Self-Deployable Current Source Fabricated From Edible Materials

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Statement of Purpose: Flexible biodegradable electronics devices have received growing attention to fulfill the demand for the application of biomedical devices and sensors. Biodegradable elastomers synthesized from simple naturally-occurring monomers have become a promising candidate for use as bulk materials inflexible biodegradable electrodes. Here we extend the concept of biodegradability and biocompatible to include edibility. Edible biomaterials-based electronics will open up new avenues in medical devices for applications including non-invasive sensing, controlled release, and beyond. Powering medical devices continues to be a broad challenge. Inductive coupling using RF coils to supply power requires precise orientation and relatively large device dimensions to achieve the sufficient wattage. Edible devices would ideally deliver the power in a non-invasive manner. Herein we introduce the concept of a current source that is powered by a battery fabricated from materials that are currently consumed in everyday life.

Methods: The device consists of edible materials; PGS polymer (simple metabolizable monomers), cinnamic acid (found from cinnamon and native plants), truxillic acid (a derivative of cocoa leaves), silver (eaten as garnish in some desserts), carbonaceous material (detoxification role), and MnO_2 (RDA=~10mg). Solutions of silver nanowires (AgNW) in ethanol were diluted in isopropyl alcohol (IPA). AgNW solutions were spin coated on a pre-cleaned quartz substrate to form AgNW coating, which was followed by annealing process at 200 ^oC for 30 minutes. Poly(glycerol-*co*-sebacate) cinnamic acid (PGScin) prepolymer was dropcast onto AgNW network. PGScin was then crosslinked under UV irradiation (l = 265 nm) for 8 hours. AgNW-PGScin was fully dried in ambient conditions. AgNW-PGScin electrodes were fabricated by embedding pellets of sodium-charged activated carbon (AC) and λ-MnO_2. Two electrode materials were bonded to polymer film with the aid of silver paste to enhance the electrical conductivity.AgNW films were etched between the electrodes to prevent shorting. The folded AgNW-PGScin device was packaged into a gelatin capsule. To simulate the device operation in human body, the capsule was incubated in a sodium sulfate bath that served as the medium for dissolution and and an electrolyte source. Pellets made from AC and γ-MnO_2 within 5 mg served as the anode and cathode in the device, respectively. AC pellets were charged with Na^+ ion in sodium sulfate to enhance the available charge amount. In order to estimate the available energy amount, 10μA of current was continuously extracted from the device until the potential was dropped to 0V.

Results:The capsule was dissolved away in 15 minutes and the device was deployed shortly thereafter. Each side of AgNW-PGScin polymer made contact with the stainless steel sheets in 1M Na_2SO_4 solution, current flowing through exterior potentiostat was measured. AgNW networks on quartz substrates were transferred efficiently to PGScin polymer after UV irradiation (Fig1.(a)). Sheet resistance of AgNW-PGScin polymer was on the order of 15-20Ω. A micrography of the AgNW-PGScin electrodes are shown in Fig. 1(b). Total charge capacity of the device was estimated to around 0.1mAh, which infers that the device can be performed for about 10 hours with supplying the current of 10μA to external load. As a demonstration of practical operation in gastric system, the supplying current from AgNW-PGScin device was monitored under short circuit status considering the connection with the zero impedance of external load.

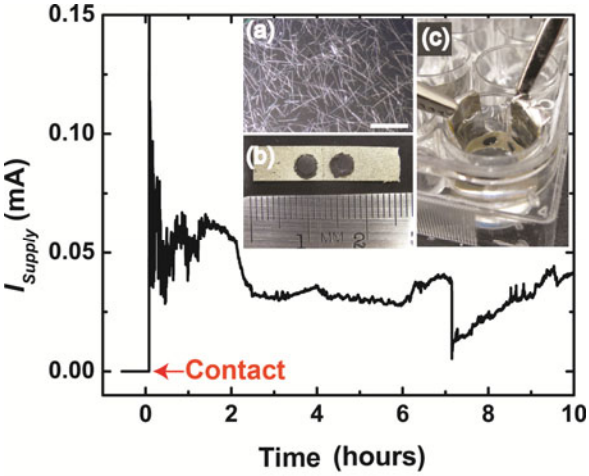

Fig. 1. Short circuit current of AgNW-PGScin device in 1M Na_2SO_4 electrolyte. (a) Microscope image of AgNW network on PGScin polymer (scale bar represents 20μm), (b) macroscopic image of device.(c) Self-deployment of device in electrolyte bath.

Conclusions: The work described herein outlines potential strategy for the non-invasive integration and powering of biodegradable electronics. This demonstration addresses two key limitations in advancing biomaterials-based biodegradable electronic devices. Also, device fabrication with edible materials is expected to accelerate regulatory approval for the envision applications.

References:

Xu F., Zhu Y. Adv Materials 2012;24:5117-5122
Bettinger CJ. Macromol. Biosci. 2011;11:467-482
Whitacre JF. et al. J. Power Sources 2012;213:255-264