Nanotube electronics: potential, reality, critique

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Carbon nanotubes can be semiconducting with a bandgap that can take a value anywhere between ~20 meV to ~2eV. They can be metallic, but capable of sustaining current density hundreds times greater than a metal. And, they might even be superconducting. A "one size fit all" magic material! No wonder, many think, and some stated, that the carbon nanotube is the greatest creation in the recent history of electronic materials development.

Is the nanotube greater than, e.g., GaAs, GaN, and organic semiconductors? Only if you factor in all the other remarkable properties it has over and beyond electronics. It is mechanically many times stronger than steel, but a few times lighter. It is thermally more conductive than most crystals. Upon charge injection it can change its length so much that it is not proper to call this effect piezoelectricity (in fact, it is not). Chemically, it can be made to change from inert to selectively active. And, it responds to light – not only in conductivity but also by changing shape! All these properties do not come about merely by coincidence, but are natural outcomes of the fact that in this system the electronic and mechanic degrees of freedom are tightly coupled, as will be shown via a first-principles model. In my view, it is this strong coupling that makes the nanotube system uniquely promising for the future evolution of information technology.

Electronics is presently largely about information processing and transmission. Nanotube electronics is capable of breaking out these narrow confines, given the rich electro-mechano-opto-chemo functionalities present in nanotubes. This breakout would be in sync with that of the information technology (IT) itself, as economic forces propel IT more towards acquiring and executing on information. Scores of reports on nanotube force, chemical and optical sensing and actuating are just some wonderful early demonstration of its potential in this light. Perhaps more important is the fact that the usual technologically challenging task of interfacing the sensing and actuating functions with electronics can also be handled by nanotubes. Moreover, nanotubes can bring innovation and improvement to the way of signal processing is done. In some cases, one can even expect nanotube-based mechanical resonators, filters, and even amplifiers with performance superior to their electronic counterparts, again due to the strong electro-mechanical coupling.

However great the nanotube's future may be, the same cannot be said of the current mainstream approaches for nanotube fabrication. Fortunately, alternative methods in development offer reasons for optimism on this front. The two-port nature of the nanotube is not really as serious a handicap as it first appeared either. On the other fronts there are causes for concern, among which I count the fixation on single-walled nanotubes and the misplaced focus on assembling nanotubes into transistor-like devices and CMOS-like circuits.