Grating-capped Hydroxypropyl Cellulose for Spatial Stress Optical Sensing Application

Wei-Jie Feng[1], Sungho Lee[2] and L. Jay Guo[1, 2]

[1]Macromolecular Science and Engineering, [2]Department of Electrical Engineering and Computer Science, The University of Michigan, Ann Arbor, Michigan 48109, USA

With the fast development of robotic technology, precise sensing apparatus capable of detecting spatial deformation and stress is highly desired. This requires the sensing material to be flexible, stretchable and durable. Mechanical deformation can be transduced as optical color change e.g. a grating structure fabricated on a polydimethylsiloxane (PDMS) substrate has been recently reported[1] for biaxial strain sensor. However, limited by its 2D nature, 3D spatial sensing can hardly be achieved. Herein, we propose a new design with both grating and chiral liquid crystal structure for a comprehensive 3D spatial sensing.

Hydroxypropyl cellulose (HPC) is a widely known polymer in the nanomaterial science community capable of forming a chiral liquid crystal phase at high concentration[2-3] (i.e. 60-70wt%), giving iridescent structural color (Figure 1). As a liquid crystal, it gives real-time response to both stress and temperature due to the change in pitch length (Figure 2). Therefore, pressure normal to the surface could be easily detected. In order to sense the lateral deformation such as tensile stress, we apply a grating-patterned encapsulation layer onto the HPC liquid crystal, which helps prevent water loss as well as maintains mechanical integrity. Optical detection can be achieved by combining light diffracted from the grating with the light reflected off from the HPC layer. HPC liquid crystal is able to create a stop band for right-handed circularly-polarized light (RCP), and having its center wavelength at $\lambda = nPcos\theta$ (n is the HPC average refractive index, P is the pitch and θ is the incident angle onto HPC layer). We can create two stopband centered at two distinguishable wavelength for the 1st and 0th diffraction order from the grating structure atop of the HPC (Figure 3). Exploiting the stop bands will make the detection easy to implement, even possible with naked eye to detect a color change. Further deformation of the structure could lead to very different shifts of these two peaks. The detailed optical design and transduction characterizations will be presented at the conference. We believe this new design of soft spatial stress sensor could be promising for sensing various mechanical deformations.

1. Quan, Y.-J., et al. *ACS Nano* **14**, 5392–5399 (2020).
2. Kamita, G. *et al. Adv Opt Mater* **4**, 1950–1954 (2016).
3. Liang, H.-L. *et al. Nat Commun* **9**, 4632 (2018).

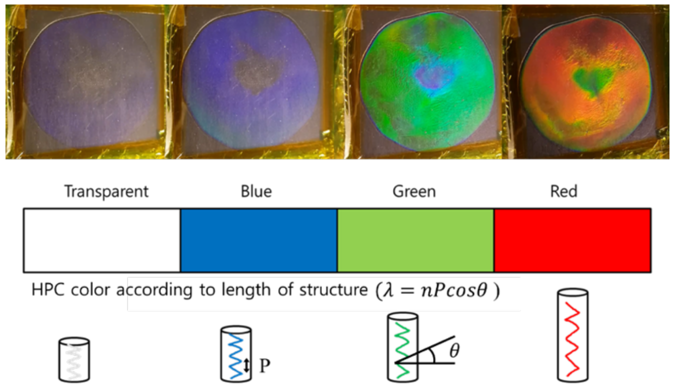

Figure 1 | HPC color change according to length of structure

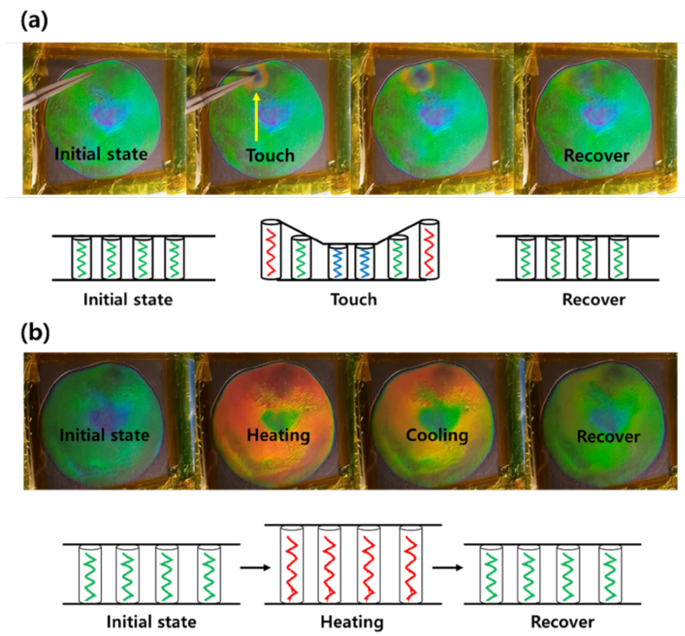

Figure 2 | Feasibility of utilization of the HPC (a) Pressure response property of HPC for touch sensor (b) Temperature response property for temperature sensor

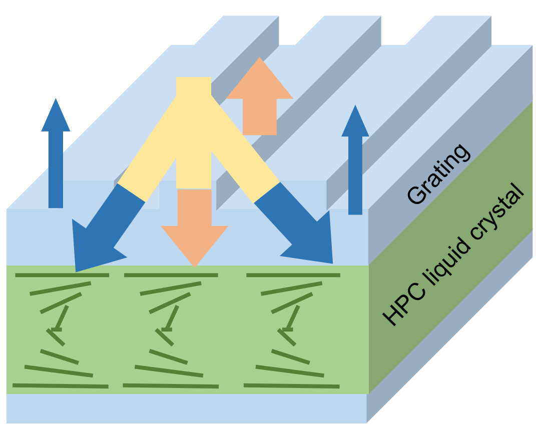

Figure 3 | Schematic illustration on a grating-HPC structure with normal incidence. Blue arrows correspond to retro-reflection from 1st diffraction order while red arrow corresponds to reflection from 0th order.