# BNL Microelectronics capabilities

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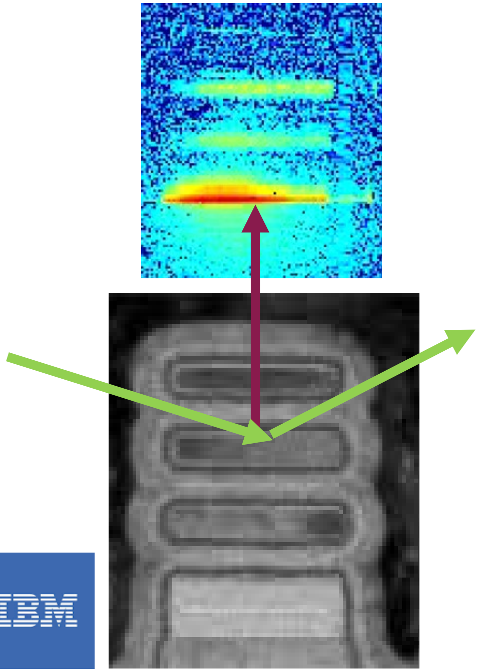
# Photon Solutions for Microelectronics

## Measurement Needs

- Non-destructive, in-situ
- Profiling from surface to bulk tunability
- Nanoscale strain imaging
- Nanoscale 3D imaging
- Interface/defect characterizations
- In-situ failure analysis
- PPM dopant profiles
- Work function mapping

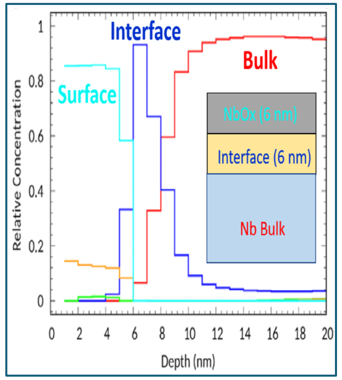
## National Synchrotron Light Source-II Capabilities fill measurement needs using the state-of-the-art capabilities

- Strain imaging: 10 nm (now), 5 nm at CDI (2026)
- 3D nanoscale imaging: ~8 nm
- Elemental mapping with PPM sensitivity
- Bandgap imaging
- Surface potential/work function mapping:~10 nm
- Suite of spectroscopic tools for probing electronic state, binding energy, and chemical states
- Scattering methods sensitive to ferroelectric, magnetic and correlated domains
- Photon Emission Electron Microscopy to characterize electronic work function.



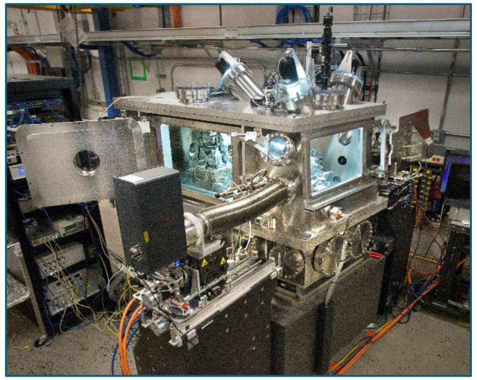
*Strain imaging in nanosheets (Collaboration IBM & Albany Nanotech)*

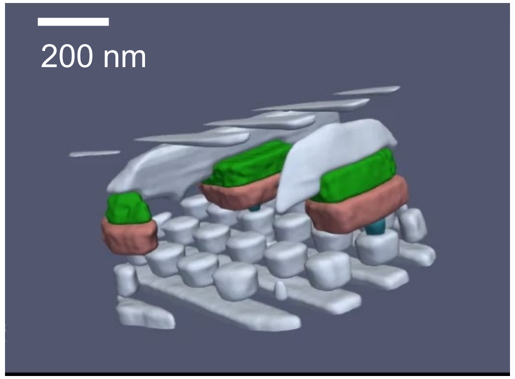
## Depth Profile




*National Synchrotron Light Source - II*

*HXN X-ray Microscope for 10 nm imaging*



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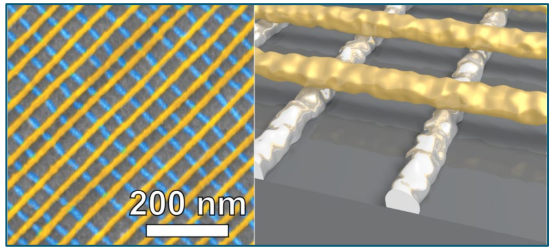
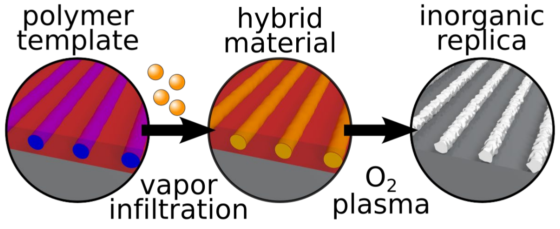
https://www.bnl.gov/nsls2/

