UNIVERSITY OF LOUISVILLE

MICRO/NANO TECHNOLOGY CENTER

Micro/Nano Technology Center (MNTC)

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FY17 Annual Report

http://louisville.edu/micronano

Executive Summary

This document serves as the MNTC's official annual report for FY17 ending June 30, 2017. The University of Louisville's Micro/Nano Technology Center (MNTC) is a service center established in 2004. The class 100/1000 $30M 10,000 ft^2 cleanroom facility is used for fabrication of novel materials and devices. The facility includes a 1,000 ft^2 packaging and characterization lab with a 300 ft^2 design/layout/simulation lab for MEMS and IC devices. The University of Louisville faculty, other academic institutions and external businesses utilize the facility for research while the MNTC also provides micro and nanofabrication services well beyond its borders.

The principal highlight for FY17 was incorporation and upgrade of the Huson Nanotechnology Core Facility (HNCF) within the operations of the MNTC. This facility vastly added imaging and characterization capabilities to the MNTC, but for significant cost to the MNTC. Additional processing equipment was installed the cleanroom facility whereby the SPTS μetch vapor hydrofluoric acid etching system was implemented in the cleanroom and Chemical Mechanical Polishing was added to the packaging lab. Finally, the MNTC hosted a cleanroom experience for the Research Experience for Undergraduates (REU) program and one summer camp for high school students.

Personnel

Dr. Shamus McNamara, Director

Julia Aebersold, Ph.D., Manager

Evgeniya Moiseeva, Ph.D., Senior Process Engineer

Xiaojin Wang, Ph.D., Senior Process Engineer

Curtis McKenna, Research Engineer Scientist

Mary Watson, Business Manager

Education & Outreach

The MNTC was used as a laboratory for the ECE 544 and ECE 634 classes. The MNTC also hosted a summer camp in June for high school Sophomores, Juniors and Seniors. Students learned and performed similar microfabrication techniques used by the semiconductor industry, Figure 1. Fabrication processes were discussed for solar cells, gyroscopes, pressure sensors, temperature sensors and light emitting diodes that are incorporated in ubiquitous life functions. Additionally, students experimented with developing breadboard electronic circuits with electrical components to program the Arduino microcontroller. These lessons bridged how devices fabricated in the cleanroom can be integrated with devices such as the smart phone.

Figure 1. High school participants from the MNTC's summer camp and fabricated wafer.

Facilities and Infrastructure

The primary change to the MNTC was addition of the Huson Nanotechnology Core Facility (HNCF). This facility expanded the SEM imaging, AFM characterization and thin film ellipsometry capabilities of the MNTC. However, significant time, efforts were incurred to repair, upgrade, clean and provide training to the MNTC staff to make the facility in working order again. This does not include the $48,540 annual maintenance contract that was needed to keep both SEM tools functional. Facility Online Management (FOM) was also expanded on each tool in the Huson

Lab to incorporate physical interlocks for tool usage, sharing prevention and an adequate reservation system.

No major changes to infrastructure equipment or facilities were made in FY 2017 other than regular maintenance and replacements to aging equipment. However, it is noted that costs for infrastructure maintenance rose sharply due to the numerous failures of components that have been functioning since the facility opened in 2007. Appendix B contains a summary of the facilities maintained by the MNTC.

Due to the specialized needs of the cleanroom, the MNTC is directly and financially responsible for many systems that are typically serviced by Physical Plant in other buildings and at other academic institutions. Examples include the reverse osmosis (RO) and deionized (DI) water systems, air makeup and filtration systems, chiller for the air makeup handler, motorized exhaust systems, acid waste neutralization, compressed air and vacuum systems.

When the Shumaker Research Building was completed an agreement was developed with Physical Plant and Speed School of Engineering (SSoE) to support $32,000 of support were to be provided to pay for maintenance of these infrastructure items. These funds are not reflected in the financial section of this report, yet, all funds for infrastructure maintenance were consumed this past year and developed a deficit of $11,630. It is anticipated that costs will escalate as the infrastructure ages. Unfortunately, these funds will not be available in FY18 and will negatively affect the operations of the facility.

Research Equipment

With support of the Kentucky Multi-Scale Manufacturing and Nanointegration Node (KYMMNIN) and the National Nanotechnology Coordinated Infrastructure (NNCI) the MNTC installed a vapor hydrofluoric acid isotropic etching system. The SPTS μetch system was installed in the cleanroom during FY17, Figure 2.

Figure 2. The newly installed SPTS μetch system that can perform etching with hydrofluoric acid in a vapor form.

A Logitech CCP chemical polishing system was donated to the MNTC by an external client and installed this past year in the packaging lab room 213, Figure 3. Addition of this tool helped increase the suite of processing capabilities for MNTC enabling one external client to move most of their processing efforts to the MNTC from another cleanroom facility. Strengthening of this type of relationship is foreseen as an essential key to the future growth of the MNTC.

Figure 3. The donated Logitech CCP mechanical polishing system installed in the packaging lab of the MNTC.

Appendix A has a listing of the equipment in both the cleanroom, packaging lab and the Huson Lab. Systems in the cleanroom require regular maintenance and consume significant amounts of chemicals, gases and supplies. The MNTC employs experienced engineers that maintain and repair most issues that arise. On occasion, an OEM vendor or 3rd party contractor will be brought to the facility to service equipment.

Facility Usage

The MNTC is utilized by both internal and external users. Faculty that perform research with the MNTC have post-doctoral or graduate students trained on tools needed for their process. When time, experience or logistical issues arise then the MNTC staff is utilized to process for internal and external clients. During FY17 the MNTC continued to experience external revenue outpacing internal revenue for the second straight year, Table 1.

Table 1: Percent usage of the cleanroom calculated from revenue.

External Clients	54.5 %
Internal Clients	45.5 %

Usage of the cleanroom is the monitored by access entries into the facility, with exception to staff entries, and the center's Facility Online Management (FOM). Access fees are only counted and charged once per 24-hour period regardless of the number of entries. Tables 2 and 3 show the number of entries per month for internal users and by department. A marked increased is noted of 24.3% for FY16 of 649 entries as compared to FY17 of 857. The increase was attributed to new usage of the cleanroom by the Mechanical Engineering, Electrical & Computer Engineering departments and the external start-up company.

Table 2. Individual entries per month into the cleanroom.

