Towards Power-free Sensors: Scalable Manufacture of Mechanochromic Materials based on Modular Assembly of Photonic Hydrogel Microspheres

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Energy Efficiency

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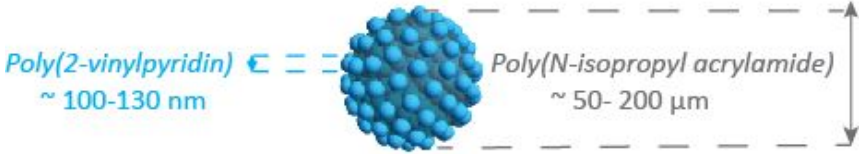
Introduction

Majority of widely used **sensors** rely on electrochemical or electromechanical measurements, demanding **power** supplies, and external signal processing and transfer to report changes in their local environment. **Colorimetric sensors** provide an alternative to circumvent such needs, by taking advantage of **stimuli-responsive materials** that sense and signal the local change by a display of **color change**, with no need for external power. **Soft photonic materials** with **structural colors** are known to successfully serve this purpose. Structural coloration originates from coherent scattering or constructive interference of visible light with nanostructures of the material. Therefore, unlike pigmentary coloration, these colors are tunable, and durable, and can be created from less or non-toxic materials. With such attributes, soft photonic materials are versatile platforms for sensing and signaling in biomedical, chemical and mechanical application scenarios.

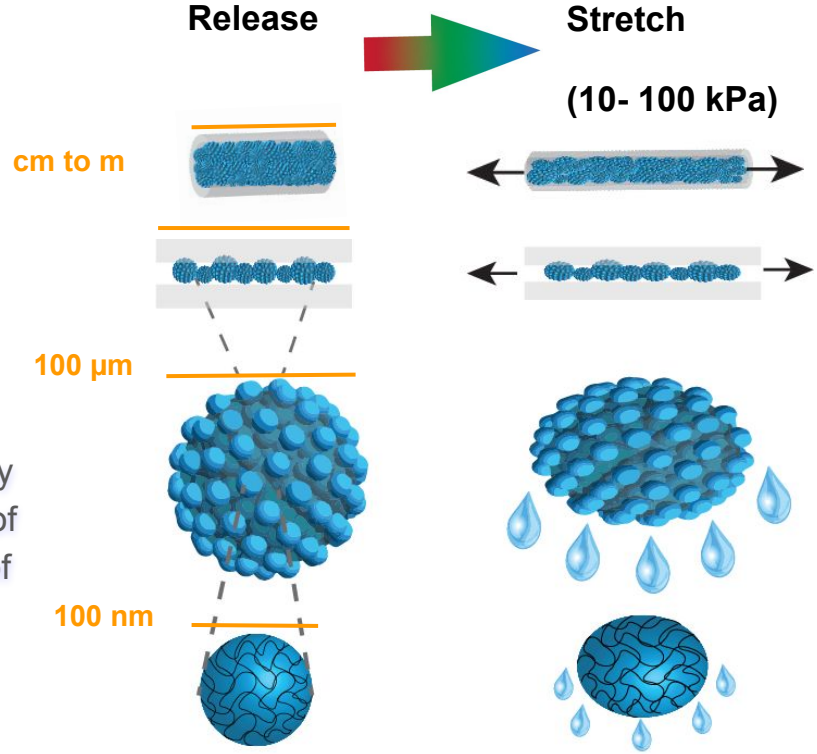
Objective

Many concepts of lab-scale creation of soft photonic materials are known, however a lack of **efficient and scalable production methods** with sufficient control of properties persists.

Here we introduce **soft photonic microspheres** formed from **stimuli-responsive colloidal crystals**. Such spheres will serve as building blocks.



We then present a **modular assembly** strategy that enables a scalable manufacture of **mechanochromic sensors** as an example of such responsive materials.