# Beyond CMOS: Next-Generation Materials and Integration

### Material Needs

- Novel materials
  - Neuromorphic
- 2D control and integration
  - e.g. twistronics
- 3D integration
  - Self-assembly
  - Precision



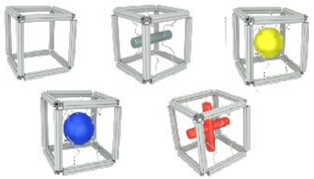




*3D integration by BCP 3D-DSA*

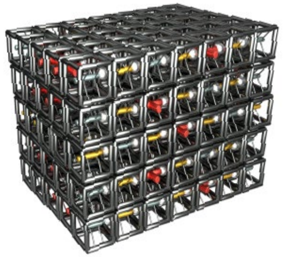
### Center for Functional Nanomaterials Capabilities: 3D Fabrication

- 3D Directed Self-Assembly (3D-DSA)
  - DNA materials voxel assembly
  - Block copolymer (BCP) self-assembly
  - Vapor-phase infiltration synthesis

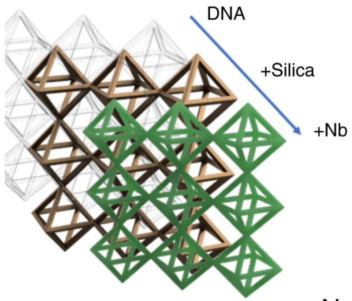
*Material nano-voxels: DNA frames with functional payloads*

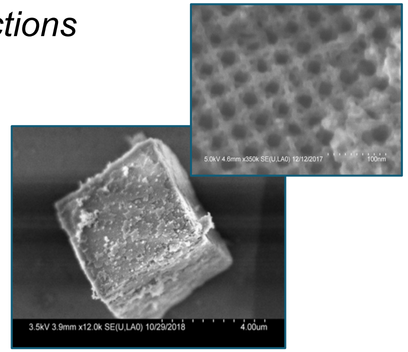


*Assembly of voxels in designed 3D architectures*



*3D array of Josephson junctions*



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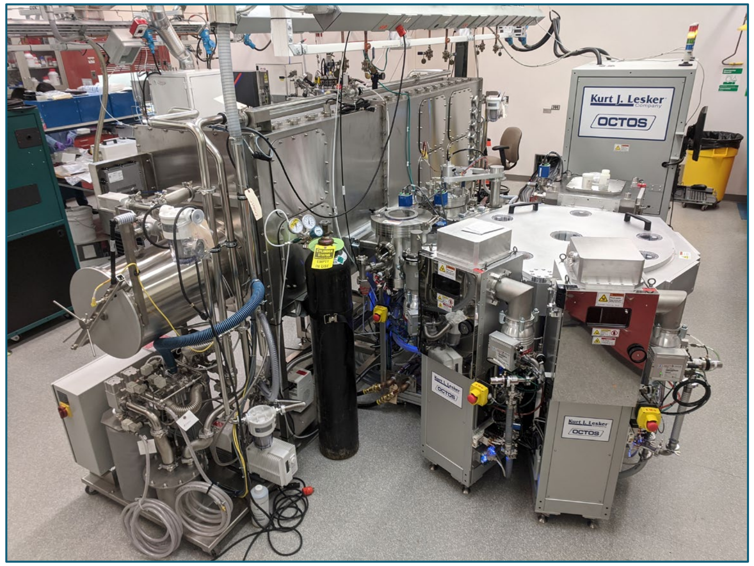
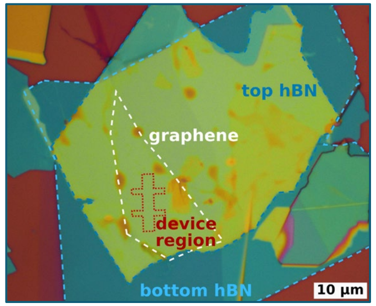
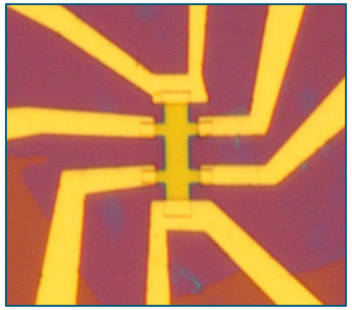
### QPress: Automated fabrication of 2D heterostructure & devices

- AI-aided 2D heterostructure fabrication and device integration



*Stacked 2D heterostructure and devices*

https://www.bnl.gov/cfn/

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# Ion implantation with Tandem accelerators

