WIMS Center Facilities

Micro- and Nanofabrication Facilities

The University of Michigan Robert H. Lurie Nanofabrication Facility

The Lurie Nanofabrication Facility (LNF) in the College of Engineering began operation in September 1986 and today offers complete capabilities for the fabrication and characterization of solid-state materials, devices, and circuits using silicon, compound semiconductors, and organic materials. The LNF supports research on integrated photonics and optoelectronics, organic and molecular electronics, optical displays, microwave devices and circuits, semiconductor materials and metrology, nanotechnology and nanofabrication, integrated circuits, solid-state sensors and actuators, microelectromechanical systems (MEMS), and integrated microsystems. Research in compound semiconductors focuses on the growth and characterization of wide- and narrow-bandgap semiconductors, new high-speed and microwave device structures, optoelectronics, and millimeter-wave heterostructure devices. Work in integrated photonics and optoelectronics includes III-V semiconductor growth by molecular beam epitaxy, self-organized quantum dots, photonic crystal devices for quantum computing, single-photon light sources, and integrated bio-photonics. Research in organic and inorganic thin-film devices focuses on thin-film transistors, integrated circuits and light-emitting devices on glass and plastic substrates, hydrogenated amorphous silicon thin-film transistors for flat-panel displays and sensors, and active-matrix organic light-emitting displays. Research on integrated circuits includes low-power, high-precision sensor interface circuits, ultra-low-power embedded computing, wireless telemetry, and high-speed, analog-to-digital converters. A major focus of the LNF is research on microsystems, merging low-power electronics with high-frequency MEMS resonators, inertial devices (accelerometers, gyros), integrated physical and chemical sensors, microfluidic cell sorting and diagnostic systems, implantable biomedical sensors, neural interfaces, environmental monitoring systems, energy scavenging systems, and advanced wafer-level hermetic packaging. Thus, the LNF supports a

very broad array of technologies and processes for programs that address a wide number of important national priorities.

The LNF is supported by a laboratory manager, 4 area supervisors, and 18 engineers. Additional staff provide direct support for various research programs. Graduate students perform most of the processing in the LNF as part of their doctoral thesis projects.

The Lurie Nanofabrication Facility.

One of the new cleanroom bays in the expanded LNF.

The original LNF consisted of 7,000 square feet of Class 100/10 work area located in five process bays and in rooms dedicated to lithography, metrology, and materials growth. The LNF was recently expanded by adding 5,000 square feet of new cleanroom backed up by 38,000 square feet of new state-of-the-art infrastructure space. This expansion was supported entirely by gifts to the University and is now being equipped to support microsystems research and nanotechnology. The new equipment includes 20 diffusion/oxidation-CVD furnaces, two STS Pegasus DRIE systems, 2 AM P5000 cluster tools for CVD and dry etching, facilities for carbon nanotube growth, a state-of-the-art electron-beam lithography system, and an imaging SEM capable of sub-10nm resolution.

The following table summarizes the fabrication, packaging, and testing capabilities in the LNF. A more detailed list of equipment is available at **www.LNF.umich.edu.**

Summary of Major Equipment and Capabilities in the LNF

New equipment added in 2009 shown in bold italic.

