Characterization of Micrometer-Sized Thin Films of Electrocoated Carbazole with p-Tolylsulfonyl Pyrrole on Carbon Fiber Microelectrodes

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Carbazole (Cz) monomers with p-tolylsulfonyl pyrrole (pTsp) (used as self-dopant) were electrochemically coated onto micrometer-sized carbon fiber by potentiodynamic method. The resulting micrometer-sized thin films of homopolymer and copolymers were characterized by using electrochemical methods (i.e., cyclic voltammetry), solid-state conductivity measurements (four-point probe), spectrophotometric methods (in situ spectroelectrochemistry), Fourier transform infrared reflectance spectroscopy, and scanning electron microscopy. Cyclic voltammetric results indicate that an increase of pTsp concentration in copolymer formation (while the Cz concentration was kept constant) current density increases randomly. The maximum anodic current density was obtained as 0.49 μA cm^{-2} by the initial feed ratio of $[pTsp]_0/[Cz]_0=5$. This is three times higher than the anodic current density of polycarbazole (PCz) (0.15 μA cm^{-2}). The electrocoated copolymer corresponding to an initial feed ratio of $[pTsp]_0/[Cz]_0=5$ was observed as polaron and bipolaron on indium tin oxide (ITO) by UV-vis spectrophotometry. The solid-state conductivity was measured with a four-point probe apparatus. Results show that a tenfold increase in Cz concentration leads to an increase in conductivity from 0.08 to 6.36 mS cm^{-1}, and also raises yields from 13.69% to 97.72%. In contrast, a 10 times increase in pTsp concentration leads to a decrease in conductivity from 0.39 to 0.02 mS cm^{-1}, and also decreases yields from 21.72% to 2.82% which is due to the polymer's bulky structure. The efficiency of the electropolymerization process on the carbon fiber surfaces by cyclic voltammetry, depending on the experimental conditions, was evaluated to ascertain the effects of copolymer thickness, dopant, optical bandgap (E_g), and the redox parameters (anodic and cathodic potentials, E_a,E_c), oxidation peak potentials, E_{ox}, and stability test of electrodes.

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