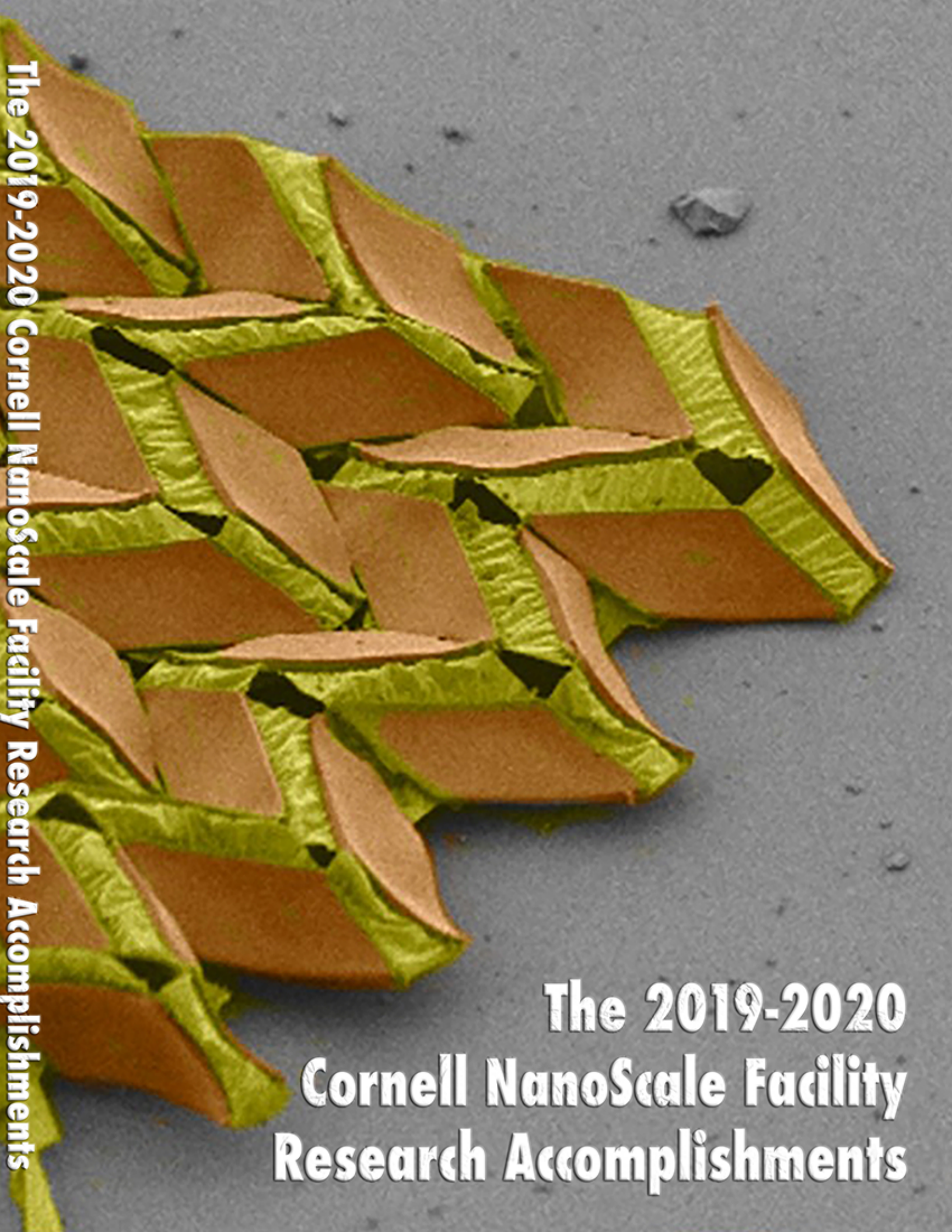
The 2019-2020 Cornell NanoScale Facility Research Accomplishments
The 2019-2020
Cornell NanoScale Facility
Research Accomplishments

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Cornell NanoScale Facility 2019-2020 Research Accomplishments

CNF Lester B. Knight Director:
Christopher Kemper Ober

Director of Operations:
Ronald Olson

Cornell NanoScale Facility (CNF) is a member of the
National Nanotechnology Coordinated Infrastructure *(www.nnci.net)*
and is supported by the National Science Foundation under Grant No. NNCI-1542081,
the New York State Office of Science, Technology and Academic Research,
Cornell University, Industry, and our Users.

The 2019-2020 CNF Research Accomplishments are also available on the web:
http://cnf.cornell.edu/publications/research_accomplishments

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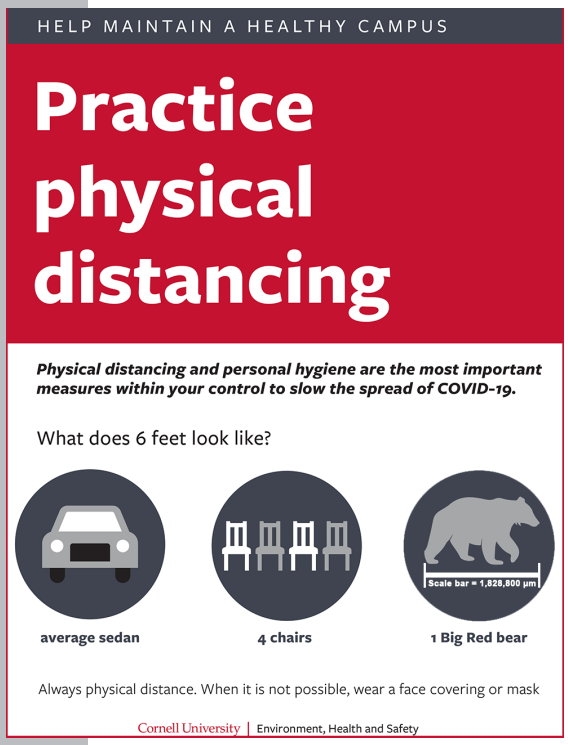
2019-2020 Research Accomplishments • Directors' Welcome

Cornell NanoScale Facility (CNF) is proud to present the 2019-2020 CNF Research Accomplishments! We are pleased to showcase the research excellence demonstrated by the users and research groups who are making use of CNF. Users continue to benefit from interaction and collaboration with expert staff, an expansive tool set, and nanofabrication capabilities enabling realization of unique, diverse state-of-the-art results. In addition to the 90 featured research reports contained in this book, a section on CNF-research-related patents, presentations, and publications (close to 400 in 2019) has been included.

CNF's "2020 vision" was disrupted by the COVID-19 pandemic; however, even with University directives to close the cleanroom, office, second floor labs and CAD room on March 17th, focus was never lost for the user community.

