

“Dare Mighty Things”

The Center for Functional Nanomaterials in 2022

Charles (Chuck) Black
CFN Director

May 12, 2022



After 2+ years of COVID-19, who are we now?

C.D.C. Eases Outdoor Mask Guidance for Vaccinated Americans

Mask On or Off? Life Is Getting Back to Normal, and We're Rusty.

What You Can Do Post-Vaccine, and When

When Can We Start Making Plans?

We asked Dr. Anthony S. Fauci and other experts when they thought life would start to feel more normal.

What Normal Life Looks Like

It's different for everyone.

What Is Normal Life?

And when will we get back to it?

Who We Are Now

As we look ahead to life after the pandemic, many people are wondering what will be different in our lives.

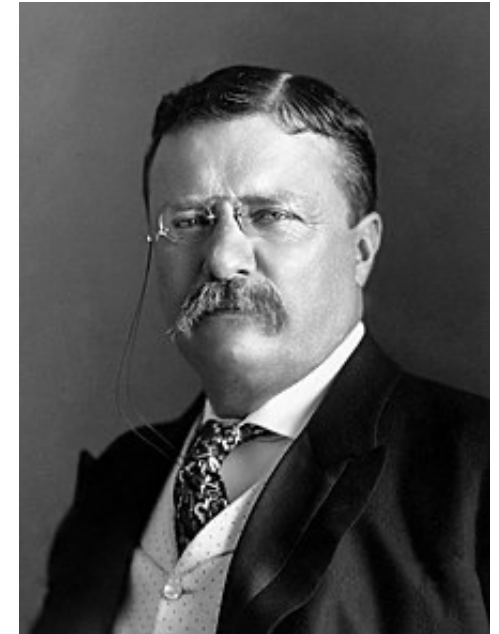
Will we go back to living the way we did before? And what if we do?

Dare Mighty Things

“Far better it is to dare mighty things, to win glorious triumphs, even though checkered by failure, than to take rank with those poor spirits who neither enjoy much nor suffer much, because they live in the gray twilight that knows not victory nor defeat.”

“The Strenuous Life” (1899)

- Our world has big challenges that science must solve.
- Let’s resist the urge to say *‘those problems are too big.’*
- Instead, let’s seize our opportunity to do work that matters.



Theodore Roosevelt
26th US President
(Youngest ever to become
US President, at age 42!)

Let's Dare Mighty Things

“Far better it is to dare mighty things, to win glorious triumphs, even though checkered by failure, than to take rank with those poor spirits who neither enjoy much nor suffer much, because they live in the gray twilight that knows not victory nor defeat.”

“The Strenuous Life,” (April 1899)

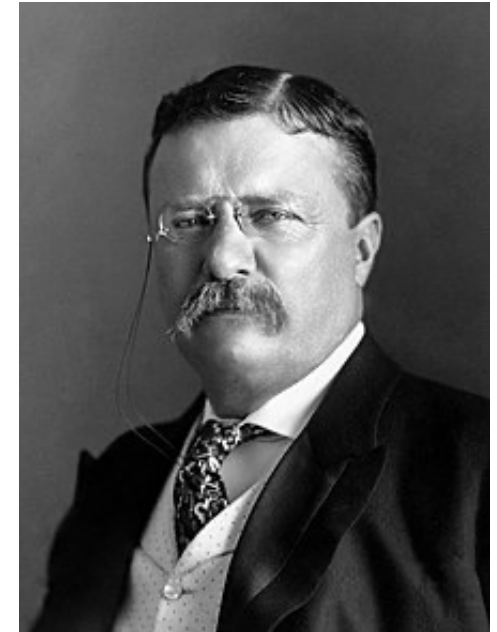


Mission: To search for signs of ancient microbial life, which will advance NASA's quest to explore the past habitability of Mars.

<https://mars.nasa.gov/mars2020>



Perseverance Landing on Mars: Feb. 18, 2021



Theodore Roosevelt
26th US President
(Youngest ever to become
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Topics for this evening:

- The CFN Mission
- Stories of CFN Research
- What Comes Next?

Dare Mighty Things

The CFN in 2022

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The CFN mission is to advance nanoscience

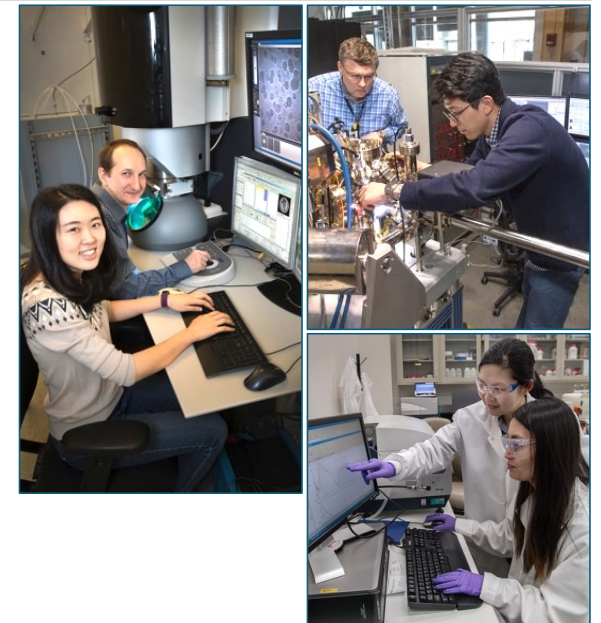
A national scientific user facility operated for the U.S. Dept. of Energy

- Permanent staff: 40+ (30 scientists)
- Nearly 600 users/yr; 330+ publications/yr

14 years of user facility operations

We accomplish our mission by:

- Enabling the research of a **productive user community**
- Delivering **breakthrough nanoscience discoveries** through internal research
- Providing **essential nanoscience capabilities** for the scientific community
- Training staff and users to **work safely**



Cooperative nanoscience to advance society

Who we are:

We believe in **collaboration**.

Our skill and expertise **brings value to our users**.

We **balance** our support for user science and achieving our personal research goals.

We strive for **excellence**.

We are **resilient**. We use challenges as opportunities to get better.

In accomplishing our mission, **we serve the nation** and the world.



The CFN aspires to be at the forefront of the nanomaterial advances of the 21st century



20th Century: e.g., Silicon, Steel, Plastics, ...



21st Century

What will these materials be?

The CFN goal is contributing to impactful research that matters.

It's not easy to do work that matters.

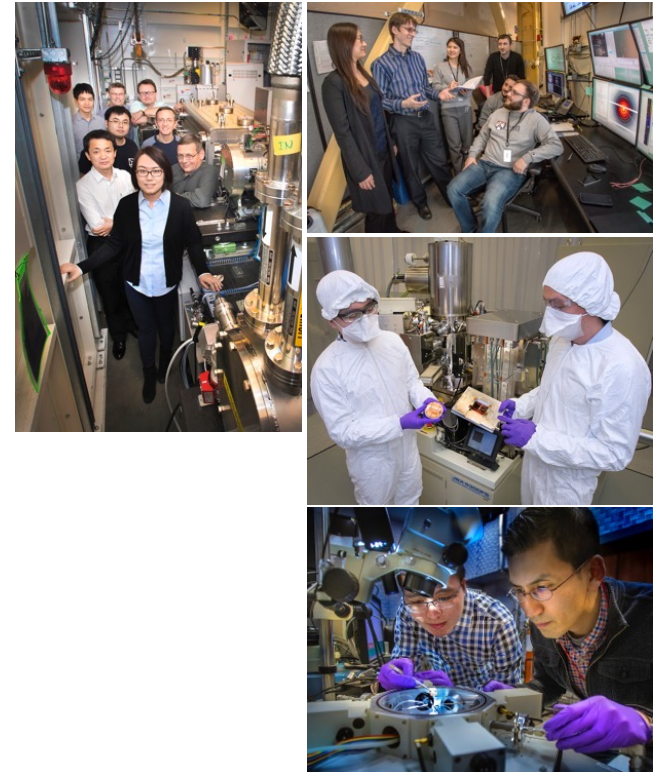
We must be **smart**. We must be **daring**.

We must have **passion**.

We must be relentlessly **optimistic**, and **willing to fail**.

We must find partners, **build the best teams**, and work together.

We must **truly believe** that we can make a difference.



