Sydney Nano: small matters for big impact

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The University of Sydney Nano Institute

The University of Sydney Nano Institute (Sydney Nano) was launched in 2016 as an integral part of the University of Sydney's Strategy 2016–20 to enhance multi-disciplinary research. The mission of Sydney Nano is to discover and harness research at the nanoscale. Researchers who are part of this institute address distinct themes with high societal and economic impact: Energy & Environment; Health & Medicine; Communication, Computing & Security. These themes have four ubiquitous research domains: Quantum Science; Materials on the Nanoscale; Nanophotonics; and Molecular Nanoscience. The themes and domains are represented by seven theme and domain leaders, who are led by the institute director.

The Sydney Nanoscience Hub (SNH)

With AUD\$ 30 million in Australian Government support from the Commonwealth Education Infrastructure Fund, the University additionally invested a total of AUD\$ 120 million for the purpose-built infrastructure, the Sydney Nanoscience Hub (SNH). This is the headquarter building for Sydney Nano, on the Camperdown campus, behind the physics

building. Just as the University's physics building was purpose-built for a specific type of physics experiment, the SNH was built specifically for the highly controlled environments required to perform experiments with a high degree of precision and accuracy. For example, the building itself was constructed into a hill for geological stability, with more sensitive equipment being located further into the hill, into rock. These experiments include nanoscale microscopy, nanoscale fabrication, nanophotonics, quantum nanoscience and bionano. The building houses laboratories, cleanrooms and teaching spaces. We will focus on the research laboratories and cleanroom space in this article.

Research laboratories

There are three categories of laboratories, labelled Class A (with the most stringent environmental controls), Class B or Class C. The laboratories have been custom-designed to meet tight physical constraints: temperature, stability, vibration, pressure and electromagnetic interference. In addition, generous services corridors run throughout the building to provide services to the laboratories.

Class A labs Includes metal doors, and the lab is lined with metal to act as a Faraday cage. The Quantum Control labs are 120 m² of space that cost \$10 million to build and is one of the most environmentally stable spaces in the world. This is needed to enable research in controlling matter and light at the nanoscale: individual electrons, atoms and photons. The specifications of these labs are as follows.

- Temperature is maintained at 21 °C (± 0.025 °C) and humidity kept constant at 40% (± 5 %)
- Sliding doors open from an airlock to reduce air turbulence and pressure changes
- Floor vents draw air out of the lab, with new air entering via controlled dispersion units
- The air in the space is replaced every 68 s

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- Electromagnetic shielding with 0.2 in. of aluminium sheeting surrounding the lab to block unwanted interference, e.g. from mobile phones
- Active Magnetic Field Cancellation System checks for fluctuations, with the ability to respond in 1/1000th of a second
- Electric currents pumped through wires within the wall cancel out magnetic interference from nearby buildings, lifts, traffic etc.
- Architecturally independent to minimise vibrations; surrounded by 11 in. of floating concrete slab decoupled from the rest of the building and glass-fibre reinforcement is used instead of steel to minimise electromagnetic interference

Microscopy laboratories The two labs alongside the cleanroom are dedicated to microscopy analysis using the latest aberration-corrected transmission electron microscopes (TEMs). These labs were carefully constructed to provide the ideal environment for this equipment, with the first TEM having been installed in September 2017. The space here needs to accommodate for highly sensitive measurements and this means a highly controlled environment, namely, temperature, stability, vibration, pressure and electromagnetic interference.

NanoProbe Laboratory The NanoProbe Laboratory focuses on capabilities that support biomedical research. This facility features the southern hemisphere's first Single-Cell Inductively Coupled Plasma Spectrometer (SC-ICP-MS). The technique is based on the ability to measure discrete signals generated from a single cell when it enters the plasma and allows for the quantification of metals and metallic nanoparticles in individual cells. SC-ICP-MS promises to measure the metal concentrations down to the attogram (10^{-18} g) level, to yield critical data about the metal distribution in the cell population, yielding up to 100,000 data points per second.

Research cleanroom

The SNH contains 900 m² of two levels of cleanrooms: ISO 5 and ISO 7.

Precision air conditioning in the cleanroom continuously supplies 25,000 cubic metres per hour of highly filtered and conditioned air that maintains the particulate level to less than 100 particles for ISO Class 5 and 10,000 for ISO Class 7 (at a size no greater than 0.5 µm) per cubic foot of air. This is 100 times cleaner than air in a medical operating theatre. A deionised water plant can supply 5000 L of 18.2 MOhm ultrapure water to the cleanroom.

Presently, the list of tools in the cleanroom include:

- Electron beam lithography, 2–5-nm resolution capability
- i-Line Stepper, sub-micron lithography capable of high throughput of wafers
- Laser direct write system, typically used to make photo-masks, 250 nm
- Maskless lithography system capable of ~ 1 µm features
- Reactive ion etcher, capable of dry etching nanoscale features
- Atomic layer deposition equipment
- Optical microscopes and a profilometer for characterisation

Research community

The Sydney Nano community comprises well above 160 researchers at the University of Sydney across these themes and domains. Sydney Nano-related research projects benefit from the multi-disciplinary research community, external engagement platforms with other universities and industry, as well as from state-of-the-art and purpose-built facilities such as the Research & Prototype Foundry and cleanroom (nanofabrication) and the Sydney Microscopy & Microanalysis high-resolution, TEM suites located in the SNH.

In addition, some of the Microsoft Quantum research and technical community will join the Sydney Nano research community to perform the latest quantum nanoscience research, as part of a partnership between Microsoft and the University of Sydney.

Research case study: sustainable nanotechnology

Human and environmental exposure to nanomaterials is inevitable, and as the use of these nano-enabled products become more widespread, so too will concerns around their safety and impact on human and environmental health. To provide fundamental mechanistic insights into the effects of nanoparticles on living organisms, Sydney Nano develops a holistic research approach, correlative nano-bio-spectroscopy to test the interactions of nanoparticles with individual proteins, human cells, 3D printed tissue-like models, bacteria (microbiome) and tissues using state-of-art characterisation tools (resolution ~ 10 nm). Detailed data on nanoparticle safety address an unmet regulatory need and are critically needed to protect both health and the sustainability and benefits of nanomaterials.

Sydney Nano generates methodologies for nanotoxicity testing to guide safer-by-design drug formulations, food products and cosmeceuticals. It could ultimately decrease nano-specific risks of nano-enabled products, including food, while it will pave the way for a more sustainable nanotechnology industry.

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Ethical approval This article does not contain any studies with human participants or animals performed by the authors.

Compliance with ethical standards

Conflict of interest Wojciech Chrzanowski declares that he has no conflict of interest. Anna V. Ceguerra declares that she has no conflict of interest.