Technology	Equipment	Comments/Capabilities
Lithography	Suss MA-6 & MA-45, MJB3 2 Electronic Vision 620 Raith 150 E-Beam System ***E-beam Lithography System*** Suss ACS 200 GCA I-Line Stepper	Contact, Min. Feature 1.5μm Double-Side Alignment/Lithography Direct-Write E-Beam, <100nm ***State-of-the-Art Lithography, <10nm*** Bond Alignment Automated Photoresist Coat/Develop
Diffusion/Oxidation/ Annealing	17 Thermco Furnaces 4" Wafers, Auto-Load Rapid Thermal Processing ***10 6" Tempress Furnaces***	P and B Diffusion Field and Gate Oxidation Contact Annealing ***Diffusion/Oxidation/CVD***
LPCVD	3 Thermco 4" Furnaces ***10 Tempress 6" Furnaces***	LPCVD Nitride/Oxide, LTO, Poly ***LTO, Poly, Doped Poly, TEOS,. . .***
PECVD	2 PECVDs ***1 AM P5000 Cluster Tool***	Low-Stress SiN, Doped Poly, LTO ***CVD, 4 Chambers***
PVD Thin-Film Deposition	4 E-Beam Evaporators 2 Sputtering Systems ***Sputtering Films System*** ***SCS PDS 2035 System***	Evaporate Metals, Sputter Metals, Dielectrics, Compounds ***AIN Deposition System*** ***Parylene Deposition***
Dry Etching	9 Dry Etch Systems Plasma, RIE, DRIE, ECR 1 XeF_2 Etcher 1 Trion Oracle RIE ***2 STS Pegasus DRIE*** ***1 AM P5000 Cluster Tool*** ***Hitachi 308 Etcher***	Standard RIE for Various Materials 1 Deep Si RIE Etching (STS) 1 ECR Nanoetching Photoresist Ashers, Wax Etching ***Deep Silicon Reactive Ion Etching*** ***Dry Etching, 4 Chambers*** ***Metal Etching***
Wet Processing	6 Wet Benches	Standard Wafer Clean and a Variety of Wet Chemical Processing
Wet Si Etching	Hoods and Benches	EDP, KOH, TMAH, and HF/HNO_3
Metrology	1 Zygo, 1 Flexus, 2 Spectrometers, 2 Elipsometers, 3 Profilometers Nikon Microscopes ***1 Veeco Nanoman AFM*** ***Hitachi HR Imaging SEM***	Wafer Surface Topography Wafer Stress Measurement Film Thickness Measurement Film Metrology
Mask Making	Optical PG	Feature Sizes Down to 1.5μm
Wafer Bonding	EVG 501s Bonder Suss SB-6e Bonder ***EVG 510 and 520IS*** Suss np12 nanoPrep Suss CL200 Cleaner	Silicon-Glass Bonding in Vacuum Si-Si: Fusion, Eutectic, Polymer ***Wafer Bonders***
Materials Growth	3 MBEs, 1 MOCVD, 1 VPE ***FirstNano 3000***	Growth of All Compound Semiconductor Materials ***CNT Growth System***
Other Process Capabilities	Bake Oven, Critical Point Dryers, Rinser/Dryers, Polyimide Processing, Organic Processing Disco 150mm Dicing Saw	
Wire Bonding Packaging	Several Wedge and Ball Bonders, Solder Reflow	Standard Wire Bonding Solder Reflow, Vacuum Packaging
Electrical Tests	8 Probe Stations	Laser Cutting, Automated Testing
Environmental Testing	Humidity and Temperature Chambers, Autoclaves	Long-Term Testing and Characterization

In 2009, the LNF was used by 282 researchers (226 internal and 56 external) for a total of about 50,000 hours. These users represented 12 departments within the University of Michigan, 12 other universities, and 20 companies. There were also 26 remote users who had their processing done by LNF staff members. During the past decade, 18 startup companies have been launched by LNF faculty and students, building a high-tech critical mass that could dramatically improve the local, state, and national economies.

The LNF is one of 14 nodes that comprise the NSF-funded National Nanotechnology Infrastructure Network (NNIN). The NNIN is responsible for providing open access to the facilities of its member universities in support of all aspects of micro- and nanodevice fabrication, characterization, computation, and analysis. Like the WIMS ERC, the NNIN supports a number of outreach and educational programs and acts as a platform for addressing social-ethical issues involved in nanotechnology. The LNF provides expertise in general micro- and nanofabrication, MEMS, BioMEMS, integrated microsystems, packaging, circuit fabrication, and sensor-circuit integration to this network. More detailed information about the capabilities of the NNIN can be found on its Web site (**www.nnin.org**) or on (**www.LNF.umich.edu**).

Microfabrication Facilities at Michigan Technological University

The Microfabrication Facility (MFF) at Michigan Technological University (http://www.microfabrication.mtu.edu) continued to expand its technological capabilities in 2009 for micro- and nanosystem research. The facility increased its utilization again, and the number and type of system capabilities continued to increase through capital equipment purchases and equipment transfers from the University of Michigan Lurie Nanofabrication Facility.

An additional Mellen 3-zone benchtop furnace was installed and characterized for dopant diffusion during 2009.

Several enhancements were made to existing fabrication capabilities along with new instrument additions. The UV lamphouse and optics for the Electronic Visions Group EV620 photolithographic aligner were enhanced this year to increase UV light intensity twofold. The process automation of the two benchtop Mellen

The transfer of several well-equipped chemical processing stations from the University of Michigan's Lurie Nanofabrication Facility expands the MTU Microfabrication Facility's capability and scope.

furnaces was completed and the facility now boasts full process capabilities for atmospheric oxidation. Several wet chemical processing stations were transferred from the University of Michigan and have been facilitized in the MFF. DI water, process gas, and exhaust capabilities have been installed to these systems. New capabilities include a broad bandwidth J.A. Woollam V–VASE spectroscopic ellipsometer purchased to enable the characterization of photonic materials, and a Denton electron beam evaporator transferred from the University of Michigan.

