Abstract and Keywords

This dissertation presents a comprehensive investigation of charge transport and bio-interfacing in single-walled carbon nanotube (SWCNT)–based devices, highlighting their potential as core materials for next-generation bioelectronic systems. The work first examines how surface functionalization modifies the structural, electrostatic, and conductive properties of SWCNTs. Advanced scanning probe techniques-Kelvin Probe Force Microscopy (KPFM), Electrostatic Force Microscopy (EFM), and Conductive Atomic Force Microscopy (C-AFM)- are employed to elucidate the local electrostatic landscape and nanoscale charge transport within SWCNT bundles. The results show that charge transport and surface potential depend strongly on bundle geometry, alignment, and height, confirming that SWCNTs actively modulate local work function rather than acting as passive conductors. Integration of SWCNTs with conductive substrates such as gold (Au) and indium tin oxide (ITO) leads to enhanced charge injection, reduced contact resistance, and measurable current flow even near zero external bias.

Building upon this optimized nanocarbon platform, the thesis explores biologically driven charge transfer by employing Escherichia coli (E. coli) as an active bio-interface. Systematic experiments reveal that bacterial activity induces spontaneous changes in current across Au-SWCNT electrodes in aqueous environments, consistent with mediator-free, E. coli–mediated electron transfer to the electrode. Real-time electrical responses correlate with bacterial concentration and attachment, indicating dynamic charge exchange at the bio–electrode interface. In the final phase of the work, bacterial metabolism is shown to drive measurable current in Au–SWCNT-Au devices without applied external bias, with the SWCNT network facilitating energy-level bridging between the bacterial membrane and metallic contacts.

Overall, this research unifies concepts from materials science, nanotechnology, and microbiology to demonstrate how functionalized SWCNTs can be engineered to optimize charge transport and tailor interfacial energetics in hybrid bioelectronic platforms. The findings provide a foundation for low-power, self-sustained, and highly sensitive carbon-based bioelectronic systems that couple living processes to electronic functionality.

Keywords: **Single-walled carbon nanotubes (SWCNTs); electronic devices; charge transport; Kelvin Probe Force Microscopy (KPFM); Electrostatic Force Microscopy (EFM); Conductive Atomic Force Microscopy (C-AFM); *Escherichia coli* (E. coli); charge transfer; microbial energy conversion; nano-bio interface.**