

NNCI MANTH: Mid-Atlantic Nanotechnology Hub



An NSF-National Nanotechnology Coordinated Infrastructure Node

Singh Center for Nanotechnology, University of Pennsylvania; and Community College of Philadelphia

September 2018 NNCI Annual Meeting, University of Washington

Focus Areas and Key Capabilities

- MANTH strives to be a comprehensive nano maker space for all researchers; as such, it has **a full complement** of lithography, etch, deposition and characterization equipment and associated expertise
- In addition, MANTH has a unique suite of equipment to facilitate the regional emphasis on medical and materials nano research:
 - Two laser micromachining systems (3 wavelengths) for microfluidic device and medical device fabrication
 - Nanoscribe lithography tool for sub-micron scale additive 3D printing
 - Multiple atomic layer deposition tools, including a plasma-enhanced ALD to deposit new materials
 - Scanning probe facility with a suite of bio-centric characterization enhancements, including the ability to operate in aqueous environments



Student researcher utilizing one of MANTH's laser micromachining systems



Drybox and loadlock for PEALD system.
Community College of Philadelphia

Focus Areas

- **Medicine/Bioengineering**
 - Strong ties with Philadelphia-area medical schools
 - Penn HealthTech initiative (healthtech.upenn.edu)
 - Synergy with NSF STC on mechanobiology
 - Cooperation with Philadelphia area FabNET Program
- **Materials and Device Research**
 - Quantum efforts (quantum nanoparticle devices, diamond fabrication)
 - Synergy with NSF MRSEC on soft matter
- **Emerging: Micro/Nanodevices for IoT**
 - MEMS
 - Photonics
 - Robotics (both small robots and robots carrying small things)

Key Capabilities – New Equipment

- 2 Transmission Electron Microscopes
 - JEOL NEOARM Atomic Resolution Microscope
 - JEOL 2200F (TEM/STEM)
- High Temperature Furnaces
 - Oxidation
 - Annealing (2) tubes
 - SiN_x deposition
- Scanning Probe improvements
 - New laser (491nm) for Raman-NSOM
 - DISCO (rotating laser source) to enhance total internal reflection fluorescence (TIRF) Probe

Coming Soon:

FEI Krios CryoTEM

NSF MRI-supported FIB for soft matter

Piezo film sputter deposition system



Impact of MANTH

Impact on the Mid-Atlantic region's nano-scale research and commercialization:

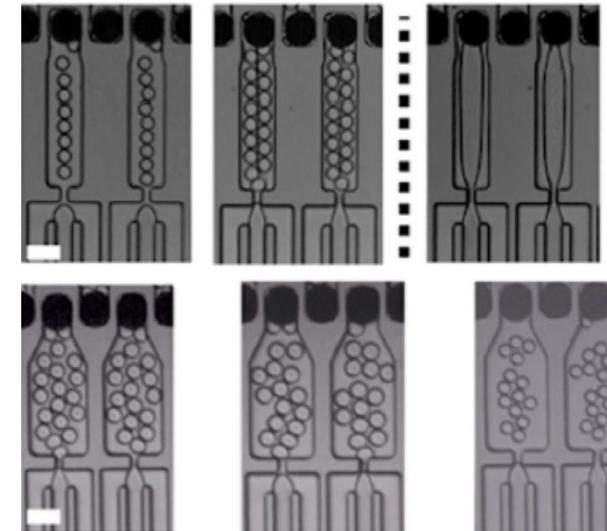
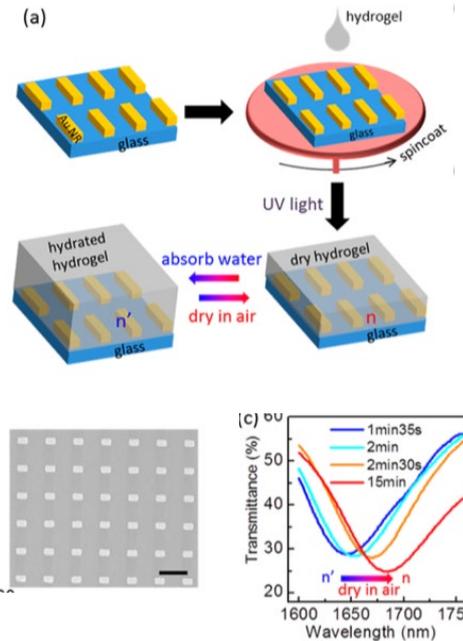
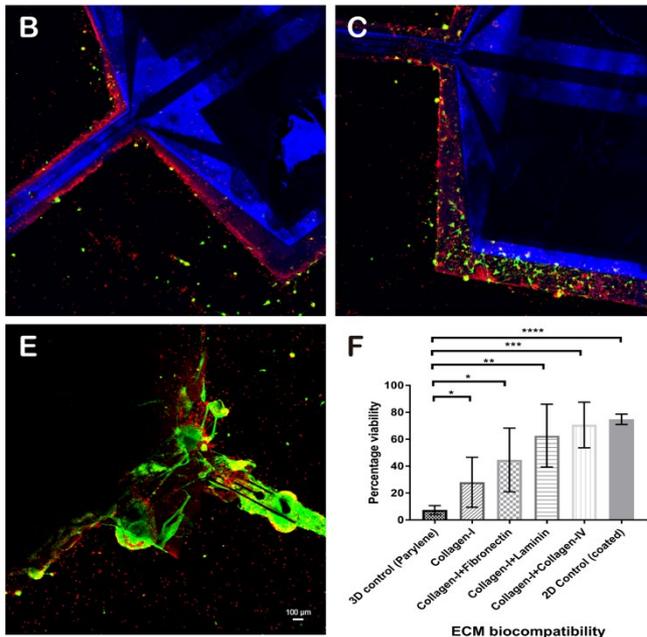
- Enabling research in both **traditional and non-traditional** nanotech areas
- Stimulating **new companies** to explore nanotechnology through our Seed Grant Program, and supporting **existing companies** located throughout the extended Northeast region to look into new product areas
- Cultivating the **biomedical and materials research** of our neighboring academic institutions
- Providing nanotech solutions to gain understanding in **medicine** by creating relationships across technical fields
- Sharing nanotech knowledge with a diverse community-at-large through education and outreach and publishing **web-based technical reports and best practices**
- Expanding the capabilities of researchers who are unable to use the facility themselves by granting them **remote access** through staff fabrication and characterization services

Selected Research Impact

Microfabricated collagen neural electrodes exhibit increased functionality persistence *in vivo*

Nanoengineered remotely interrogatable moisture sensors for smart agriculture

Terascale generation of polymer microparticles for pharmaceutical applications (GSK collaboration)



Shen et al., *Microsystems & Nanoengineering*, 2018

Chen et al., *ACS Applied Nano Materials*, 2018

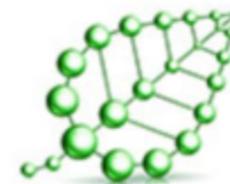
Yadavali et al., *Nature Communications*, 2018

Research Impact: Seed Grants and Spinoffs

2018 Seed Grant Competition awards provide a total of \$17,500 in laboratory and equipment time funding for 9 startup and entry-level businesses.

- A 2016 Seed Grant winner, **Graphwear Technologies**, used its grant to create a nano-based sweat sensing technology and has since received \$4.2M Series A Funding for further development.
- A 2017 and 2018 Seed Grant winner, **Visiplate**, created a nano-scale drainage implant to defend against blindness from open-angle glaucoma (OAG) by reducing intraocular pressure based on ultrathin ALD alumina nanoplates. These researchers were subsequently awarded the University of Pennsylvania's President's Innovation Prize which includes \$100k to further develop their technology and \$50k in stipends for each researcher.