Name	Advisor	Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	Total
ASPT (Advanced Semiconductor Processing Tech)									2		1	3		6
Intelligent Data Recovery	Ext (Former AC	1	2	1	1			1	2	2	1	1		12
Pouya_Ethal	Nauganeedles	1												1
Beharic_Jasmin	Harnett (ECE)	1		9	2	1		2					1	16
ECE634	Walsh (ECE)													0
Marei, Mohamed	Chromatograpy		4	3	1	1			1	2				12
Wu_Yan	Yang (IE)						2							2
Harnett_Cindy	Harnett (ECE)						1		2					3
Hickman Robert	Sunkara(CHE ENG)		5											5
Allegier, Brian	Berfield (ME)	4	6	7	14	10	7	12	13	1	9	14	13	110
Hoveyda Farzan	Smadici (PHY)	1					4	7						12
Kaht, Kelsey	Baldwin (CHEM)	3		1		1				1	1	3	11	21
Sowmya, Kolli; Lin George	Alphenaar (ECE)	9	8	2	1				8	10	5	9	10	62
Larin_Alexander_A	Dobrokhotov(PHYS)	3	3	3	2	1		3	1		1	2		19
Li_Qi	Fu (CHE ENG)		2	2		4	2		1	1	2			14
ECE	Alphenaar (ECE)		2	14	8	20					3	2		49
Zhang, Ruoshi	Popa (ECE)		6				5		6	9	7	3		36
MEMStim, LLC	Ext	7	6			3	9	14	10	17	27	41	42	176
Marei_Mohamed_M	Keynton (BE)		1											1
Ogunwale_Mumiye_A.	Fu (CHE ENG)													0
Baptist, Joshua	Popa (ECE)	6	7		4	8	8	3	2	1	7	1	7	54
Wei, Danming	Popa (ECE)	17				5		1	6	8	5	9		51
Ratnayake_Dilan	Walsh (ECE)	7	3	3	2	1	1							17
Senousy, Yehya	Fu (CHE ENG)		5	1	7	9								22
Shuvra_Pranoy_Deb	Alphenaar (ECE)	12	19	11	19	6		16	5	8	12	7	1	116
Smadici_Serban	Faculty (PHY)													0
McGrady, Garrett	Walsh	3											1	4
	Walsh (REU)											3	8	11
Vaon											1	3		4
White, Robert	Spurgeon (CC)/CH													0
Wu_Yan	Yang (IE)							1						1
	Kopechek (BE)								1					1
Rashed, Mohamed	Williams (ME)	4				3			1				6	14
	Yang, Zhong (ECE)										1			1
Yuan_Hanwen	Keynton (BE)				1		2				1			4
		79	79	57	62	73	41	60	61	60	84	98	100	857

Table 3. Cleanroom entries by department and external clients.

IE	3
ME	124
CHE ENG	41
BE	6
ECE	420
EXT	211
CHEM	21
PHY	31
	857

The MNTC's equipment is reserved, schedules and accessed by using FOM. During the fiscal year the number of tools controlled by FOM was increased to provide additional data and provide a more complete picture of utilization in the cleanroom. Figures 4 and 5 show equipment usage captured by FOM during FY17 for the cleanroom, packaging lab and Huson lab. Each entry represents one equipment reservation per day by person, regardless of the duration used or number of wafers processed.

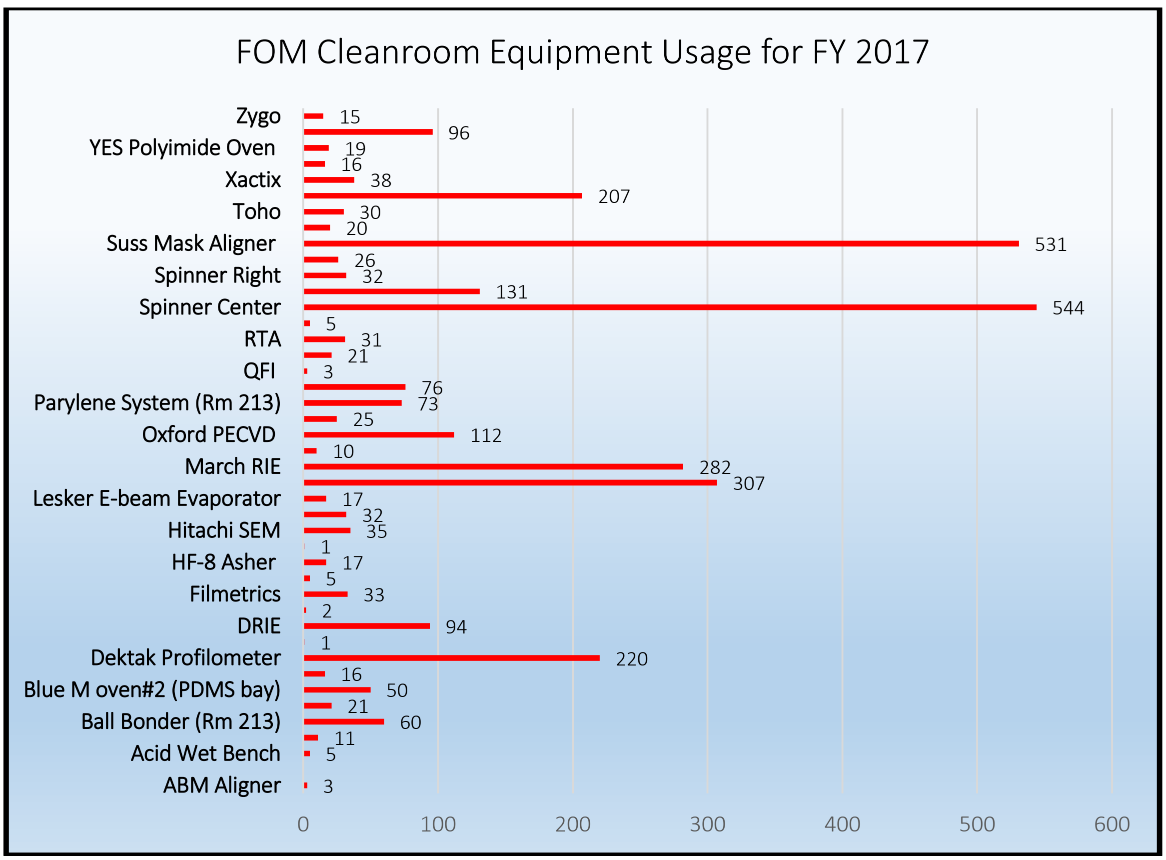

Figure 4. Annual utilization of tools in the cleanroom and packaging lab from the FOM system.

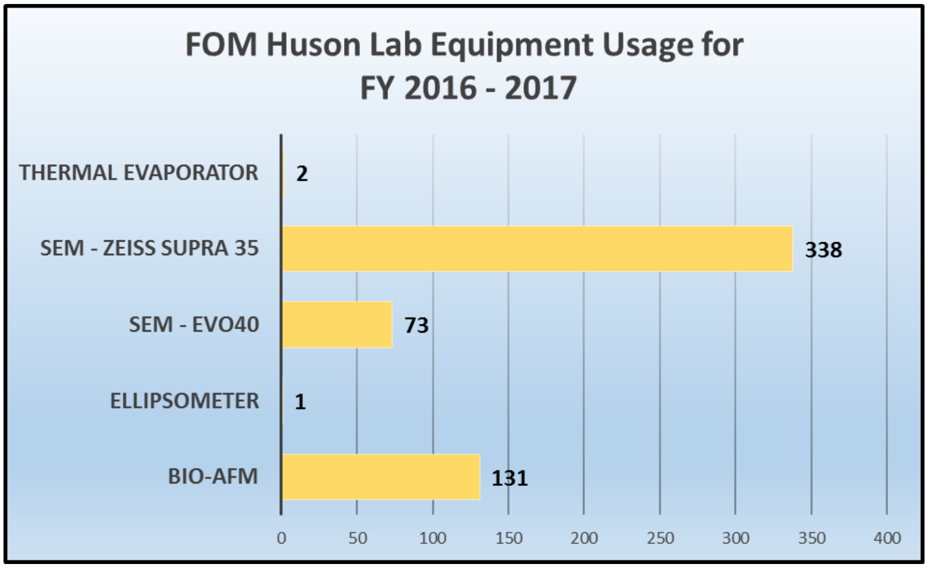

Figure 5. Annual utilization of tools in the Huson Lab from the FOM system.

