Electrically Responsive Protein Based Soft Actuators

Bianca D. Costa, Matthew Griswold, and Leila F. Deravi
Biomaterials Design Group, Department of Chemistry and Materials Science
University of New Hampshire

Background

- **Some marine animals such as cephalopods have evolved unique and complex adaptive camouflage abilities based on microscale optical mechanisms.**
- **The iridophore and the chromatophore are both light organs in cephalopods that contribute to adaptive coloration**
- **Iridophores are light reflective and diffractive structures while chromatophores are pigmented color filters, both used for camouflage**

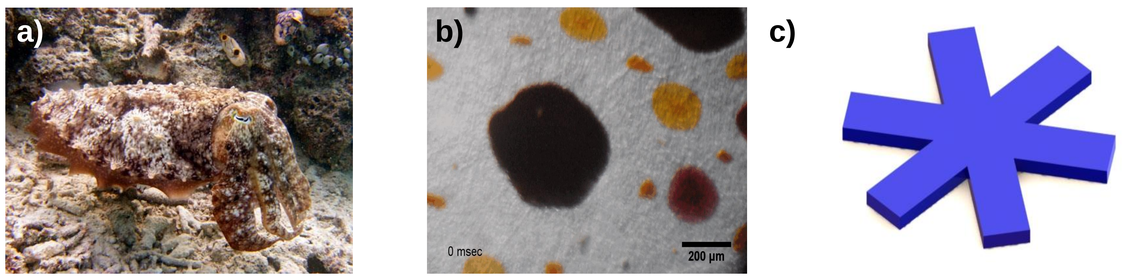


Figure 1. A) Cuttlefish *Sepia officinalis* can camouflage by changing its color and 3D texture. B) Chromatophores populating the cephalopod dermal tissue (200 µm scale). C) Bio-inspired artificial structure inspired by cephalopod light organs.

- **Our goal is to build artifial light organs using inkjet printing using a combination of customized protein and carbon nanotubes inks.**
- **Expectation: The patterned protein structure will mimic the functionality (color and size change) of the native cephalopod light organs. Multiple methods for actuating the artificial iridophores structures will be explored. Electro-wetting and electromagnetic field are considered as suitable techniques.**

Methods: Inkjet Printing

Inkjet Printing

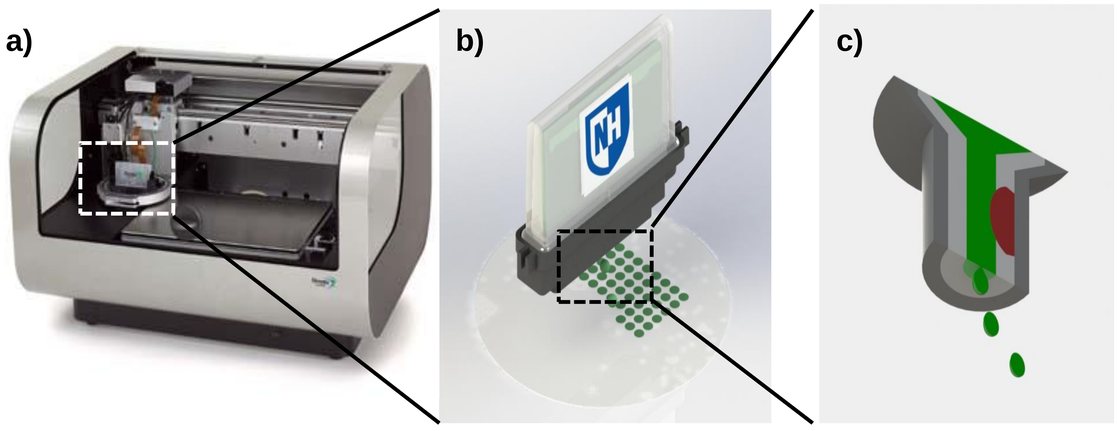


Figure 2. Inkjet printing method Drop-on-Demand. A) Dimatix FUJIFILM DMP-2800 pinter B) Material Depositon cartridge model C) Piezoelectric nozzle view. Piezoelectric material (red) experience a mechanical strain resulting from an applied electrical field (voltage), releasing the droplets consequently.

