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Supporting Information

Polydiacetylene-based sensors to detect food spoilage at low temperatures

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CNCs derived from microcrystalline cellulose

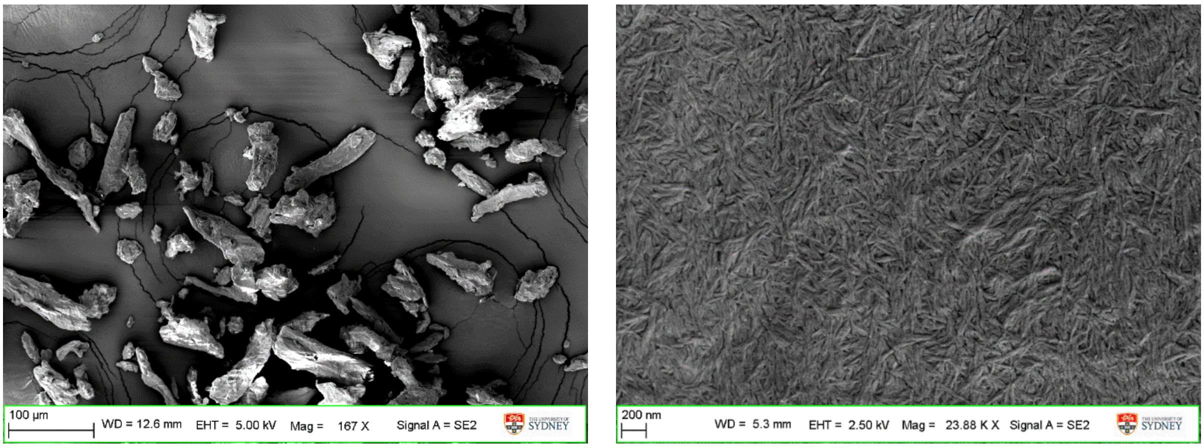


Fig. S1. SEM images of microcrystalline cellulose (MCC, left) and cellulose nanocrystal (CNC, right).

Characterization of PDA composite films with and without CNCs

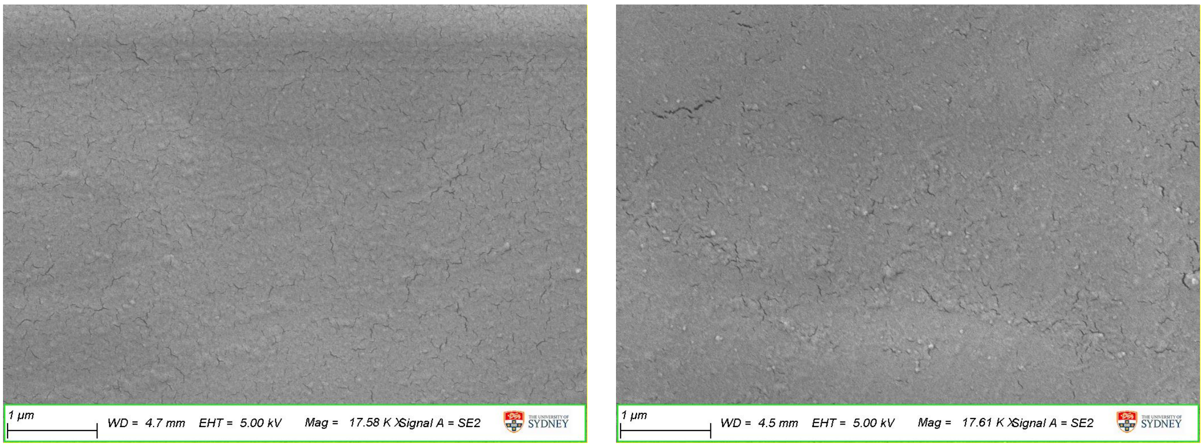
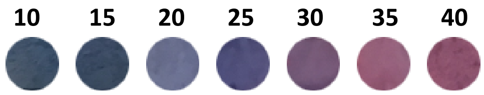


Fig. S2. SEM images of PDA/chitosan film (left) and PDA/CNC/chitosan film (right).