After 2.5 months of closure (the longest in CNF history) a reactivation plan was authorized in June for the gradual reopening of the CNF. This plan allowed for the return of local, internal academic users in accordance with State and University guidelines intended to preserve the safety and well-being of CNF users, employees, and the Campus Community. During these initial stages of reopening, the CNF staff and users worked on assigned teams with limited hours. Beginning in mid-August the CNF offered expanded hours of access to users.



Cornell puts its own unique spin on physical distancing! We added the scale bar to the bear.....

We are pleased to let you know that CNF is currently back to 24/7 operational status for users who have been approved and retrained. While some things have changed, one thing remains paramount — the CNF's firm commitment to protecting its community. Anyone seeking to re-gain access to the CNF is required to complete re-training aimed at providing continued education on new COVID safety and social distancing protocols. CNF continues to follow Cornell University and New York State travel guidelines for users seeking approval for cleanroom access. New user orientation and user equipment training protocols have been updated and include remote Zoom training, pre-recorded on-line training videos, and one on one training with social distancing. The CNF will start equipment training and accepting new users in September.

A sincere thank you is extended to our users for their continued patience and understanding. The community efforts to follow newly established protocols for social distancing, surface cleaning, face mask wearing, and hand sanitizing is testimony to their dedication to keeping our facility safe. The CNF staff continues to show resilience and tenacity when presented with challenges. Their enthusiasm as they work together to discover creative ways to teach new users while working to solve difficult and interesting problems is impressive and much appreciated.

Despite the uncertainty the future may present, opportunities for positive change exist. As we continue to collaborate and improve, there is no doubt we will emerge stronger on the other side.

"The difference between STUMBLING BLOCKS and STEPPING STONES, is how you use them."
~ Unknown

Staffing News

WELCOME

This year we are pleased to announce the addition of a new Associate Director, ***Prof. Claudia Fischbach-Teschl***, presently Director of Cornell's Physical Sciences Oncology Center (PSOC). Dr. Fischbach-Teschl's charge is multi-faceted. She will work to drive strategies, lead CNF efforts to better understand, serve, and communicate with the life science community, integrate the new Multiscale 3D Fabrication Facility (M3FF) and the 3D Visualization Facility (3VF) while fostering new convergent and life science activities.

In January, ***George "Mac" McMurdy*** joined the CNF family after graduating from the Rochester Institute of Technology with a master's degree in Microelectronic Engineering.

We look forward to George establishing himself as a key staff member dedicated to the support of our user programs.

With your support, we look forward to continued membership in the 16-site National Nanotechnology Coordinated Infrastructure (NNCI) and ongoing support from the National Science Foundation (NSF) as well as maintaining our strong reputation as one of the major academic, nanofabrication facilities in the United States. In the words of Walton Peyton,

"We are stronger together than we are alone."

THANK YOU FOR YOUR SERVICE

The CNF continues to thrive due to the efforts of its staff members. We are grateful for the service and dedication of the following members of the CNF family and we extend best wishes as they enter retirement. Thank you, you will be missed!

- ***Denise Budinger***, with 26 years of service at CNF, retired on August 7th. *(Left)*

- ***Jerry Drumheller***, with 26 years of service at CNF, retired on January 31st. *(See Jerry below at one of our short courses showing off the sputtering system he managed for years!)*

- ***Kathy Springer***, with 17 years of service at CNF, will retire on September 15th. *(Left)*

We wish all of you continued health and wellbeing and look forward to seeing you back on campus.

Christopher Ober
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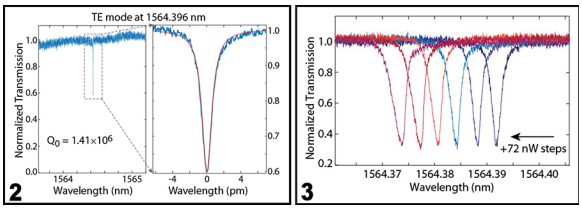
Comments, feedback, and suggestions about CNF are always welcome. Feel free to use our online User Comment Form at https://www.cnfusers.cornell.edu/user_feedback

Full Color Versions of Some Research Images



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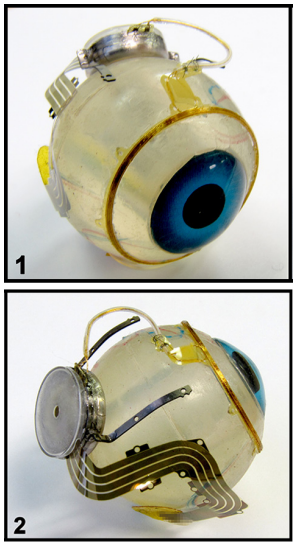

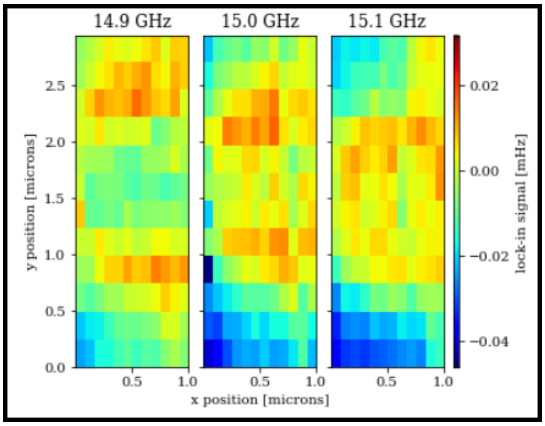

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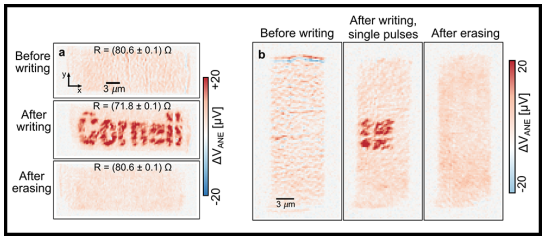

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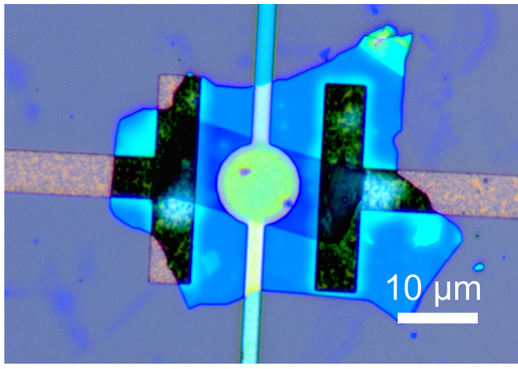

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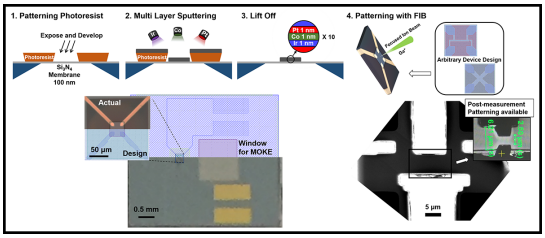

