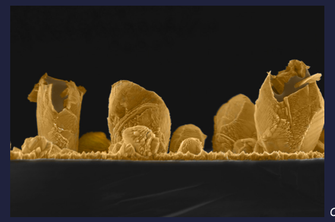
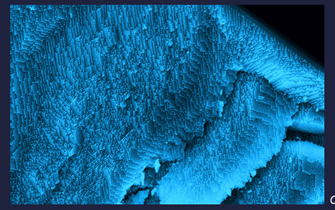


Credit: Zakaria Al Balushi

GALLIUM NITRIDE SHELL FORMATIONS

Field-emission scanning electron micrograph of the growth of gallium nitride at low temperatures on CVD graphene that has been transferred onto float glass illustrates the formation of hollow gallium nitride shell structures. The formation of these gallium nitride shells results from the competition between the nitridation of the surface of the gallium droplets and desorption of gallium atoms from the droplets during the growth process.



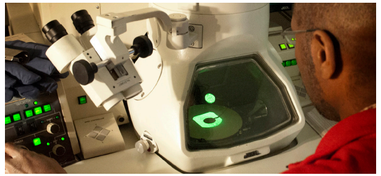
Credit: Shih-Ying Yu

FESEM OF SILICA OPAL INFILTRATED WITH SILICON

A cross section of the successful infiltration of silicon inside a silica opal template. To create ordered three-dimensional structures, a close-packed lattice of silica spheres with a diameter of 30nm was used as a template. Silicon is then grown inside the voids of the opal template by means of high pressure chemical vapor deposition (HPCVD). The three-dimensional artificial solid is defined as metalattice and they are periodic on a scale under 60nm. It is expected that the silicon inverse opal metalattice can provide a platform to study the fundamental electrical and thermal properties of semiconductors.

PennState
Materials Research Institute

The Materials Research Institute
N-317 Millennium Science Complex
University Park, PA 16802
814-863-8407 or visit: mri.psu.edu



A Collaboration of Experts

The Materials Research Institute (MRI) is the university-wide resource for 245 faculty at Penn State, providing centralized facilities and expert staff to help train the next generation of scientists and engineers and to perform the ground-breaking research that generates innovations in technologies and advances in knowledge.

Fast Facts

- 245 faculty in materials research
- ~1000 graduate students and post-docs
- 60-plus visiting scientists and research associates
- 35 research support staff
- 5 colleges and 15 science and engineering departments represented

MCL
The Materials Characterization Lab

MCL is made up of an interdisciplinary team of scientists and engineers passionate about education and collaborative problem solving. It is a fully staffed, open access analytical research facility charged with enabling research and educating the next generation of highly qualified researchers.

NANOFAB
The Nanofabrication Lab

We provide open access to MRI facilities for fabrication at the nano- and micro-scale in conjunction with materials and device characterization utilizing the most advanced techniques available and a suite of computational modeling capabilities backed by faculty experts.

MCC
The Materials Computation Center

The MCC's primary aim is to support faculty working in computer-based simulations of materials across the various length and time scales. This support includes building connections with experimental and industrial partners – specifically connecting to the Nanofabrication and Materials Characterization Laboratories.

2DCC
2-Dimensional Crystal Consortium

A National Science Foundation Materials Innovation Platform (NSF MIP), the 2DCC will establish Penn State as a world leader in the discovery and development of 2D materials for next generation electronics.

The 2DCC-MIP is funded by NSF cooperative agreement DMR-1539916.

> *"We have been using the MRI facilities to build and characterize our development devices for five years. The equipment is well maintained by a knowledgeable, capable, and helpful staff so it's ready when we are. We've saved millions in capital and operational expenditures; more importantly, we saved precious time. Great job, keep it up!"*
>
> Joe Marcanio, Owner & CEO, Marcanio Co., Greensburg, PA

