Supporting Information

Designing Tubular Conducting Polymer Actuators for Wireless Electropumping

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1. Materials and methods

2. Experimental Movies

Movie S1. Cross sectional view of the periodic swelling and shrinking of the tube.

Movie S2. Axial view of bi-directional pumping of dye.

Movie S3. Axial view of uni-directional pumping of dye.

Movie S4. Axial view of expulsion of a glass sphere

1. Materials and methods

Materials

Pyrrole, $LiClO_4$ and Sodium dodecylbenzene-sulfonate were purchased from Sigma-Aldrich. Silver paint and 4-methylpentan-2-one (diluent of silver paint) was purchased from Agar scientific. All solvents used for the experiments are of analytical grade. Glass spheres were purchased from Sigma Aldrich (G1152, 710-1,180 μm (16-25 US sieve) and the most suitable diameter for the expulsion experiment was 850 μm.

Synthesis of polypyrrole tubes

For the synthesis of a polypyrrole tube, a solution of pyrrole monomer (0.2 M) and dodecylbenzene sulfonate (0.25 M) was prepared in ultrapure water (Milli-Q station, resistivity 18.2 MΩ.cm at 25°C). After complete dissolution of the two chemicals, copper wires of different diameters coated with silver paste were dipped in a beaker containing 12 mL of precursor solution and used as working electrodes. A cylindrical platinum sheet surrounding the working electrode was used as counter electrode and Ag/AgCl as reference electrode. A current of 0.7, 1.25 and 2.5 mA was applied to the copper wires with 0.4, 0.8 and 1.2 mm diameter for 30 min while keeping them at a depth of 1.6 cm in the solution. This allows obtaining polypyrrole tubes with different inner diameters, but with the same wall thickness and length. To make tubes with varying wall thickness, a current of 1.25 mA was applied for 30, 60 and 90 min, respectively. After completion of the polymerization, the polymer coated copper wire was kept in acetone for 15 min. Afterwards the polymer tube was slowly pulled off from the copper wire coated with silver paint. Silver paint contamination was washed out by sonication for 15 min in acetone. The resulting tubes were dried and used for the pumping experiments.

Bipolar electropumping

For bipolar electropumping, the polypyrrole tube was fixed in the middle of the bipolar cell. An optical fiber was used to illuminate the inner part of the tube from one extremity, allowing better visualization with a camera at the opposite extremity. The hollow tube was either filled with an agarose gel/dye mixture (Brilliant blue, E133) or a glass sphere was inserted at one extremity. The agarose gel was prepared with a dye saturated aqueous solution. 5 mg of agarose were dissolved in 150 µL water and 100 µL of dye saturated solution. After mixing, the solution was kept in hot water (60°C) for gelation of agarose. The tube was filled with gel with a syringe. The bipolar cell was equipped with two graphite feeder electrodes (4 cm apart) and the polymer tube was positioned in such a way that each extremity was facing one feeder electrode. 0.5 M $LiClO_4$ was used as electrolyte to provide the ions necessary for charge compensation during the bipolar electrochemical reactions. Actuation and pumping were recorded using a macroscope (LEICA Z16 APO) in video mode.

Area measurement of polypyrrole tubes during swelling and shrinking

The swelling and shrinking effect of hollow tubes was measured quantitatively with ImageJ software (version 1.46r). The total area of the tube, expressed in pixels, was measured in the swollen and shrunken states, respectively. The pumping efficiency is expressed in percentage of area change.