Polymer–Carbon Nanotube Interactions for Energy Level Modulation in Field-Effect Transistors

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Abstract

Carbon nanotube field-effect transistors are promising candidates for high-performance electronic devices due to their excellent carrier mobility and stability. In this study, we compared **PNDI-2T** with our newly designed **PNDI-BTI**, which features lower HOMO/LUMO energy levels. The devices fabricated with PNDI-BTI exhibit significantly higher switching ratios (Ion/Ioff) and reduced threshold voltages (Vth), leading to improved device efficiency. These results demonstrate that energy-level tuning through polymer design is an effective strategy to optimize CNT-FET performance.

Introduction

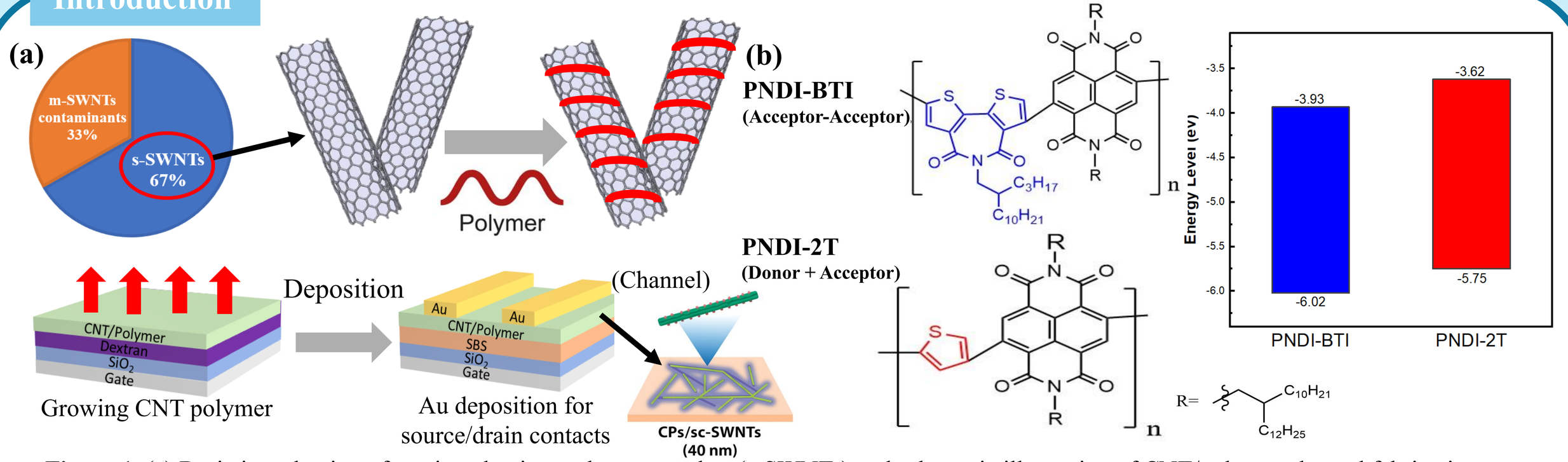

Figure 1. (a) Basic introduction of semiconducting carbon nanotubes (s-SWNTs) and schematic illustration of CNT/polymer channel fabrication process. (b) Chemical structures of PNDI-BTI and PNDI-2T with corresponding energy levels.