Financials

The MNTC ended FY17 with a deficit of ($9,637.93). This is in contrast to previous years of ending with a surplus due to heavily investing in operations of the Huson Lab that included system upgrades, training and the $48,540 SEM maintenance contract. Overall revenue and expenses for the MNTC are listed in Table 4. Expenses outpaced revenue by ($32,637.60) which again were primarily attributed to expense overruns in the Huson Lab.

Table 4. Overall revenue and expenses for FY16

Revenue	$221,482.23
Expenses	$254,119.83

Revenue

Revenue is derived from two categories of internal and external revenue. Table 5 lists revenue by internal and external clients. Table 6 is a breakdown of revenue by internal clients and their accompanying departments.

Table 5. FY16 revenue from internal and external clients.

External Revenue	$ 120,730.00
Internal Revenue	$ 100,752.23
Total	$ 221,482.23

Table 6. FY16 internal revenue sources by client and department.

INTERNAL REVENUE		Jul-16	Aug-16	Sep-16	Oct-16	Nov-16	Dec-16	Jan-17	Feb-17	Mar-17	Apr-17	May-17	Jun-17	TOTALS
TOTAL		**$ -**	**$ 25,199.30**	**$ 11,707.90**	**$ 641.00**	**$ 7,787.40**	**$ 14,775.53**	**$ 10,171.30**	**$ 7,807.20**	**$ 2,584.90**	**$ 584.00**	**$ 9,481.00**	**$ 10,012.70**	**$ 100,752.23**
Alphenaar	ECE		$ 5,950.10	$ 4,427.00		$ 2,165.90	$ 2,831.30		$ 4,136.40			$ 895.00	$ 3,094.10	**$ 23,499.80**
Baldwin	CHEM		$ 431.20	$ 590.30		$ 60.00		$ 25.00		$ 290.00	$ 150.00	$ 25.00	$ 125.00	**$ 1,696.50**
Bara	BIO								$ 45.00					**$ 45.00**
Berfield	ME		$ 588.00	$ 586.60		$ 637.10	$ 3,529.20	$ 1,199.30	$ 1,500.00				$ 2,314.40	**$ 10,354.60**
Burns	CHEM													**$ -**
Cohn	ECE		$ 30.00											**$ 30.00**
ECE Class	ECE							$ 5,517.00					$ 1,926.90	**$ 7,443.90**
Fried	CHE ENG													**$ -**
Fu	CHE ENG		$ 170.00	$ 1,103.80		$ 183.60	$ 2,513.50	$ 254.00				$ 455.70	$ 45.00	**$ 4,725.60**
Grapperhaus	CHEM		$ 395.00	$ 45.00			$ 45.00	$ 45.00					$ 151.40	**$ 681.40**
Gutierrez	PHYSICS													**$ -**
Harnett	ECE		$ 687.60		$ 381.00	$ 857.40	$ 339.00	$ 116.80	$ 344.00			$ 205.20		**$ 2,931.00**
Keynton	BE		$ 25.00	$ 25.00		$ 367.30	$ 47.33	$ 50.00		$ 45.00		$ 25.00	$ 125.00	**$ 709.63**
Kopechek	BE					$ 1,086.00		$ 195.00		$ 115.00				**$ 1,396.00**
Lian	ME											$ 387.00		**$ 387.00**
Mashuta	CHEM													**$ -**
McNamara	ECE													**$ -**
O'Callaghan	Ath/Golf											$ 792.00		**$ 792.00**
Park	ME													**$ -**
Popa	ECE		$ 3,619.10	$ 418.00	$ 45.00	$ 844.80	$ 2,590.80	$ 2,569.20	$ 518.20	$ 1,075.00	$ 59.00	$ 3,895.20	$ 1,164.20	**$ 16,798.50**
Remold	BIO					$ 45.00								**$ 45.00**
Smadici	PHYSICS													**$ -**
Soucy	BE		$ 45.00				$ 90.00					$ 45.00		**$ 180.00**
Spurgeon	ConnCtr				$ 35.00									**$ 35.00**
Stolowich	CHEM		$ 180.00	$ 45.00	$ 45.00	$ 45.00	$ 45.00		$ 45.00			$ 90.00		**$ 495.00**
Sunkara	CHE ENG		$ 3,102.20	$ 3,863.40		$ 449.50				$ 789.90		$ 1,565.20		**$ 9,770.20**
Walsh	ECE		$ 6,899.70	$ 378.80		$ 910.80	$ 87.50						$ 105.00	**$ 8,381.80**
Williams	ME		$ 821.40				$ 2,476.90		$ 968.60			$ 263.70	$ 916.70	**$ 5,447.30**
Worley, Micah	BIO			$ 90.00									$ 45.00	**$ 135.00**
Yang	IE							$ 110.00	$ 25.00		$ 375.00	$ 432.00		**$ 942.00**
Yanoviak	BIO		145.00											**$ 145.00**
Zamborini	CHEM		$ 1,795.00											**$ 1,795.00**
Zhang	CHEM		$ 315.00	$ 135.00	$ 135.00	$ 135.00	$ 180.00	$ 90.00	$ 225.00	$ 270.00		$ 405.00		**$ 1,890.00**

Among faculty that utilize grants to pay for their facility activity in the MNTC, Table 7, is a comparison of their overall awards with revenue accumulated by the MNTC. This is reflective of research activity where an overall leverage factor of 106.60 can be calculated to show how the facilities help gain awards for faculty for research funding.

Table 7. Grant awards utilized by the faculty as compared to revenue and calculated leverage factor.

	Grant Award	**MNTC Revenue**	**Leverage Factor**
Alphenaar	$ 1,050,000	$ 23,499.80	44.68
Berfield	$ 332,757	$ 10,354.60	32.14
Fu	$ 749,342	$ 4,725.60	158.57
Grapperhaus	$ 420,000	$ 681.40	616.38
Harnett	$ 255,228	$ 2,931.00	87.08
Walsh	$ 1,272,164	$ 8,381.80	151.78
Williams	$ 1,274,398	$ 5,447.30	233.95
Yanoviak	$ 600,000	$ 145.00	4137.93
Zamborini	$ 390,000	$ 1,795.00	217.27
Zhang	$ 36,458	$ 1,890.00	19.29
Total	$ 6,380,347	$ 59,851.50	106.60

Expenses

Expenses incurred by the MNTC are listed in Figure 6 for a total of $100,752.23. Equipment expenses, $67,433.14, were the highest category this year due to maintenance and repair of existing equipment. The second highest category was Equipment Maintenance or Huson Lab expenditures at $61,295.22.

