Proceedings of 2005 5th IEEE Conference on Nanotechnology
Nagoya, Japan, July 2005

Molecular Mechanics and Molecular Electronics

James R. Heath

Elizabeth W. Gilloon Professor & Professor of Chemistry
Caltech Division of Chemistry and Chemical Engineering
M/C 127-72 Pasadena, CA 91125
heath@caltech.edu

Electronic devices containing molecules as either passive (resistive or rectifying) or active (switching) components present the opportunity for scaling electronic circuitry down to near-molecular dimensions. In this talk I will discuss how molecular switching devices can be optimized in a feedback loop that involves chemical synthesis at one end, and device performance at the other. The key parameters that connect these two domains are the kinetic and thermodynamic properties of bistable molecular mechanical switches known as catenanes[1] and rotaxanes. I will then discuss architectural concepts and fabrication methods that are allowing us to construct relatively large (10^5 devices) memory and logic circuitry[2] at device densities of $10^{11}\cdot cm^{-2}$ and higher. In such a circuit the electrodes (Si or Pt) are only 10 nm wide and produced at a half-pitch of 15 nm.[3] Although these circuits can be fabricated with excellent electronic characteristics,[4] they also have unique challenges associated with them. One such challenge revolves around the issue that no current lithographic technique scales to these dimensions. We have developed and demonstrated a defect-tolerant, binary tree demultiplexer architecture that is capable of bridging these length scales, using Order $\log_2 N$ submicron (lithographically patterned) wires to address N nanowires. The construction and testing of this demultiplexer has raised a number of key materials issues that are likely to be critical for any extreme scaling of Si, and those issues and potential solutions, will be discussed. Finally, I will briefly describe some of the 'value-added' applications that accompany the ability to fabricate such nano/molecular electronic circuitry. Aside from the traditional applications of memory, logic, and routing, new opportunities that include actuation, sensing, energy management, and possibly even peptide sequencing are enabled by these nanofabrication approaches.

---

[1] C.P. Collier, G. Mattersteig, Y. Li, E. W. Wong, K. Beverly, J. Sampaio, F. Raymo, J.F. Stoddart, and J. R. Heath, "A [2]-Catenane Based Solid-State Electronically Reconfigurable Switch," *Science,* **289**, 1172-75 (2000).

[2] Y. Luo, C.P. Collier, K. Nielsen, J. Jeppesen, J. Perkins, E. DeIonno, A. Pease, J. F. Stoddart, and J. R. Heath, "Molecular Electronics Random Access Memory Circuits," *ChemPhysChem* **2002**(3), 519 (2002).

[3] N. Melosh, A. Boukai, F. Diana, B. Geradot, A. Badolato, P. Petroff, and J. R. Heath, "Ultrahigh density Nanowire Lattices and Circuits," *Science*, **300**, 112 (2003).

[4] R Beckman, E. Johnston-Halperin, Y. Luo, N. Melosh, J. Green, and J.R. Heath, "Fabrication of Conducting Silicon Nanowire Arrays," *J. Appl. Phys.* **96** (10), 5921-5923 (2004).