

# Texas Nanofabrication Facility (TNF)

- Cleanroom nanofab capabilities, nano-metrology and nanomanufacturing with ~130 major tools, and ~30 staff
- Located at University of Texas at Austin
  - **Microelectronics Research Center** (cleanroom fab for nano)  
S.K. Banerjee- Site Director; S.Majumder- Coordinator
  - **Texas Materials Institute** (nanometrology)  
R.Manthiram
  - **NASCENT ERC** (nanoimprint and roll-to-roll nanomanufacturing)  
S.V. Sreenivasan
  - **SEI**  
L.A. Kahlor

# TNF: Facilities and Tools

- ❑ JEOL Aberration Corrected TEM (funded internally) (\$3M)
- ❑ Kurt J Lesker PVD E-beam evaporator (\$300k)
  - With load lock and 6 pockets
- ❑ AJA International Ion Milling System (\$275k)
  - RF sputter source for post-milling deposition
  - End-point detector
- ❑ VK-X1100 Optical profilometer for TMI facility (\$120k)
- ❑ Park NX10 Atomic force microscopy for TMI facility (\$100k)
- ❑ Laser Direct Writer from Advanced Micro Patterning for 0.5 micron litho and mask making (\$175k)

# Research Highlight: Human Technology Frontier External Small Company User (GraphAudio)

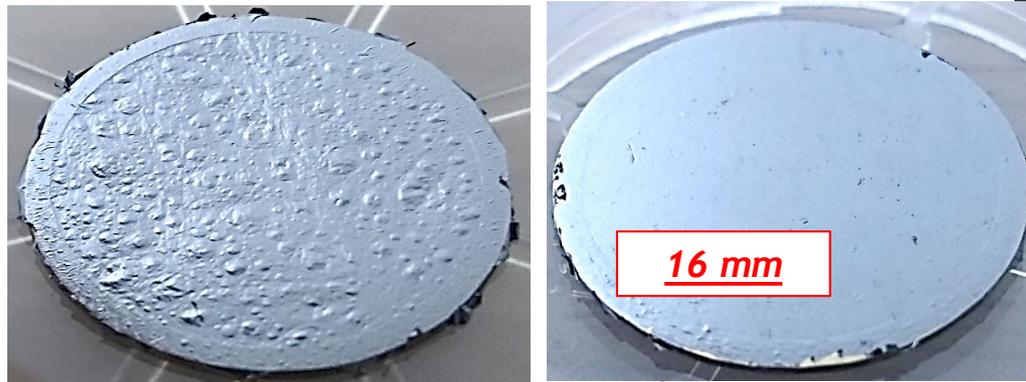
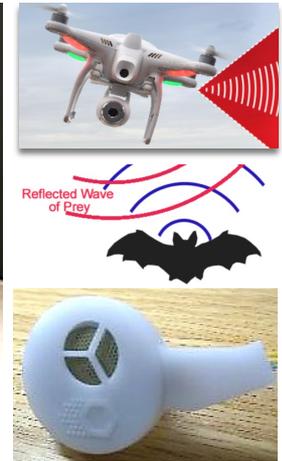
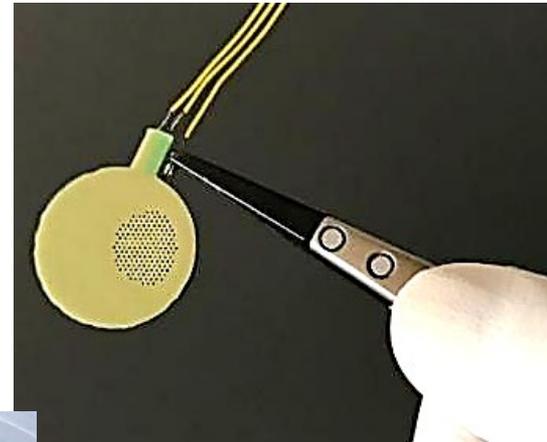
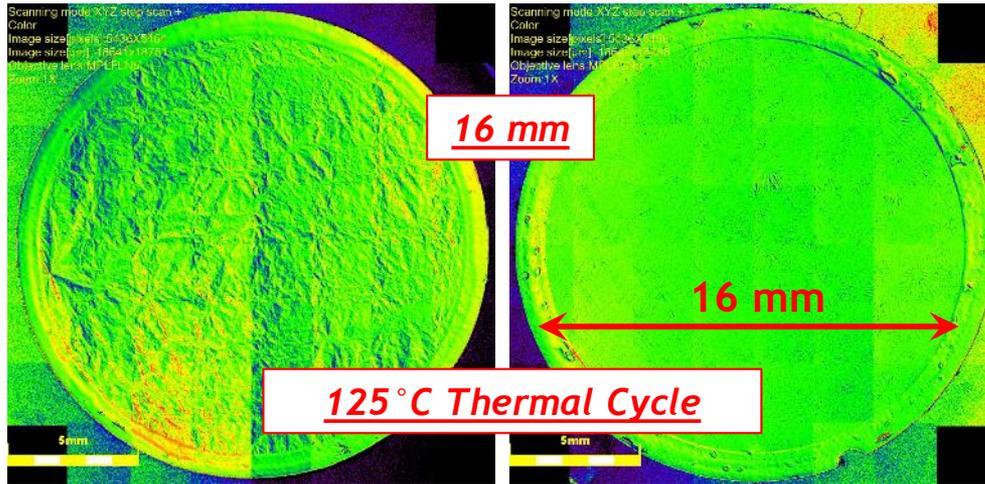
- Reliable Multilayer Graphene Growth on Ni foil for *Graphene-Enhanced Audio Transducers*
- Graphene Transfer process enables *Large-Area Graphene Suspensions* (8 - 20 mm diameter)
- Optimized process flow to achieve *Smooth Graphene Surface Morphology & High Thermal Stability!*

