Birck Nanotechnology Center Technical Overview

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Birck Nanotechnology Center Technical Overview*

(*note: please see EVPRP e-Pubs site UNIVERSITY RESEARCH CORE FACILITY DESCRIPTIONS for bulleted core facility text on the Scifres Nanofabrication Laboratory: https://docs.lib.purdue.edu/ovprcores/15/)

The Birck Nanotechnology Center (BNC) is an interdisciplinary research unit that provides infrastructure for 160 affiliated faculty members and their research groups from 36 academic units at Purdue. The 187,000 sq ft. facility includes a 25,000 sq ft. ISO Class 3-4-5-6 (Class 1-10-100-1000) nanofabrication cleanroom – the Scifres Nanofabrication Laboratory – that includes a 2,500 sq. ft. ISO Class 6 (Class 1000) pharmaceutical-grade biomolecular cleanroom. In addition to the cleanroom, the facility provides about the same number of square feet of specialized laboratories and offices for 60 resident faculty members, 30 post-docs, 30 staff, and approximately 220 graduate students. Much of the equipment in the BNC is shared, and is accessible to qualified and trained users from Purdue and from academic, industrial, and government laboratories outside Purdue. Most of the major equipment is available through recharge centers that support maintenance, supplies, and support staff.

The Scifres Nanofabrication Laboratory

Cleanroom. The nanofabrication cleanroom consists of 25,000 sq. ft. of bay-chase cleanroom, with 20% of the bays operating at ISO 3 (Class 1), 50% operating at ISO 4 (Class 10), 15% operating at ISO 5 (Class 100), and the remaining 15% operating at ISO 6 (Class 1000). The three-level structure consists of a full subfab, the cleanroom level, and an air-handling level above the cleanroom. A perforated raised floor ensures unidirectional airflow and bulkhead-mounted equipment separates operational functions from maintenance functions. A combination of careful control of the airflow path, multiple stages of filtration, careful choice of materials, and non-ionic-steam humidification ensure the control of both particulate and molecular contamination. A very tight waffle slab provides NIST “A” vibration rating, approximating quiet, slab-on-grade construction.

Lithography. Lithographic capability spans the nano- and micro-scale, with the capability of integrating nanoscale structures within micro-scale devices. A JEOL 8100 electron-beam lithography system provides the capability of 6 nanometer lines in resist and a Raith e-beam nanolithography system provides 20 nanometer resolution. A Heidelberg MLA 150 maskless lithography laser system is used for linewidths down to 1.0 µ on optical photomasks and directly on wafers. A nanoinprint-lithography tool replicates images created on the e-beam lithography system.

Optical lithography is used in many operations in BNC, and is supported by Suss contact aligners, spinners, and a Suss wafer bonder.
**Etching.** Wet- and dry-etch capabilities allow the etching at high aspect ratios in a variety of materials. Two STS Deep Reactive Ion Etch (DRIE) systems, a Panasonic chlorine-fluorine DRIE, a xenon difluoride etcher, and a PlasmaTherm system anchor the dry-etching capabilities. A Branson asher removes photoresist by use of an oxygen plasma, and two general purpose March Jupiter etchers are available to researchers. Several conventional acid and solvent hoods, as well as two high-temperature-acid hoods, provide space for wet etches and cleans.

**Deposition.** Physical vapor deposition is a strength in the BNC. Eight evaporators and six sputterers allow the deposition of more than 24 different materials. Additionally, plasma-enhanced deposition systems and an LPCVD system provide further capabilities. Of special interest are four atomic-layer-deposition (ALD) systems designed especially for high-integrity high-k dielectric films.

**Furnaces.** Three three-tube banks of process furnaces include clean (i.e., gate) oxidation, drive, LTO, and LPCVD capabilities. This is supplemented by a separate two-tube pyrogenic oxidation system and several smaller high-temperature tubes and lower-temperature annealing tubes. Low temperature annealing and activation can be performed on three rapid-thermal-processing systems.

**Ultra-Pure Water.** The ultra-pure water (UPW) system at BNC supplies all laboratories and the cleanroom with incredibly pure water. Termed nano-grade water, this water is below the measurement limits of 15 parts per trillion of boron, the ion most loosely bound to the mixed beds and therefore the most likely ionic impurity in the water. This water also contains less than 225 parts per trillion of total oxidizable carbon (TOC) and less than 1 part per billion of dissolved oxygen.

**Biocleanroom.** Integrated into the Scifres Nanofabrication Laboratory is a pharmaceutical-grade cleanroom to allow sterile processing. This cleanroom is entered through a separate gowning room and has a completely separate air-handling system, but has a pass-through to the nanofabrication cleanroom to allow materials to be transferred into this facility without compromising cleanliness. Designed for sanitization, it trades a perforated floor for coved sheet-vinyl flooring and boasts a special pharmaceutical wall and ceiling system. Outside the entrance to the biocleanroom is an enclosed overhead walkway to Bindley Bioscience Center.

**Specialized Laboratory Facilities**

In addition to the cleanroom, the BNC includes a suite of specialized laboratories that provide outstanding capabilities to researchers. All BNC laboratories are designed for low acoustic noise, less than 1 milligauss EMI, and +/- 1 degree C temperature stability. Additionally, the first-floor laboratories achieve NIST A vibration rating. From this base, certain laboratories have been modified to provide even more stringent limits to accommodate specialized needs. For example, the TEM laboratory has tighter temperature controls, has specialized airflow patterns, and has special acoustic materials on the walls and floors.