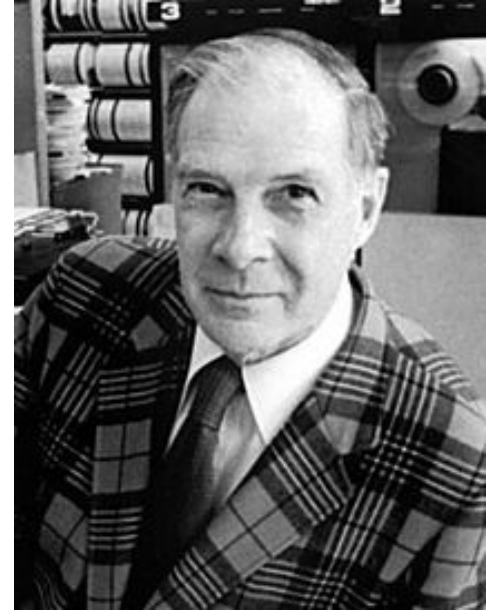
From “You and Your Research,” talk given at Bell Labs, 1986

Richard Hamming, American Mathematician

- Worked on the Manhattan Project at Los Alamos
- During research career at Bell Labs, he made many contributions to the mathematics of computing

“At Los Alamos I was brought in to run the computing machines.... I saw quite a few very capable people.”

*“I became very interested in the difference between **those who do**, and **those who might have done.**”*



“I think it is important because, as far as I know, each of you has only one life to live.
Why shouldn't you do significant things in this one life?”

Seize the Day

*“Gather ye Rose-buds while ye may,
Old Time is still a-flying:
And this same flower that smiles today,
Tomorrow will be dying.”*

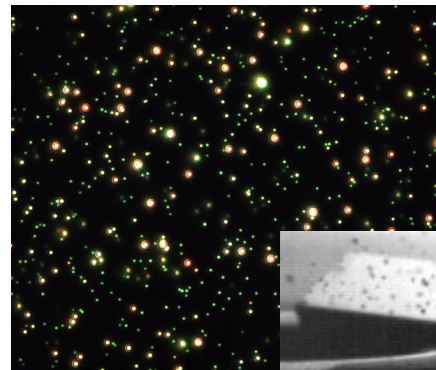
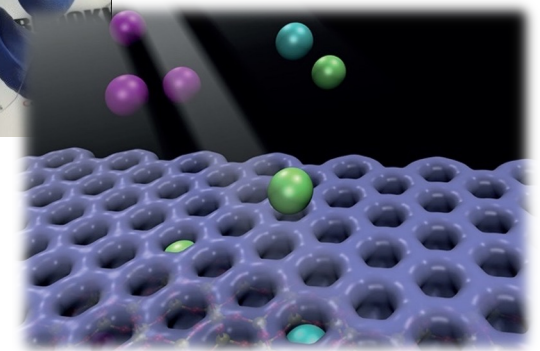
“To the Virgins, to Make Much of Time” (1648)



Robert Herrick (1591-1674)
Lyric poet and Anglican cleric

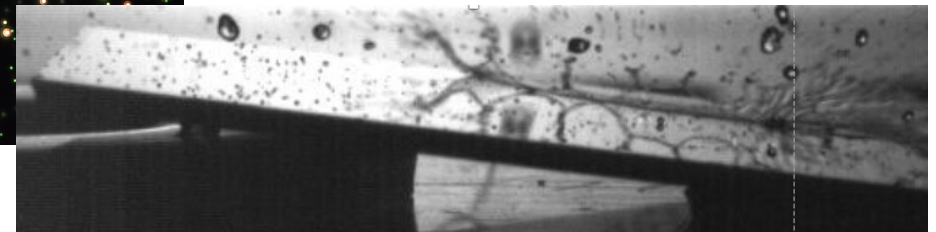
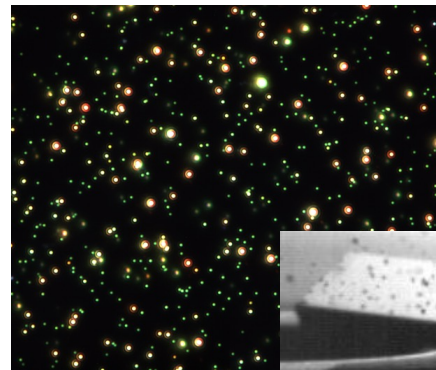
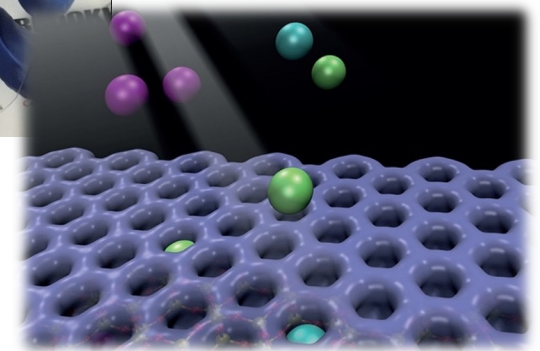
Stories of CFN Research

- Invisible Glass
- Catching Radioactive Gases
- Nanoscience-based Home COVID Test
- Two Promising Discoveries We Let Go (sadly)



Stories of CFN Research

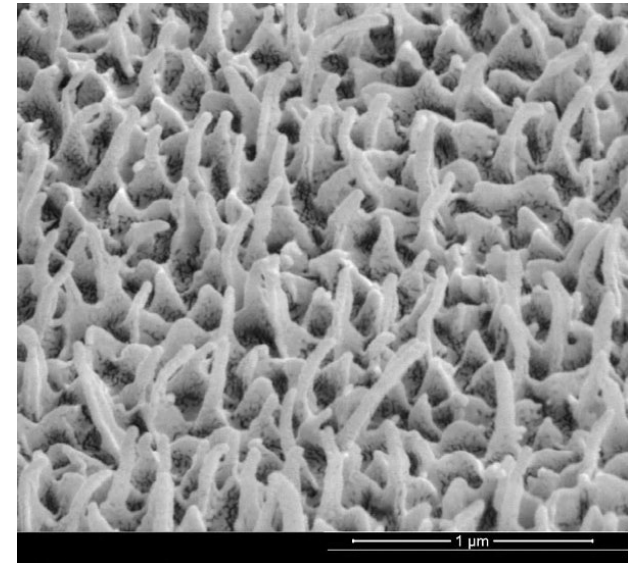
- **Invisible Glass**
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How Nature eliminates reflections

The glasswing butterfly (Greta Oto) has evolved highly transparent wings for camouflage

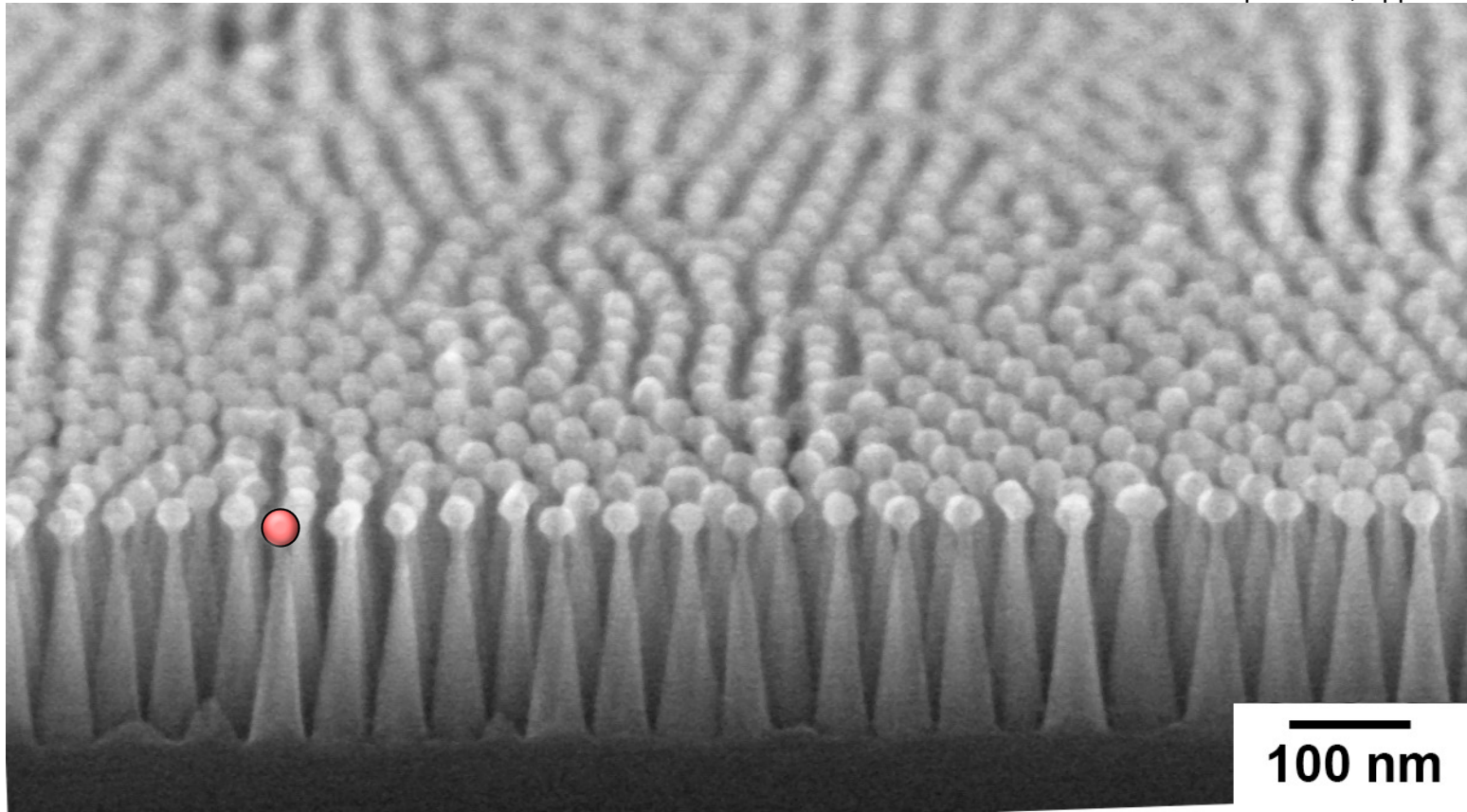
Nanoscale textures on their wings eliminate reflections of all colors of light