Big Ideas through
Small Technology



Spinoffs: Enachip, a MANTH spinoff manufacturing nanolaminated magnetics for compact electrical power conversion, received \$2M in seed investment*

*Disclaimer – Allen holds an equity position in Enachip.
Enachip did not participate in the seed grant competition.

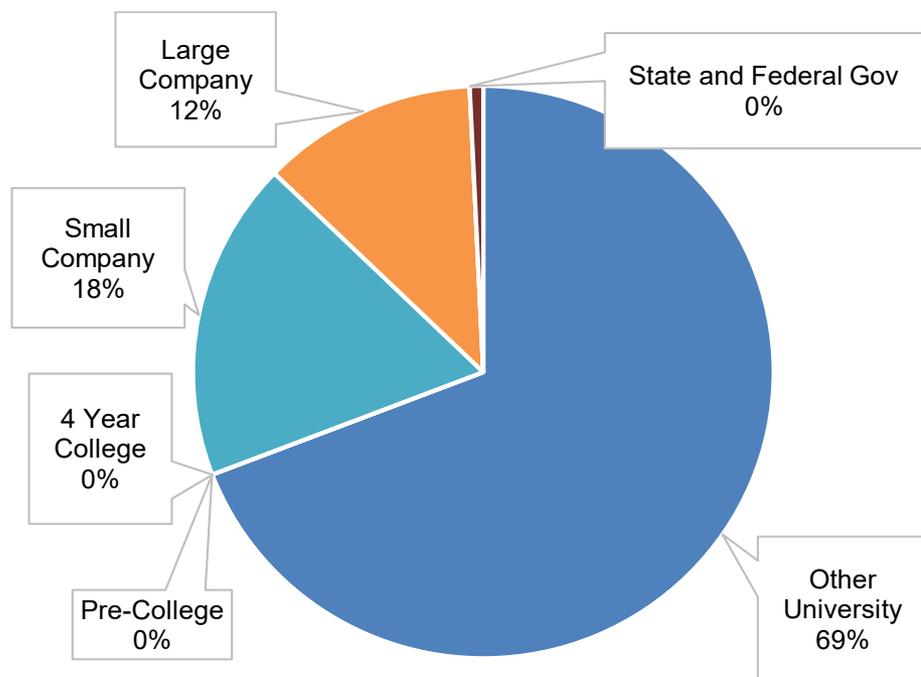


MANTH User Data

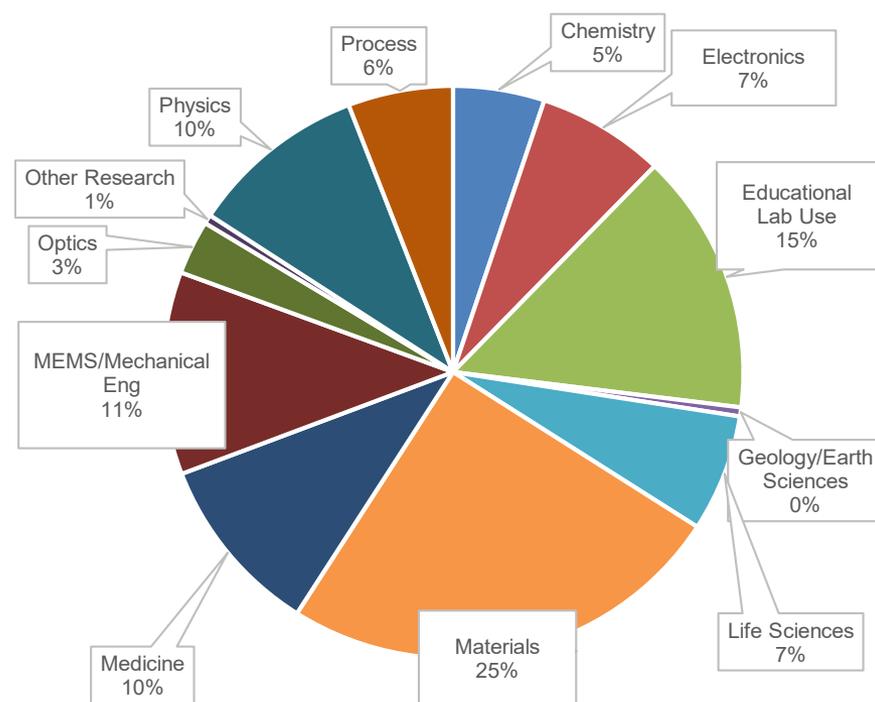
Yearly User Data Comparison			
	Year 1	Year 2	Year 3 (6 months)
Total Users	482	589	393
Internal Users	368	393	259
External Users	114 (24%)	196 (33%)	133 (34%)
External Academic	48 (42%)	121 (62%)	92 (69%)
External Industry	65 (57%)	67 (34%)	40 (30%)
External Government	0	2 (1%)	0
External Foreign	1 (1%)	6 (3%)	1 (1%)
Total Hours	36970	37933	16187
Internal Hours	34545	31524	13067
External Hours	2425 (7%)	6409 (17%)	3120 (19%)
Average Monthly Users	171	194	186
Average Ext. Monthly Users	28 (17%)	44 (23%)	46 (25%)
New Users Trained	270	339	134
New External Users Trained	73 (27%)	96 (28%)	61 (45%)

MANTH User Data

External User Affiliations



All User Disciplines



Education and Outreach



Student Development: Graduate Student Fellow Program

- The GSF Program was created to allow masters' students the opportunity to conduct research and development in the MANTH cleanroom
- Projects are both device and process-centric; based on this work they create technical reports and process notes that are published in the web-based searchable repository Scholarly Commons
- GSFs gain teaching experience as TAs in laboratory courses and will be instrumental in our Community College of Philadelphia training partnership