**Hall Nanometrology Laboratory.** For highly sensitive functions, the Kevin G. Hall Nanometrology Laboratory provides enhanced control of temperature, vibration, acoustic noise, and EMI. Temperature is controlled to +/- 0.01 degree C, EMI is controlled to less than 0.1 milligauss, acoustic noise is within NC-35 criteria, and vibration is controlled to NIST A-1 criteria.

**Scanning Laser-Doppler Vibrometry.** A specialized laboratory that meets NIST A-1 vibration criteria houses the Scanning Laser-Doppler Vibrometer. The Polytec MSA-400 Micro System Analyzer uses a variety of methods to characterize motion in micro- and nanostructures.
**Scanning Probe Microscopy.** Nine atomic force microscopes provide topographical data on surfaces as well as allowing the manipulation of materials at the nano scale. Two systems are designed especially for analyzing biological samples, with one located in a BSL-1 laboratory and the other in a BSL-2 laboratory.

**Electron Microscopy.** Four electron microscopes provide the ability to image nanoscale devices and materials, as well as to study reaction mechanisms at the atomic scale. A Fisher Scientific double aberration-corrected Field Emission Environmental Transmission Electron Microscope – Scanning Transmission Electron Microscope provides single-atom resolutions. The system contains an in-situ reaction chamber, and is equipped with a high-performance camera and data server.

Supplementing the capabilities of the TEM are a Fisher Scientific Apreo low-voltage Field-Emission Scanning Electron Microscope, a Helios Focused Ion Beam – Scanning Electron Microscope system, and a JEOL table-top general purpose SEM.

**Surface Analysis.** The surface analysis laboratory contains a Kratos Imaging x-Ray Photoemission Spectrometer (XPS) with an in-situ reaction cell and an Omicron surface analysis cluster tool. The XPS has a 15 micrometer spot size, and provides atomic-level analysis of materials. The cluster tool contains multiple devices to characterize the surfaces of materials, including a high-resolution electron-energy-loss spectrometer (EELS), a scanning electron microscope (SEM), a scanning auger spectrometer, a hemispherical electron spectrometer for XPS, AES, UPS, ISS, a focused ion beam (FIB) system and an Omicron UHV Scanning Tunneling Microscope – all connected under ultra-high vacuum. An inert atmosphere glove box is available for sample preparation in inert conditions.

**X-ray Diffraction.** The x-ray diffraction laboratory contains a high-resolution PANalytical “x”Pert Pro x-ray diffraction system with a heated chuck accessory.

**Epitaxy.** The BNC laboratories contain equipment for specialized, highly precise epitaxial growth. Two ultra-clean Molecular Beam Epitaxy systems for III-V epitaxy, an Epigress VP-508 hot-wall CVD reactor for SiC and graphene.

**Deposition.** Axic PECVD and PlasmaTherm High Density plasma-enhanced chemical vapor deposition systems allow film growth of specialized materials. A specialized Parylene deposition system deposits type C and N polymer onto a variety of substrates.

**Biosafety Level 2 Laboratories.** The BNC has five biosafety level 2 (BSL-2) laboratories. The biocleanroom also houses a small BSL2 cell culture room for work requiring live cells in a pharmaceutical-grade environment. These specialized laboratories allow for the safe handling of pathogenic biological materials used in the development of devices and delivery methods. One of the BSL-2 laboratories is dedicated to human/mammalian cell culture, including human and animal blood and tissue, while another is dedicated to bacterial culture work.

**Biosafety Level 1 and Nanochemistry Laboratories.** The BNC provides three laboratories rated at biosafety level 1 (BSL-1) for less hazardous nano-bio and nanochemistry research – including the main biocleanroom space. These laboratories are used for both mechanical and wet-chemical research activities.

**Electrical Characterization Laboratories.** A significant amount of BNC laboratory space is allocated to electrical characterization. From an 8 Tesla, liquid-helium-cooled Hall Effect measurement system to multiple shielded probe stations with hot and cold testing capabilities, these laboratories provide the equipment and facilities necessary to evaluate new materials, structures, and devices. We also offer a Lakeshore planar magnetic probe station.

**Laser Laboratories.** Specialized laboratories for optical materials development, optically enhanced deposition, and optical characterization methods have been implemented in the BNC. Using lasers of various power levels – up to Class 4 – BNC researchers are able to develop materials, processes, and devices for energy conversion and other applications. These laboratories also support research strengths
in nanoelectronics and nanophotonics.

**Roll-to-Roll Nanomanufacturing.** A newly created laboratory is dedicated to mid-volume nanomanufacturing utilizing roll-to-roll processing tools. A plasma-enhanced deposition tool, and micro/nanogravure system, and a 3D printing system comprise the fabrication tool set. Additionally in the cleanroom E-Bay is a 40-Ft extremely versatile roll-to-roll system with a variety of optional capabilities including electric and magnetic field alignment, electrospinning, various drying techniques and other capabilities.

**3D Cell Culture.** The BNC provides a laboratory area and two isolated cell-culture rooms for 3D cell culture, allowing a more authentic representation of biological structures.

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