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Nanotechnology for the next generation of solar PV, batteries, sensors, and beyond

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Nanowires

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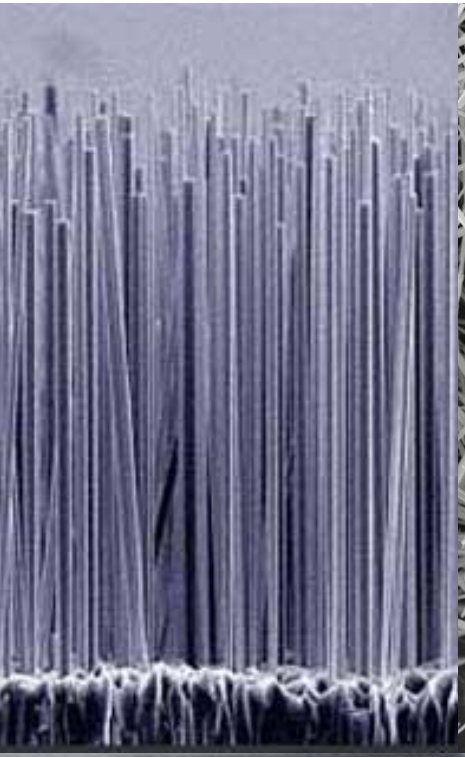

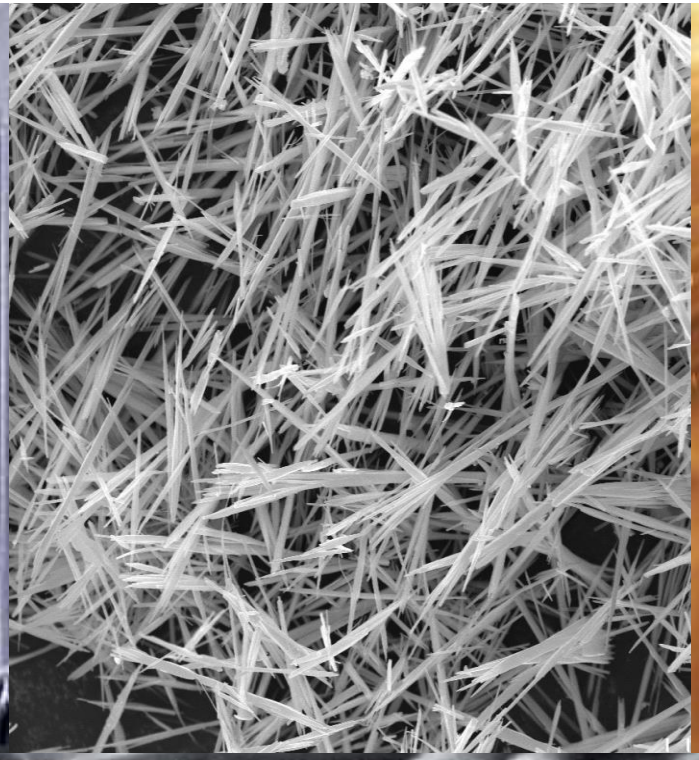

have the potential to change the world

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History of Support for Nanotech in the USA

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- Support for nanotechnology in the US since 1999 when Mihail Roco presented to the White House. Consistent support since.
- On December 3, 2003 Bush signed into law the 21st Century Nanotechnology Research and Development Act which authorizes expenditures for totaling $3.63 billion over four years
- President Bill Clinton, 21 January 2000 at the California Institute of Technology

"Some of our research goals may take twenty or more years to achieve, but that is precisely why there is an important role for the federal government."

- Revenue from nano-enabled products
  - $339 billion in 2010
  - $731 billion in 2012

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ASG's nanowire/nanotexture

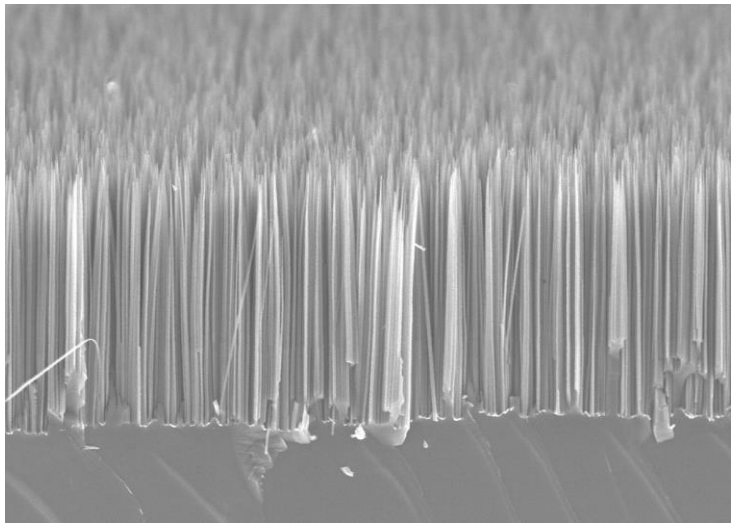
Metal Assisted Chemical Etching of Silicon