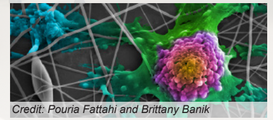
PennState
Materials Research Institute

A Culture of Interdisciplinary Research

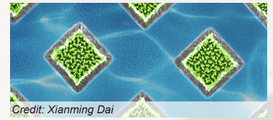
Credit: Quinn Cambell

Credit: Damoon Sohrabi Baba Heidary

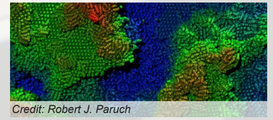
Credit: Yu-Chuan Lin



Credit: Pouria Fattahi and Brittany Banik



Credit: Xianming Dai



Credit: Robert J. Paruch

PennState
Materials Research
Institute

A World Leader in Research and Education

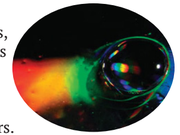
Penn State's support of research has catalyzed a steady climb in national and world rankings over the past two decades. In the latest National Research Council rankings of major research universities, Penn State stood at #8, ahead of any other public university and among a group of elite world-class institutions. Perhaps most significant is the broad range of Penn State's strengths, which include not only high rankings in the physical sciences and engineering, but also in biology, geology, health and human development, astronomy, psychology, and the liberal arts. New initiatives and investments, notably in research computing and bioengineering, are further broadening the impact of Penn State's research program.

A Culture of Interdisciplinary Research

Penn State's investment in its interdisciplinary research institutes, including the Materials Research Institute (MRI), has created a culture of strong collaborations across disciplines. At Penn State, many researchers have the support of both their academic departments and the university-wide institutes, such as MRI. By encouraging crosscutting research, MRI and its sister institutes open up traditional silos of knowledge to the stimulus of other viewpoints and new ideas. This mingling of disciplines, often called "convergence," brings together the physical and life sciences with engineering and computation to solve the most complex problems facing society today and in the future.

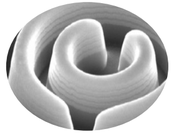
Research Impact

Bio-inspired Engineering



The bio-inspired invention, called slippery liquid-infused porous surfaces, or SLIPS won the inventors a 2012 R&D 100 Award. Both Tak-Sing Wong's group at Penn State's MRI and his post-doctoral research group at Harvard continue to develop the technology. And because there is so much left to develop, so many pathways to pursue, Wong expects SLIPS research to be one of the major focuses of his lab for the next several years.

In Situ Characterization



The ability to observe a chemical reaction under an electron beam in a controlled environment is a big issue in science. The new capabilities available with in situ TEM will benefit researchers in chemistry, physics, electrical engineering, mechanical science, and materials. Penn State's Titan Transmission Electron Microscopy (TEM) with in situ stages will provide researchers with a laboratory inside a microscope.

First-of-its-kind IP Policy

Four Principles for Industry Engagement

1. Penn State will not require ownership of IP resulting from industry-sponsored research.
2. A new Sponsored Research Agreement has been created that will significantly shorten negotiation times and lead to greater success in finalizing agreements.
3. Many research services for which Penn State is uniquely qualified to perform can be agreed to with a simple Research Services Agreement.
4. For research funded through federal dollars, Penn State will provide a fixed-cost licensing option at the time the agreement is executed. This is a completely new process that will give industry time to assess the commercial potential of the IP.

Research Impact

2D & Layered Materials and Coatings

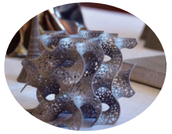
Scientists at MRI are devoted to the understanding and synthesis of materials at low dimensions (one atom thick) and the new phenomena that appear when these materials are stacked in layers with other 2D materials or used in coating applications. Penn State currently maintains three unique centers in this area: the 2-Dimensional & Layered Materials Center (2DLM), the Center for Atomically Thin Multifunctional Coatings (ATOMIC), and the 2-Dimensional Crystal Consortium (2DCC).

Humanitarian Materials Engineering

The process of building and testing for harsh conditions can be pivotal to the success of technologies in low resource regions. Researchers at MRI are building the capacity to test the ruggedness of materials and devices before they are deployed overseas, simulating field conditions while saving time and money.

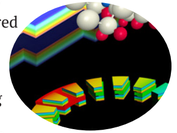
Research Impact

Additive Manufacturing



Penn State's Center for Innovative Materials Processing through Direct Digital Deposition (CIMP-3D), coupled with the extensive expertise of the Center team, provides unparalleled potential for advancing and deploying AM technology. Current research activity within the Center is directed at the development of technologies that will enable greater utilization of additive manufacturing in industry.

Thermally Functional Materials



Electrocaloric effect (ECE)-based cooling technology could be a radically different energy solution compared to conventional vapor compression refrigeration. ECE is a phenomenon in which a material exhibits a reversible temperature change when an electrical field is applied. Researchers at Penn State are finding practical applications of ECE in room-temperature refrigeration for air conditioning, compact solid state refrigerators, and on-chip cooling devices.

Building and lab photography: Paul Hazi