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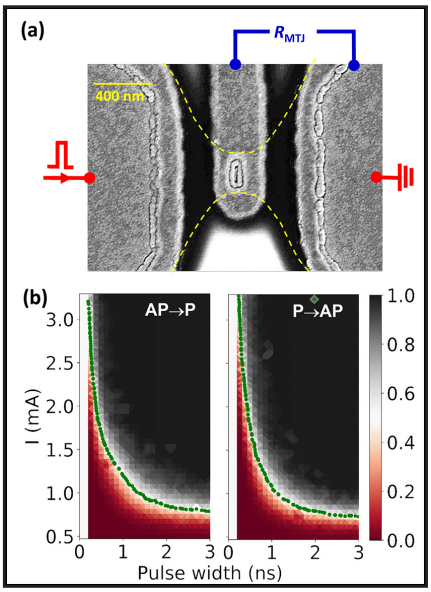

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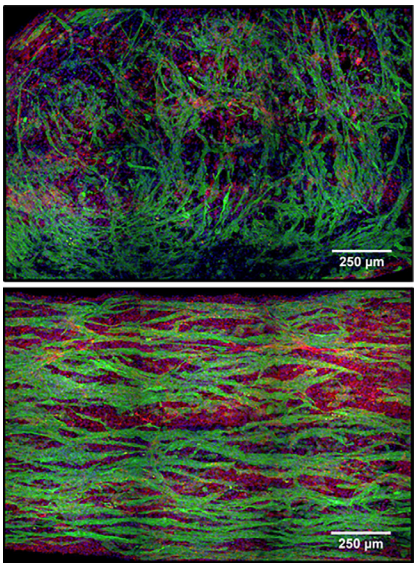

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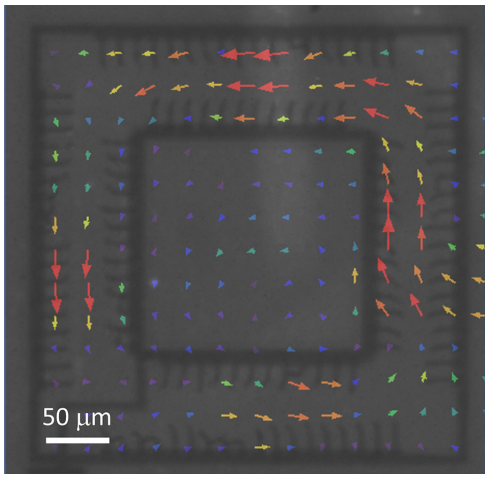

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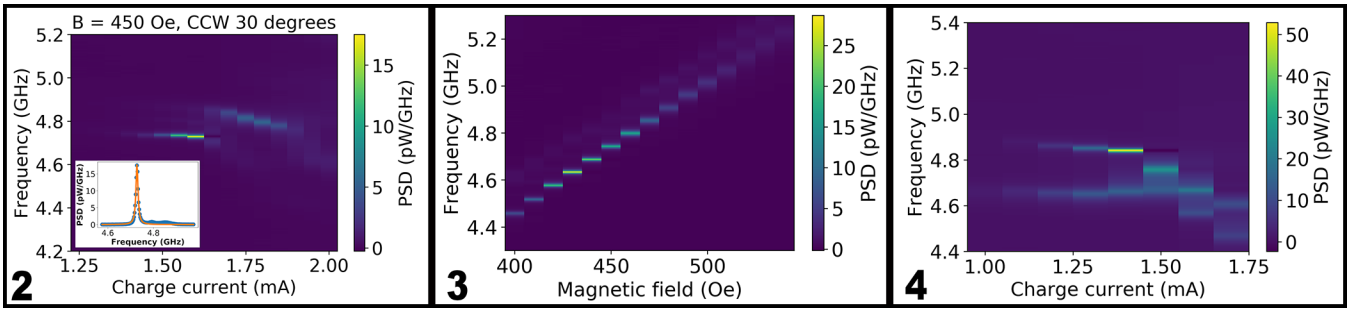

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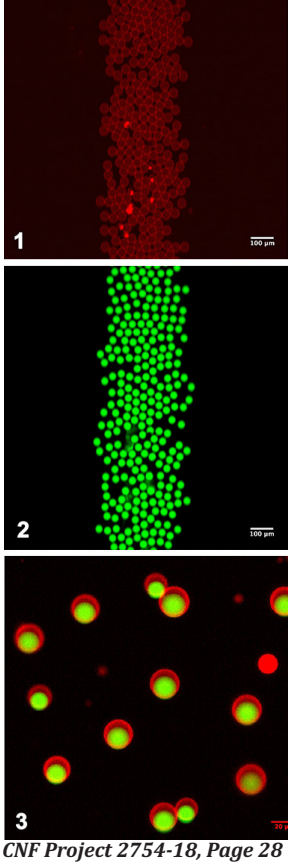

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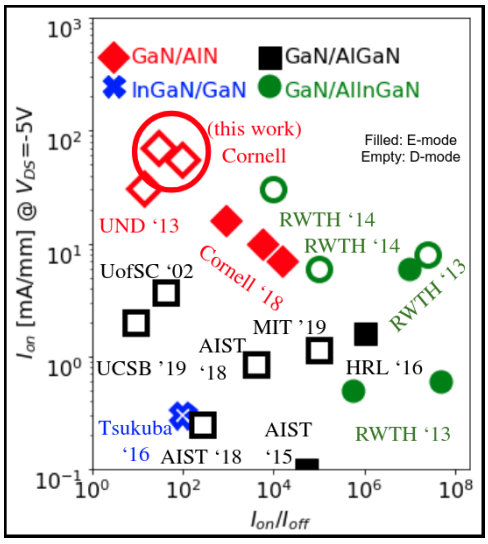

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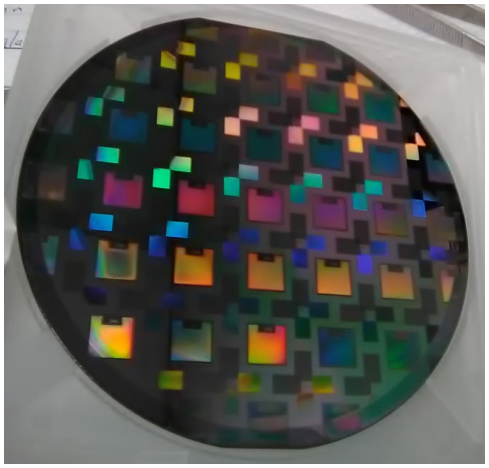