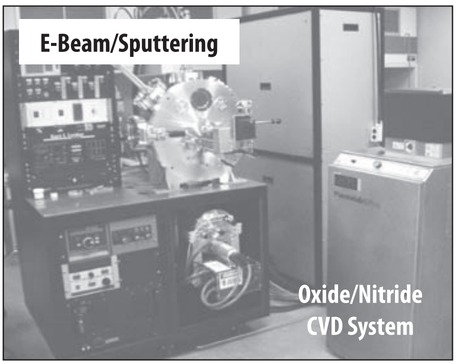
As in previous years, the Microfabrication Facility has been flexible with space requirements, completing the transfer of the testing and packaging laboratory space to Michigan Technological University's new Animal Care Facility for new space adjacent to the MFF's cleanroom laboratories. This relocation will be completed in January 2010, and serves as a net improvement in the facility utilization and efficiency. The buildout of the cleanroom by an additional 750 square feet is in planning, with an expected expansion build scheduled for late 2010, completed in 2011.

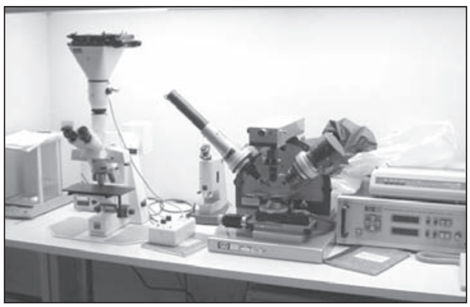
A Denton electron beam evaporator system replaces an aging Veeco thermal evaporator with improved process control.

Microfabrication Facilities at Michigan State University

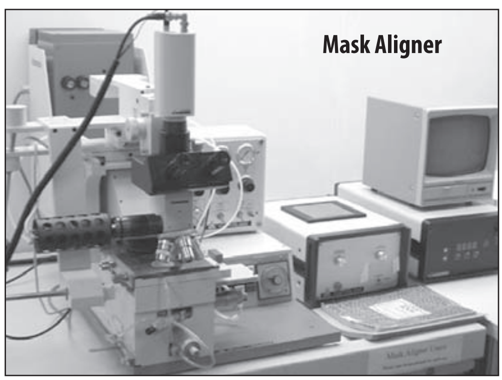
The major facilities used for WIMS research at Michigan State University are the Microfabrication Lab (cleanroom), Micro- and Nano-Technologies Laboratory (MANTL), and Sensor Interface Laboratory. During 2004, a major addition to MANTL was the RF-MEMS resonator test equipment. For the first time at Michigan State University, poly-C micromechanical resonators were tested in MANTL in the summer of 2004. This is one of a number of new research capabilities brought to MSU by the NSF WIMS ERC during the last six years.

The microfabrication facility is now equipped with an e-beam evaporator that has sputtering capability, an oxide/nitride deposition system, a dry etching system for diamond etching, a mask aligner, oxidation/annealing furnaces, an ellipsometer, and wet stations. A major upgrade of the cleanroom was completed in December 2006. New equipment and better air quality in the cleanroom is now available.





Ellipsometer, Microscope



Microfabrication (Cleanroom) Laboratory at MSU.

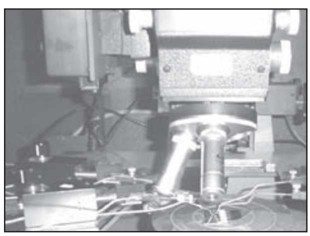
The MANTL is equipped with diamond and nanotube growth systems, a new Astex system for diamond growth that is under construction, a wire bonder, a portable chemical hood, a poly-C annealing chamber, test systems for nanotubes, RF-MEMS resonator test equipment, sensor interface chip testing, test facility for piezoresistive sensors, and testing WIMS packaging. Most of the equipment in MANTL was added during 2000–2004, using WIMS ERC and associated funding. MANTL is being used for poly-C and CNT research for WIMS, as a test facility for WIMS courses, for microsystems testing, and for innovative K–12 education projects. A new nanosensor test facility was added in 2005–2006. An important addition to MANTL in 2007 was new equipment for characterization of diamond neural probes.

Wire Bonder

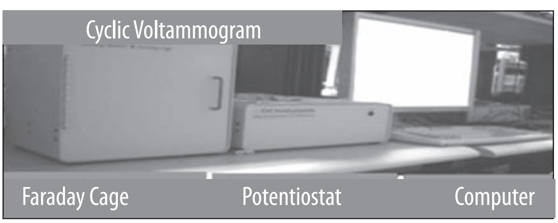
MPCVD System for
Poly-C and CNT Growth

RF-MEMS Test Station

Poly-C Annealing Chamber



Probe Station



Micro- and Nano-Technologies Laboratory (MANTL) at MSU.