Edible Electronics: Next generation medical devices for oral delivery

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ABSTRACT SUMMARY

Electronic medical implants serve as a key pillar in many therapeutic strategies. Although the sophistication of these implants has increased over recent years, many persistent challenges limit the impact of permanent device-based therapies including infection, chronic inflammation, and costly surgical procedures. Edible electronics represents a class of electronically active medical devices that can be deployed orally, reside in the gastrointestinal tract temporarily, and eventually pass through the body harmlessly with the feces. Edible electronics would have far reaching diagnostic and therapeutic applications including devices for in vivo biosensing and controlled release of biologically active macromolecules. This work describes the design, synthesis, and characterization of batteries prepared from biological materials that can be used to power edible electronics.

EXPERIMENTAL METHODS

NatMel (melanin from Sepia officinalis), SynMel (melanin, synthetic), and tetrabutylammonium percholate (TBAP) were purchased from Sigma Aldrich (St. Louis, MO USA). X-ray photoelectron spectroscopy (XPS) was performed using Kratos Analytical Axis Ultra. Raman spectra were collected using an inverted Raman confocal microscope. A three-electrode cell was configured with melanin as working electrode against platinum counter electrode and Hg/Hg₂SO₄ reference electrode. Multichannel potentiostat/galvanostat was used to measure cyclic voltammetry (CV) and galvanostatic discharge profiles.

Fig. 1. Electrochemical characterization of eumelans. (A-C) Cyclic voltammetry of melanins in 1 M Na₂SO₄. Galvanostatic half-cell discharge of melanins with Pt counter and MSE reference electrodes are shown in (D-F). Potential plateaus at 0.2 V indicate the release of sodium ions from Na⁺-loaded melanin electrodes.
RESULTS AND DISCUSSION

Biologically-derived organic electrodes composed of melanin pigments can serve as biocompatible battery materials for use in biocompatible energy storage devices. Natural (from Sepia officinalis) and synthetic melanins were both evaluated as anode materials in aqueous sodium-ion storage devices. Na+-loaded melanin anodes exhibit specific capacities of 30.4 ± 1.6 mAh g⁻¹ (Fig. 1). Full cells composed of natural melanin anodes and λ-MnO₂ cathodes exhibit an initial potential of 1.03 ± 0.06 V with a maximum specific capacity of 16.1 ± 0.8 mAh g⁻¹ (Fig. 2). The performance of natural melanins exceeded that of synthetic melanins when used as anodes owing to the confluence of desirable chemical, electrical, and physical properties exhibited by the former.

CONCLUSION

Taken together, these results suggest that biologically-derived melanin pigments may serve as a suitable biocompatible energy storage system to power biodegradable electronics devices. Materials for edible electronics would not only be non-toxic and safe for use in the human body, but would also be composed of ingestible materials including the possibility of natural biopolymers. The first application of biologically-derived melanin-based batteries will be in electronically active devices for use in oral controlled release applications.

REFERENCES


Fig. 2. Natural melanins are suitable anode materials for edible sodium-ion batteries because they can reversibly bind sodium at high densities.

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