Molecular Dynamics and Optical Tests

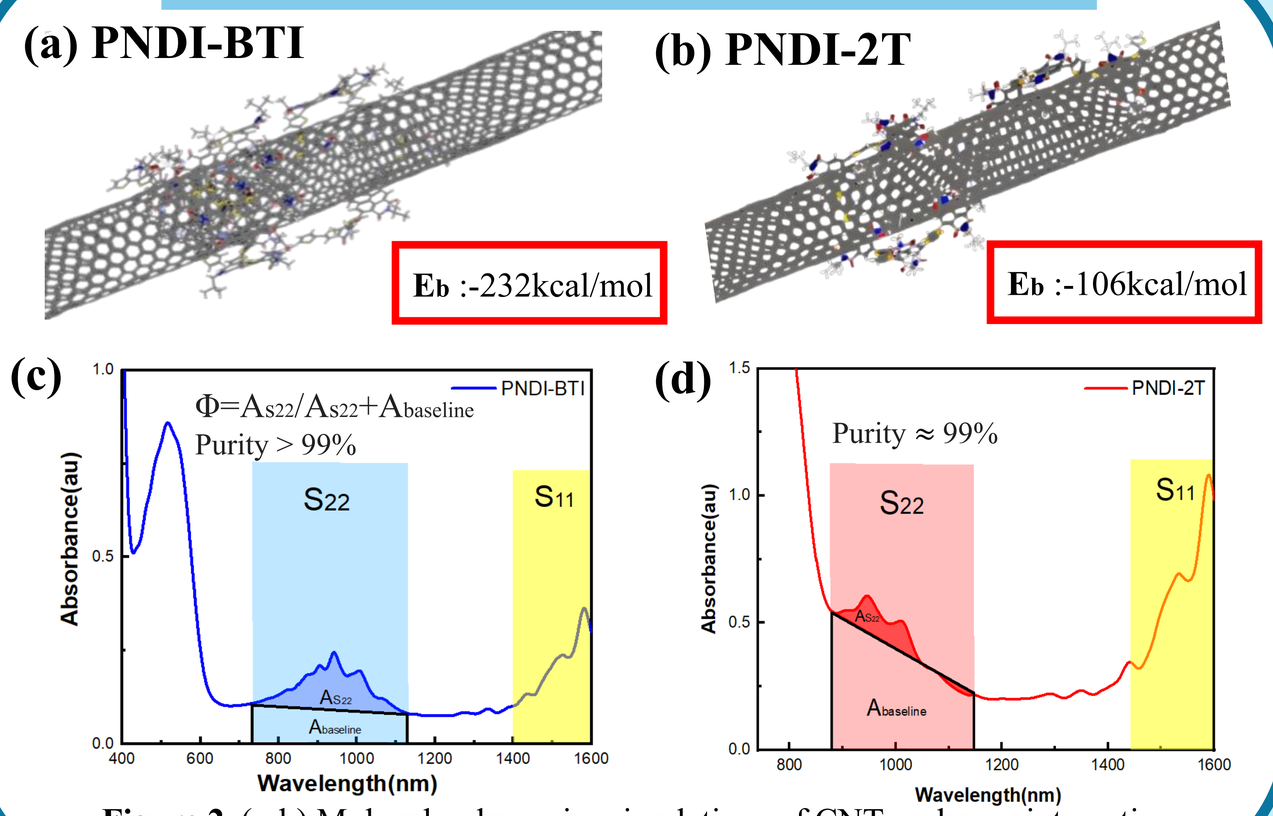

Figure 2. (a-b) Molecular dynamics simulations of CNT–polymer interactions. (c-d)UV–Vis spectra of sorted CNTs