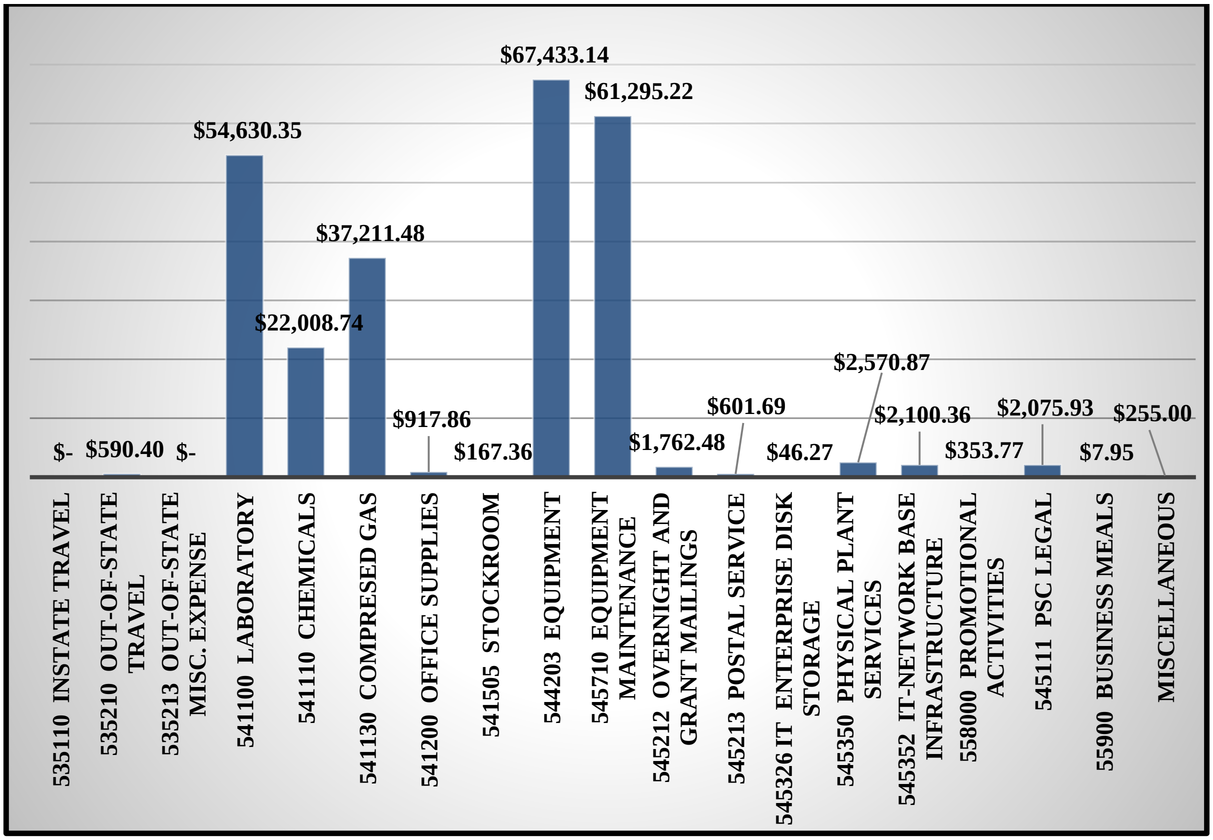

Figure 6. Itemized expenses for FY16.

Historical Perspective and Future Trends

Figures 6 and 7 show historical data of revenues and expenses for the lifetime of the MNTC since 2004. It is noted that the current cleanroom did not come online until 2007 in the Shumaker Research Building after it was moved from Lutz Hall.

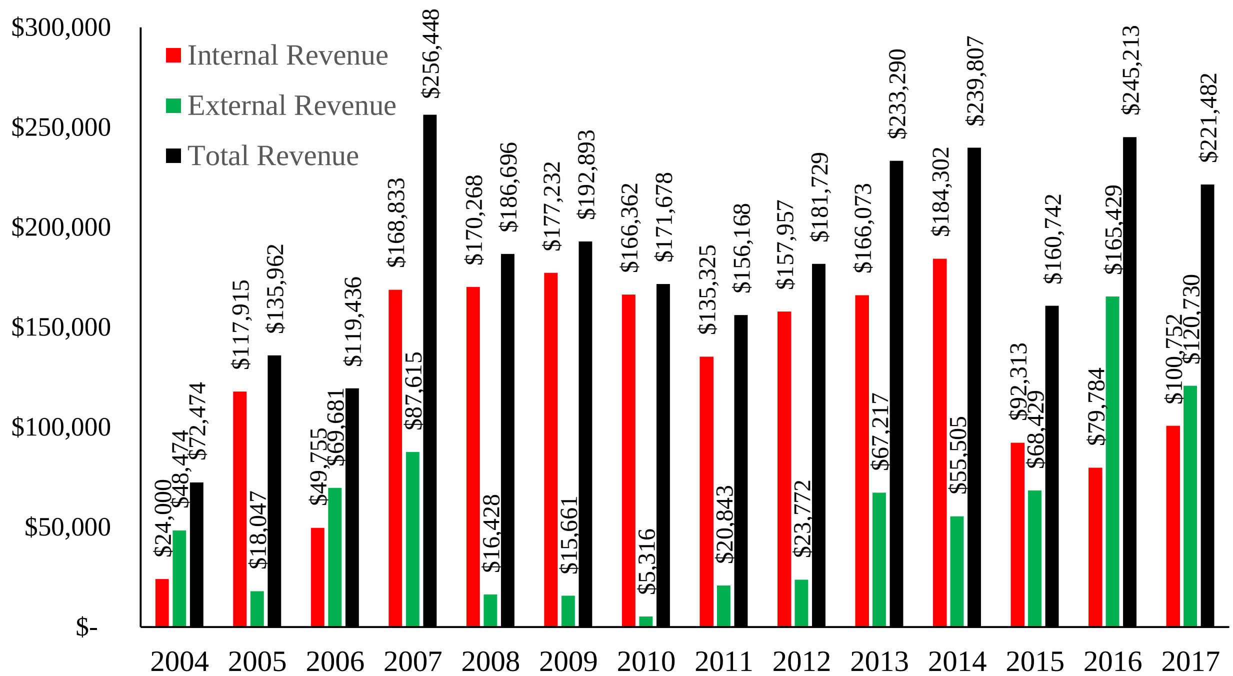

Figure 6. A comparison of internal and external revenue over the life time of the facility.