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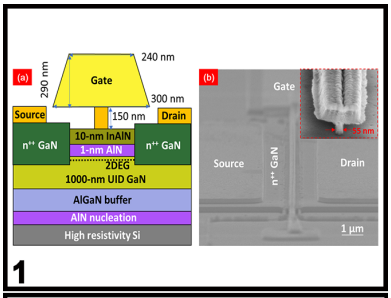

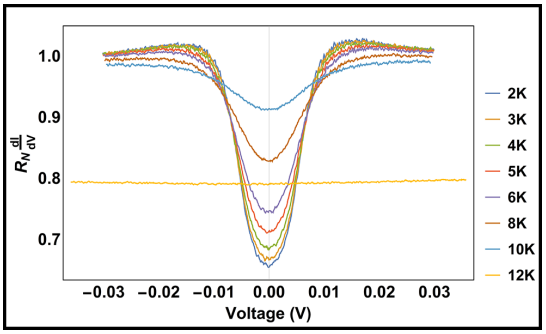

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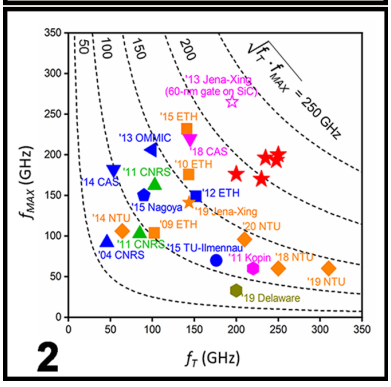

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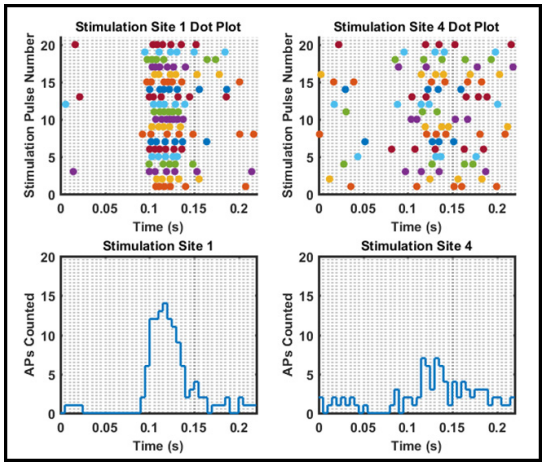

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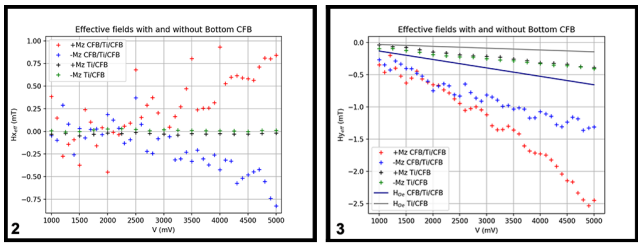

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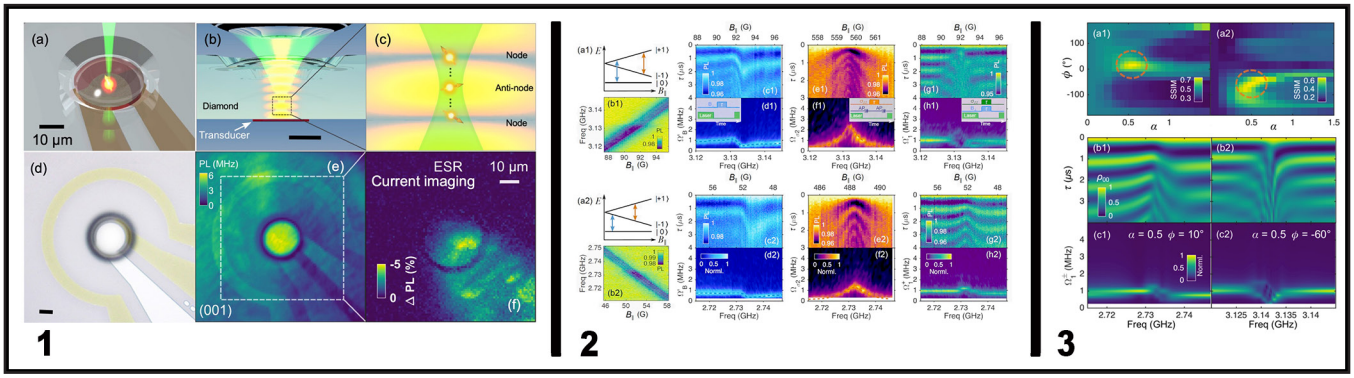

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A Selection of 2019 Cornell NanoScale Facility Research-Related Patents, Presentations, and Publications

"1.6 kV vertical Ga2O3 FinFETs with source-connected field plates and normally-off operation"; Hu, Zongyang, Nomoto, Kazuki, Li, Wenshen, Jinno, Riena, Nakamura, Tohru, Jena, Debdeep, Xing, Huili, 2019 31st International Symposium on Power Semiconductor Devices and ICs (ISPSD), IEEE, page(s) 483-486 (Cornell University).

"3D ElectroStatic Comb Actuators (3D-ESCA) for Micro Robotics"; Amit Lal, Robert Shepherd, 8578, Filed by Cornell, 3/22/19, Invention (Cornell University).

"A high-voltage p-channel FET based on III-Nitride heterostructures"; Samuel Bader, Reet Chaudhuri, Debdeep Jena, Huili Grace Xing, 8358-02-US, United States, US from PRV, Filed, 11/6/19, 16/676, 083 (Cornell University).

"A Highly Selective, Tunable High-Pass X-Ray Filter System and the Method of Fabrication"; David Agyeman-Budu, Arthur Woll, 8827-01-US, United States, MPR-Manuscript Provisional, Filed, 8/2/19, 62/882, 259 (Cornell University).

"A max activity filter for regulatory DNA elements"; Nathaniel Tippens, Haiyuan Yu, 8796, Unfiled, 6/4/19, Invention (Cornell University).

"A mechanically tunable GHz passive voltage element using microstrip resonator"; Di Ni, Adarsh Ravi, K B Vinaya Kumar and Amit Lal, Journal of Physics: Conf. Ser.1407 012051 (2019) (Cornell University).

"A micro-synthetic jet in a microchannel using bubble growth and collapse"; Ehsan Sourtiji, Yoav Peles, Applied Thermal Engineering, Volume 160, September 2019, 114084, https://doi.org/10.1016/j.applthermaleng.2019.114084 (University of Central Florida).

"A New Kind of Magnetic Microscope: Using Ultrafast Heat Pulses to Image Spin-Orbit Torques and Dynamics in Ferromagnetic and Antiferromagnetic Devices"; Fuchs, G., Condensed Matter Physics Seminar, Texas A&M University, College Station, TX 2019 INVITED (Cornell University).

