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Nanotube-Based Ultrafast Electrochromic Display

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Electrochromic display is one of the most attractive candidates for paper-like displays,[1–4] so called electronic paper, which will bring revolutionary advances in the display technology, owing to attributes such as thin and flexible materials, fast switching time, low-power consumption. However, current electrochromic technologies need to be improved to play moving images due to their slow color-switching rates.[1,2,5–7] Poly(3,4-ethylenedioxythiophene), PEDOT, and its derivatives are an ideal electrochromic material of conducting polymers for the electronic paper due to their good color and mechanical stabilities and facile fabrication.[5–8] Much work has been performed to improve contrast ratios and color switching rates by synthetic approaches.[5–8] There seems to be, however, no examples of their use in electrochromic display having moving-image speeds since the color-switching rate of the PEODT is limited by the diffusion rate of counter-ions into the film during the redox process. The diffusion time (t) of ions to reach a saturation concentration in a polymer film, that implies switching time, is proportional to the square of film thickness (x): $t \propto x^2/D$, where D is the diffusion coefficient of an ion in a polymer film. Therefore, the simplest way to overcome the slow switching rates is to decrease the diffusion distance of ions, that is, to reduce film thickness. Based on the reported switching time of 2.2 seconds for a 300-nm thick PEDOT film,[5] we expect the switching time to be about 10 ms for a 20-nm thick film. However, the coloration of such a thin film is never sufficient for display applications.

An array structure of PEDOT nanotubes provides an attractive solution to both of these limitations, slow switching rates and extent of coloration. Fig. 1 explains that the wall thickness of PEDOT nanotubes can provide ions with short diffusion distance on the order of 10–20 nm, which allows very fast switching rates, while the micron-length of the PEDOT nanotubes in an array structure can produce strong coloration for the display system. In this presentation, we will show that an extremely fast electrochromic display (switching time less than 10 ms) can be fabricated based on well-defined nanotube arrays of PEDOT. Thin nature of the nanotube walls offers a short ion-diffusion distance and results in ultrafast switching rate. The arrayed long-nanotube structure gives a strong coloration with color contrast value of 6. A mechanism for the electrochemical synthesis of PEDOT nanotubes will be also proposed.

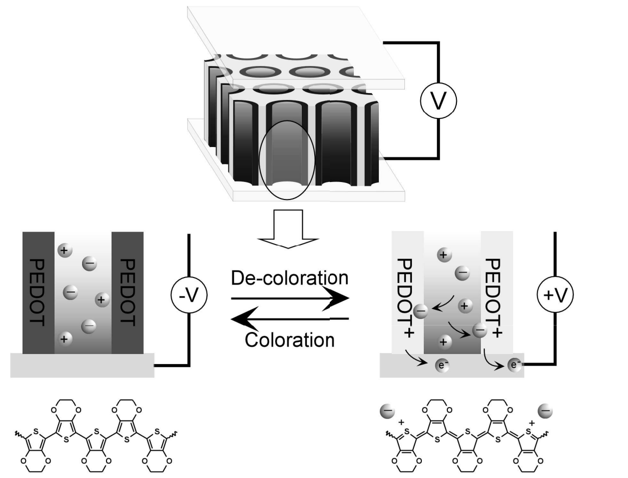

Fig. 1. Schematic diagram of the ultrafast electrochromic device based on PEDOT nanotube arrays. Counter-anions (negatively charged grey balls) diffuse into thin layer of PEDOT nanotube wall (10–20 nm in wall thickness to provide the short diffusion distance) when PEDOT nanotubes are oxidized by applying positive potential on the ITO glass electrode (light yellow). The color of PEDOT turns from a deep blue to a transparent pale blue.

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