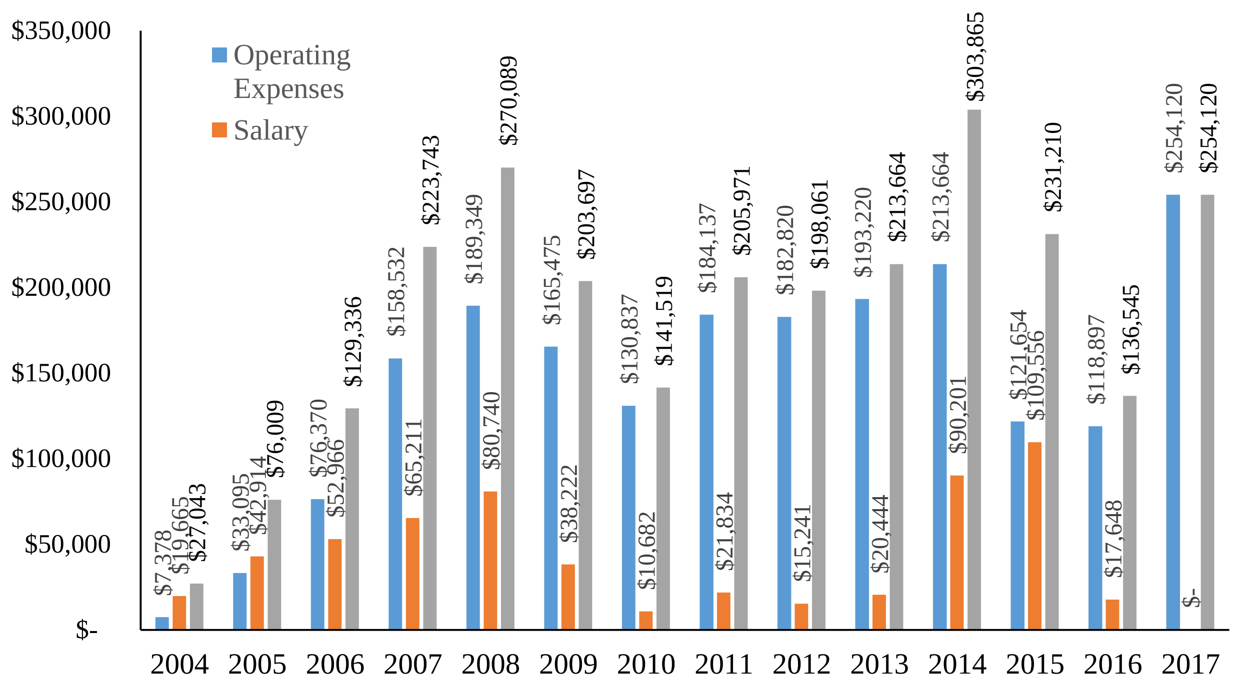

Figure 7. A comparison of expenses over the life time of the facility.

There are several conclusions that may be drawn from Figures 3. First, generated external revenue outpaced internal revenue for the second straight year and external revenue is somewhat lower than the record previous year. This is attributed to a prominent contract ending in FY16 and the

MNTC achieving exceptional customer service. Second, internal revenue shows increased activity attributed to new faculty utilizing the facility and bringing operations of the Huson Lab onboard with the MNTC.

Figure 8 shows a small decline of internal clients or students using the facility, but the number of faculty have risen due to the MNTC staff performing service work for the faculty rather than utilizing graduate students. A small increase in the number of external clients is a welcomed trend that is desired to keep growing in the oncoming years.

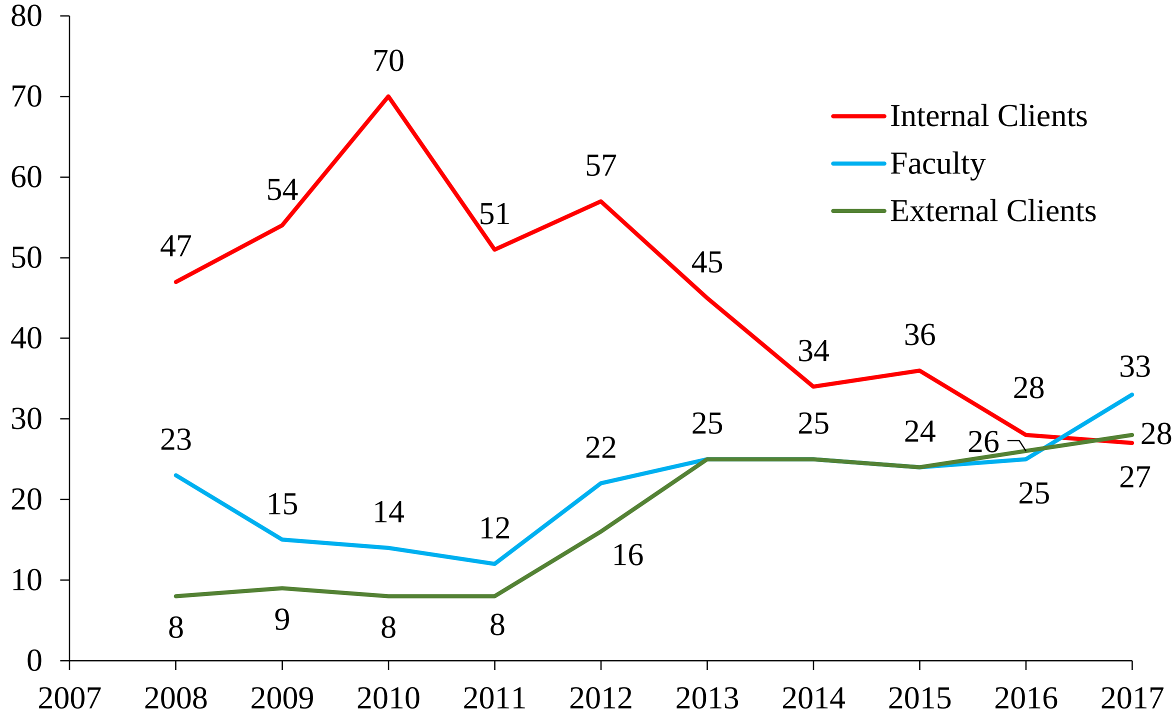

Figure 8. Historical data of clients utilizing the MNTC.

Figures 6 and 7 show utilization of the tools within the cleanroom, packaging lab and Huson Lab as tracked by FOM. The annual compilation represents client usage of the tools per day. An event was considered as one occurrence regardless the number of times a client logged in and off within 24 hours.