## Before Optimization\*

## After Optimization^

## Speaker Transducer

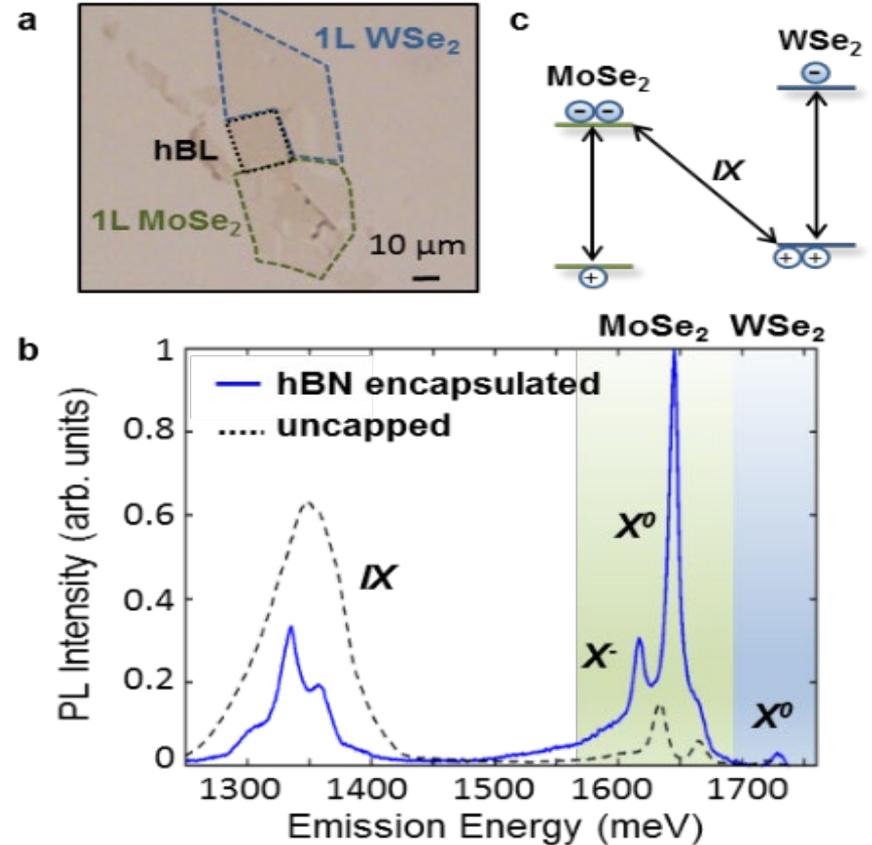
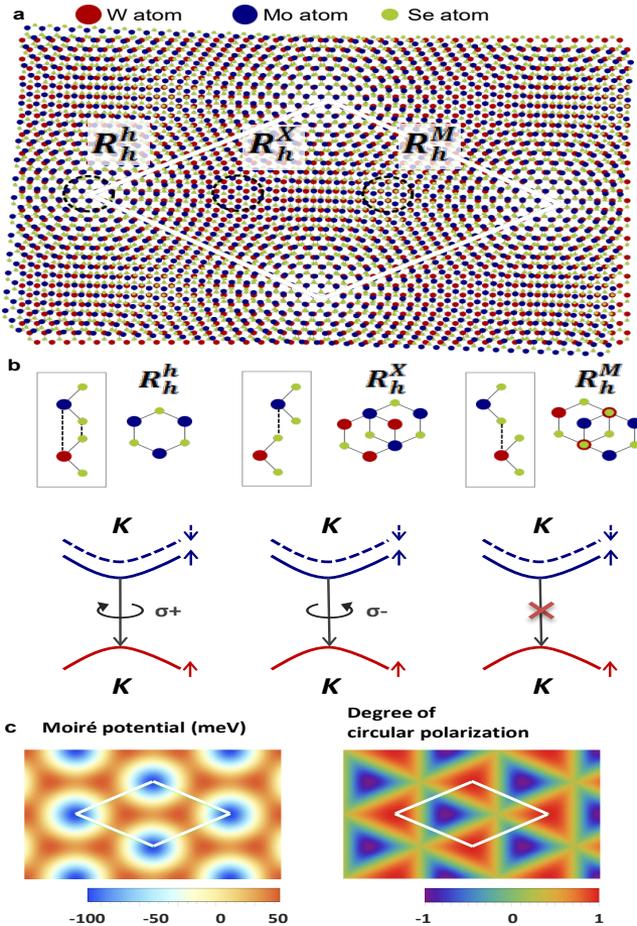
## Applications



# Research Highlight: Quantum Leap

## Internal-External-Academic-National Lab-International (TNF, NIST, Argonne, Korea)

### Moiré Excitons in Van der Waals Heterostructures



K. Tran, ... S.K. Banerjee... and X. Li, Nature, 567 (7746) March 7 2019

# TNF: Education & Outreach



TNF 2018-2019 Education & Outreach Events	
TNF Location	# Participants
<b>K-12 Students</b> <b>Girl day at TMI facility</b>	8781
National nanotechnology day: October 9th	20
Alice in Wonderland	30
<b>REU Recruitment</b>	12
Distinguished Seminar Series and lectures	300
<b>Total GT</b>	9143

- *Top: Dr. Gearba is showing students Electron Microscope to image transistors and crystals.*
- *Bottom: Dr. Jarvis is explaining how atoms are arranged in a crystal*

# TNF: Education & Outreach

*Results from the attitudinal assessment of high school student participants in Alice in wonderland and nanotechnology day*

Summary of two K-12 event (nanotechnology day and Alice in wonderland) at MER

N = 50	Not at all	Slightly	Moderately	A lot
Increased my knowledge of nano	0%	9%	36%	55%
Increased my interest in science & engineering	0%	7%	33%	60%
Helped me understand how nano relates to real world	0%	1%	35%	63%
Increased my interest in studying science & engineering in college	0%	15%	55%	30%