"A polarization-induced 2D hole gas in undoped gallium nitride quantum wells"; Chaudhuri, Reet, Bader, Samuel James, Chen, Zhen, Muller, David A., Xing, Huili Grace, Jena, Debdeep, Science, Vol. 365, Issue # 6460, page(s) 1454-1457 (Cornell University).

"A Polymer Brush Approach to Controlling Biological Binding to Surfaces"; Christopher K. Ober, CDT Summer School, invited talk, University of Sheffield, Sheffield, UK, July 24, 2019 (Cornell University).

"A Polymer Brush Approach to Controlling Biological Binding to Surfaces"; Christopher K. Ober, MSE Seminar, invited talk, University of Pennsylvania, Philadelphia, PA, Oct. 3, 2019 (Cornell University).

"A practical and efficient method for filtering x-ray radiation"; David Agyeman-Budu, Arthur Woll, 8827, Filed by Cornell, 6/26/19, Invention (Cornell University).

"A review of giant correlation-length effects via proximity and weak-links coupling in a critical system: 4He near the superfluid transition"; J K Perron, M O Kimball and F M Gasparini, Reports on Progress in Physics, Volume 82, Number 11, Published 2 October 2019 • © 2019 IOP Publishing Ltd (University at Buffalo).

"A Tool to Improve Reproductive Management and Performance of Ruminant Females through Determination of their Reproductive Physiological Status"; D Erickson, J Giordano, M Masello, 9089, Unfiled Invention, 8/20/19, (Cornell).

"Absorption coefficient estimation of thin MoS2 film using attenuation of silicon substrate Raman signal"; Joon Young Kwak, Results in Physics, Volume 13, June 2019, 102202, Elsevier, https://doi.org/10.1016/j.rinp.2019.102202 (Morgan State University).

"Acoustic Sensing Systems, Devices and Methods"; M Abdelmejeed, J Kuo, A Lal, 7683-02-PC, Patent Cooperation Treaty, Filed, 2/4/19, PCT/US2019/016564 (Cornell).

"Acousto Electro Optic Modulator"; Amit Lal, 9105, Filed by Cornell, 8/22/19, Invention (Cornell).

"Acousto-Optic Modulation of Water in a Microfluidic Channel Using Planar Fresnel Type GHz Ultrasonic Transducer"; Adarsh Ravi, Mamdouh Abdelmejeed, Justin Kuo, Amit Lal, 2019 IEEE International Ultrasonics Symposium (IUS), 6-9 Oct. 2019, Glasgow, United Kingdom, United Kingdom, DOI: 10.1109/ULTSYM.2019.8925614 (Cornell University).

"Adaptive Illumination Apparatus, Method, and Applications"; Michael Buttolph, Kriti Charan, Bo Li, Chunhui (Chris) Xu, 7610-03-US, United States, US from PCT, Filed, 4/23/19, 16/344, 157 (Cornell University).

"Adaptive Illumination Apparatus, Method, and Applications"; Michael Buttolph, Kriti Charan, Bo Li, Chunhui (Chris) Xu, 7610-04-EP, Europe, EPC-European Patent Convention, Filed, 5/9/19, 17871203 (Cornell University).

"Adsorption-controlled growth and properties of epitaxial SnO films"; Mei, Antonio B., Miao, Ludi, Wahila, Matthew J., Khalsa, Guru, Wang, Zhe, Barone, Matthew, Schreiber, Nathaniel J., Noskin, Lindsey E., Paik, Hanjong, Tiwald, Thomas E., [PDF] diva-portal.org, Vol. 3, Issue # 10, page(s) 105202 (Cornell University).

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"Advancements in Design and Application of Microfluidic Devices to Study Cell Migration in Confined Environments"; Windsor, Aaron Joseph, Cornell Theses and Dissertations, Date Issued 2019-05-30, https://doi.org/10.7298/4ht2-t728 (Cornell University).

"All-glass, large metalens at visible wavelength using deep-ultraviolet projection lithography"; Park, Joon-Suh, Zhang, Shuyan, She, Alan, Chen, Wei Ting, Lin, Peng, Yousef, Kerolos MA, Cheng, Ji-Xin, Capasso, Federico, Nano letters, 2019, 19, 12, 8673-8682, November 14, 2019, https://doi.org/10.1021/acs.nanolett.9b03333 (Harvard University).

"Aluminum Nitride-based High Electron Mobility Transistor"; Samuel Bader, Reet Chaudhuri, Austin Hickman, SM Islam, Debdeep Jena, Huili Grace Xing, 8773-01-US, United States, MPR-Manuscript Provisional, Filed, 6/7/19, 62/858, 531 (Cornell University).

"An Atmosphere-breathing Refillable Biphasic Device for Cell Replacement Therapy"; Duo An, Alexander Ernst, James Flanders, Minglin Ma, Longhai Wang, 9204-01-US, United States, EPR-Enhanced Provisional, Filed, 12/5/19, 62/944, 169 (Cornell University).

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"An Integrated Microfluid Device for Capture and Spectroscopic Characterization of Live Cells Under Various Treatment Conditions"; H Huang, G Kelp, G Shvets, 8311-02-PC, Not Applicable (PCT App), PCT-Patent Cooperation Treaty, Filed, 7/25/19, PCT/US1943439 (Cornell University).

"Anomalous Charge Noise in Superconducting Qubits"; B. G. Christensen, C. D. Wilen, A. Opremcak, J. Nelson, F. Schlenker, C. H. Zimonick, L. Faoro, L. B. Ioffe, Y. J. Rosen, J. L. DuBois, B. L. T. Plourde, and R. McDermott, Physical Review B 100, 140503(R) - 24 October 2019 (University of Wisconsin).

"Antibiotic Susceptibility of Escherichia coli Cells during Early-Stage Biofilm Formation"; Huan Gu, Sang Won Lee, Joseph Carnicelli, Zhaowei Jiang, Dacheng Ren, George O'Toole, Editor, Journalof Bacteriology, September 2019 Volume 201 Issue 18 e00034-19 (Syracuse University).

"Apparatus for Improved Energy Resolution in Electron Microscopy"; Cameron Duncan, Jared Maxson, David Muller, 9107-01-US, United States, MPR-Manuscript Provisional, Filed, 9/3/19, 62/895, 300 (Cornell University).

"Apparatus for Improved Energy Resolution in Electron Microscopy"; C Duncan, J Maxson, D Muller, 9107, Filed by Cornell, 8/26/19, Invention (Cornell University).

"Application of metasurface-enhanced infra-red spectroscopy to distinguish between normal and cancerous cell types"; Kelp, G., Arju, N., Lee, A., Esquivel, E., Delgado, R., Yu, Y., Dutta-Gupta, S., Sokolov, K., Shvets, G., Analyst, Vol. 144, Issue # 4, page(s) 1115-1127 (Cornell University).

