Discovery Platforms™ for Nanoscience

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Scientific Thrust Area: Nanoscale Electronics and Mechanics

Research Achievement:

The Center for Integrated NanoTechnologies (CINT) has a special focus topic in "chip-based nanoscience". We call these chips *Discovery Platforms™ (DPs)*, and they are designed to enable a CINT User to perform nanoscience experiments easily with little to no additional sample processing. In the first generation of DPs, two chips were mass-produced and widely used: (1) the Cantilever Array Discovery Platform (CADP) and (2) the Electrical Transport and Optical Spectroscopy Platform (ETOPS).

<u>Cantilever Array Discovery Platform</u>: The CADP is a multipurpose chip that is designed for experimenters wishing to perform research in the areas of nanomechanics, novel scanning probe technologies, chemical and biological sensing, magnetization studies, *in situ* TEM measurements, and physics of coupled mechanical systems. The platform is the same size as typical atomic force microscope (AFM) chips, and it can be mounted in most AFMs. Unlike an AFM chip, this platform has multiple cantilevers projecting from all edges, and it contains special microelectromechanical systems (MEMS) test structures in the center (see Fig. 1).

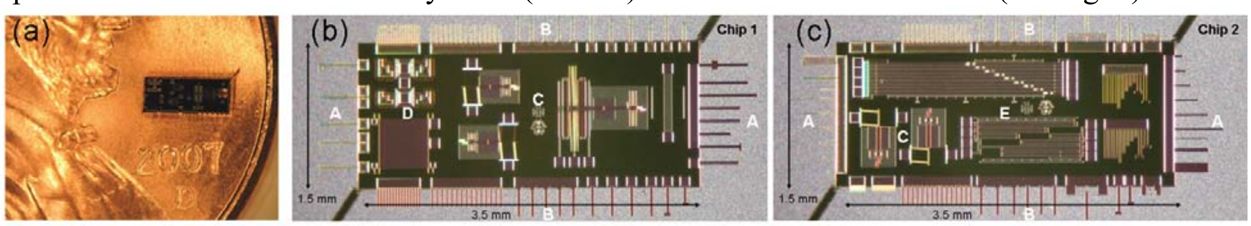

***Figure 1**. (a) The CADP is the size of an AFM chip. There are two versions, chip 1 (b) and chip 2 (c). Separate experiments are performed in different regions of the chip: (A) beams for scanning probe microscopy studies, (B) beams for nanomechanics, cantilever-based sensing, coupled oscillators, (C) MEMS structures for mechanics testing of samples, (D) structures for magnetization studies, and (E) silicon beams for surface adhesion studies.*

Examples of experiments with the CADP performed by CINT Users are shown in Fig. 2. These include investigating the physics of high resolution sensing using arrays of mechanically-coupled oscillators *[A]*, measuring the mechanical behavior of metal nanowires under tension *[B]*, and developing techniques for precise local strain measurements in microscale samples *[C]*.

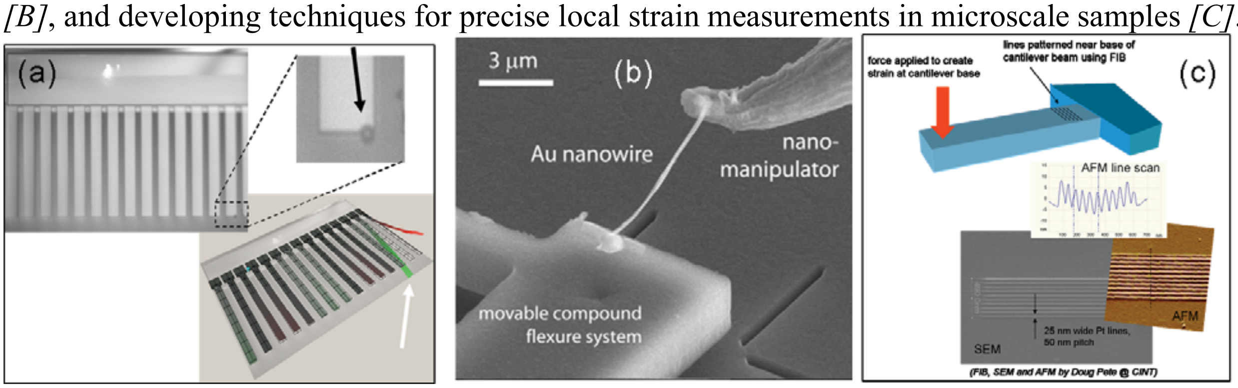

***Figure 2**. (a) Sensing using coupled oscillators. Particle attachment (black arrow) leads to large changes in array eigenmodes (white arrow). (b) Nanomechanics testing of nanowires using the CADP load cells. (c) Patterning nanoscale line arrays at the base of CADP cantilevers for local strain measurement using an AFM moiré technique.*

Electrical Transport and Optical Spectroscopy Platform: The ETOPS has been designed to enable fundamental investigations of the optical, electronic, and transport properties of a wide variety of materials by providing a simple and well-characterized means of electrically or optically interfacing with nanoscale samples. The platform contains arrays of electrical contacts in a wide variety of geometries that thenfan out to contact pads, thus enabling electrical connection to a variety of samples (see Fig. 3).