Compared to other processes:

- Repeatable
- Uniform
- Controllable (diameter, density, length, taper)
- Low-cost
- High throughput

Silicon nanowires

Bulk silicon wafer



Over 30 patents filed/issued

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Applications: Multiple Billion $ Markets

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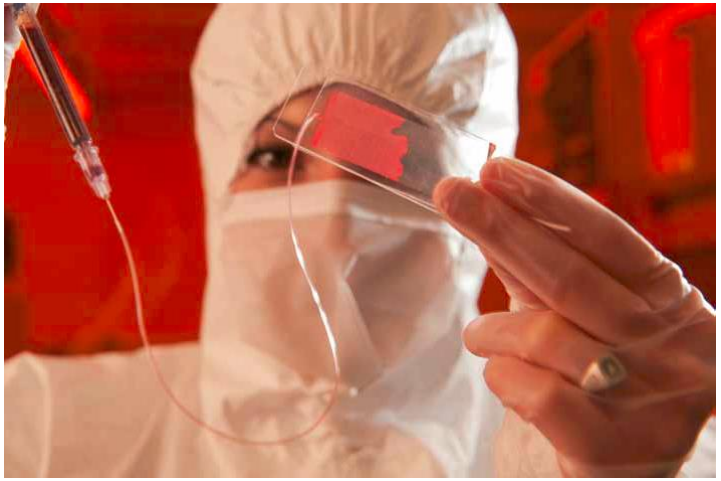
Biosensors: $22 billion

Battery anodes: $12 billion

Lab-on-chip: >$2 billion



Solar cells: $110 billion

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Silicon Nanowires for Li-ion Battery Anodes

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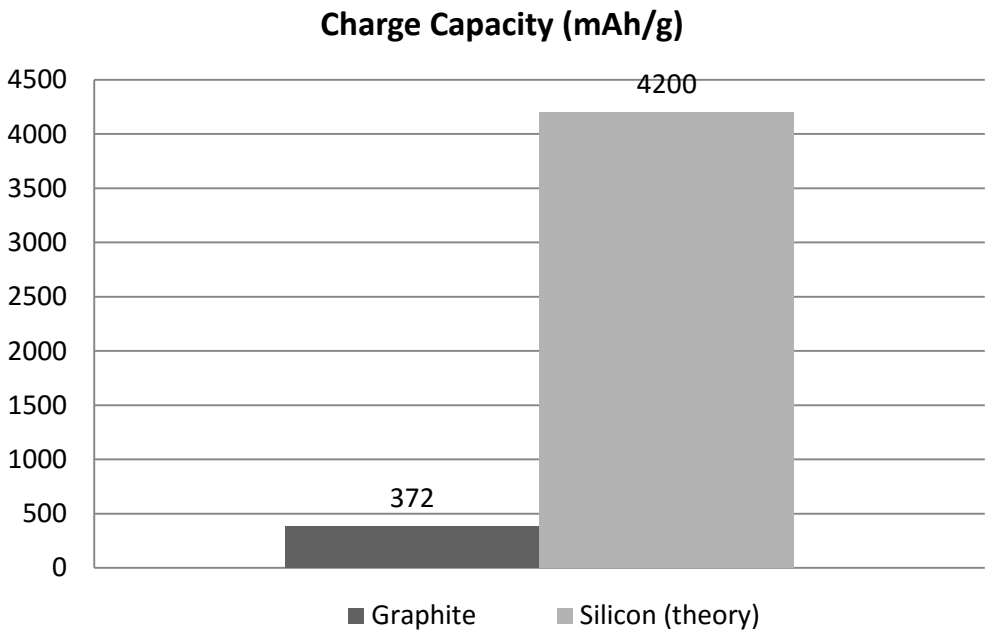
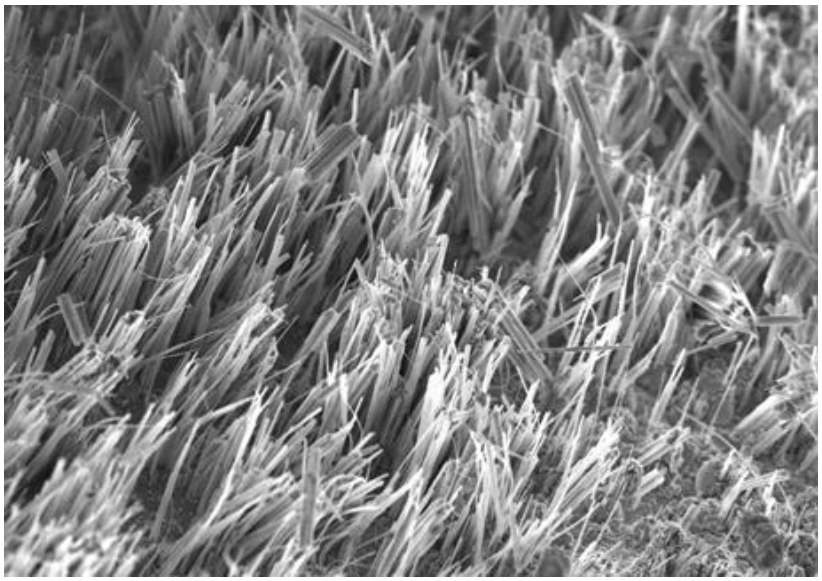
- Silicon has highest theoretical lithium absorption capacity
- ~10x the capacity of what is used today (graphite)
- Inexpensive, abundant, safe, well studied



