.06277318
	4	1.8835	3.238	71.91398991
			Average	**73.99196297**
CHI-MA-Tetrazine	1	1.629	4.495	175.9361572
	2	1.5577	4.2774	174.5971625
	3	1.5587	3.9494	153.3778148
	4	1.5845	3.8065	140.2335121
			Average	**161.0361617**

II. Compression Test Results

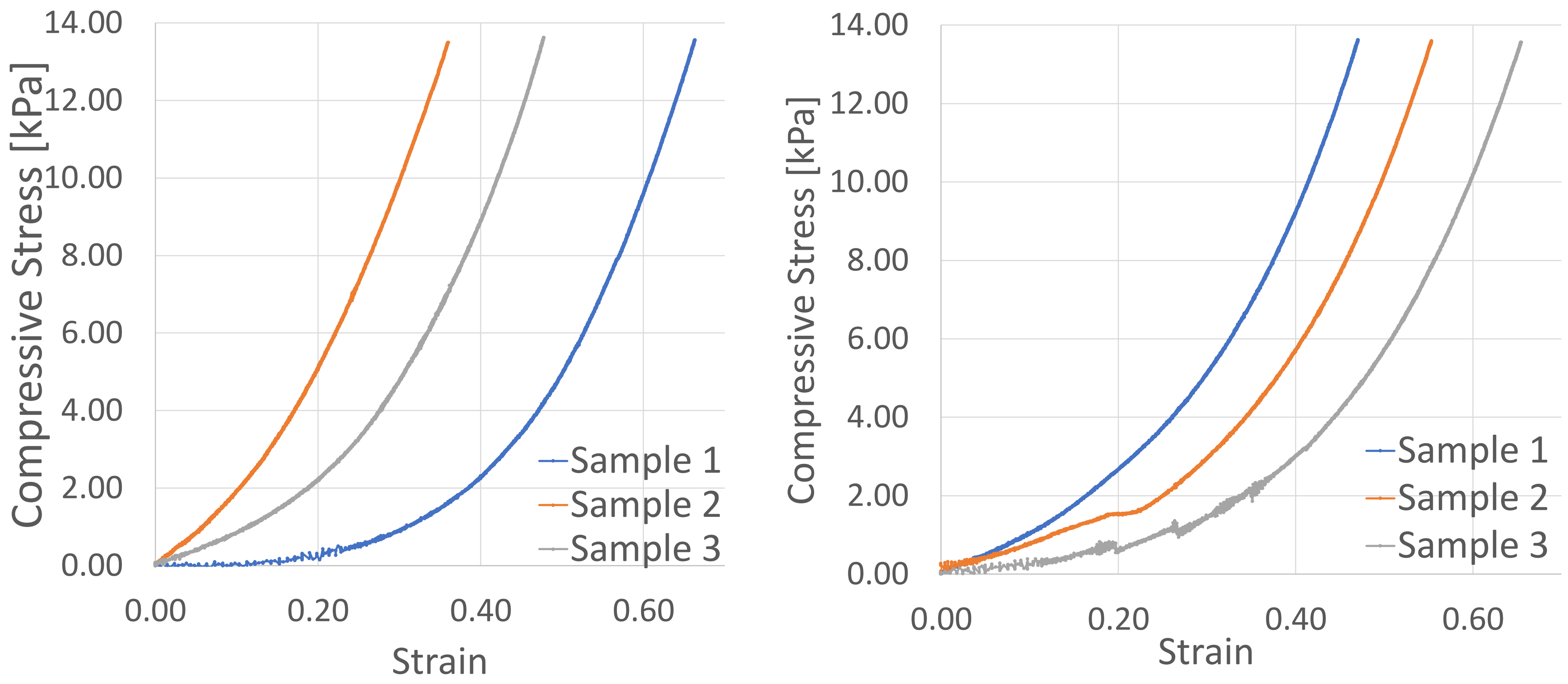

Figure 5[a]: [Left] Stress-Strain graph for the three samples of CHI-MA hydrogels. **[b].** [Right] Stress-Strain graph for the three samples of CHI-MA Composite hydrogels.