<https://commons.wikimedia.org/w/index.php?curid=40901135>

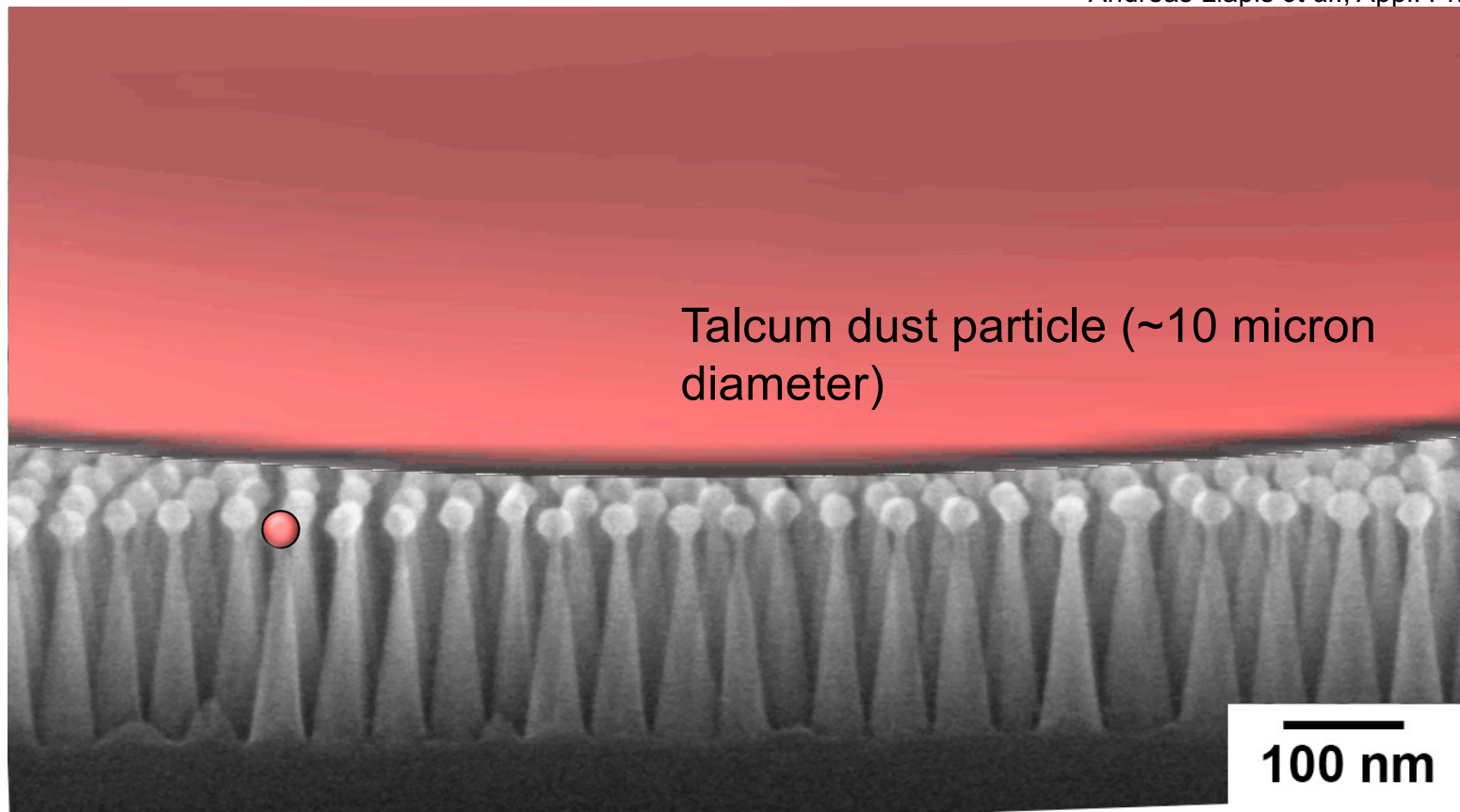
Artificial 'glass wing butterfly' nanotextures made in CFN

Atikur Rahman *et al.*, Nat. Commun. (2015).
Andreas Liapis *et al.*, Appl. Phys. Lett. (2017).

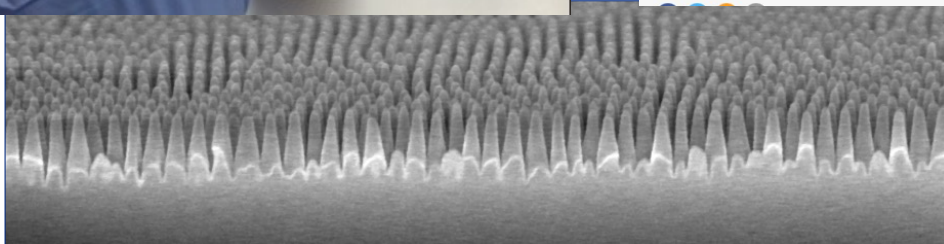
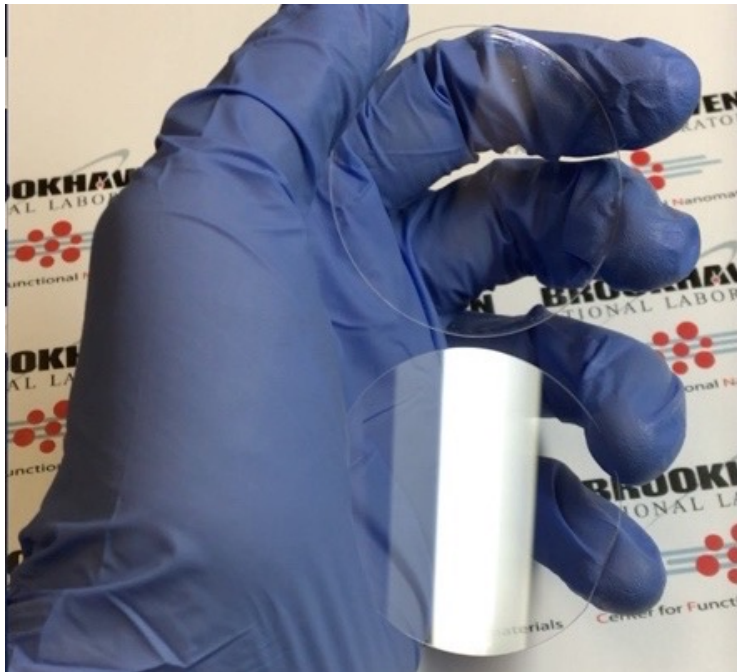


Artificial 'glass wing butterfly' nanotextures made in CFN

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Can you see the Invisible Glass?

