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Nanotech Facility Hosts ESTECH Tour

Photo: Hal Amick, Colin Gordon and Associates

As part of a focus on nanotechnology, ESTECH 2008 offered attendees the opportunity to tour the state-of-the-art Birck Nanotechnology Center (BNC) at Purdue University. The tour group spent a day exploring cleanrooms and research laboratories in the $58-million, 186,000-square-foot facility.

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Imagine designing a cleanroom facility to meet the needs of dozens of diverse interests and objectives. This was the challenge faced by Purdue University when initiating the Birck Nanotechnology Center (BNC) in 2001.

"The design kickoff meeting had more than 200 participants," Ahmad Soueid told the 20 attendees who visited the BNC May 8 in conjunction with ESTECH 2008, the 54th annual technical meeting of the Institute of Environmental Sciences and Technology (IEST). Soueid is principal/senior vice president with HDR Architecture, the firm that designed the facility for the Purdue campus in West Lafayette, Indiana. HDR cosponsored the tour, along with AdvanceTec, LLC, contractor for the BNC cleanroom construction.

Collaboration is critical in the multidisciplinary field of nanotechnology research, and the BNC was designed to support that concept, noted Soueid. The building sees 150 faculty from 34 Purdue schools and departments and nearly 200 researchers working on projects.

The product of the cooperative design effort is a three-story facility with 25,000 square feet of cleanroom space, 22,000 square feet of laboratories, and support services such as ultra-high-purity gases and nanotechnology-grade water. A significant amount of glass was designed into the cleanroom perimeter and the cleanroom interior walls to encourage protocol adherence, enhance safety, and expose cleanroom activities without breaching the cleanroom, according to John Weaver, facilities manager of the BNC and host for the tour.[1]

"I very much enjoyed the opportunity to take this tour," commented David Bunzow, manager of research services at North Dakota State University's Center for Nanoscale Science and Engineering (CNSE) and a participant in the IEST tour. "It was a 'can't miss' experience that was both educational and professionally rewarding. The BNC is pristine, well-organized, and able to become a leading multidiscipline nanotechnology center as it moves forward to maturity."

Integrated cleanrooms

In an example of how nanotechnology links diverse disciplines, scientists are combining active biological agents with microelectromechanical systems (MEMS) and nanoelectromechanical systems (NEMS) sensors to develop specialized environmental detectors and medical diagnostic devices. Such efforts require both semiconductor-style and pharmaceutical-grade cleanrooms—facilities with different structural designs and operating protocols. To that end, the BNC integrates a nanofabrication cleanroom with a biomolecular cleanroom.

For maximum flexibility, the main cleanroom was built to accommodate the more complex fabrication requirements, and the biocleanroom is a modification to that design. Biocleanroom air handling is segregated from that of the nanofabrication cleanroom, i.e., there is no air interchange between the cleanrooms; there are separate entries, gowning areas, and protocols. Entry to the fabrication cleanroom is through a typical two-stage gowning process with dual air showers.

Discovery to Delivery

Researchers are working on emerging applications of nanotechnology in the fields of medicine, energy, computing, and sensors, BNC director Tim Sands told the ESTECH 2008 tour group. "Academic research emphasizes the development of active devices, such as smart particles and functional systems," said Sands. "The focus is on delivery—from discovery to commercialization."

By 2015, Sands predicted, nanotechnology will be in everyday use for solid-state lighting, cooling, and power generation; targeted drug delivery, organ transplants, and other medical procedures; wireless sensor networks for real-time chemical, biological,and other environmental detection; and smaller, more powerful computers. Some current BNC projects include:

- Research on nanocantilevers, devices coated with antibodies to capture viruses. Findings could be crucial in designing a new class of ultra-small sensors for detecting viruses, bacteria, and other pathogens.
- Wafers containing several "micropump" cooling devices small enough to fit on a computer chip. The tiny pumps circulate coolant through channels etched into the chip.
- A prototype wireless device smaller than a grain of rice. When implanted in a cancer tumor, these devices would send signals to pinpoint the tumor, guide a radiation treatment beam, and tell doctors the precise dose of radiation being received.

The cleanroom uses a cost-effective bay-chase design that segregates operations from maintenance, distributes utilities to the cleanroom, and allows for modification of bay and chase sizes. Currently there are 13 bays and 15 chases; six bays meet ISO Class 3 specifications, five bays are ISO Class 4, and two bays are ISO Class 5.

"The width of the cleanroom support bays was particularly impressive," noted Bunzow. By contrast, "in industry, we often use dollars/square foot as a figure of merit for efficiency and cost objectives." This approach can result in limited spaces in which to perform preventive maintenance and repairs, he explained.

The biocleanroom is a bacteria-free zone. A once-through disposable garment system is used for bacteria control. A glovebox that has ports in both cleanrooms allows researchers to transfer items between the cleanrooms and perform a decontamination or encapsulation process within the glovebox.

Photo: Hal Amick, Colin Gordon and Associates

A view through the window into the BNC cleanroom. Glass allows visitors to observe operations without contaminating or interfering with processes.

Modular laboratories

The BNC laboratory space is made up of 88 modules, each 11 × 22 feet. Individual laboratories are created from one to seven modules. An adjacent service galley furnishes utilities to the laboratories and provides a location for noisy, vibration-inducing support equipment.