But, silicon expands 4X

Leads to pulverization and fade

- Silicon nanowires allow for high capacity batteries without the issues of pulverization
- High power as well as high energy density
- Low process is low cost and controllable



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Silicon Nanowire Sensors for Cancer Detection

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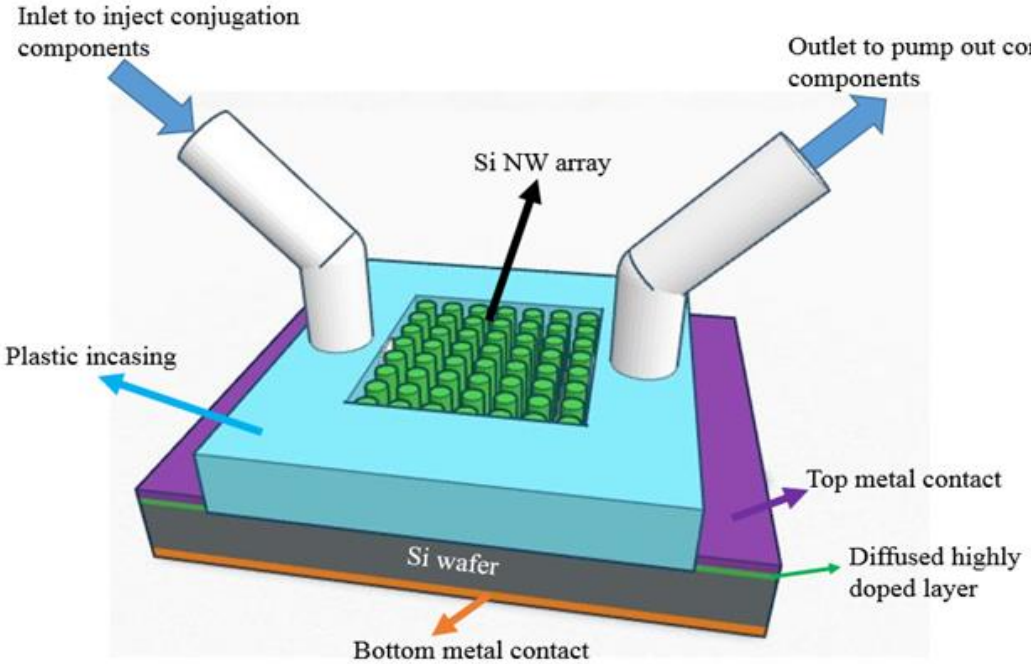
- Health care costs in 2011 for cancer in the US were $88.7 billion
- Our sensor will improve early detection of cancer
- Lowering costs and saving lives