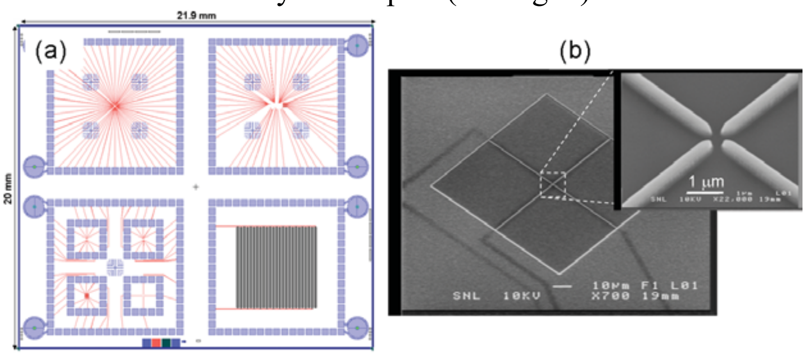

***Figure 3**. ETOPS Platform showing overall view (a) and a close-up of one of several electrode patterns (b). In this pattern, 4 leads approach a central point with sub-micron spacing.*

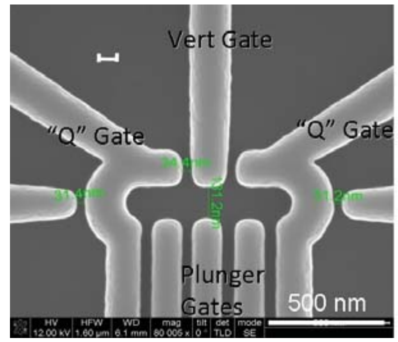

***Figure 4**. SEM image of a coupled quantum dot structure on the modified ETOPS platform.*

Using a modified version of this Platform, CINT researchers have been investigating the physics of coupled quantum dots in silicon (see Fig. 4). These structures show great promise for creating practical qubits for quantum computing applications.

Future Work:

We have two new second-generation Discovery Platform chips that are in fabrication. The first platform is an update of our original CADP, called CADP 2.0. Given the success of the first version, we have kept most of the original structures, but we have added a number of additional features to permit the thermal, electrical, thermodynamic, and electromechanical characterization of nanoscale materials (see Fig. 5). This Platform is expected to be released in June 2009.

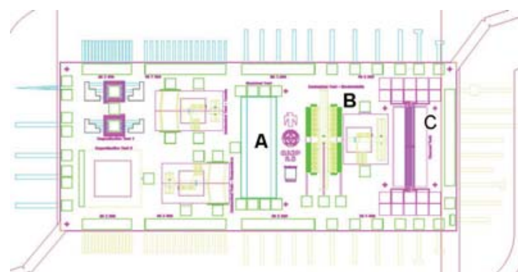

***Figure 5**. Chip 1 of CADP 2.0 showing new structures for electrical (A), electromechanical (B), and thermal(C) property measurements of nanowires.*

The second new Platform is called the Nanowire Discovery Platform. It is designed to promote the synthesis, integration, and electrical characterization of nanowire specimens. Some of the specific structures on this Platform include unique trench geometries to enable the growth and integration of vertical arrays of nanowires (see Fig. 6). This platform is expected to be released in late summer 2009.

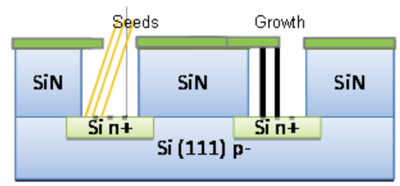

***Figure 6**. Cross-section view of a portion of the Nanowire Discovery Platform showing the concept for growth and electrical integration of vertical nanowire arrays.*

Publications:

[A] M. Spletzer, A. Raman, H. Sumali, and J. P. Sullivan, Appl. Phys. Lett. **92**, 114102 (2008).
[B] C. Volkert, unpublished.
[C] H. Jin and W.-Y. Lu, unpublished.