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"Atomic Force Microscopy Apparatus, Methods and Applications"; R Dwyer, J Marohn, S Nathan, 7633-03-US, United States, US from PCT, Filed, 11/11/19, 16/612, 473 (Cornell University).

"Atomic layer deposition for membranes, metamaterials, and machines"; K Dorsey, T Pearson, E Esposito, B Bircan, Y Han, S Russell, D Muller, I Cohen, P McEuen, Paul, APS Meeting, https://doi.org/10.1002/adma.201901944 (Cornell).

"Atomic Layer Deposition for Membranes, Metamaterials, and Mechanisms"; Kyle J. Dorsey, Tanner G. Pearson, Edward Esposito, Sierra Russell, Baris Bircan, Yimo Han, Marc Z. Miskin, David A. Muller, Itai Cohen, Paul L. McEuen, Advanced Materials, Volume 31, Issue 29, First published: 30 May 2019, https://doi.org/10.1002/adma.201901944 (Cornell).

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"Bidirectional Folding with Atomic Layer Deposition Bimorphs for Autonomous Micro-Origami"; I Cohen, B Bircan, M Miskin, R Lang, K Dorsey, P McEuen, APS March Meeting 2019, abstract id.X57.001 (Cornell University).

"Biometric Thin Card Reader With Energy Harvesting"; Amit Lal, US20190278953A1 United States, 2019-09-12 Publication of US20190278953A1 (Cornell University).

"Block Copolymer Self-Assembly Directed Hierarchically Structured Materials from Nonequilibrium Transient Laser Heating"; Tan, K. W., and Wiesner, U., Macromolecules 52, 395-409 (2019) (Cornell University).

"Block copolymers containing stable radical and fluorinated blocks with long-range ordered morphologies prepared by anionic polymerization"; Alicia Cintora, Hiroki Takano, Mohit Khurana, Teruaki Hayakawa, Christopher K. Ober, Polymer Chemistry, 2019, DOI: 10.1039/C9PY00416E (Cornell).

"Blue (In, Ga) N light-emitting diodes with buried n+-p+ tunnel junctions by plasma-assisted molecular beam epitaxy"; Cho, Y., Bharadwaj, S., Hu, Z., Nomoto, K., Jahn, U., Xing, H.G., Jena, D., Japanese Journal of Applied Physics, Vol. 58, Issue # 6, page(s) 60914 (Cornell University).

"Blue (In, Ga)N Light-Emitting Diodes with Buried n+−p+ Tunnel Junctions by Plasma-Assisted Molecular Beam Epitaxy"; Y Cho, S Bharadwaj, Z Hu, K Nomoto, U Jahn, HG Xing, D Jena, 2019 Compound Semiconductor Week, 19-23 May 2019, DOI: 10.1109/ICIPRM.2019.8819130 (Cornell).

"Breakdown Walkout in Polarization-Doped Vertical GaN Diodes"; Fabris, E., De Santi, C., Caria, A., Nomoto, K., Hu, Z., Li, W., Gao, X., Jena, D., Xing, H.G., Meneghesso, G., IEEE Transactions on Electron Devices, Vol. 66, Issue # 11, page(s) 4597-4603 (Cornell University).

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Common Abbreviations & Meanings

µl. . . . . microliter
µm. . . . . micron, micrometer
µN. . . . . micro-Newtons
µs . . . . . microsecond
Ω . . . . . Ohm
<. . . . . is less than
>. . . . . is greater than
~ . . . . . approximately
1D. . . . . one-dimensional
2D. . . . . two-dimensional
2DEG . . . . . two-dimensional electron gas
3D. . . . . three-dimensional
^3He helium-3
α-Al_2O_3. . . . . sapphire
α-Si . . . . . amorphous silicon
AC. . . . . alternating current
AFM . . . . . atomic force microscopy/microscope
AFOSR . . . . . Air Force Office of Scientific Research
Ag . . . . . silver
Al . . . . . aluminum
Al_2O_3 . . . . . aluminum oxide
ALD. . . . . atomic layer deposition
AlGaAs. . . . . aluminum gallium arsenide
AlGaN. . . . . aluminum gallium nitride
Ar . . . . . argon
ARC. . . . . anti-reflective coating
ArF . . . . . argon fluoride
As . . . . . arsenic
atm . . . . . standard atmosphere (as a unit of pressure)
Au. . . . . gold
AuNPs . . . . . gold nanoparticles
B. . . . . boron
B. subtilis. . . . . *Bacillus subtilis*
Bi . . . . . bismuth
BOE. . . . . buffered oxide etch
Br . . . . . bromine
C. . . . . carbon
C. . . . . centigrade
C-V. . . . . capacitance-voltage
C_3N_4. . . . . carbon nitride
$CaCl_2$ . . . . . calcium chloride
$CaCO_3$ . . . . . calcium carbonate
CAD. . . . . computer-aided design
CaF_2 . . . . . calcium fluoride
CCMR . . . . . Cornell Center for Materials Research
Cd . . . . . cadmium
CdS . . . . . cadmium sulfide
CdSe. . . . . cadmium selenide
CDW . . . . . charge-density-wave
Ce . . . . . cerium
CF_4. . . . . carbon tetrafluoride or tetrafluoromethane
CFD . . . . . computational fluid dynamics
CH_4 . . . . . methane
CHESS . . . . . Cornell High Energy Synchrotron Source
CHF_3. . . . . trifluoromethane
Cl. . . . . chlorine
Cl_2. . . . . chlorine gas
Cl_2/SF_6. . . . . chlorine sulfur hexafluoride
cm. . . . . centimeter
CMOS. . . . . complementary metal oxide semiconductor
CMP . . . . . chemical mechanical polishing
CNF. . . . . Cornell NanoScale Science & Technology Facility
Co . . . . . cobalt
CO_2 . . . . . carbon dioxide
Co_3O_4. . . . . cobalt oxide
CoFeAl . . . . . cobalt iron aluminum
CoFeB. . . . . cobalt iron boron
CoP . . . . . cobalt porphyrin
CPC . . . . . colloidal photonic crystal
CPD. . . . . contact potential difference
CpG . . . . . cytosine-phosphate-guanine
Cr . . . . . chromium
CRDS . . . . . cavity ring-down spectrometer
cryoSAXS . . . . cryogenic small angle x-ray scattering
CTE . . . . . coefficients of thermal expansion
CTL . . . . . confinement tuning layer
Cu . . . . . copper
CVD. . . . . cardiovascular disease
CVD. . . . . chemical vapor deposition
CW . . . . . continuous wave
CXRF . . . . . confocal x-ray fluorescence microscopy
DARPA . . . . . Defense Advanced Research Projects Agency
DC. . . . . direct current
DCB. . . . . double cantilever beam
DCE. 1,2-dichloroethane
DCM. . . . . dichloromethane
DEP. . . . . dielectrophoresis
DFT. . . . . density functional theory
DFT. . . . . discrete Fourier transform
DI . . . . . de-ionized
DMF. . . . . dimethyl formamide
DNA . . . . . deoxyribonucleic acid
DNP . . . . . dynamic nuclear polarization
DOE. . . . . United States Department of Energy
DPPC 1,2-dipalmatoyl-sn-glycero-3-phosphocholine
DRAM. . . . . dynamic random access memory
DRIE . . . . . deep reactive ion etch
DSA. . . . . directed self assembly
dsDNA . . . . . double-stranded DNA
DUV . . . . . deep ultraviolet
e-beam . . . . . electron beam lithography
E. coli. . . . . *Escherichia coli*
EBL . . . . . electron-beam lithography
EDS . . . . . energy dispersive spectroscopy

