Structure-Property Engineering and Device Fabrication of Conjugated Polymers by Chemical Vapor Deposition

by

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Technical Summary

This thesis focuses on the *in-situ* molecular engineering of chemical vapor deposition (CVD)-synthesized soft materials and device applications. High quality and large-scale synthesis of soft materials are the foundation of soft electronics. CVD approach has proved to be a low-cost and scalable technique to synthesize a wide variety of soft materials with desired properties. The first part will be dedicated to the record high electrical conductivity in CVD-grown poly(3,4-ethylenedioxythiophene) (PEDOT) thin films with controllable crystallization and morphology. The polymeric conducting thin film can be used as flexible and transparent electrodes in many electronic devices. Previously, the key problem limiting the electrical conductivity of PEDOT is the difficulty of maintaining a high carrier mobility simultaneously with a high carrier density in this polymer. In order to solve this problem, we developed a facile CVD technology to effectively control the carrier mobility at high carrier density by controlling the crystallite configuration and morphology of PEDOT through molecular engineering. As a result, we successfully synthesized wafer-scale PEDOT thin films with a conductivity of 6259 S/cm, which is comparable to the widely used expensive indium tin oxide (ITO). This is the record high conductivity for large-scale thin film PEDOT. In addition, we also constructed a detailed theoretical model based on Boltzmann transport in order to understand the charge carrier transport mechanism. As a wafer-scale demonstration, we directly synthesized the highly conductive PEDOT thin film on a 4-inch silicon wafer and successfully fabricated PEDOT-Si diode arrays operating at 13.56 MHz, which can be used as high frequency rectifiers for RFID readers. The second part will be dedicated to the enhancement of thermal properties of conjugated polymers synthesized using CVD technology. We developed a self-assembling CVD growth method for intrinsic poly(3-hexylthiophene) (P3HT) thin films and successfully achieved record high cross-plane thermal conductivity (>10x common polymers) in soft materials. Such a unique CVD growth mechanism results in an extended chain structure with good π-π stacking in P3HT, which significantly enhances the thermal transport within the CVD P3HT thin films. The third part will be about the fabrication of chemical sensors based on various nanostructured PEDOT and related copolymers, taking advantage of their ultrahigh surface-to-volume ratio.

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