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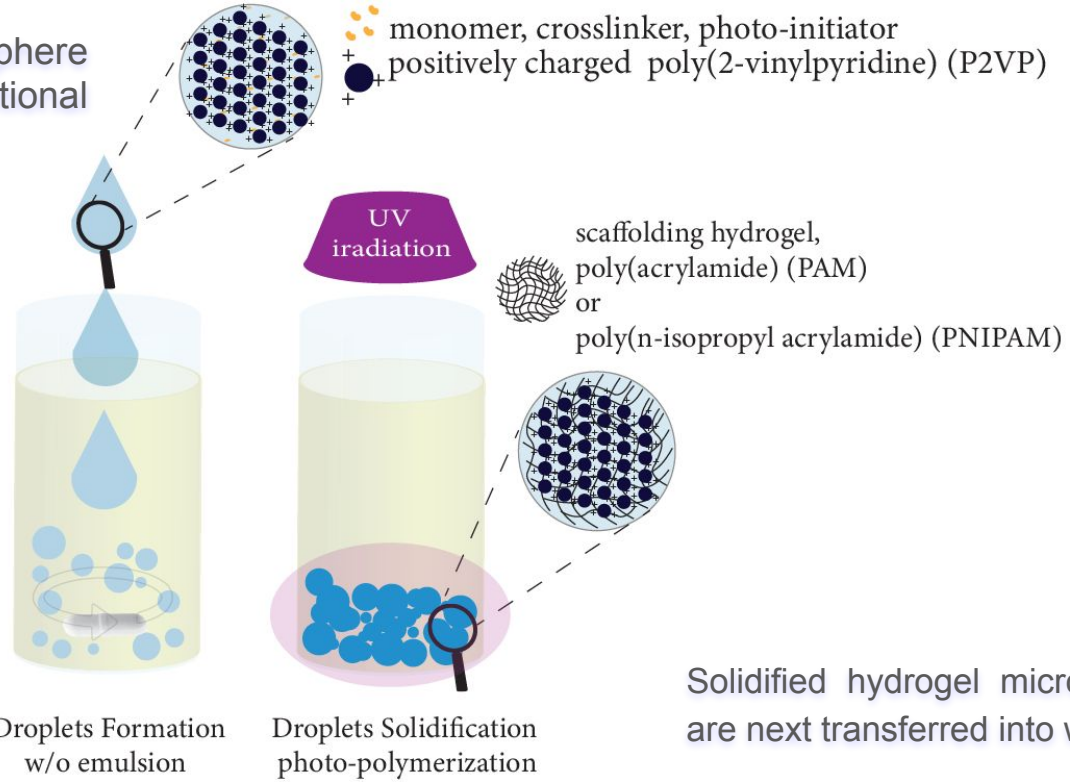
Methods

Producing hydrogel microsphere as building blocks via conventional water in oil emulsion



Solidified hydrogel microspheres are next transferred into water.