EELS ..... electron energy loss spectroscopy
EG..... ethylene glycol
EIS..... electrochemical impedance spectroscopy
ELISA..... enzyme-linked immunosorbent assays
EO..... electro-optic
EOT..... equivalent oxide thickness
EPICs..... electronic photonic integrated circuits
Er ..... erbium
ErAs..... erbium arsenide
ESM..... effective screening medium
EUV..... extreme ultraviolet
ex situ..... Latin phrase which translated literally as 'off-site' -- to examine the phenomenon in another setting than where it naturally occurs
ex vivo ..... Latin for "out of the living" -- that which takes place outside an organism
F..... fluorine
FDA..... United States Food & Drug Administration
FDMA..... fluorinated perfluorodecyl methacrylate
Fe ..... iron
Fe_2O_3 ..... iron oxide
$FeCl_3$ ..... iron(III) chloride, aka ferric chloride
FeGe..... iron germanium
FEM..... finite element method
FET ..... field-effect transistor
FFTs..... fast Fourier transforms
fg..... femto gram
FIB..... focused ion beam
FIR ..... far infrared
fJ..... femto Joules
FM..... frequency modulation
FMR..... ferromagnetic resonance
FOTS ..... fluorosilane, tridecafluoro-1,1,2,2-tetrahydrooctyltrichlorosilane
FTIR..... Fourier transform infrared spectroscopy
Ga..... gallium
Ga_2O_3..... gallium(III) trioxide
GaAs ..... gallium arsenide
GaAsN ..... gallium arsenide nitride
GaInNAs..... gallium indium nitride arsenide
GaN..... gallium nitride
GaP ..... gallium phosphide
GaSb ..... gallium antimonide
Gd..... gadolinium
Ge..... germanium
GFET ..... graphene field effect transistor
GHz..... gigahertz
GI ..... gastrointestinal
GMR..... giant magnetoresistance
GPa ..... gigapascal
GPS ..... global positioning system
h..... hours
H..... hydrogen
H_2O_2..... hydrogen peroxide
HBAR..... high-overtone bulk acoustic resonator
hBN..... hexagonal boron nitride
HBr ..... hydrogen bromide
hcp ..... hexagonal close packing
He..... helium
HEMTs..... high electron mobility transistors
Hf ..... hafnium
HF..... hydrofluoric acid
HfB_2..... hafnium diboride
HFEs ..... hydrofluoroethers
HfO_2..... hafnium dioxide
Hg..... mercury
high-κ ..... high dielectric constant
HMDS..... hexamethyldisilazane
HRS..... high resistance state
HSQ..... hydrogen silsesquioxane
HSQ/FOx..... negative electron beam resist hydrogen silsesquioxane
Hz..... Hertz
I-V..... current-voltage
I/O..... input/output
IARPA..... Intelligence Advanced Research Projects Activity
IC ..... integrated circuit
ICP..... inductively coupled plasma
ICP-MS..... inductively coupled plasma mass spectroscopy
ICP-RIE..... inductively coupled plasma reactive ion etcher
IFVD ..... impurity free vacancy diffusion
IID..... impurity induced disordering
IIEI ..... ion implant enhanced interdiffusion
In ..... indium
in situ..... Latin phrase which translated literally as 'in position' -- to examine the phenomenon exactly in place where it occurs
in vitro..... Latin for "within glass" -- refers to studies in experimental biology that are conducted using components of an organism that have been isolated from their usual biological context in order to permit a more detailed or more convenient analysis than can be done with whole organisms
in vivo..... Latin for "within the living" -- experimentation using a whole, living organism
InAlN..... indium aluminum nitride
InAs..... indium arsenide
InAs NWs ..... indium arsenide nanowires
INDEX ..... Institute for Nanoelectronics Discovery and Exploration
InGaAsN..... indium gallium arsenide nitride
$InGaZnO_4$ ..... indium gallium zinc oxide
InP..... indium phosphide
IPA..... isopropyl alcohol
IR ..... infrared
IrO_2 or IrO_x ..... iridium oxide
ITO ..... indium tin oxide
JP-8..... Jet Propellant 8
κ..... dielectric constant
K..... Kelvin (a unit of measurement for temperature)
K..... potassium
KFM..... Kelvin force microscopy
kg ..... kilogram
kHz..... kilohertz
KOH..... potassium hydroxide
La ..... lanthanum