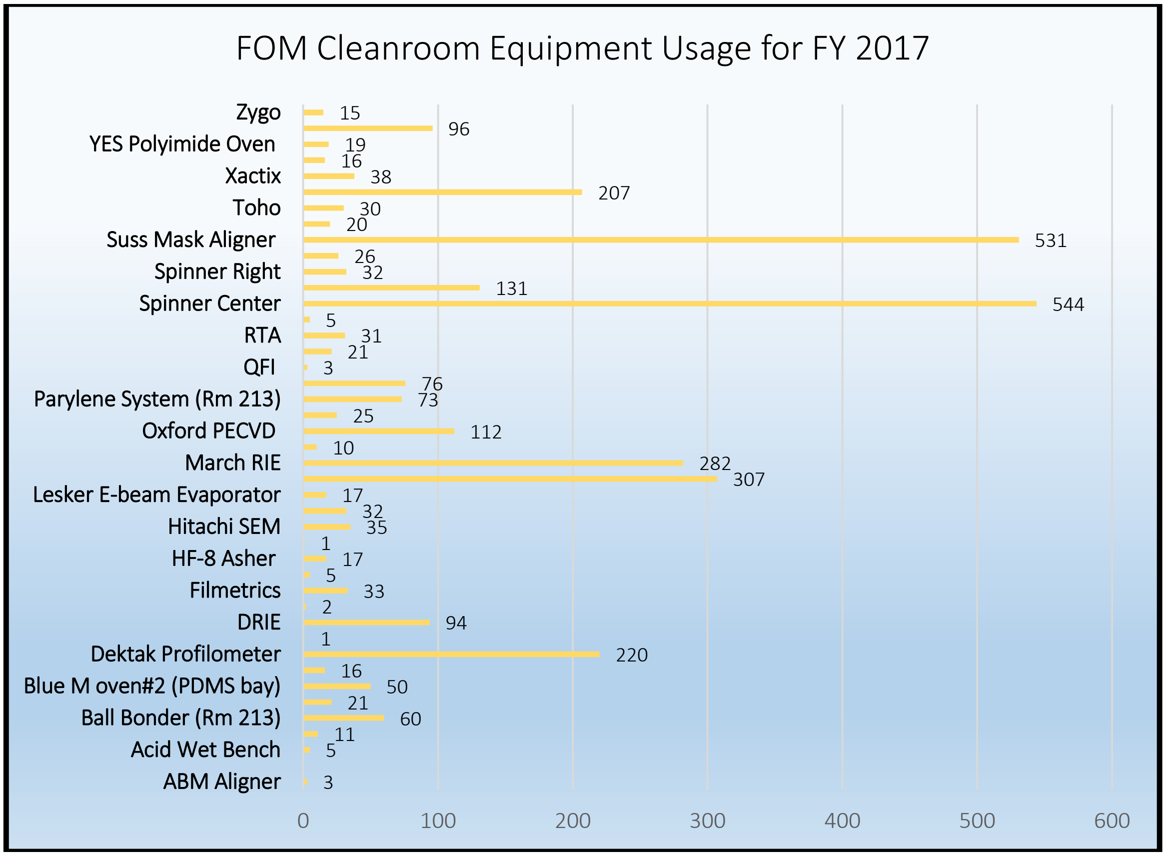

Figure 6. Annual utilization of tools in the cleanroom and packaging lab from the FOM system.

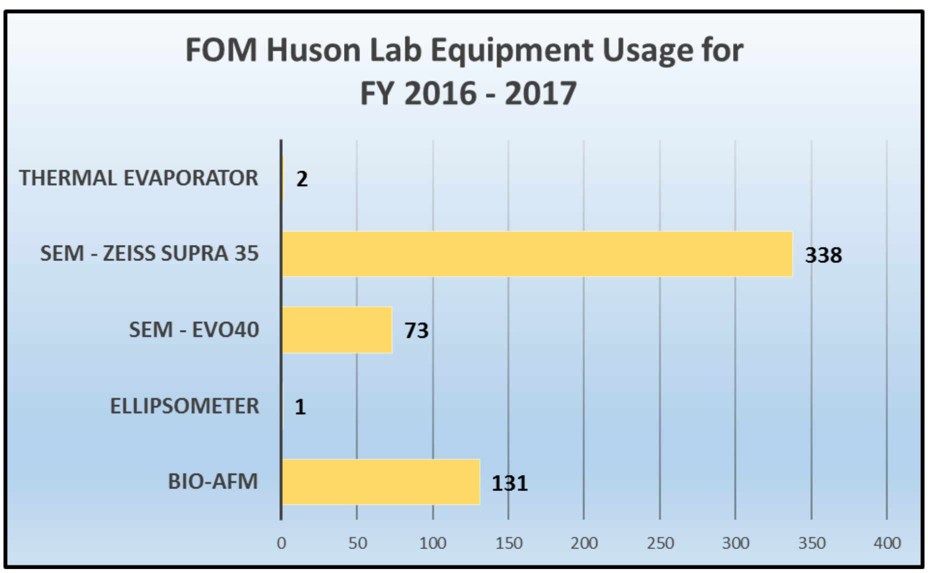

Figure 7. Annual utilization of tools in the Huson Lab from the FOM system.

Appendix A: Equipment

The MNTC has many capabilities for clients to perform their research in the facility. The following is a listing showing the equipment by category.

Photolithography

Photomasks and Direct Write:
A Heidelberg DWL 66FS UV laser patterning system for the generation of photomasks and direct write onto substrates, such as wafers or individual die. The Heidelberg can provide write resolution capabilities down to 600 nm for substrates up to 9” square. Additionally, it can perform direct write on wafers or individual die and write 128 levels of grayscale.

Contact Photolithography: Suss MA6 and AB-M mask aligners provide front and backside alignment capabilities. Alignment can be performed on individual die up to 6" wafers.

Image Reversal: An ammonia based photoresist image reversal systems by YES that can also perform HMDS vapor prime.

Thin Film Deposition

Plasma Enhanced Chemical Vapor Deposition system: Oxford PECVD system capable of depositing silicon nitride, silicon dioxide, oxynitride, amorphous silicon (undoped/doped), polycrystalline silicon (undoped/doped), silicon carbide, silicon nanowires and generation of carbon nanotubes. The Oxford tool includes a 650°C high temperature chuck and a TEOS delivery system.

Sputtering: Lesker PVD 75 three source tool and Technics two source system for deposition of both metals and dielectrics. The PVD 75 features RF, DC, RF/DC stacking and ion beam assisted sputtering, which includes throttled pressure control and reactive gas mixing.

Electron Beam and Thermal Evaporation: A Lesker electron beam and a Denton thermal evaporation system for depositing a variety of thin films on substrates up to 6”.

Parylene Coating: An SCS vapor deposition tool for Parylene C and Parylene N.

Molecular Vapor Deposition: An Applied MST MVD system for the conformal deposition of hydrophobic coatings for lubricants, anti-stiction layers, molecular glues, reactive adhesion layers, or to change the surface contact angle.

Electroplating: Pulse or continuous DC electroplating systems for Au, Cu and Ni processing using high aspect ratio photoresists.

Atomic Layer Deposition: A Beneq ALD system for the deposition of alumina (Al_2O_3), zinc oxide (ZnO) and titanium dioxide (TiO_2) films.

Thermal Processing

Oxidation, Diffusion & Annealing: Multiple tube furnaces for thermal processes include wet/dry oxidation, high temperature annealing and boron/phosphorous diffusion.

Rapid Thermal Processes: An RTP system for silicon based gate oxide growth and rapid thermal annealing of implanted layers. Additionally, an RTA system for annealing of metal contact layers.

LPCVD Furnace: Low pressure chemical vapor deposition of polysilicon for 4"and 6" wafers.

Vacuum Cure Oven: Multiple programmable vacuum ovens capable of heating to 400°C.

Etching, Machining and Bonding

Deep Reactive Ion Etch (Silicon): An STS DRIE tool for anisotropic (vertical only) silicon deep trench etching using the Bosch process. This tool has a pulsed plate bias to minimize "footing" at oxide etch stops.

Anisotropic Silicon Wet Etching: KOH and TMAH wet etchants for silicon substrates.