Characterization of Sorted CNTs

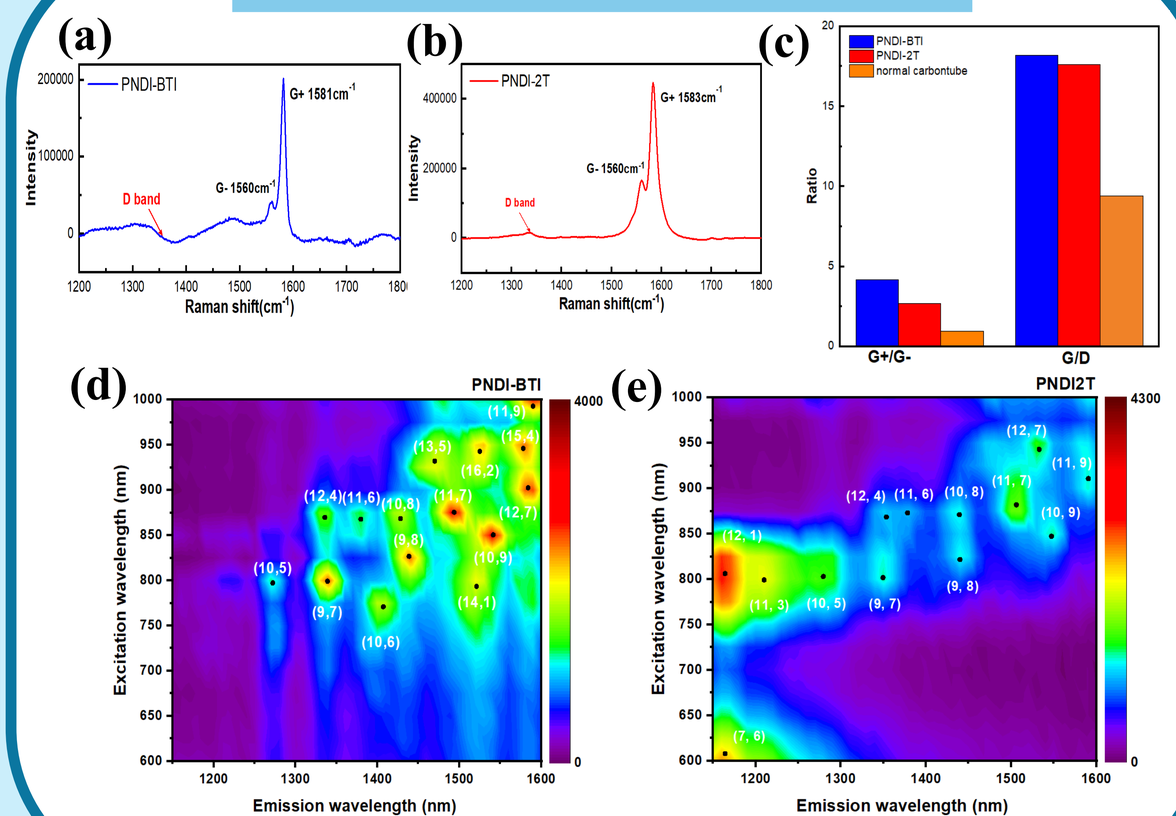

Figure3. (a–c) Raman analysis of CNT sorting (d, e) PLE maps of sorted CNTs showing chirality distribution.