- GSFs have gone on to careers at large companies such as Global Foundries and Halma International; startups such as Tetrels and Graphwear; and graduate programs at Penn, MIT, Utah, Arizona State, and Washington



2018 Graduate Student Fellows
and Cleanroom Staff Mentors

Impact of Education & Outreach Activities



Tours, Talks/Lectures, Demos (On-Site)

Events =1 h – full day; Majority for audiences who only visit once; Oct. 1, 2017 – July 31, 2018

Audience	Events	Participants
Community group	2	13
Non-Penn college/univ	3	21
K-12	14	467
Penn department, program, etc.	2	17
Penn visitor (external) - individuals, speakers, company, recruitment, etc.	22	255
Total	43	773

REU Program

2018 Cohort (5 of 6 responded – anon feedback survey)

- 4 of 5 responded that REU increased interest in STEM (1 = interest unchanged)
- Ranked 4.8 on scale of 1-5 (5=highest) on value of REU for academic, scientific, professional, personal growth
- 5 of 5 would recommend program to peers

Alums (2016, 2017; N=12)

- 6 in PhD programs (2 NSF Grad Res Fellows)
- 1 in STEM job
- 3 of 5 of the continuing undergrads known to have participated in research during summer 2018



NanoDay@Penn (Oct. 3, 2017)

Students: Interest in STEM (N=127; 82 (64.6%) increased, 42 (33%) stayed same, 3 (2.4%) decreased); ave .4.2 out of 5 (best) rank for visit

Teachers: Value of visit for students = ave. 4.5 (N=15) out of 5 (very valuable); Stimulated ideas for teaching STEM = ave. 4.8 (N=16) out of 5 (strongly agree)

Community College Partnership

Preparing to offer new Nanotechnology course for Spring Semester at CCP

Nanotechnology Technician Training Program: Industry Feedback and CCP Implementation