*Top: cleanroom tour; bottom: Squishy dough Circuit challenge by high school students*

# TNF: Societal and Ethical Implications (L.A.Kahlor)

## • Output

- Developed an evidence-based training module that is accessible via Youtube at <https://youtube/4wz8Kifsd4U>
- Training module is required for TNF users.
  - We collect data to test the impact of the training



[NanoEthics](#)  
April 2019, Volume 13, [Issue 1](#), pp 37-52 | [Cite as](#)

### Development and Pilot Testing of an Evidence-Based Training Module for Integrating Social and Ethical Implications into the Lab

Authors [Authors and affiliations](#)

Lee Ann Kahlor ✉, Xiaoshan Li, Jacy Jones

Original Paper  
First Online: 08 March 2019

30  
Downloads

# TNF: Societal and Ethical Implications (L.A.Kahlor)

## NanoEthics Results

### T-test Results

Perceived likelihood of SEI impact at four levels

	Pretest		Posttest		n	t	df
	M	SD	M	SD			
Individual (personal)	<b>3.33</b>	1.01	<b>3.91</b>	1.06	44	<b>-3.60**</b>	44
Workplace	<b>3.49</b>	0.99	<b>3.91</b>	1.02	44	<b>-3.09**</b>	44
Environment	<b>3.53</b>	1.18	<b>4.02</b>	1.08	44	<b>-2.65*</b>	44
Society	<b>3.56</b>	1.12	<b>3.93</b>	1.10	44	<b>-2.41*</b>	44

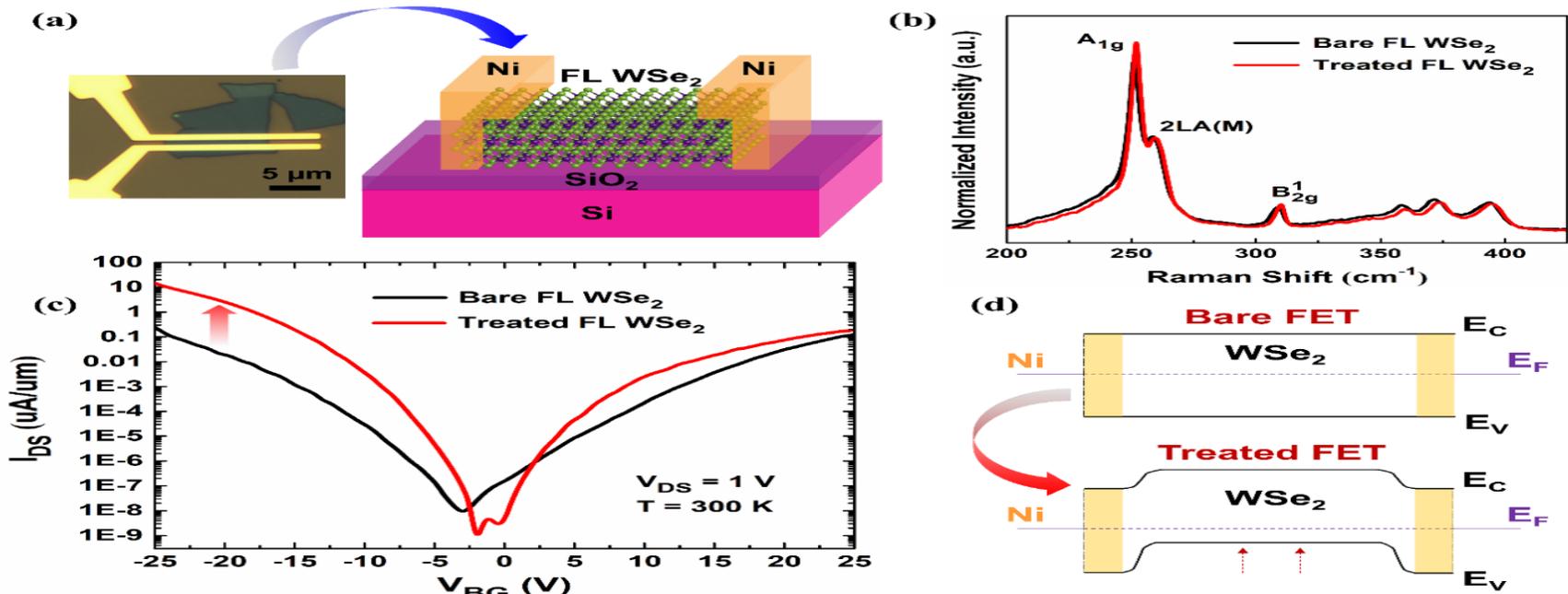
Response options were strongly disagree (1) to strongly agree (5); \*  $p < .05$ . \*\*  $p < .01$