Effect of UV irradiation time on colorimetric response of PDA/CNC/chitosan films when exposed to spoiled meat

(a)



(b)

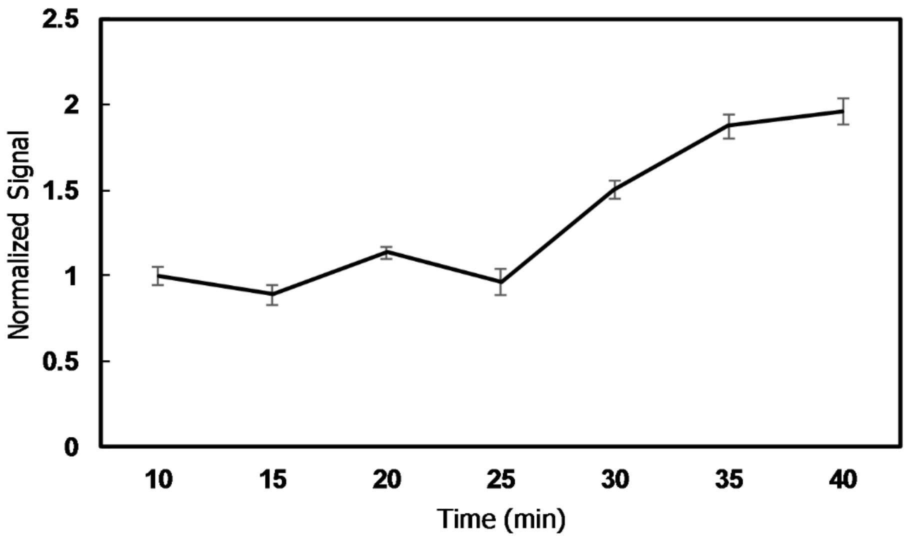


Fig. S3. (a) The colorimetric response of PDA/CNC/chitosan films to spoiled meat at varying UV irradiation time. (b) RGB analysis of PDA/CNC/chitosan films corresponding to the colorimetric response.

PDA/CNC/chitosan film treatment using KOH 0.1 N in methanol

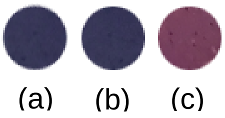


Fig. S4. The colorimetric response of PDA/CNC/chitosan films: (a) control non-treated film; (b) dry film treated with KOH; and (c) film pre-immersed in water then treated with KOH.

Formation of PDA/CNC complexes in chitosan matrix

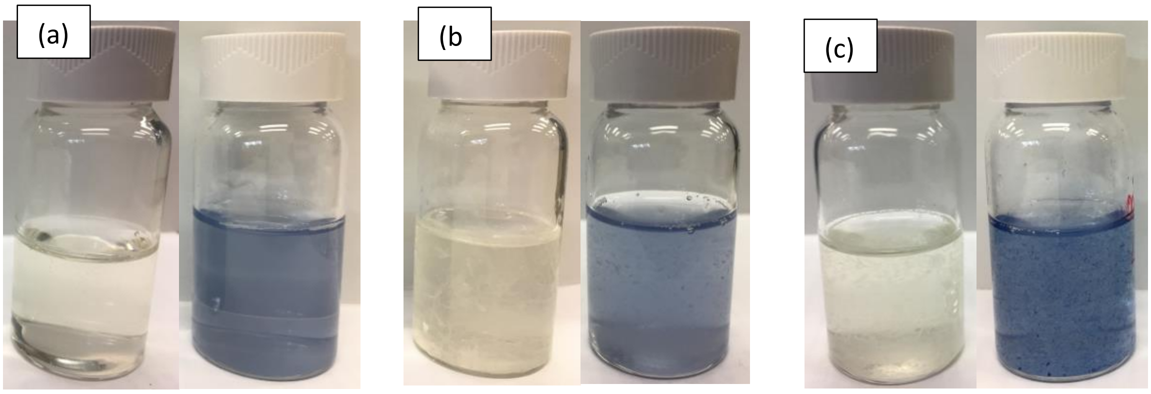


Fig. S5. (a) PCDA/chitosan; (b) PCDA + CNC/chitosan; and (c) PCDA/CNC + chitosan before (clear) and after (blue) UV polymerization.

Exposure of dried PDA/CNC@chitosan film to ammonia at -20 °C

Fig. S6. The colorimetric response of PDA/CNC@chitosan films: (a) control and (b) after exposure to ammonia at -20°C for 3 h.