- Local industry panels (18 participants) were convened at MANTH to discuss nano technician needs. Most industry participants stated that their companies were currently or would in the future be interested in hiring technicians with the type of nano- and/or micro-scale training discussed in the meetings
- Most CCP students would be seeking work that is within very short commuting distance from Philadelphia. Not all industry participants fit this need.
- CCP decided to begin its training program by adding a single nanotechnology course to its curriculum, and observing how the uptake and interest progressed from that course.
 - Course development and CCP administrative approval process will be completed during Fall 2018
 - First offering of course in Spring 2019.
 - Course and lab content are also being informed by materials used by the NACK Network, nanoHUB, and Nano-Link to leverage existing resources and expertise.
- Industry and other feedback also uncovered a demand for additive manufacturing training. CCP has started to collect initial information about the appropriate content by meeting with the Penn AddLab staff (MANTH affiliate).

NNCI Cooperative Network Activities (1/2)

Network-Wide

- MANTH Leadership in NNCI Working Groups and Committee
 - Commercialization Committee - led by Mark Allen
 - Equipment, Maintenance and Training Working Group - led by Meredith Metzler
 - Photolithography Working Group - led by Pat Watson
 - Technical Workshops Working Group - led by Eric Johnston
- REU Convocation Attendance: 6/6 students in 2017; 5/6 in 2018

On Behalf of the Network

- Host of the October 2017 NNCI Meeting
- Representation of the Network at the 2017 NSF NNI meeting in Washington



Network-Wide Activities (2/2)

Multi-Site

- UGIM conference, chaired by Noah Clay, an international symposium concerning cleanroom operations, attended by several NNCI site members in June 2018 including Cornell, Harvard, Georgia Tech
- MAEBL, Mid-Atlantic Electron Beam Lithography Workshop (attended by multiple regional facilities as well as NNCI member Cornell)
- Coordinated Mid-Atlantic Nanofabrication Manager's Meetings, October 2017, hosted at George Washington University, and April 2018 hosted at Carnegie Mellon University
- Led effort to negotiate prices, using the size of the network as leverage, of nanolab materials and consumables for all NNCI sites
- Worked with Stanford to organize a photolithography working group meeting coinciding with a direct-write lithography symposium, hosted at Stanford. NNCI members from Harvard, Cornell, Montana, UCSD, U Washington, Minnesota and Nebraska attended. Travel partly funded by NNCI coordinating office.

Panel Topic - Commercialization (1/2)

- Assessment – Our sites, and the network, have tremendous economic impact. How do we count? What are our metrics?
 - Job creation (self-reported count)
 - Number of startups utilizing your node
 - How much money have they raised / have you helped them raise (SBIR, investment, etc.)
 - Harder to identify a metric, but we should consider a metric for large companies as well, beyond just ‘use’
- Tell our story
 - Collect a list of SBIR awards ‘our’ companies have won
 - Contact users and extract a 20-second video testimonial of how the facility has helped them
 - Facility directors reach out individually and get print testimonials (picture, quote, paragraph description)
 - Information ‘push’ – ping web/conventional media with results from our sites

Panel Topic – Commercialization (2/2)

- Facilitization of our translational users
 - Seed grant programs – could be transformational for 1-2 person organizations
 - Letters of support for grants; this could range from ‘we are available’ to detailed scientific support depending on the need and ask
 - Host a conference for small businesses in your local area to facilitate networking and opportunity
 - Assistance in grant preparation, expertise matching between faculty/staff and companies to assist in fundraising
- Network greater than the sum of its parts
 - Compiled statistics and their nationwide impact
 - Facilitate our companies’ transition OUT of our facilities and into foundries, which are nationwide; many of us have knowledge and expertise about local foundries that can be diffused throughout the network
 - Coordination with I-CORPS Programs distributed among member sites
 - Coordination of career placement data and available positions in locations across the network to facilitate student placement in industry