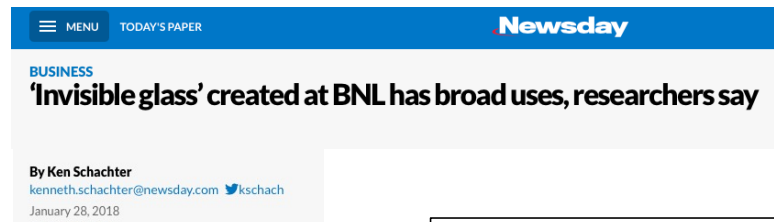


Self-assembled nanotextures impart broadband transparency to glass windows and solar cell encapsulants
Appl. Phys. Lett. 111, 183901 (2017); <https://doi.org/10.1063/1.5000965>
© Andreas C. Liapis^{1,2,a)}, Atikur Rahman^{1,3,a)}, and Charles T. Black^{1,b)}

2016 R&D100 Award Winner

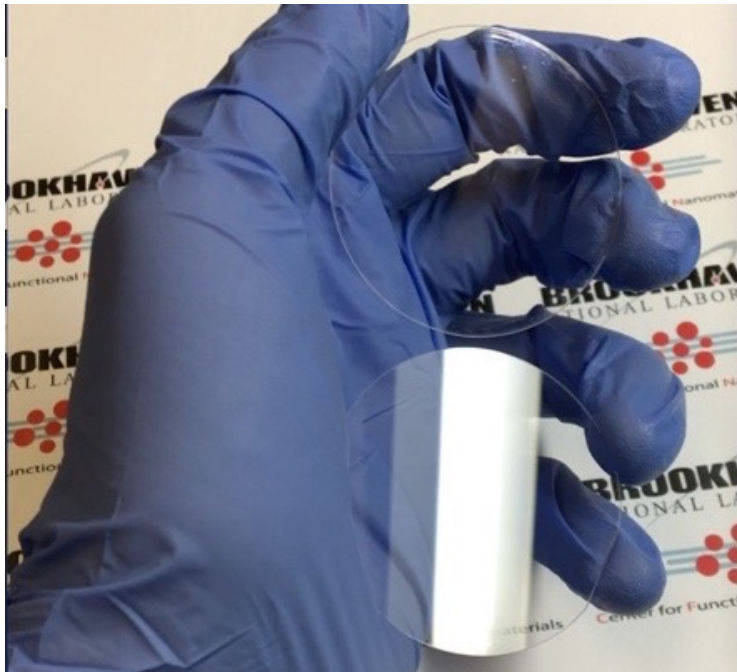


2018 Grand Prize Winner



Worked with BNL Tech Commercialization and Intellectual Property Departments
US Patent 10,290,507 B2
US Patent 10,189,704 B2

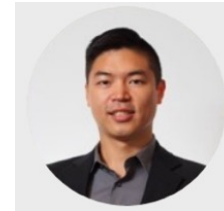
Can you see the Invisible Glass?



Because of the science, publicity, and IP, we were approached by business incubator TandemLaunch, about a possible technology license



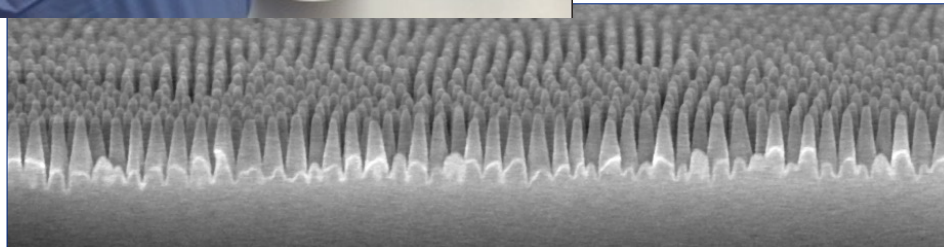
Bio-Inspired Light
Management



Calvin Cheng

Montréal-based start-up company is commercializing CFN Invisible Glass nanotextures for consumer electronics

Partnership was made possible by essential contributions from many across BNL: **Tech Transfer, Intellectual Property, & BHSO**



Edgehog Light Management Solutions

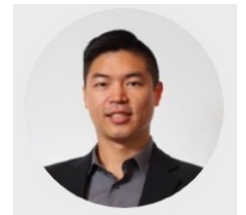
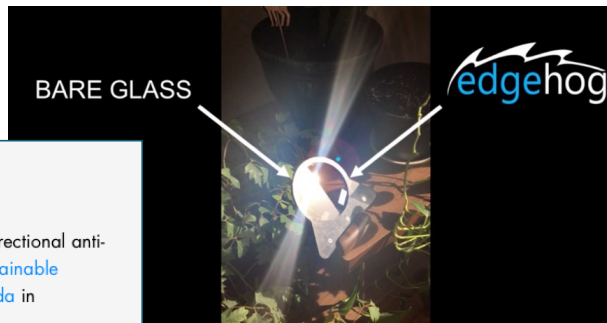
<http://www.edgehogtech.com>

Edgehog receives 2.5M CAD from STDC

We're excited to share that Edgehog has begun our scale-up project for our omnidirectional anti-reflection glass for solar panels. We are grateful for \$2.5 million in funding by [Sustainable Development Technology Canada - Technologies du Développement Durable Canada](#) in collaboration with consortium partners [Heliene Inc](#) and [Université de Sherbrooke](#).

Edgehog received 250k CAD contribution from Canadian Space Agency (CSA)

Edgehog is proud to announce that we've received a #STDP contribution from the Canadian Space Agency (CSA) to develop our anti-reflection technology for space solar modules. We are excited to join the growing Canadian presence in the space industry.



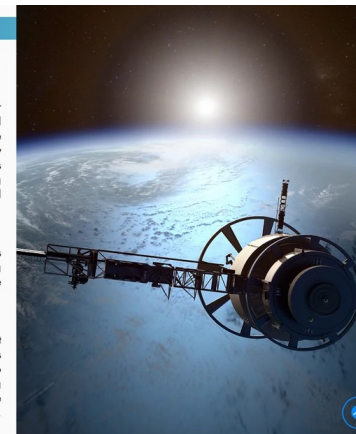
Calvin Cheng

Edgehog is now in its 4th year of operations, and has 5 employees

SPACE SOLAR

Highest energy generation

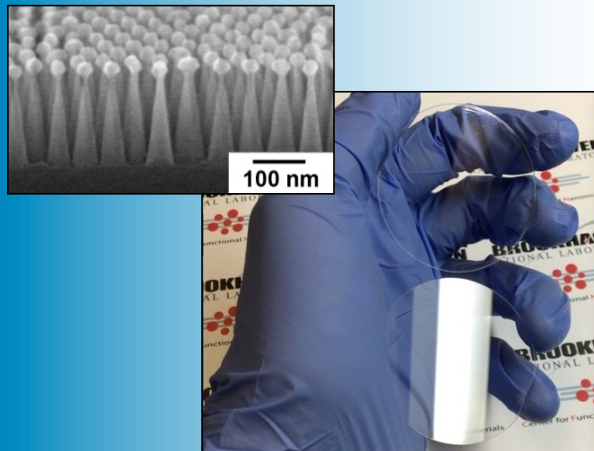
- ! Sunlight is the main source of energy for satellites and rovers. Especially for small satellites, solar panels may not track the sun, resulting in significant losses in energy production due to reflection off the glass surface. Furthermore, in the fast-growing low earth orbit (LEO) sector, conventional AR coatings suffer from peeling.
- ⊕ The omnidirectional property increases energy output under all conditions including by up to 25% at unfavourable incidence angles.
- ⊕ Edgehog glass is integrated into the best commercial coverglass interconnected cells (CIGs). Our AR technology is applied to space-qualified cover glass without adding any foreign material, making it a reliable AR solution for use in all space conditions, including LEO missions.



CFN Invisible Glass

CFN Basic Science

CFN scientists discovered a unique nanotexturing method to create antireflection and water-repellent surfaces on silicon, glass, and plastics



Rahman *et al.*, Nat. Commun. **6**, 5963 (2015).
Liapis *et al.*, Appl. Phys. Lett. **111**, 183901 (2017).

Applied R&D and Commercialization

Demonstrated near total antireflection, with unparalleled broad spectrum and wide-angle performance

US Patent 10,290,507 B2
US Patent 10,189,704 B2



Enhances display contrast.
Decreases power consumption through lower screen brightness.

Brookhaven Lab licenses the technology to venture capital-backed Edgehog Advanced Technologies

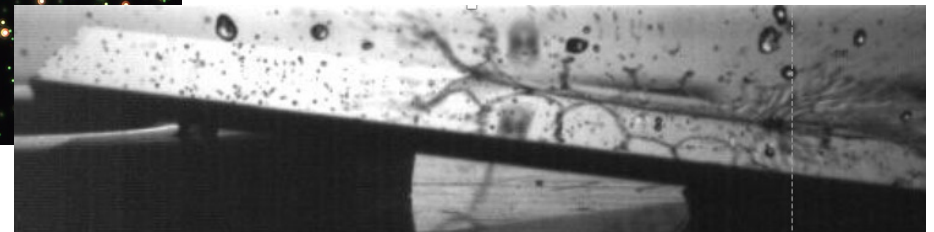
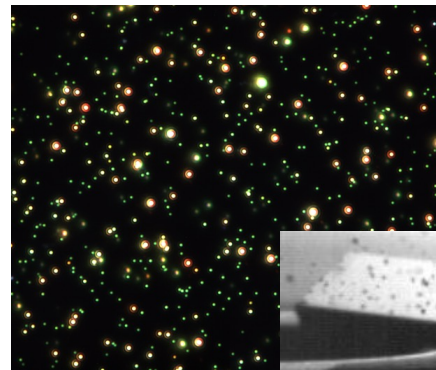
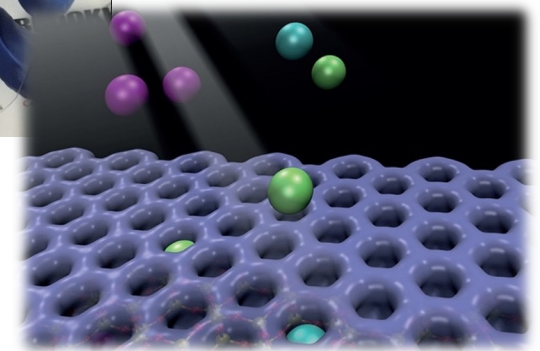


- Technology enhances annual solar cell output by 6-12%
- Edgehog currently testing technology in solar cells for use in space.