Plasma Etching: Multiple reactive ion etching (RIE) and oxygen/plasma based systems capable of providing selective silicon, SiO2 and Si_3N_4 etching and oxygen plasma ashing.

Trion Phantom III Reactive Ion Etch System: A Trion ICP Phantom Minilock III Etcher for etching nitrides, oxides, polymers, metal, compound semiconductor and other materials using fluorine (CHF_3, SF_6, CF_4), oxygen and corrosive (Cl_2 and BCl_3) chemistries.

Xenon Di-Fluoride Etching: A Xactix XeF_2 system for isotropic (vertical and lateral) dry etching of silicon microstructures prone to stiction.

Wafer Level Bonding: A Suss SB6e for wafer level bonding of silicon/glass anodic bonding, glass/glass or gold/gold thermal compression bonding and Si/Si fusion bonding. All processes are capable of a 5 micron alignment with the adjacent Suss MA6 mask aligner.

Critical Point Dryer: A critical point CO_2 dryer for drying substrates, where stiction needs to be avoided.

Vapor Hydrofluoric Acid Etching: An anhydrous vapor HF delivery system that can be utilized when wet etching mechanisms are not preferred to remove oxides or release structures on SOI wafers.

Chemical/Mechanical Polishing: A Logitech CCP system to planarize 4" substrates.

Packaging

Dicing: A Disco programmable saw for dicing silicon, glass and alternative substrates up to a 6" diameter.

Wire Bonding: Multiple Kulicke & Soffa wedge, ball and deep access wire bonders for aluminum and gold 1-mil wire bonding.

Flip Chip Packaging: A Finetech Fineplacer "Pico" system for flip chip die placement accuracy up to 5 microns. This tool can accommodate surface-mount components SMCs with a side length up to 17 mm.

Metrology & Testing

Thin Film Stress Measurement: A Toho thin film stress measurement system using non-contact multi-wavelength surface flatness techniques for evaluating thin film stresses from room temperature to 500°C.

3-D Contact Profiling: A Veeco contact profilometer that can provide down to a 7.5 angstrom step height measurement with a vertical range up to 1 mm and a maximum scan length of 200 mm. The low stylus force allows scratch-free measurement of soft materials.

Non-contact 3D Optical Profiler: A Zygo non-contact profilometer that is capable of measuring surface topology of micro scale systems. Its capabilities include field stitching and dynamic module for measuring MEMS devices during actuation.

Filmetrics systems for non-contact thin film thickness measurements and determining optical constants of single and multilayer films.

Testing: Veeco FPP-5000 Four-point Probe and suite of probe stations and electronic test instruments for measuring sheet resistance and resistivity.

Design, Layout and Modeling

A full suite of computer-based tools for photo mask layout, custom analog and digital IC design, micro-scale tooling, and 2D/3D finite element models for virtual device evaluation. Software packages include: Tanner EDA, Silvaco TCAD, CoventorWare®, Solid Edge. These packages are available for academic purposes only.

Huson Lab

Scanning Electron Microscope (SEM): Zeiss Supra 35 with sub 100 nm resolution, STEM detector, Backscatter Detector, Energy Dispersive X-Ray (EDS) Spectroscopy, Zyvex 5 nm resolution nano-manipulator and gold-palladium sputter coater.

Scanning Electron Microscope (SEM): Zeiss EVO-40 Extreme Variable Pressure (3000 Pa) scanning electron microscope, Peltier stage -25C to 50C, Humidity control option with Heating Peltier stage up to 1100°C.

Atomic Force Microscope: Asylum MF3D Bio-AFM with liquid cell option for biomaterials and thermal/vibration control and an additional Asylum MF3D Conductive AFM.

Ellipsometry: VASE Woollam Variable Angle Spectroscopic Ellipsometer for non-contact thin film thickness measurements and determining optical constants of single and multilayer films.

Mid-wave Thermal Imaging System: A Quantum Focus Instruments (QFI) thermal imaging system for capturing thermal images and video of devices featuring 0.1°C temperature and 5 μm spatial resolutions.

Appendix B: MNTC Facilities

The MNTC is located throughout the Shumaker Research Building. Some locations are solely used by MNTC or other areas contain infrastructure that are maintained by physical plant. The following is list of locations and major uses of these locations:

SRB 106: Huson Nanotechnology Core Facilty – This 1,200 ft^2 facility houses the MNTC's complete suite of Scanning Electron Microscopes, Atomic Force Microscopes, thin film characterization system and thermal imaging capabilities.

SRB 121: Cleanroom & Chase Areas- The cleanroom is a 10,000 ft^2 class 100/1000 facility that houses multiple pieces of equipment available to clients. Chase areas are corridors adjacent to the open bay areas of the cleanroom and along the exterior wall of the cleanroom. This space is used for return air from the cleanroom, various utilities, location of chillers, pumps and other auxiliary equipment, storage for supplies and chemicals, gas cabinets, and transport of equipment and supplies in and out of the cleanroom.

SRB 119A: Hazardous Production Materials (HPM) Room – This explosion proof room contains chemical storage cabinets for chemicals waiting to be transferred to the service corridor, gas cabinets for pyrophoric and toxic gases with an associated scrubber and several inert cylinders that supply the cleanroom.

SRB 119: Loading Dock - This room is adjacent to the HPM room, service corridor and outdoor loading dock. The area is utilized to move equipment in and out of the cleanroom and is location of the primary DI water tank and pumping station that supplies the cleanroom. The location also serves as the 90 day satellite location for the pickup of non-hazardous or hazardous waste for DEHS.

SRB 199J: Service Corridor – This backside hallway allows for entry chemical storage, movement of supplies and tools into the cleanroom, gas cabinets, utilities and fire exits.

SRB 111: Machine Shop - This dirty space is utilized for repair of equipment and sandblasting of components from the cleanroom to remove deposition buildup.

SRB 113B – DI Water Filtration Station – This small room houses the primary and secondary filter banks for DI water provided to the cleanroom.

SRB142 – Interstitial Space - This door provides access to the elevated catwalk above the cleanroom, which house fourteen air handlers to receive and circulate incoming air from the air make up handler in the penthouse and chase areas in the cleanroom. The air handlers discharge filtered air through the HEPA filters.

SRB 139B: Fire Command Center – This small room houses the TGM server and fire command center.

SRB 213: Packaging Lab - This room contains packaging equipment for wirebonding, Parylene C deposition, chemical /mechanical polishing and a variety of bench top test equipment.

SRB 226: TCAD Lab - This room contains computer workstations for performing simulations and developing CAD drawings for photomasks.

SRB Liquid Nitrogen Cage – This caged and enclosed area contains the 6,000 gallon liquid nitrogen tank and liquid to gas expansion system that supplies the cleanroom. A fill area is adjacent to the tank that allows clients to refill LN_2 dewars. This area also serves as the outdoor bunker for the 5% and 100% Silane gas cabinets.

SRB Basement: The basement contains the cleanroom's vacuum and compressed air systems, chiller for its dedicated air makeup handler in the penthouse, RO water filtration and pumping system and acid waste neutralization (AWN) system and back-up generator. This space is serviced by Physical Plant with exception to the AWN system.

