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Assembly, physics, and application of highly electronic-type purified semiconducting carbon nanotubes in aligned array field effect transistors and photovoltaics

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Recent advances in (1) achieving highly monodisperse semiconducting carbon nanotubes without problematic metallic nanotubes and (2) depositing these nanotubes into useful, organized arrays and assemblies on substrates have created new opportunities for studying the physics of these one-dimensional conductors and for applying them in electronics and photonics technologies. In this talk, I will present on two topics that are along these lines. In the first, we have pioneered a scalable approach for depositing aligned arrays of ultrahigh purity semiconducting SWCNTs (prepared using polyfluorene-derivatives) called floating evaporative self-assembly (FESA). FESA is exploited to create FETs with exceptionally high combined on-conductance and on-off ratio of 261 μS/μm and $2x10^5$, respectively, for a channel length of 240 nm. This is 1400x greater on-off ratio than SWCNT FETs fabricated by other methods, at comparable on-conductance per width of 250 μS/μm, and 30-100x greater on-conductance per width, at comparable on-off ratio of 10^5-10^7. In the second, we have discovered how to efficiently harvest photons using semiconducting SWCNTs by driving the dissociation of excitons using donor/acceptor heterojunctions. The flow of energy in SWCNT films occurs across a complex energy landscape, temporally resolved using two-dimensional white light ultrafast spectroscopy. We have demonstrated simple solar cells driven by SWCNT excitons, based on bilayers between C60 and ultrathin (5 nm) films of SWCNTs that achieve a 1% solar power conversion efficiency (7% at the bandgap). High internal quantum efficiency indicates that future blended or multijunction cells exploiting multiple layers will be many times more efficient.