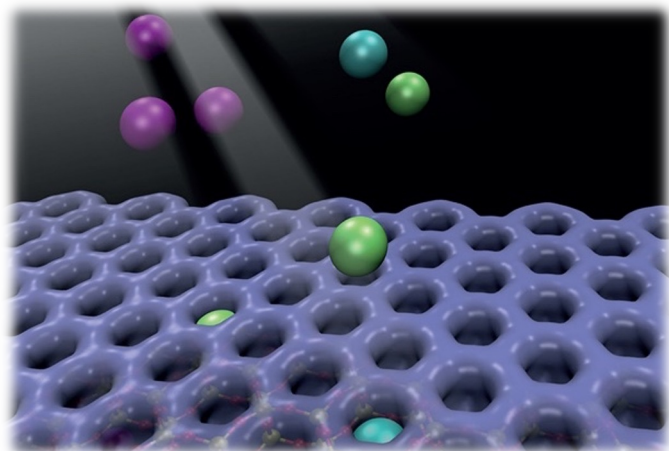
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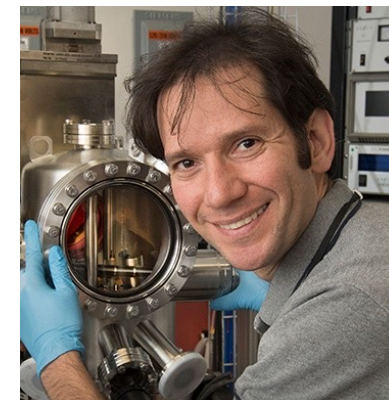
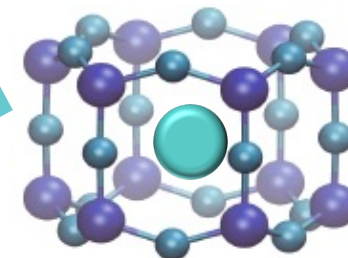
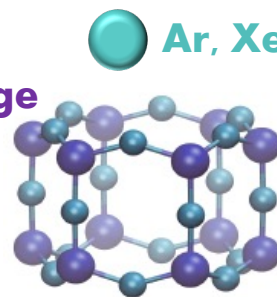
Catching Noble Gases

In 2016, CFN scientist Anibal Boscoboinik discovered that porous materials he synthesized could trap single atoms of Argon, and other noble gases



Silica
Nanocage

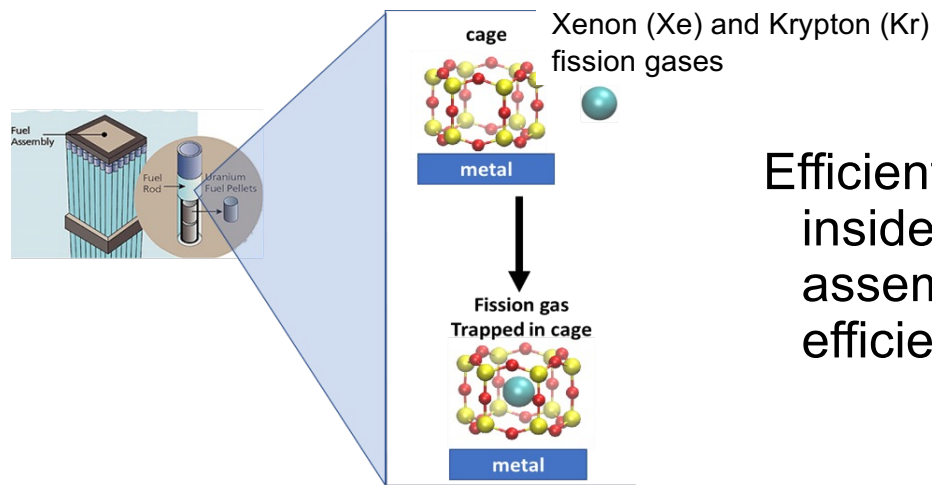
Noble gas:
Ar, Xe, Kr, Rn



Noble gases are not so easy to trap, because they are non-reactive
This was unexpected and neat, and resulted in a number of scientific publications....

Catching Noble Gases in Nuclear Reactors

In conversations with nuclear scientists, we learned that noble gas isotopes (radioactive, and non-radioactive) are an unwanted by-product of nuclear fission



Efficient noble gas trapping inside nuclear fuel rod assemblies can improve efficiency and lifetime

CFN is currently working with two companies: **Forge Nano** for nanomaterial scaleup, and **NuScale** on implementing the material in reactor designs

Here too, this partnership was made possible by essential contributions from many across BNL: **Nuclear Physics, Tech Transfer, Intellectual Property**

Catching Noble Gases in Nuclear Reactors

CFN Basic Science

Applied R&D and Commercialization

CFN scientists discovered that silicate nanocages can reversibly trap Argon at room Temp

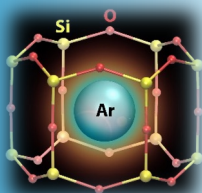


Illustration of an Ar atom trapped inside a silicate nanocage

Nature Communications **8**, 16118 (2017).

Expanded to trapping to Krypton, Xenon, and Radon. Elucidated the trapping mechanism.

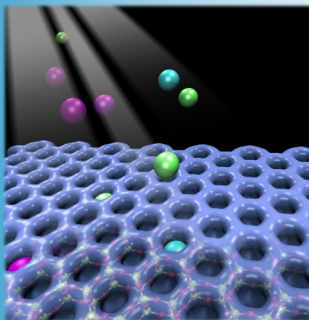
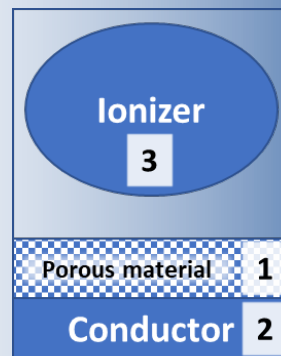


Illustration of individual atoms of Ar, Kr, and Xe trapping in a 2D-array of silicate nano-cages.

Adv. Funct. Mater. (2019).

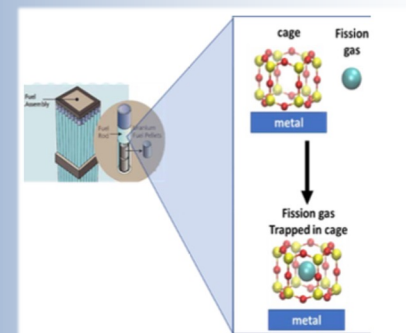
BNL Patent Application describes material architecture, method, and applications (2020).



Elements of the invention to trap noble gases:

- (1) A porous silicate material
- (2) in contact with a conductor
- (3) An ionizer may be needed, depending on the application.

BNL & Forge Nano awarded DOE Technology Commercialization Fund grant to develop scaled-up trapping material for Nuclear Energy applications (2020).



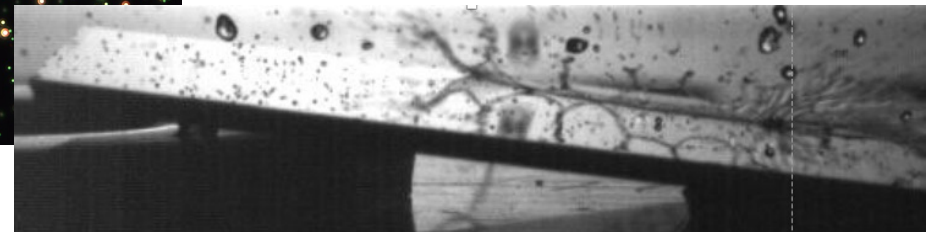
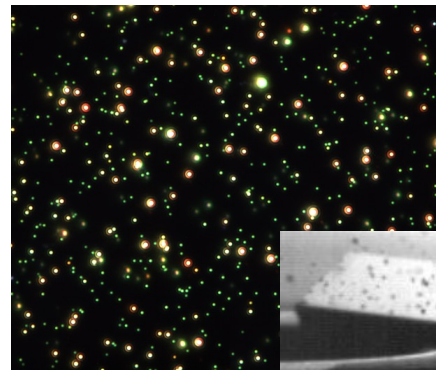
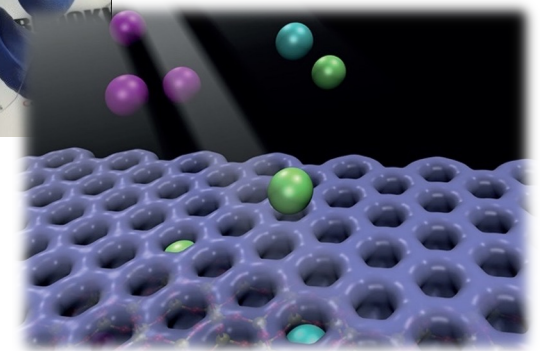
Idea: Silicate cages are located inside fuel rods to trap noble gases from nuclear fission reactions.