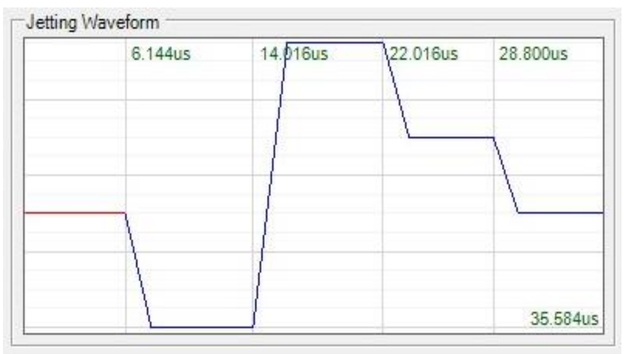


Figure 3. Jetting Waveform for Gel/CNT ink printing (Gelatin and carbonanotubes) in voltage x microseconds.

- **The gelatin was used as the protein base for the ink, and the carbon nanotubes are responsible for cross link with the gelatin.**
- **We used three types of carbon nanotube inks: Multi-walled with semiconductors (MWCNT), Multi-walled with metals (MWCNTm) and Pure Single Walled (SWCNT). The Gel inks were made by varying the concentration of gelatin in 0.5, 1, 5 and 10% (weight %) in carbon nanotube inks.**

Results: Gel/CNT hybrid materials

Proposed assembly mechanism for Gelatin crossed link with Carbon nanotubes:

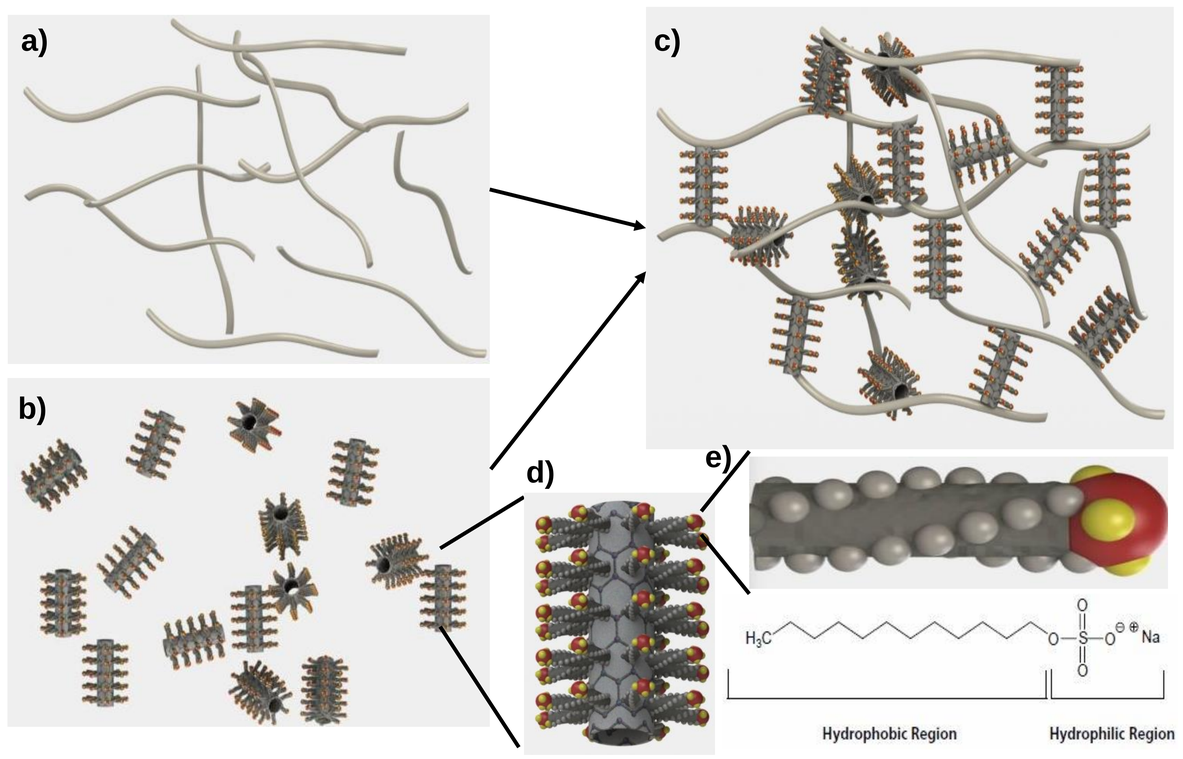
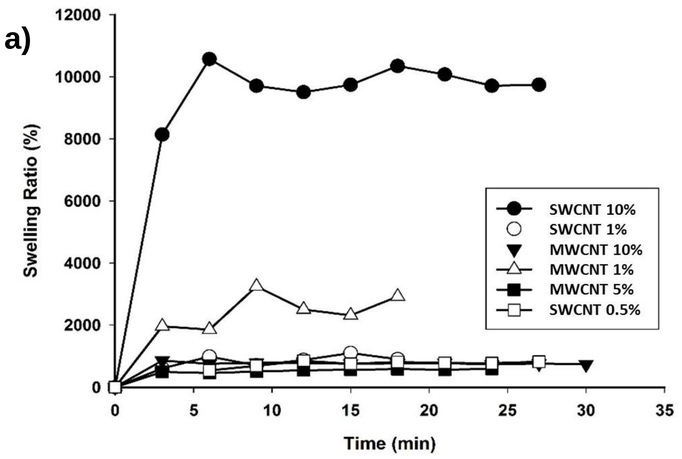