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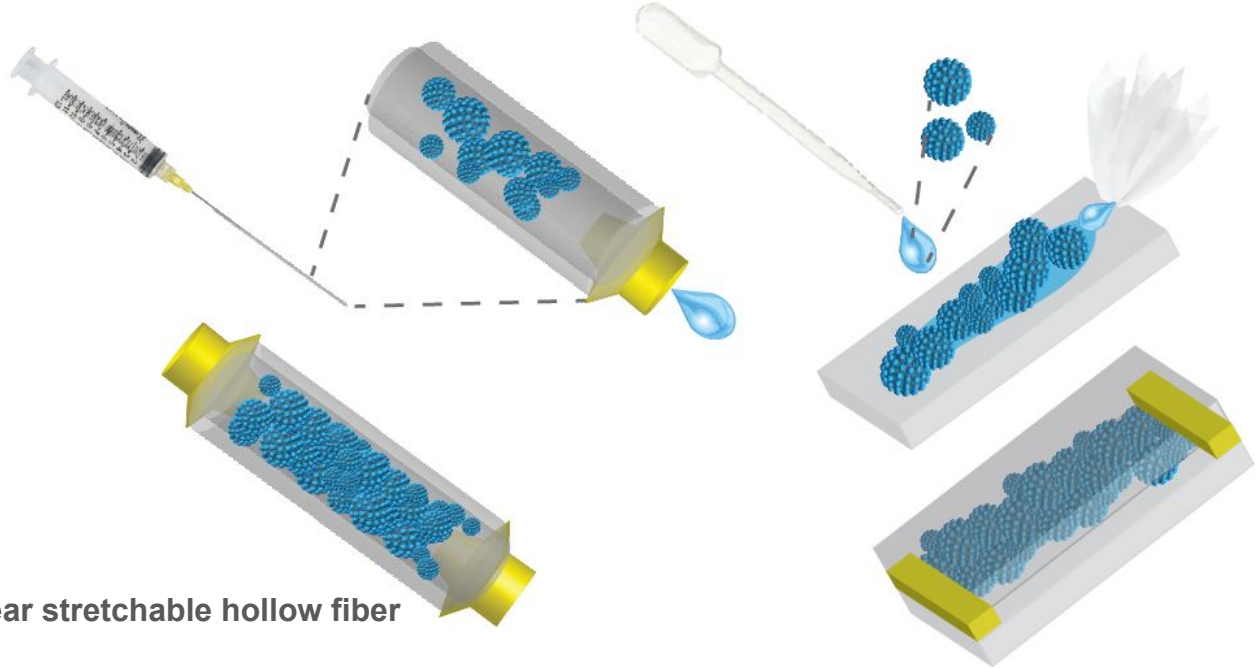
Methods

Modular assembly of Photonic microspheres within macroscale confinements:



Packing between clear stretchable sheets

Packing in a clear stretchable hollow fiber

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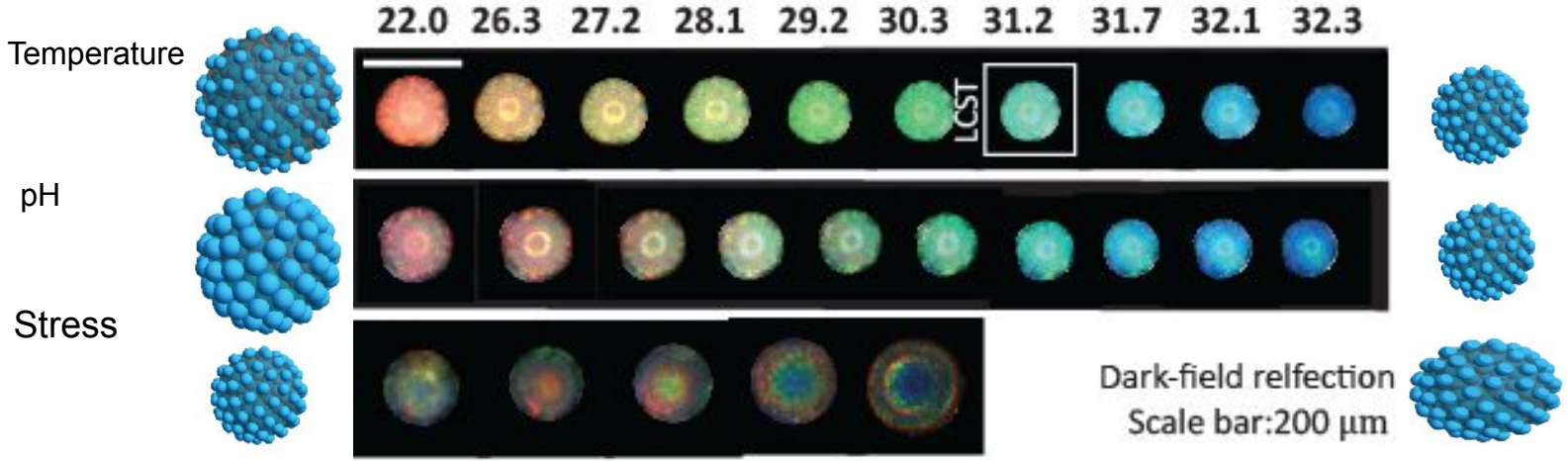
Results