Forge Nano is a leader in surface engineering & precision nano-coating technology, using Atomic Layer Deposition.

Stories of CFN Research

- Invisible Glass
- Catching Radioactive Gases
- **Nanoscience-based Home COVID Test**
- Two Promising Discoveries We Let Go (sadly)



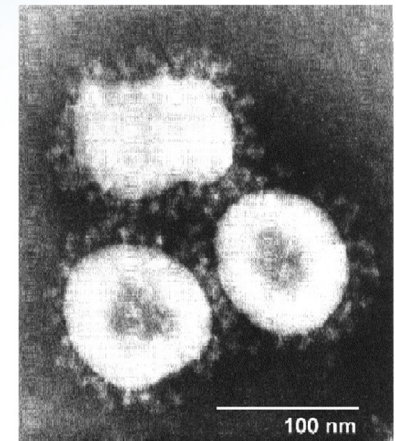
The CFN and SARS-CoV-2

- Here is a slide from the March 18, 2020 CFN All-hands Meeting:

CFN staff discussed this five days before BNL transitioned to **Minimum Safe Operations**

Get mad and take action. Don't be a victim.

- Think seriously about your ideas for how your skills can be used to solve COVID-19.
- The coronavirus is a nanomaterial, not a monster
- Find a biology/medical colleague and talk with them. Develop your ideas.
- Bring your best ideas to your manager and me. CFN will support them.**
- We all own this. Let's do our parts.

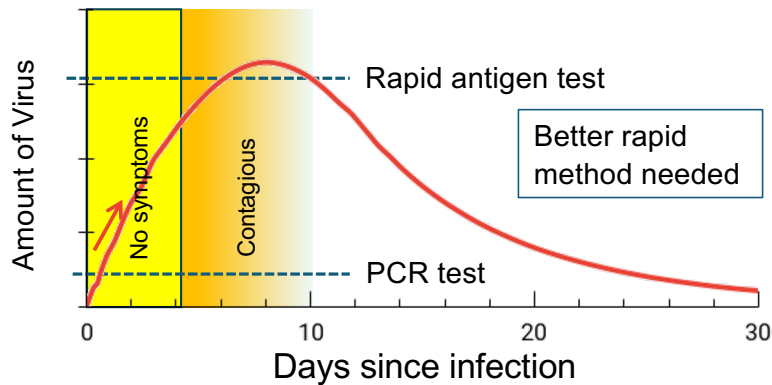


Michelle Hsiang's
Coronaviridae Webpage

Since summer 2020, CFN and BNL scientists have been developing a nanoscience-based home COVID-19 test



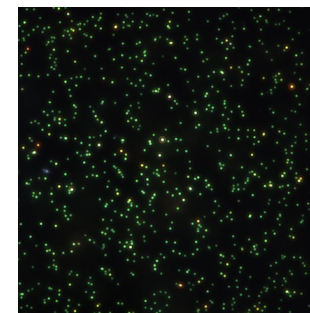
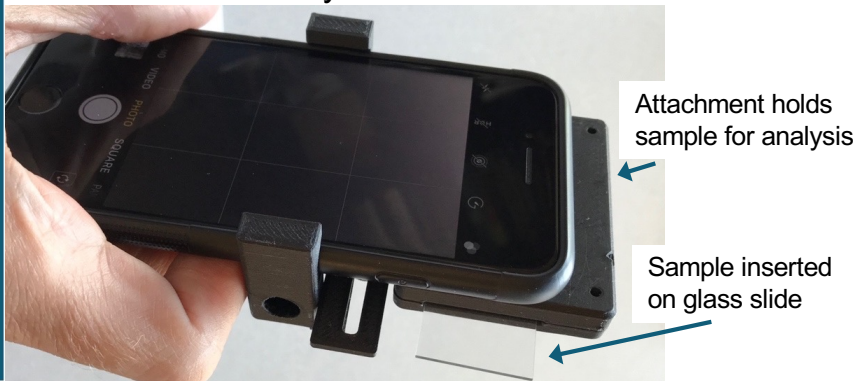
O. Gang M. Liu F. Teng H. Zheng J. Haupt C. Deane P. Upadhyha
BNL Instrumentation
BNL Tech Transfer



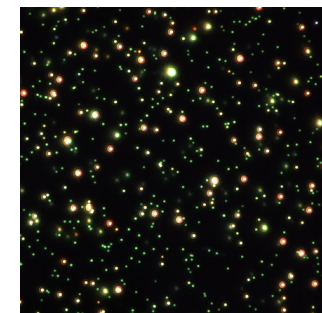
Goal: Home/Point-of-Care COVID test

- Target speed of rapid antigen test, but better sensitivity
- Accurate & easy to perform
- Use only reagents from rapid antigen test; cellphone for readout

Photographs of samples taken with microscope camera



No COVID



COVID

- We've made some progress. Lots of challenges remaining.
- Regardless of ultimate success or failure, it is significant that we're trying.

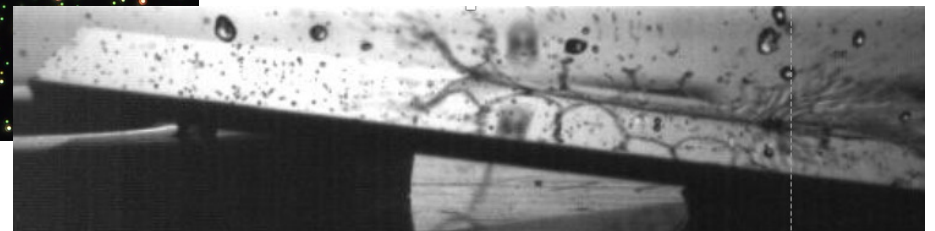
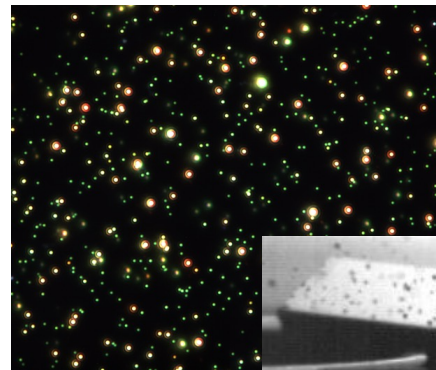
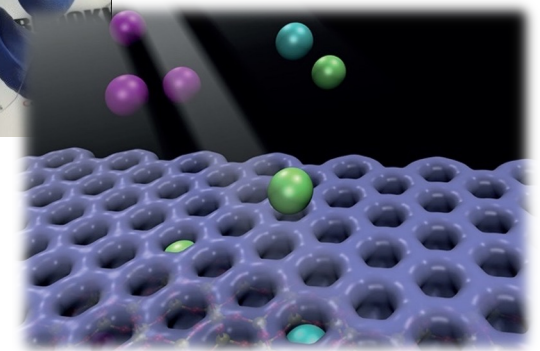
BNL cellphone attachment for optical test readout