All of the laboratories were designed to minimize outside influences, such as vibration, electromagnetic interference (EMI), and temperature excursions. First-floor laboratories meet vibration criteria under National Institute of Standards and Technology NIST-A, and all laboratories have less than 0.1 milligauss EMI levels and 1.0 °C temperature control. The transmission electron microscopy (TEM) suite controls temperature to 0.1 °C and provides extremely low acoustical noise levels.

A highlight of the laboratory tour was the Kevin G. Hall nanometrology lab, which contains an ultra-high-vacuum scanning tunneling microscope and other instruments capable of imaging individual atoms. Tight environmental controls that enable the repeatability of experiments include temperature within 0.01 °C, vibration in compliance with NIST A-1, and electromagnetic interference within 0.01 milligauss.

Other laboratories in the facility are specially designed to support research in nanophotonics, bio-nanotechnology, molecular electronics, MEMS and NEMS, and other disciplines. It took about one year to move the 185 tools into the facility.

Versatility/modifiability

The BNC is designed to be flexible to accommodate changing research needs typical in the university environment. Flexibility features include the capability to improve the cleanroom cleanliness level if required. The area of the penthouse housing the recirculation units has designated locations for additional air handlers that would allow a substantial increase in airflow to the cleanroom, and the distribution and ceiling system allows additional terminal-filter modules to be placed in the ceiling grid.

The design allows modification of the wall, floor, and ceiling system to expand or reduce the biocleanroom as needed; cleanroom floor space can be added by reducing the chase area. The flexible wall system also facilitates changing equipment sets. "Modifications for the installation of a light-controlled room for interference lithography have already made use of this flexibility," said Weaver.

State-of-the-art Instrumentation

Tour participants examined some of the sophisticated equipment the BNC offers researchers for etching, patterning, deposition, and doping of materials in a clean environment. These instruments include:

- A $6-million ultra-high resolution photolithography system that uses an electron beam to create nanoscale patterns as fine as 6 nanometers on wafers.
- A transmission electron microscope (TEM) that resolves images to 0.05 nanometers and allows the observation of reactions that take place under the microscope.
- An ultra-high-vacuum surface analysis system that identifies materials within a 5-micrometer area one molecular layer deep. This system also allows reactions to take place in the chamber and be analyzed without breaking vacuum.
- An optical pattern generator that creates photo masks for patterning silicon wafers. This instrument rests on a 4000-pound granite table in a lab that is specially lit to protect photo-sensitive images on the chips.
- A $2-million reactive ion etcher that uses high-energy plasma to create ions to selectively etch a pattern into a wafer.
- Two deposition systems enabling researchers to add thin films with atomic layer precision.
- Systems that allow the deposition of 24 different materials on virtually any surface that will withstand a vacuum. Materials include a wide variety of metals and dielectric materials.

Utilities

Highlighting the tour for Bunzow was the portion related to basic support facilities (heating, ventilating, and air conditioning; hazardous materials; nanotechnology-grade water; etc.) and the amount of space provided for these facilities compared to the cleanroom spaces they support. "I would love to have had that kind of space available during our planning and implementation phases," he said of the CNSE.

Utilities are distributed to the cleanroom via a subfab that houses vacuum pumps and other contaminating equipment. Support functions that can be performed without cleanroom garments are located in the subfab when practical. To control vibration in the cleanroom above, the subfab features dense column spacing and poured-concrete wing walls for structural rigidity. A deep waffle slab forms the cleanroom subfloor, yielding an NIST-A vibration rating.

A penthouse above the cleanroom houses the recirculation and make-up air handlers. The recirculation handlers use a multiple-fan system that provides redundancy in event of fan failure and eases maintenance of the fans.

Standard utilities include clean power, standard power, and instrument ground; process vacuum; bulk gases (nitrogen, oxygen, helium, argon); on-site generated hydrogen; cooling water; and liquid nitrogen. Other utilities, such as higher voltages and currents, and specialty gases (inerts, toxics, flammables, and pyrophorics), are made available as needed.

The ultrapure water system produces nano-grade water, meeting purity specifications of < 15 parts per trillion (ppt) boron; < 225 ppt total oxidizable carbon (TOC); and 1 part per billion dissolved oxygen.

IEST connection

IEST President and tour participant Chuck Berndt summed up the view of many visitors in describing the Birck Center as "a very impressive, state-of-the-art, multidisciplinary research facility serving the cutting edge needs of a wide variety of nanotechnology-related research and development objectives.

"Most interestingly," observed Berndt, "work currently underway at IEST is reflected by some of the operations of the BNC. For example, Recommended Practices and Guidelines under development at IEST include *Considerations for Planning, Design, Construction, and Operation of Facilities Established for Research or Production at the Nanometer Scale* and *Nanotechnology Safety: Applying Prevention through Design Principles to Nanotechnology Facilities*. Efforts such as these replicate the insight and technical excellence that the BNC has so effectively demonstrated."

Reference

1. Weaver, John R. 2005. A Design for Combining Biological and Semiconductor Cleanrooms for Nanotechnology Research. *Journal of the IEST* (48) 1: 75-82.