# TNF: Impact

Metric	Milestone	Year 1	Year 2	Year 3	(10/18-3/19)
Number of unique NNCI-TNF users	500	653	696	833	475
Number of external users (companies, non-UT academic, national labs) using NNCI-TNF	120 (~25%)	153 (~23%)	167 (24%)	159 (19%)	94 (20%)
Non-federal funds coming into UT leveraging NNCI TNF facilities	\$1.5M	\$1.9M	\$1.9M	\$5.1M	\$1.0M
Number of peer-reviewed publications from NNCI-TNF	250	220	100	148	NA
Patents by NNCI-TNF users	10	8	8	4	NA
Percentage of URM and Women NNCI-TNF users	25%	56% 26%	43% 24%	61% 26%	62% 32%
Percentage of NNCI-TNF facilities users and faculty passing the NNCI-UTX SEI training module	90%	Module under development	Module under development	Work in progress	Work in progress
Number of Longhorn Startup and NSF ICorps, and Austin Technology Incubator Teams using NNCI-TNF	2	2 NSF I-Corps	1 NSF I-Corps	2 NSF I-Corps	NA

# TNF: Network Collaboration (TNF, SDNI and CNF)

## Band Structure Engineering of Layered WSe<sub>2</sub> via 1-Step Chemical Functionalization



Spectroscopic and electrical characterization of a FL WSe<sub>2</sub> FET. (a). Optical image and schematic diagram of the back-gated FL WSe<sub>2</sub> FET with Ni/Au top contact electrodes. (b). Raman spectra taken on a FL WSe<sub>2</sub> device flake (~ 4 nm thickness) before and after (NH<sub>4</sub>)<sub>2</sub>S(aq) treatment. (c). Room-temperature back-gated transfer characteristics of the FL WSe<sub>2</sub> FET shown in (a) before (black curve) and after (red curve) (NH<sub>4</sub>)<sub>2</sub>S(aq) treatment. A clear enhancement of I<sub>ON</sub> in the p-branch is observed after (NH<sub>4</sub>)<sub>2</sub>S(aq) treatment. (d). Qualitative equilibrium band diagrams along the FL WSe<sub>2</sub> FET channel before (top) and after (bottom) (NH<sub>4</sub>)<sub>2</sub>S(aq) treatment explaining the measured FET current-voltage behavior.

J. Park, A.Rai, ...G. Xing, K. Cho, S. K. Banerjee and A. C. Kummel (Device Research Conference, ACS Nano 2019)

# TNF: Network Collaboration

- L.A. Kahlor interacts with other sites on SEI.
- S. Banerjee serves on the NNCI Metrics sub-committee
- S. Majumder serves on the etch-committee.
- TNF staff have participated in various technical workshops that were organized (ALD- Harvard and Stanford, Etch- Cornell and Stanford, EBL-Georgia Tech, Soft Lithography- Harvard).