LED . . . . . light-emitting diode
LER . . . . . line edge roughness
Li. . . . . lithium
low-κ . . . . . low dielectric constant
LPCVD . . . . . low pressure chemical vapor deposition
lpm . . . . . liter per minute
LRS . . . . . low resistance state
Lu . . . . . lutetium
LWR. . . . . line width roughness
MBE. . . . . molecular beam epitaxy
MEMs. . . . . microelectromechanical systems
MFMR . . . . . microfabricated micro-reactors
MgO . . . . . magnesium oxide
MGs. . . . . molecular glasses
MHz . . . . . megahertz
micron . . . . . micrometer, aka μm
min . . . . . minutes
ml . . . . . milliliter
mm . . . . . millimeter
mM . . . . . millimolar
Mo. . . . . molybdenum
MOCVD. . . . . metal oxide chemical vapor deposition
MOS . . . . . metal oxide semiconductor
MoS_2 . . . . . molybdenum disulfide
$MoSe_2$. . . . . molybdenum diselenide
MOSFET . . . . . metal oxide semiconductor field effect transistor
MRAM . . . . . magnetic random access memory
MRFM . . . . . magnetic resonance force microscopy
MRI . . . . . magnetic resonance imaging
ms. . . . . millisecond
MSM . . . . . metal-semiconductor-metal
mTorr. . . . . millitorr
mV. . . . . millivolt
MVD. . . . . molecular vapor deposition
MΩ . . . . . megaohms
N . . . . . nitrogen
N_2 . . . . . nitrous oxide
nA. . . . . nanoAmperes
NaCl. . . . . sodium chloride
NASA . . . . . National Aeronautics & Space Administration
Nb. . . . . niobium
Nb_3Sn . . . . . triniobium-tin
NCs . . . . . nanocrystals
Nd. . . . . neodymium
NEMs. . . . . nanoelectromechanical systems
NH_4F . . . . . ammonium fluoride
Ni . . . . . nickel
NIH . . . . . National Institutes of Health
NIR . . . . . near-infrared
nL . . . . . nanoliter
nm. . . . . nanometer
NMP. n-methyl-2-pyrrolidone
NNCI . . . . . National Nanotechnology Coordinated Infrastructure
NPs . . . . . nanoparticles
NPs . . . . . nanopores
ns . . . . . nanosecond
NSF . . . . . National Science Foundation
NV . . . . . nitrogen-vacancy
NVM. . . . . non-volatile memory
NW FETs. . . . . nanowire field-effect transistors
O . . . . . oxygen
O_3 . . . . . trioxygen
OFET . . . . . organic field effect transistor
OLED. . . . . organic light-emitting diode
ONO . . . . . oxide/nitride/oxide
ONR-MURI . . . Office of Naval Research Multidisciplinary University Research Initiative
OPV. . . . . organic photovoltaic cells
OTFT . . . . . organic thin-film transistor
Pa . . . . . Pascals
PAB . . . . . post-apply bake
PaC . . . . . Parylene-C
PAG . . . . . photoacid generator
Pb . . . . . lead
PBG. . . . . photonic bandgap
PbS . . . . . lead sulfide
PBS . . . . . phosphate-buffered saline
PbSe. . . . . lead selenide
PC. . . . . persistent current
PC. . . . . photocurrent
PCN. . . . . photonic crystal nanocavity
Pd . . . . . palladium
PD. . . . . photodetector
PDMS . . . . . polydimethylsiloxane
PEB . . . . . post-exposure bake
PEC . . . . . photoelectrochemical
PECVD . . . . . plasma enhanced chemical vapor deposition
PEDOT:PSS . . poly(3,4-ethylenedioxythiophene): poly(styrenesulfonate)
PEG . . . . . polyethylene glycol
PEI. . . . . polyethyleneimine
pFET . . . . . p-channel field-effect transistor
PFM . . . . . piezo-response force microscopy
PGMA. . . . . poly(glycidyl methacrylate)
pH. . . . . a measure of the activity of hydrogen ions (H+) in a solution and, therefore, its acidity
Ph.D. . . . . doctorate of philosophy
PhC . . . . . photonic crystal
PL . . . . . photoluminescence
pL . . . . . picoliter
PLD . . . . . pulsed laser deposition
PMMA . . . . . poly(methyl methacrylate)
poly-Si . . . . . polycrystalline silicon
PS . . . . . polystyrene
PS-*b*-PMMA . . polystyrene-*block*-poly(methyl methacrylate)
Pt . . . . . platinum
Pt/Ir . . . . . platinum/iridium
$PtSe_2$ . . . . . platinum diselenide
PV. . . . . photovoltaic
PVD. . . . . physical vapor deposition
Py . . . . . permalloy, $Ni_{81}Fe_{19}$
Q. . . . . quality factor

QD . . . . . quantum dots
QW . . . . . quantum well
RA. . . . . resistance-area
REU. . . . . Research Experience for Undergraduates Program
RF. . . . . radio frequency
RF MEMS . . . . radio frequency microelectromechanical systems
RIE . . . . . reactive ion etch
RMS or rms. . root mean square
RNA . . . . . ribonucleic acid
RTA . . . . . rapid thermal anneal
RTD. . . . . resistance temperature device
RTD. . . . . resonant tunneling diodes
Ru. . . . . ruthenium
s . . . . . seconds
S . . . . . sulfur
SAMs . . . . . self-assembled monolayers
SAXS . . . . . small angle x-ray scattering
Sb . . . . . antimony
Sc . . . . . scandium
sccm . . . . . standard cubic centimeters per minute
$scCO_2$. . . . . supercritical carbon dioxide
SDS . . . . . sodium dodecyl sulfate
Se . . . . . selenium
sec. . . . . seconds
SEM. . . . . scanning electron microscopy/microscope
SERS . . . . . surface enhanced Raman spectroscopy
SF_6. . . . . sulfur hexafluoride
Si. . . . . silicon
Si_3N_4. . . . . silicon nitride
SiC. . . . . silicon carbide
SiH_4. . . . . silane
SiN. . . . . silicon nitride
SiO_2. . . . . silicon dioxide, silica
Sn . . . . . tin
SnO_2. . . . . tin oxide
$SnSe_2$. . . . . tin selenide or stannous selenide
SOI. . . . . silicon-on-insulator
SPR . . . . . surface plasmon resonance
SQUID . . . . . superconducting quantum interference device
Sr_2RuO_4. . . . . strontium ruthenate
SRC . . . . . Semiconductor Research Corporation
$SrTiO_3$ . . . . . strontium titanate
STEM. . . . . scanning transmission electron microscopy/microscope
t-BOC. . . . . *tert*-butoxycarbonyl
Ta . . . . . tantalum
Ta_2O_5 . . . . . tantalum pentoxide
TaN . . . . . tantalum nitride
TAO_x. . . . . tantalum oxide
Te . . . . . tellurium
TEM . . . . . transmission electron microscopy/microscope
TFET . . . . . tunnel field effect transistor
TFT . . . . . thin-film transistor
Tg . . . . . glass transition temperature
THz . . . . . terahertz
Ti . . . . . titanium
TiN . . . . . titanium nitride
TiO_2. . . . . titanium dioxide
TM. . . . . transverse magnetic
TXM . . . . . transmission x-ray microscopy
UHV . . . . . ultra-high vacuum
USDA . . . . . United States Department of Agriculture
UV. . . . . ultraviolet
UV-Vis . . . . . ultraviolet-visible
V. . . . . vanadium
V. . . . . voltage
vdW . . . . . van der Waals
VLS . . . . . vapor-liquid-solid
VRMs. . . . . voltage regulator modules
VSM. . . . . vibrating sample magnetometry
W . . . . . tungsten
WDM . . . . . wavelength-division multiplexing
WSe_2 . . . . . tungsten diselenide
XeF_2. . . . . xenon difluoride
XPM . . . . . cross-phase modulation
XPS . . . . . x-ray photoelectron spectroscopy
XRD. . . . . x-ray diffraction
XRR. . . . . x-ray reflectivity
ZMW . . . . . zero-mode waveguide
Zn . . . . . zinc
$ZnCl_2$ . . . . . zinc chloride
ZnO . . . . . zinc oxide
ZnO:Al . . . . . zinc aluminum oxide
ZnS . . . . . zinc sulfide or zinc-blende
Zr . . . . . zirconium
ZrO_2 . . . . . zirconium dioxide
ZTO . . . . . zinc tin oxide

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