SRB Penthouse: The MNTC's dedicated air makeup handler and three exhaust systems (acid/caustic, solvent and silane) are located in this area. This space is serviced by physical plant, but expense and labor are paid by the MNTC.

Appendix C: Rate Structure

The current rate structure is listed below.

UNIVERSITY OF LOUISVILLE
MICRO/NANO TECHNOLOGY CENTER RATES
RATES EFFECTIVE FOR JULY 1, 2017
Go to the link below to learn how to gain access to the cleanroom.
http://louisville.edu/micronano/users/how-to-become-a-cleanroom-user

http://louisville.edu/micronano

Clients of the MNTC will be charged a daily cleanroom access fee and associated equipment fees. All users will be charged including faculty.

Daily Access Fee for the Cleanroom: Internal User: $10/day
External User: $34/day

Equipment Usage Fee: The usage rates are defined below for internal users, external users and services. A cap of $1,500 per month per researcher will be implemented for equipment usage, access fees and training for internal users only. This cap does not include consumables (wafers, wafer containers, tweezers, etc.) or services performed by the MNTC staff (i.e. dicing and photomasks). A cap is not instituted for external users.

Equipment	Internal Rate	External Rate	**Service Center Rate**
Flip Chip Bonder	$0.50/min	$0.75/min	$60/hour + Internal or External Rate
QFI Thermal Imaging System	$0.50/min	$0.75/min	
Zygo Optical Laser Profilometer	$0.50/min	$0.75/min	
Critical Point Dryer	$0.50/min	$0.75/min	
Ball /Wedge Bonder	$0.60/min	$0.90/min	
Hi-Speed Camera	$0.60/min	$0.90/min	
March RIE	$0.60/min	$0.90/min	
Rapid Temperature Processing (RTP/RTA)	$0.60/min	$0.90/min	
ABM Aligner	$0.70/min	$1.05/min	
DRIE	$0.70/min	$1.05/min	
Lesker E-beam Evaporator (**extra for Au)	$0.70/min	$1.05/min	
Molecular Vapor Deposition (MVD)	$0.70/min	$1.05/min	
Oxford PECVD	$0.70/min	$1.05/min	
Lesker PVD 75 (**extra for Au and Pt)	$0.70/min	$1.05/min	
Denton Thermal Evaporator	$0.70/min	$1.05/min	
Suss Aligner	$0.70/min	$1.05/min	

Suss Bonder	$0.70/min	$1.05/min	
Technics Sputterer	$0.70/min	$1.05/min	
Trion Metal Etcher	$0.70/min	$1.05/min	
Hitachi SEM	$1.00/min	$1.50/min	
Xactix XeF_2 Isotropic Etching	$1.00/min	$1.50/min	
HF Vapor Etcher	$1.00/min	$1.50/min	
Photoresist Spinners	$1.00/min	$1.50/min	
Beneq ALD	$1.00/min	$1.50/min	
Chemical Mechanical Polishing (CMP)	$1.00/min	$1.50/min	
LPCVD Polysilicon Tube	$3.00/min	$6.00/min	

	Equipment	Internal Rate	External Rate	Service Center Rate
	HF-8 Axic Barrel Asher	$30/batch	$41/batch	$60/hour + Internal or External Rate
	Reynolds Electroplating Bench	$30/batch	$41/batch	
	Tube Furnace (Anneal, Oxidation, Diffusion)	$40/batch	$54/batch	
	RCA Clean Hood (RCA Cleaning)	$40/batch	$54/batch	
Wet benches	305 Acid Hood (Nanostrip, Aluminum Etch, Chrome Etch, BOE)	$40/batch	$54/batch	
	307 Base Hood (KOH, TMAH)	$40/batch	$54/batch	
	308 EDP Etch Hood (Gold Etch, Copper Etch)	$40/batch	$54/batch	
	YES Polyimide Oven	$45/batch	$65/batch	
	YES Image Reversal Oven	$45/batch	$65/batch	
	Parylene Deposition System	$45/batch	$65/batch	

ADDITIONAL FEES

Fees	Internal Users	External Users
Training	$60/hour and is not included with tool usage fee	
**Gold/Platinum Deposition	$20/0.10 gram	$30/0.10 gram
Dicing (*Process performed by MNTC staff ONLY, Service fee included*)	$60/1st-hr flat rate $1/minute after 1st hr	$85/1st-hr flat rate $1/minute after 1st hr
Dewar Fill (LN_2)	$45/fill	N/A

Photomasks (*Process performed by MNTC staff ONLY, Service fee included*)	Internal Users	External Users
4" substrates	$125	$175

Resolution 6 um and larger		
6" substrates Resolution 6 um and larger	$225	$275
CAD File Development	$60/hour	

Smaller resolutions can be obtained down to 1 um for photomasks. Contact us for details and pricing at julia.aebersold@louisville.edu

A usage fee is not assessed for these items and does not include MNTC labor.

Dektak Profilometer, Filmetrics, Stereoscopes and Optical Microscopes, Toho Thin Film Stress Measurement System Spin Rinse Dryers Vacuum Ovens Four Point Probe, Probe Station, Solvent Wet Bench, Developer Wet Bench (LF8-1A Solvent Develop Hood), Developer Wet Bench (115X Base Develop Hood), Spinner Benches (153X Hot Plate Spinner Combo), PDMS Spinner, Blue Ovens.

HUSON NANOTECHNOLOGY CORE FACILITY

Equipment	**Membership (Internal Users ONLY)**	**Hourly Rates**
AFM's (Bio and Conductive) Ellipsometer Thermal Imaging System	$300 Membership Fee per User per Year	
SEM's (Supra and EVO) AFM's (Bio and Conductive) Sputter Coater Ellipsometer Thermal Imaging System	$1,100 Membership Fee per User per Year	
AFM's (Bio and Conductive) Sputter Coater Ellipsometer Thermal Imaging System		Internal: $25/hour External: $35/hour Training/Staff Time: $60/hour
SEM's (Supra and EVO)		Internal: $50/hour External: $100/hour Training/Staff Time: $60/hour

CONSUMABLES/SUPPLIES

Item	Internal Rate	External Rate
4"Non-Oxidized Prime SSP Wafers	$25/wafer	$34/wafer
4"Oxidized Prime SSP Wafers	$35/wafer	$48/wafer
4"Non-Oxidized Prime DSP Wafers	$35/wafer	$48/wafer
4"Oxidized Prime DSP Wafers	$45/wafer	$61/wafer
6"Non-Oxidized Wafers	$35/wafer	$43/wafer
4"Borosilicate Glass Wafers	$25/wafer	$34/wafer
4"Wafer Container	$4/each	$5.44/each

4"Wafer Container Lid	$4/each	$5.44/each
8.5"×11" Cleanroom Notebook	$12/each	$16.32/each
Metal Tipped Wafer Tweezers	$50/each	$68.00/each
Plastic Tipped Wafer Tweezers	$50/each	$68.00/each
Petri Dishes	$3/each	$4.08/each
Gel pack	$8/each	$10.88/each
Microscope Slides	$5/box	$6.80/box