O. Gang, J. Haupt, C. Deane, M. Liu. US Provisional Application S/N 63189665.

Stories of CFN Research

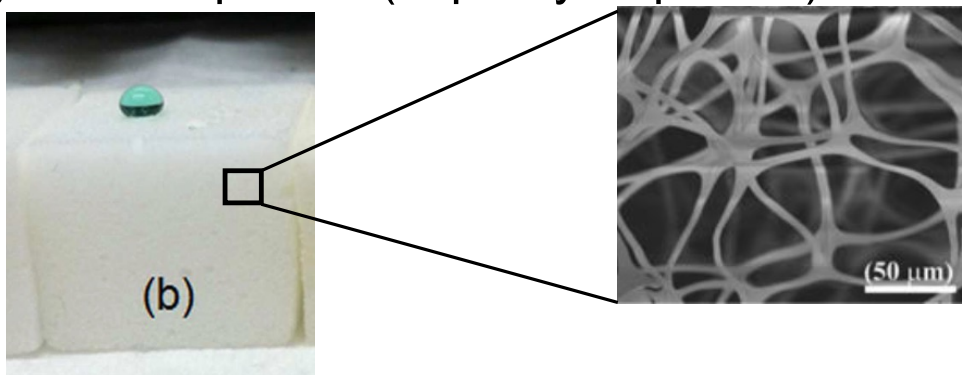
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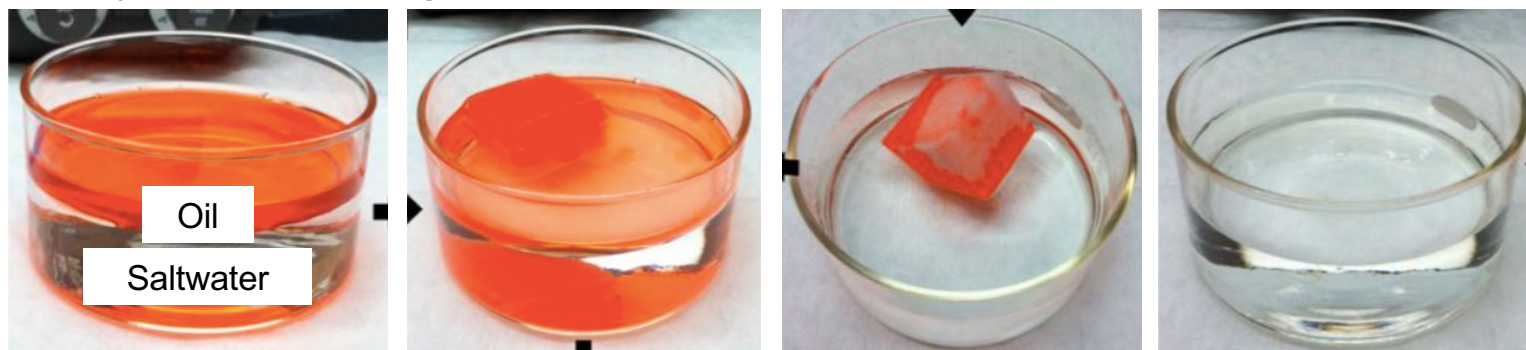
“Superhydrophobic” sponges for environmental remediation

ACS Appl. Mater. Interfaces 6, 14181 (2014).

Nanoscience-based surface treatment of melamine sponges (Magic Erasers) makes them completely water repellent (superhydrophobic)



When placed in oily water, sponges soak up the oil but not the water



“Superhydrophobic” sponges for environmental remediation

ACS Appl. Mater. Interfaces 6, 14181 (2014).

Sadly, this project is ended:

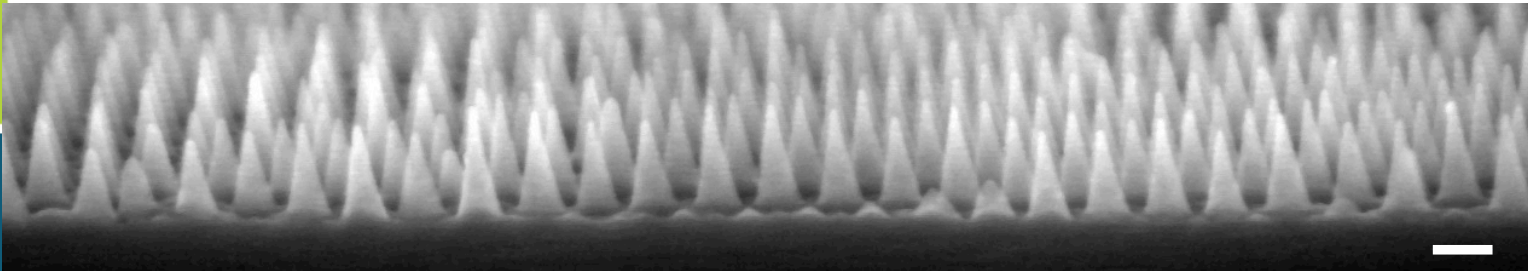
- No Intellectual Property protected
- No external partner to drive commercial development
- CFN scientist has left BNL

Wouldn't our world be better if we had these sponges in it?

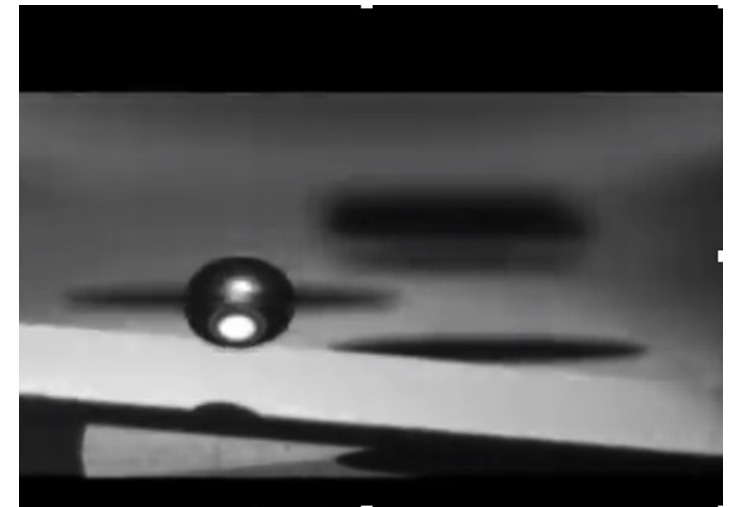
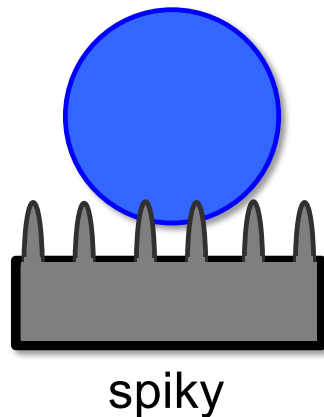


“Always Dry” surfaces

A. Checco, A. Rahman, *Adv. Mat.* (2014).



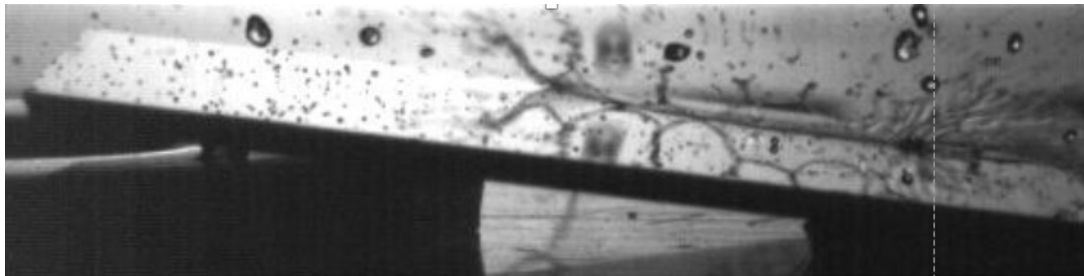
CFN staff members helped users from BNL and Stony Brook design and create surfaces that completely repel water



Bouncing water droplet

“Always Dry” surfaces

A. Checco, A. Rahman, *Adv. Mat.* (2014).



Applications in:

- Glass and plastic windows (visibility, anti-fogging)
- Touch screens
- Medical diagnostics (reduced biofouling, flow resistance)
- Plumbing (flow/corrosion resistance)
- Aircraft (anti-icing)

Sadly, this project is also ended:

- Some Intellectual Property protected
- IP licensed but not being actively developed
- User project has ended; CFN retains know-how
- Partners needed!

Wouldn't our world also be better if we had these surfaces in it?

What Comes Next?

1. Foster a CFN culture of bold scientific thinkers taking on the world's important problems

“Why shouldn't you do significant things in this one life?”

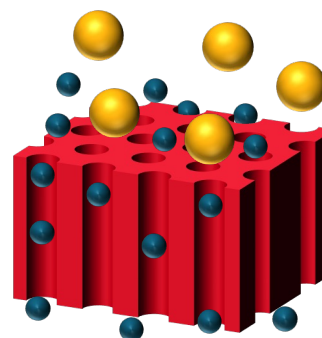
2. Support them by providing access to the tools and partners to move their discoveries beyond 'scientific presentations and publications'

“Far better it is to dare mighty things....”