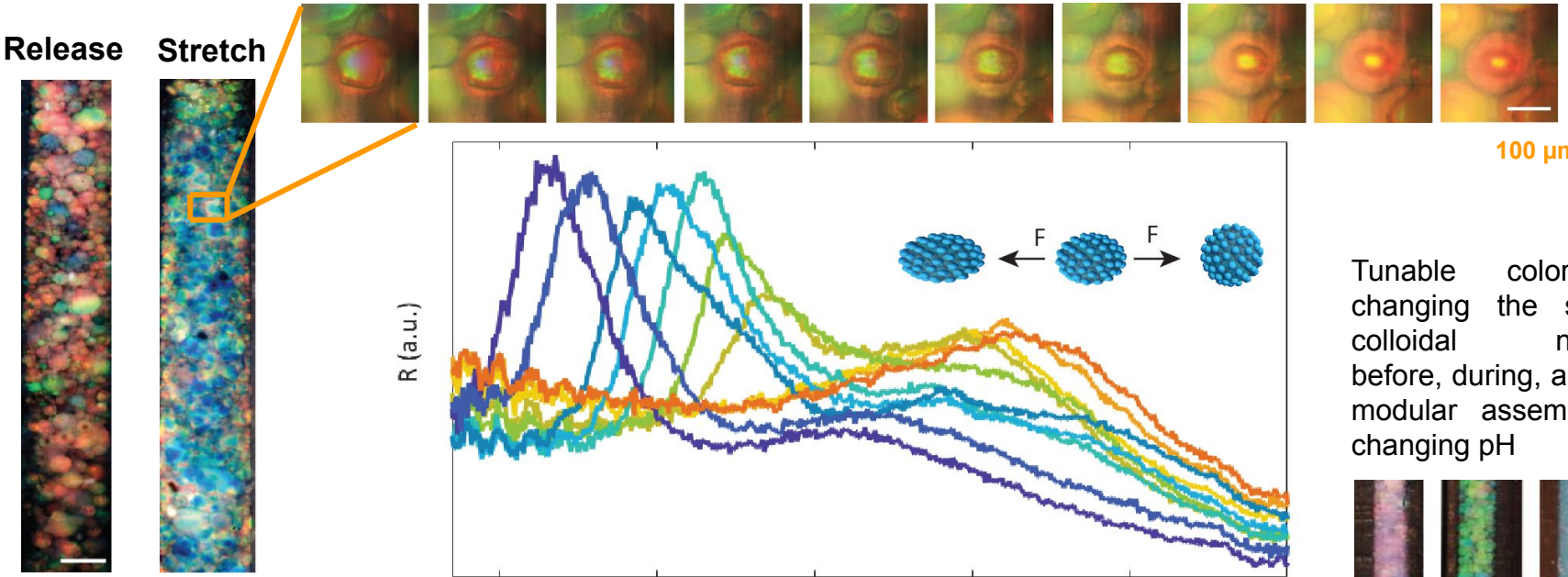
Dynamic color change of a single photonic microsphere **building block**, as a result of swelling/deswelling of the nanogels (**pH stimulus**), and scaffolding hydrogel (**temperature stimulus**), or their **mechanical deformation**.

A blue-shift through increasing:



Results

Modular assembly on macroscale- Mechanochromic fiber



Tunable colors by changing the size of colloidal nanogel, before, during, and after modular assembly, by changing pH