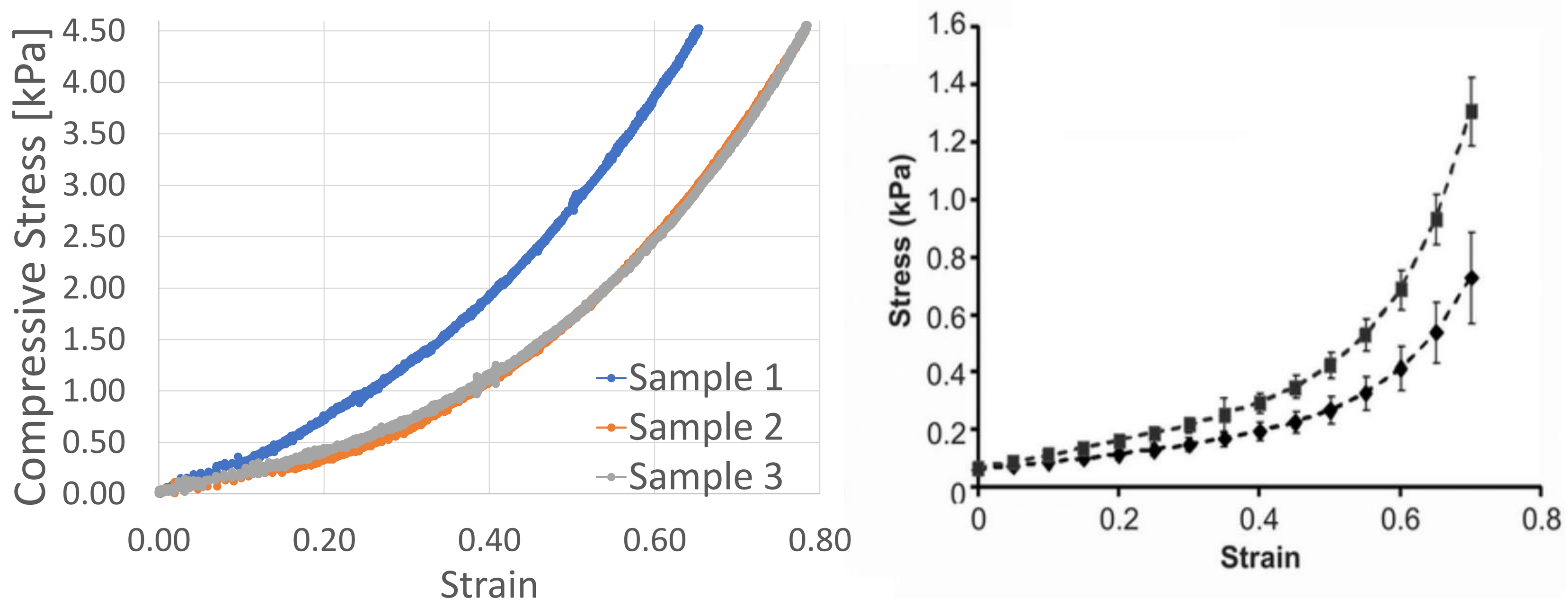

Figure 6[a]: [Left] Stress-Strain graph for the three samples of CHI-MA -Tetrazine hydrogels. **[b]:** [Right] Typical Elastic stress-strain curve for Chitosan Hydrogels [2].

Table 4: Calculated Young's Moduli for each sample

Hydrogel Type	Sample	Young's Modulus (KPa)
CHI-MA	1	28.918
	2	26.124
	3	24.156
	Average	**26.3993**
CHI-MA Composite	1	27.211
	2	38.504
	3	29.77
	Average	**31.8283**
CHI-MA-Tetrazine	1	6.9645
	2	6.4893
	3	6.1298
	Average	**6.5279**

Young's Moduli reported in literature:

- Between 4 kPa and 35 kPa[4-11].

Weakest: CHI-MA-Tetrazine

- Due to insufficient curing or overcuring
- NO previous studies

Strongest: CHI-MA Composite

- Expected a 200% to 400% increase in Young's Modulus

Conclusion

✓ Novel Reduction method is **Validated:**

- Swelling and compression tests yielded significant results.
- Method reduces cost and time associated with hydrogel fabrication without compromising hydrogel's swelling and compression abilities.

- Further Work due to time limitations:
  - Additional concentrations of Fibre and Tetrazine should be explored
  - Full compression testing
  - Fatigue and tensile testing
  - Additional print strategies such as DLP printing using grey-scale exposure should be explored as it has been found to improve the quality of printed hydrogels [3].

Supervised by: Dr Michael Bryant, University of Leeds.
Mentored by: Robert Elkington, PhD Student, University of Leeds.

References |