- 1 billion nanowires per device
  - Competition has 1-10 nanowires
- Increased sensitivity
- Decreased false positives
- Provisional patent filed 8-2015



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Nanowire and Standard Solar Cells

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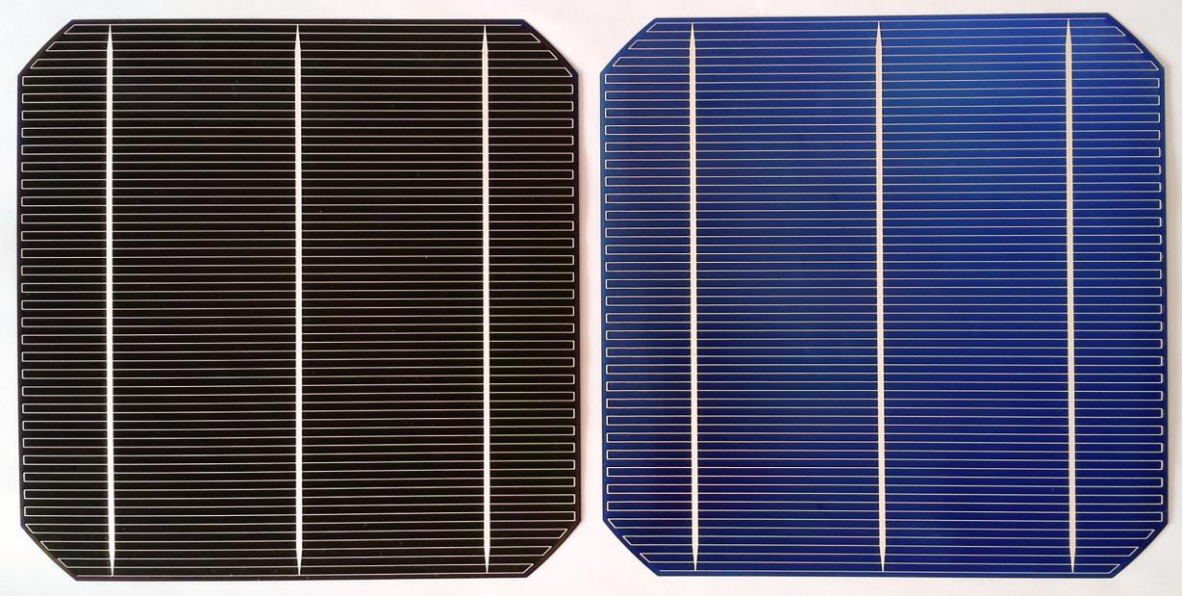
- Increases efficiency *and* lowers cost
- Doubles cell makers' margins
- Demonstrated improvement over industry process
- Based on crystalline silicon wafers
- Uses existing silicon solar infrastructure



Nanowire solar cell

Traditional solar cell

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Some Ways the Government Can Encourage Nanotech Based Startups

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- Centers
  - Shared equipment really helps getting companies started
  - Access to a full set up equipment without purchasing equipment
  - Great for testing out new processes
  - Once your company chooses a particular process, it quickly becomes cost effective to purchase new equipment
    - Is there a way to make it more affordable for startups?
- IP policy
  - US &
  - Abroad
- Grants
  - Ideas to improve this process?
    - Over 50% of senior researchers' time
    - Concept paper helps

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Government's Role in Funding Development

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- Let industry experts guide applied research
  - International Technology Roadmap for Semiconductors
  - U.S. Advanced Battery Consortium "The USABC seeks to promote long-term R&D within the domestic electrochemical energy storage (EES) industry and to maintain a consortium that engages automobile manufacturers, EES manufacturers, the National Laboratories, universities, and other key stakeholders. "
  - NSF's Icorp program
- Fund development closer to commercialization
  - help bridge the gap
- Current order of development:
  - research, spin out, find technology-market fit, develop product
- Reverse order might work better
  - Find market fit first and use that guide development
  - Maybe a reverse entrepreneur in residence program

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Questions for the Panel

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- Are there any obvious gaps in the draft goals and objectives? Are there any objectives that are no longer among the top priorities that need to be addressed?
- What will be the biggest challenges to commercializing nanotechnology in the next 5-10 years?
- Outside of additional funding, what can the Federal Government do to support activities or address challenges in the areas above?
- How will we know when the nanotechnology enterprise is successful in this area? How do we measure this?
- How does public perception impact the acceptance of nanotechnology-enabled products?

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