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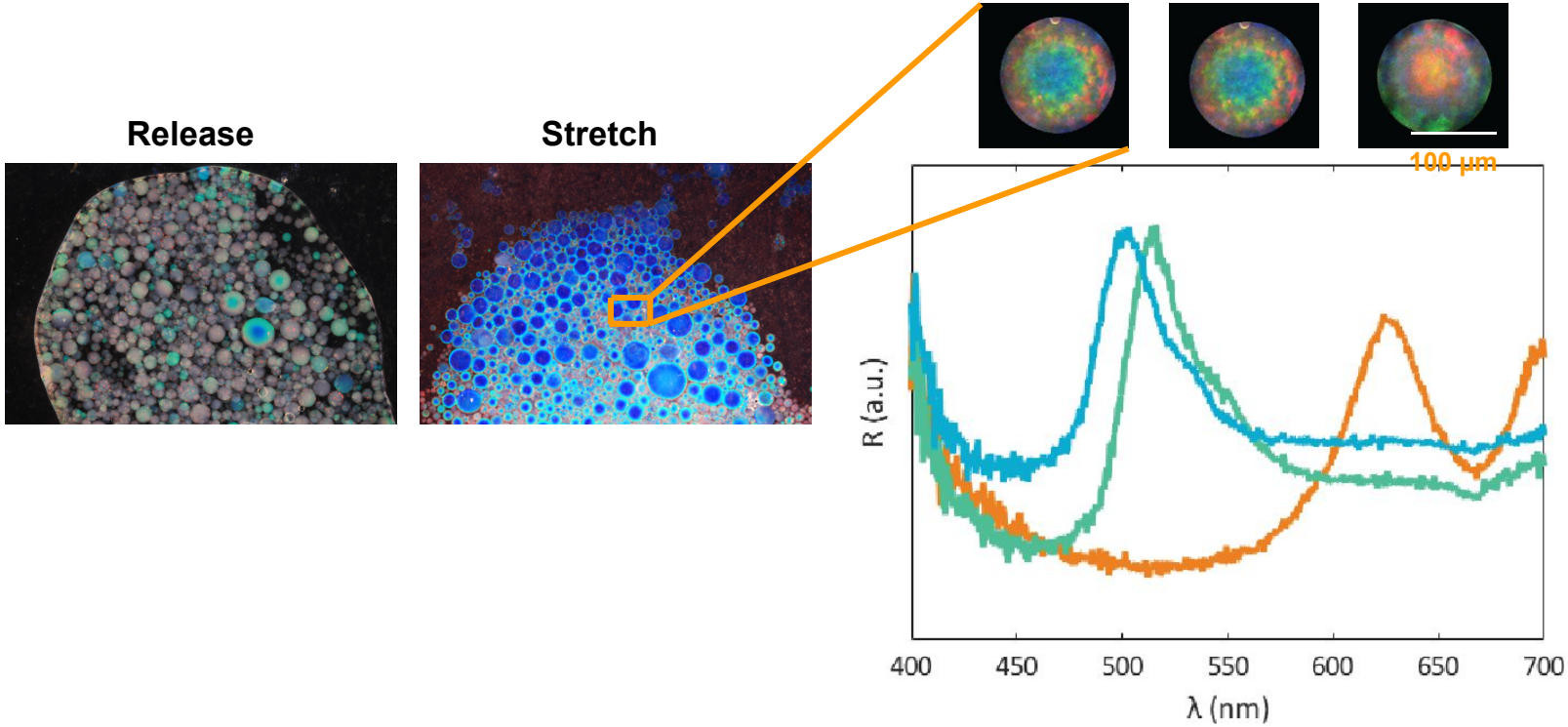
Results

Modular assembly on macroscale- Mechanochromic sheets



Conclusions

- Photonic microspheres were prepared and used as building blocks in macroscale materials.
- Photonic microspheres can be reconfigured in size and color, before, during and after assembly in a macroscale confinement.
- Production methods starting from synthesis of colloidal nanogels, to modular assembly in macroscale materials are scalable, facile, fast, and low-cost.
- Dynamic color change of photonic microspheres makes them ideal platforms for power-free sensors.
- Mechanochromic fibers and sheets could be used to develop smart wearables and in structural health monitoring for strain mapping and sensing, as well as flexible display panels.

Future work

- Optimizing the optical properties of the soft photonic microspheres towards more homogeneous coloration
- Quantitative localized feedback regarding the stress exerted on the macroscale assembly of photonic microspheres
- Weaving mechanochromic fibers into fabrics, and map the stress during the object motion for medical textiles or other smart wearable technologies

Acknowledgments

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