Morphological analysis of FET devices

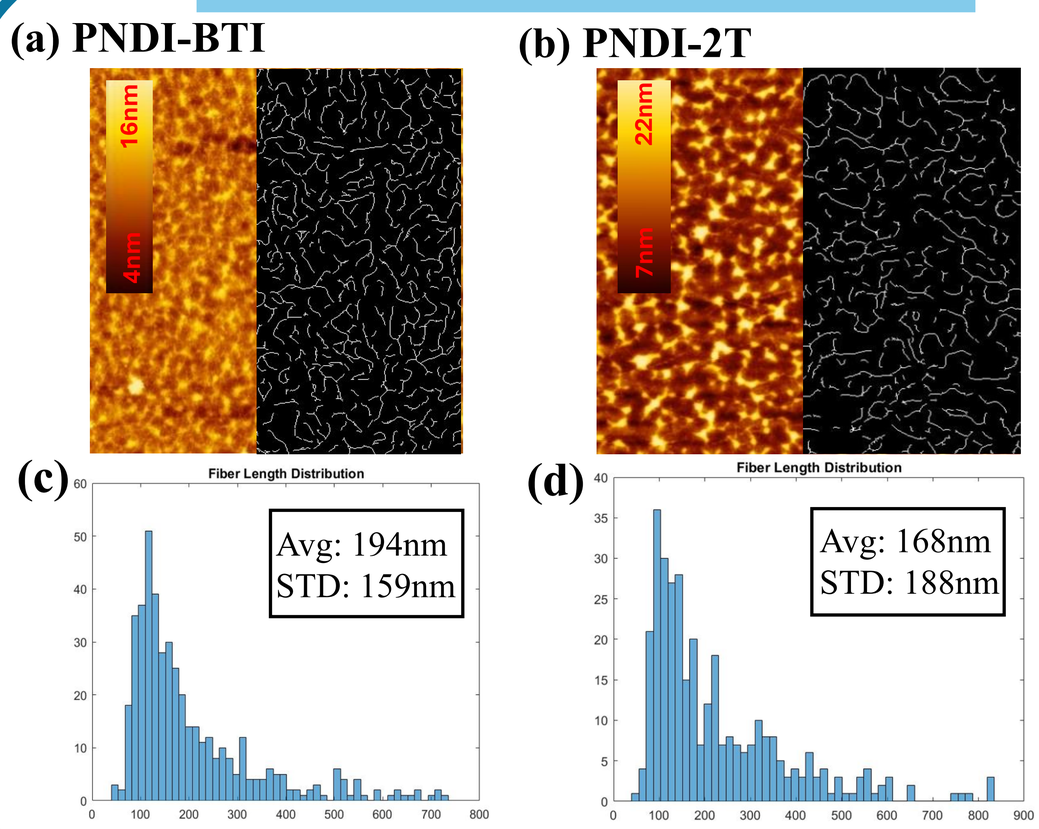

Figure4. (a–b)AFM images with GT-Fiber simulation of CNT/polymer hybrids (c–d)Statistical carbon tube length distribution

Electrical characteristics of CNT/polymer FET devices

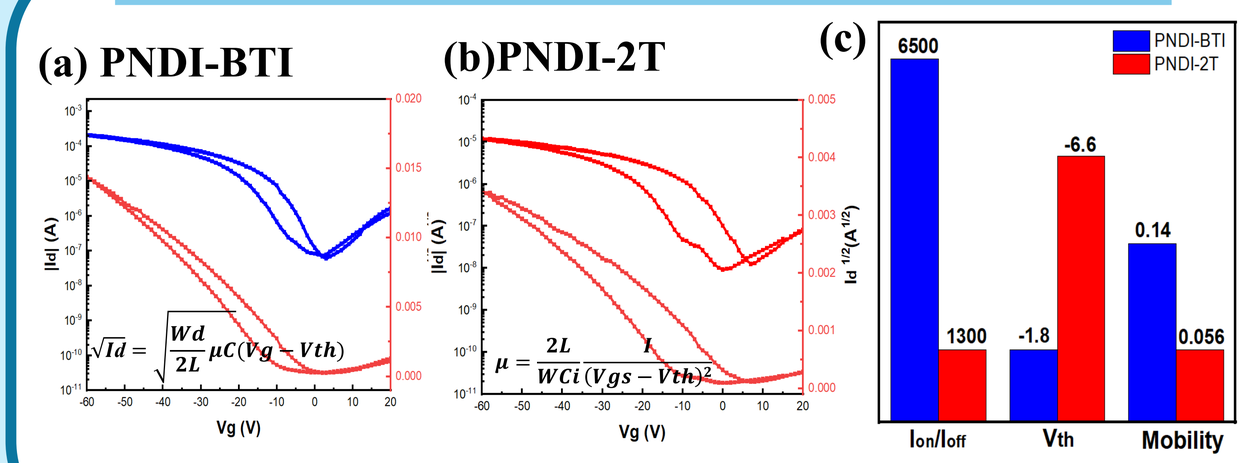

Figure5. (a–b) Transfer characteristics of CNT/polymer FET devices (c) Comparison of key electrical parameters (Ion/Ioff, Vth, and mobility)

Conclusion

- MD simulations and Raman analysis consistently revealed that **PNDI-BTI provide stronger CNT–polymer interactions and more effective CNT sorting** compared to PNDI-2T.
- Electrical measurements further confirmed that PNDI-BTI-based devices exhibit **higher on/off ratios(6500)** and **reduced threshold voltages(-1.8)**
- These findings highlight that **energy level modulation** and polymer-assisted CNT sorting are complementary strategies for **optimizing CNT-FET efficiency** and **stability**, providing valuable insights toward future high-performance nano electronic devices.