Center of Integrated Nanomechanical Systems (COINS)

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The mission of COINS[1] is to inspire and realize applications directed towards sensing of environmental conditions using nanotechnology, integrated with suitable societal implications studies and educational, outreach, and knowledge transfer programs. Specifically, the technical focus of COINS is to develop the means for realizing its three major environmental monitoring applications – Personal Monitoring, Community Monitoring and Mobile Monitoring. These platforms combine technologies of molecular recognition and signal transduction, energy harvesting and conversion, efficient signal processing and wireless communications, and mobility. A key to successful achievement of mission goals lies in the unique COINS nanoscience environment (embedded in the larger California "nano-ecosystem"), which brings together highly interdisciplinary teams to solve problems and bridge technology gaps in new ways.

The COINS environmental monitoring goal is to reduce the size, weight, noise, energy consumption, cost, sensitivity, and selectivity of these types of monitors by orders of magnitude. Successful realization of the COINS NSEC mission will lead to such major enhancements in environmental monitoring technology that completely new possibilities will emerge due to better spatial and temporal resolution. Such technology could empower community organizations with typically low funding levels to turn data into actionable insight, allowing regions and ultimately the nation as a whole to make better decisions.

The COINS Personal Monitor aims to enable real-time monitoring on one's environment using nano-enabled technologies. This sensor will be low power, selective and interface with, and eventually be embedded in, smart phones. The goal of the COINS Community Monitor is to provide robust, self-powering, cost-effective solutions to air and water monitoring enabling arrays of wirelessly communicating chemical sensor networks for real-time spatial and temporal maps of environmental conditions. For the COINS Mobile Monitor, the addition of mobility to the sensing system adds the capability to follow a particular chemical "scent". These technology enhancements will fundamentally change the way we are able to respond to disaster events (e.g., earthquakes or the release of chemical warfare agents) by providing much more accurate information, allowing for substantially better countermeasures, security, and potential rescue.

The COINS Education, Outreach and Diversity program's focus has been on "Expanding the Impact". Our mission is to contribute to a diverse and inclusive NSE workforce in industry and the academy. Since the Center's inception, we have developed, managed and partnered with programs that best utilize available COINS resources in support of this mission:

- Undergraduate Internship Program (REU at UCB; summer internships at UCM)
- Research Experience for Teachers (RET) scheduled to launch Summer 2011 at UC Berkeley

- Recruitment strategy that reaches out to underrepresented populations and creates a pipeline from our summer REU into NSE graduate programs
- Partnerships with programs and organizations that recruit and retain underrepresented students in STEM fields
- Outreach to students of all ages and general public audiences via the Web, public talks, broadcast media, and through collaborations with NISE partners and hosting special COINS event
- Summer 2011 introduced the expansion of education programs to all center partners including an undergraduate research position for a UCM student at Caltech as well as two RET positions at Stanford

Since its inception, COINS has made significant advances in nanoscale device fabrication by identifying more efficient and controlled synthesis mechanisms. In addition, major advances in understanding and controlling thermal properties at the nanoscale have been made – this encompasses a number of projects in COINS and has an important impact on energy dissipation, device integration, and quality of nanomechanical resonators. COINS has also focused on pushing the limits of nanoscale energy conversion, and in particular on using new materials to convert sunlight, heat, and mechanical vibrations into electricity. In phase 2 of the program, we are combining these scavenging techniques into integrated detection platforms. COINS has also pushed forward on the integration of multiple components into unified, functional devices, with, for example, the combination of highly selective chemical coatings with low-power carbon nanotube-based sensors. COINS has developed entirely new types of nanoscale devices, including a self-contained radio system constructed out of a single carbon nanotube, which could revolutionize communications both between device elements and among large-scale sensor networks.

Below we highlight some examples of advances that have occurred within the COINS program to date.

Fundamental Knowledge

- Controlled thermal conductance of nanotubes and reversibly tunable.
- Demonstrated ability to orient, align, and place nanotubes by fluid flow.
- Synthesis of “Nano-Abacus” nanomechanical resonators with resonance frequencies up to 4 GHz.
- Prediction of the non-equilibrium vibrational behavior of nanotube systems, predicting the pathway by which vibrational energy is redistributed towards thermal equilibrium.
- Development of a completely novel silicon nanowire synthesis process to create very long wires geared toward solar cell applications.
- Room temperature silicon nanowire showed high-frequency, high-Q resonators for ultralow power, ultrahigh sensitivity detection
- Theoretical insight into charge separation process for nano-photovoltaic devices
- Ultrafriction achieved in synthetic adhesion materials
- Solid state thermal rectifier constructed from carbon nanotubes
- Limits of nanoscale dissipation measured in CNTs

- Stability and thermal conductivity of carbon nanotubes at very high temperatures
- Electronic structure and coupled vibrational properties of new materials
- Comprehensive modeling of physical properties of semiconductor nanowires in realistic device geometries
- New microscopic understanding of the light-induced degradation in amorphous silicon solar cells
- New ultra-sensitive coatings developed for nanomechanical cantilever-based sensors
- Detailed electronic structure of diamondoids predicted by theory and directly compared with STM measurements.
- Fundamental insights on the vapor-liquid-solid mechanism of semiconducting nanowire growth
- Controlled growth of nanowires geared towards isolated nanowire-based electromechanical devices

Technology

- Demonstrated Ultra-selective, ultra-sensitive recognition peptide/ carbon nanotube-based TNT sensor
- Carbon nanotube radio constructed
- Fabricated atomic resolution mass sensor from carbon nanotube resonator
- Nanofluidic MOSFETs are designed, fabricated, and tested.
- Micromechanical energy system developed to store and release mechanical energy for mobility applications.
- Nanocavity fabricated down to 40 nm for detection using dielectric relaxation spectroscopy.
- Development of piezoresistive force sensors suitable to bio-nano systems.
- Sophisticated system integration as well as advanced target-specific nano-receptors in 2-D multiplexed cantilever array platform for high-throughput chemical sensing and analysis.
- Demonstrated out-of-plane motion of microstructures assembled from parts fabricated in a single-mask Silicon-on-Insulator (SOI) process, for “pick-and-place” micro/nano assembly.
- WetFET nanofluidic gate dielectric transistor constructed and tested
- A diode built from nanofluidic channels was successfully demonstrated
- The micromembrane sensing system integrated with phage display for increased selectivity
- Nanocontacts created between carbon nanotubes and silicon through local heating
- Actuation and sensing interface developed for single nanowire RF resonators
- Chip-to-chip nanofluidic interconnect technology developed
- Extreme thermal test platform developed
- Advances in development of integrated transduction schemes for SiNW resonators toward arrays of devices and large-scale integration.

References

[1] For further information about this project link to http://nano.berkeley.edu/coins/ or email **wmickelson@berkeley.edu**