- electrostatic Tandem accelerators produce narrow transverse beams with narrow energy spread
- Tandems have served industrial and academic users for decades with existing infrastructure and expertise
- beams were also used for ion implantation to improve performance of SiC electronic devices
- a new heated waver implantation facility is designed, and would be available to all users
- microbeams can be developed for targeted irradiation of small areas

Novel high-energy ion implantation facility using a 15 MV Tandem Van de Graaff accelerator


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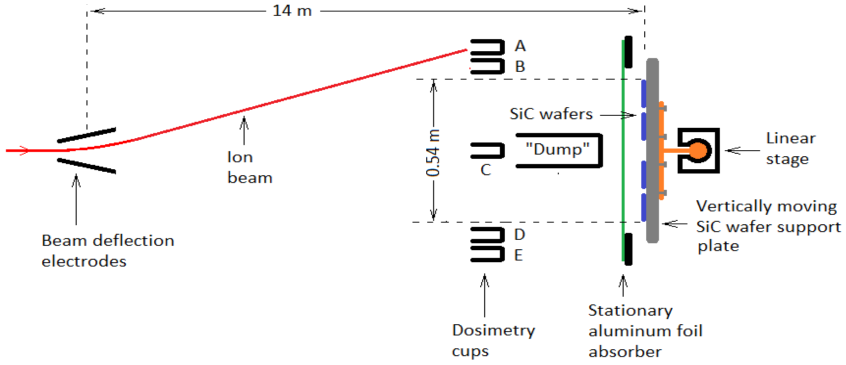
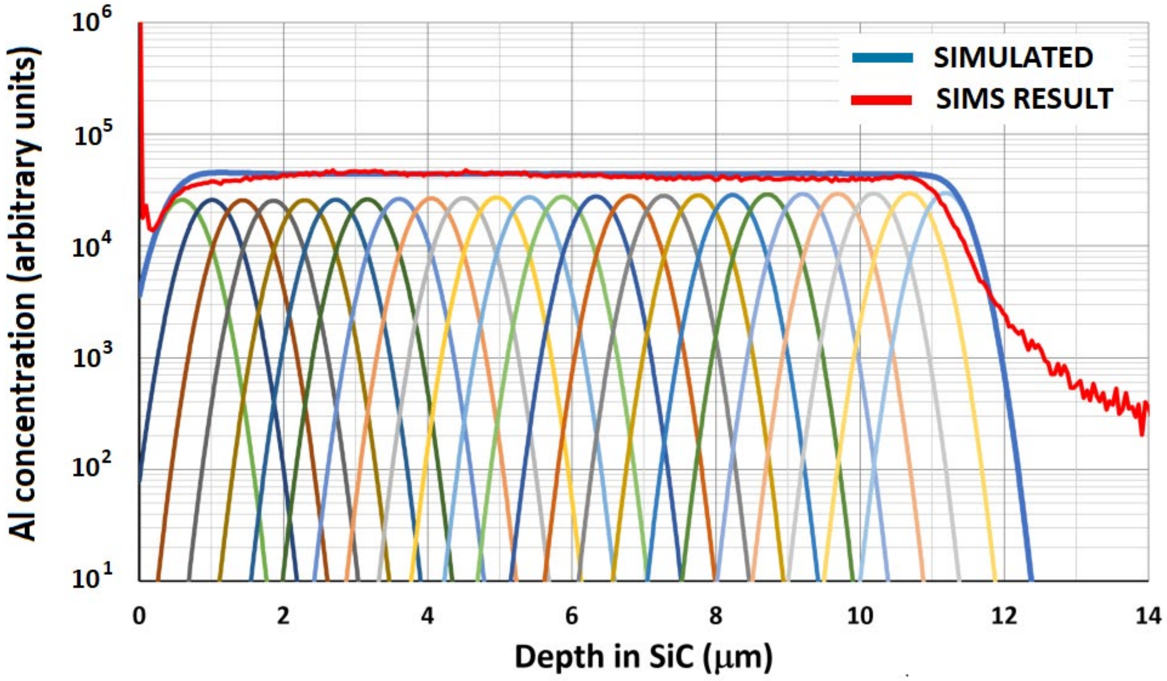



Schematic plan view of implantation and dosimetry

Maximum energies and ranges of four typical beams

| Ion species | Maximum energy | Range in SiC |
|---|---|---|
| | (MeV) | (mm) |
| B | 84 | 131 |
| N | 77 | 52 |
| Al | 91 | 20 |
| P | 126 | 23 |




Secondary Ion Mass Spectroscopy (SIMS0 results and simulated Al implantation profile in SiC with a 5.75 mm Al absorber using 24 Al beam energies ranging form 13.8 to 59.8 MeV.