The future of microelectronics is … macroelectronics

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The title is actually not as provocative as it might seem. No one debates the miraculous success of microelectronics – enshrined in Moore's law and iconified by Pentium chips – in transforming how we communicate and compute. Even as the technology – buffeted by many fundamental limits – slides into a more mature phase, the degree of miniaturization of transistors continues to amaze, e.g. the number of transistors made in a year by Intel or TSMC exceeds the number of ants or leaves in the world! Yet, the most exciting trends in electronics today are defined not by computers, but by flat panel displays, solar cells, and bioelectronics sensors. Sizing solar cells, batteries or flat panel TV to the dimension of a Pentium is obviously counterproductive, if fact for such systems – the bigger, the better. If we categorize the electronics of flat-panel displays, energy conversion and conservation devices as being macro- or large-scale electronics, presumably few would quibble with the title of this presentation. And since we have known the solar cells and flat-panel displays for decades, and batteries and capacitors have been around for centuries, surely we could train a new generation of engineers to lead this transformation from micro- to macro-electronics by simply changing a few equations and figures in our existing Powerpoint slides.

In this talk, I argue that this view of the easy transition of electronics may not be possible and that the broad/economic adoption of macroelectronics would rely on development of theory, process, and device concepts no less transformative as those of microelectronics industry. The key distinguishing feature of macroelectronics is that the economics of material/energy dictate that macroelectronics devices use very thin films processed at the lowest possible temperature. On the theory side, it means letting go the presumption of crystallinity supported via Bloch's theorem, Kronig-Penney model, Ohm's law, and isotropic transport that have been so central to the single-crystal microelectronic devices. Rather, we should view the optimization of macroelectronic devices made of amorphous/roughened/gyroid materials (solar cells and thermoelectrics) and mesoporous structures (batteries/super-capacitors) in a fundamentally new way. I will give multiple examples of (i) process models of CNT-based nanonets and spinodally decomposed donor/acceptor blends, (ii) device models of flexible carbon nanonets via finite size, nonlinear percolation theory, and (iii) reliability models intuitively simple reaction-diffusion approach, to illustrate a probable path to a new, "bottom-up" conceptual framework of macroelectronic devices.