CFN Scientist Greg Doerk awarded DOE Early Career Research Program Award

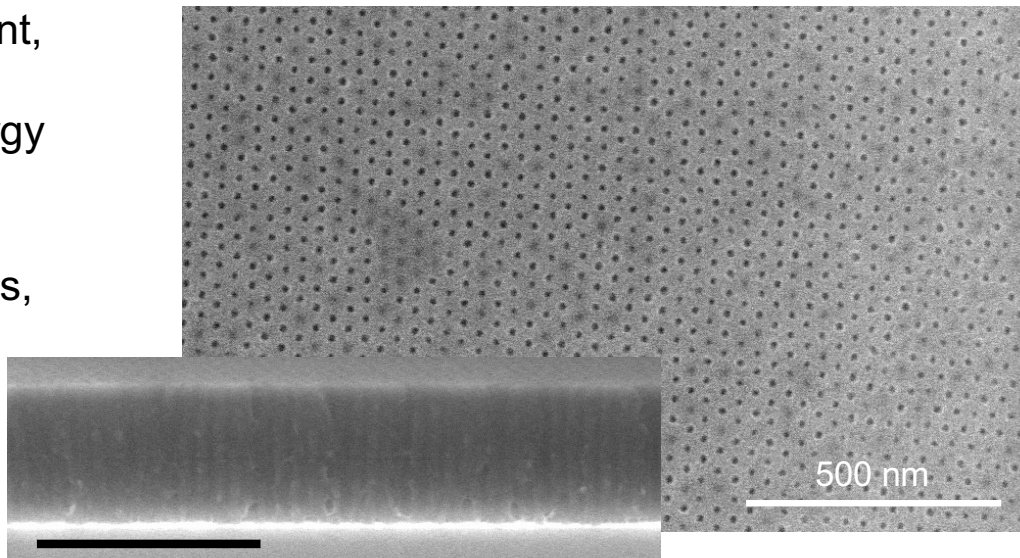
5 year, \$2.5M project

Ultimate goal is realizing a transformative membrane manufacturing approach to improve scalability & enable critical functionality (e.g., fouling resistance)

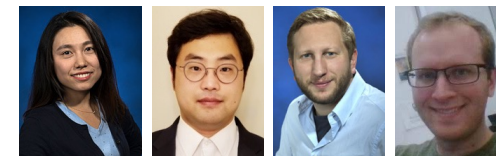


The Importance Of Separations

- Clean water (desalination, pretreatment, organics removal, ...)
- Chemical manufacturing (47% of energy consumed)
- Protein purification (virus removal)
- Resource recovery (lithium, rare earths, etc.)
- Gas separations (e.g., CO₂ capture)

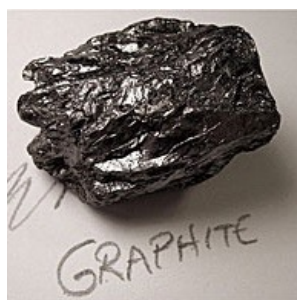


The Quantum Material Press: A unique instrument for assembling new materials with new electronic properties

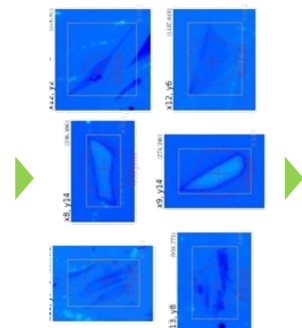


Suji Park Houk Jang Greg Doerk Kirby Schmidt

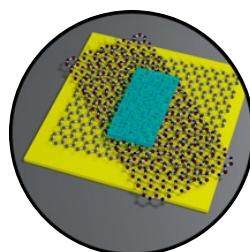
- A three-year, \$6M project, just completed
- Science commissioning (first experiments!) are underway
- Full remote operability planned (~2023)



Graphite crystal



Graphene flakes
exfoliated from crystal

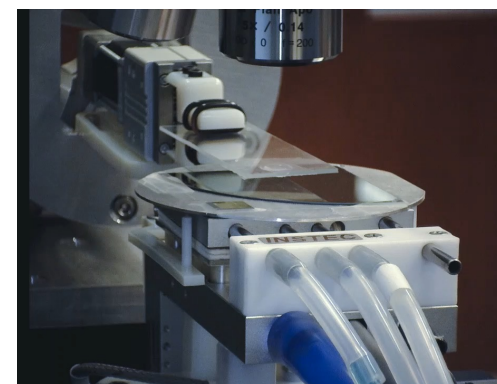


Stacked structure with new
electronic properties

- QPress robotically peels layers from graphite and other 'peelable' crystals, and assembles them back together into new arrangements not found in nature
- Lots of exciting physics and materials science to explore.



Integrated QPress instrument



QPress stacker module

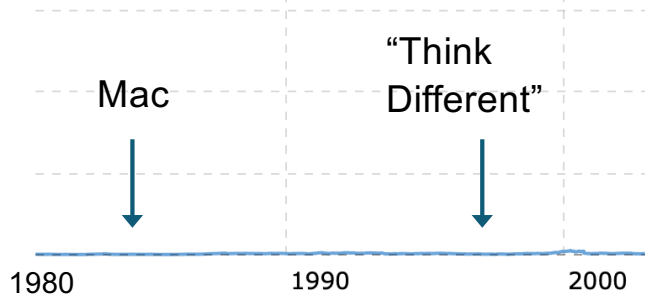
Think Different advertising campaign. Apple, Inc. (1997)



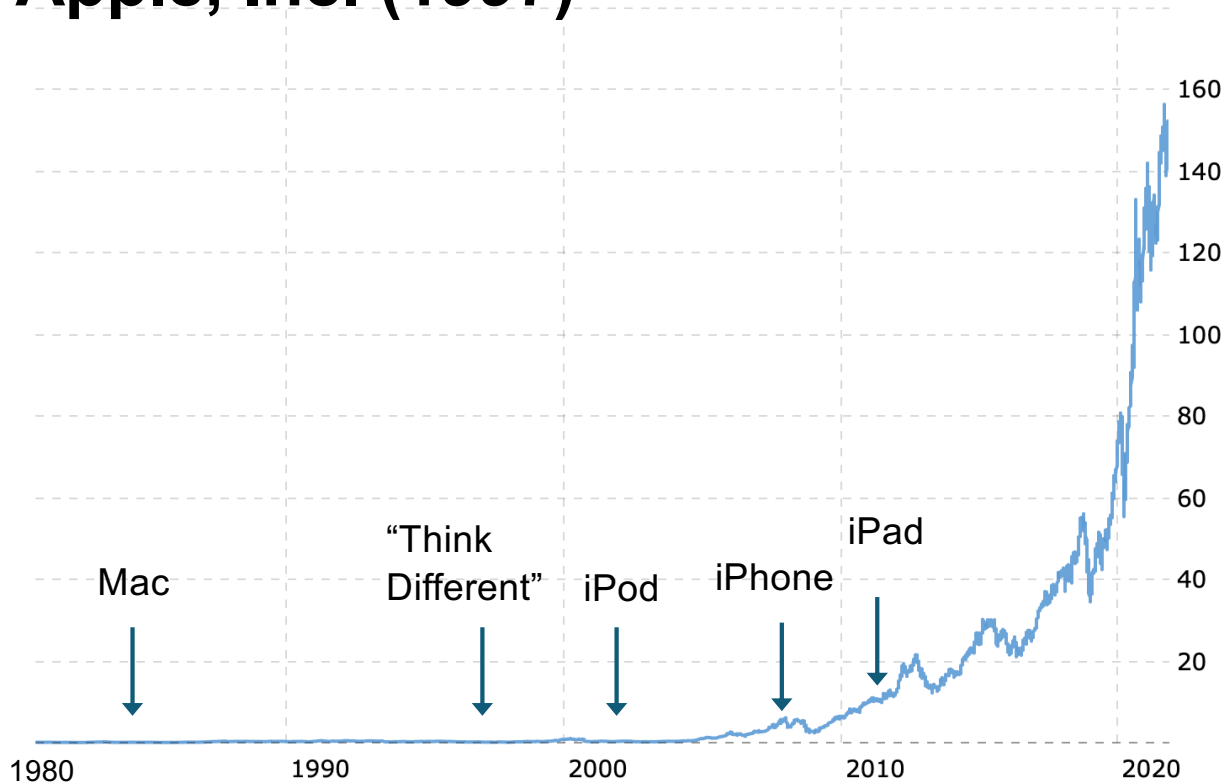
Just after launching “Think Different,”
Apple removed 70% of its product lines
from the market.



Apple, Inc., stock price
from 1980-2000



Think Different advertising campaign. Apple, Inc. (1997)



OPINION

The Chip That Could Transform Computing

Apple's custom processors suggest that computers are nowhere near hitting their performance limits.

By Farhad Manjoo

November 9, 2021

Message

The CFN mission is to advance nanoscience. We aspire to contribute to the important materials advances of the 21st century

Doing work that matters is hard, and requires building partnerships beyond basic science

We've had some successes.

We have lots of ideas.

“Gather Ye rosebuds while Ye may.”
We're committed to **Daring Mighty Things.**

(Come Visit Us!)