Mechanical properties of PDA composite films

Sensors in the form of standalone flexible films have the potential to be incorporated into food packaging without any additional complexity in the packaging process. In the present study, CNCs and chitosan were mixed to produce a mechanically strong film that can be directly used as part of the food packaging. CNCs have been used as fillers to improve the mechanical properties of chitosan-based composites. In the previous studies, CNCs were added to chitosan at different concentrations relative to the final weight of the composites, ranging from 1 to 10 wt%, with an optimum CNC concentration was determined to be ~5 wt%.[1] Therefore, in the present study, 5 wt% of CNC was introduced to the system.

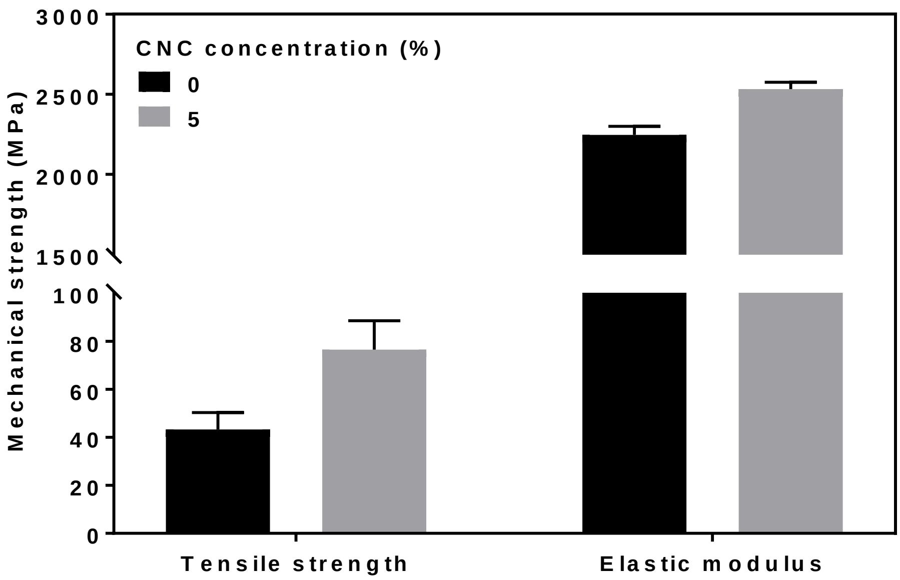


Fig. S7. Mechanical properties (tensile strength and elastic modulus) of the PDA/chitosan-based films with and without CNC.

CNCs of 200 – 300 nm were shown to be well dispersed within the chitosan matrix even without covalent linkages between CNCs and chitosan. In the presence of 5% CNC, the film's tensile strength increased as much as 76% and the elastic modulus increased by 15%. These findings are in agreement with the previous studies.[1]

Stability of PDA vesicles

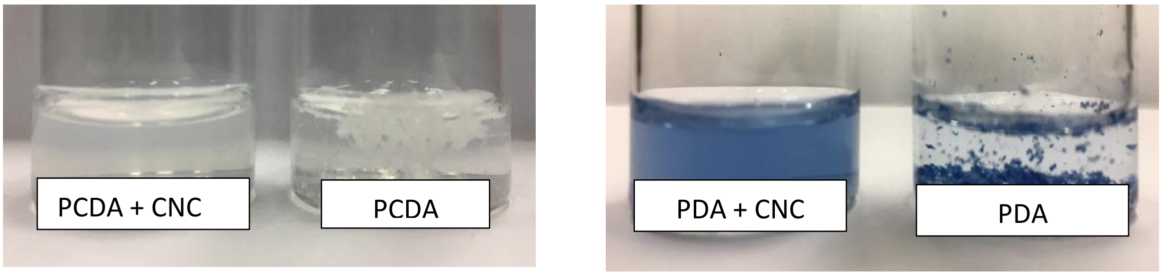


Fig. S8. Stability of PDA vesicles with and without CNC before (clear) and after (blue) UV polymerization.

References

1. A. Khan, R. A. Khan, S. Slamieri, C. L. Tien, B. Riedl, J. Bouchard, G. Chauve, V. Tan, M. R. Kamal, M. Lacroix. *Carbohydr. Polym.* **2012**, *90*, 1601–1608.