Fig 4. Proposed assembly mechanism. A) Solubilized Gelatin cartoon. B) Carbon Nanotubes dispersed in Sodium Dodecyl Sulfate (SDS) in aqueous solution. C) SWCNT – Gelatin matrix. D) SDS cartoon & formula.



b) $$Sw = \left(\frac{Wo - W}{W}\right) * 100$$

W = Dried Sample; Wo = Swollen Sample

Fig 5. Swelling Ratio for each Gel/CNT ink. The samples were dryed (60 C for 1 hour), immersed in 0.1 M NaCl and weighted regularly. A) Graph of the Swelling Ratio (%). B) Equation for the Swelling Ratio.

Printing with MWCNTm only:

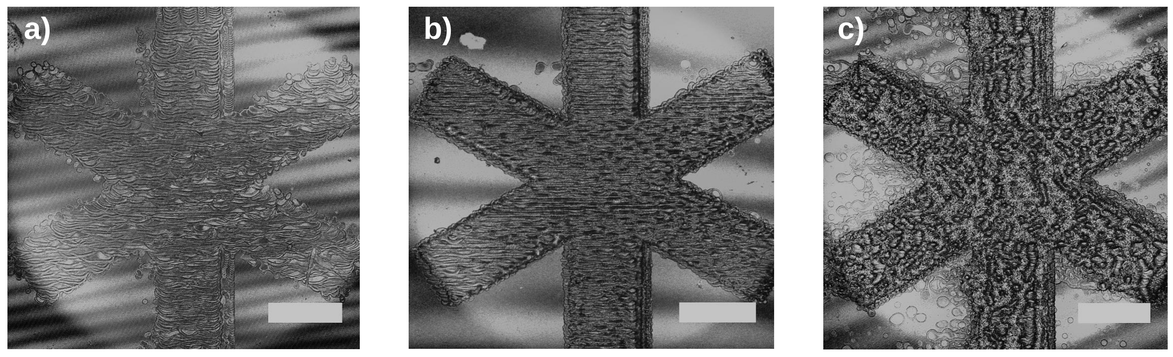


Fig 6. Confocal microscopy images of Multi-walled with metals Carbon Nanotubes, printed with Dimatix FUJIFILM printer. A) 1 Layer. B) 10 Layers. C) 30 Layers.

Summary

- **Carbon Nanotubes cross link effectively with gelatin, forming stable hydrogels.**
- **Our results suggest that inkjet printing is capable of fabricating bio-inspired optical devices, mimicking the optical organs in cephalopods**

Acknowledgments

We gratefully acknowledge the Chemistry Department and the University Instrumentation Center at the University of New Hampshire

References: Sajjad Haider et. Al. (2007) Sensors and Actuators B 127:517-528