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Adding New Capabilities to Silicon CMOS Integrated Circuits Via Directed Self-Assembly

Dr. Theresa S. Mayer
Penn State University

abstract

With CMOS nearing the physical limits of scaling, the future of the semiconductor industry is at a critical point. The International Technology Roadmap for Semiconductors (ITRS) identifies the growing need to interface new nanoscale materials and devices with Si CMOS architectures to sustain nanoelectronic circuit scaling (more-*of*-Moore) and to discover entirely new electronic systems (more-*than*-Moore). The use of a heterogeneous, system-level integration strategy that seamlessly merges one technology with another holds great promise of enabling transformational shifts in electronics, in computing, and in chemical and biological research paradigms. For example, narrow bandgap semiconductors that operate at lower voltages than Si will give low-power logic without sacrificing speed. Molecular and metal oxide nanomaterials designed to give a large electronic response to biological molecules or chemical vapors offer sensing capabilities.

This talk will describe new nanomanufacturing process to position large, diverse, and interchangeable arrays of nanowire sensors or sheets of alternative electronic materials onto fully-processed Si CMOS circuits via *directed self-assembly*. The wires and tiles are fabricated *off-chip* from many different materials tailored for a specific function. Electric-field forces are then used direct different populations of these materials to specific regions of the chip, while also providing accurate registry between each individual wire or tile and a predefined feature *on the chip*. Following assembly, conventional lithographic processes can then be used to define the nanodevices and connect them to the Si circuit. This assembly strategy eliminates constraints due to thermal budget, chemical incompatibility, lattice mismatch, and enables integration of dissimilar materials including semiconductors, metal oxides, polymers, and biofunctional structures. Several material and device integration examples will be discussed, including the assembly of bio-probe coated and metal-oxide nanowire device arrays as well as monolayer 2D transition metal dichalcogenide (TMD) crystal materials.