Trillion Sensor Technology

Engineering for the Public Good

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World-Class Engineering School

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13th in the World for Engineering, Technology & Computer Science
Academic Ranking of World Universities, 2013

8th among U.S. best public engineering schools
U.S. News ranking of graduate schools, 2013

1st in the U.S. for biomedical engineering
National Research Council, 2010

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Introduction to Abundance*

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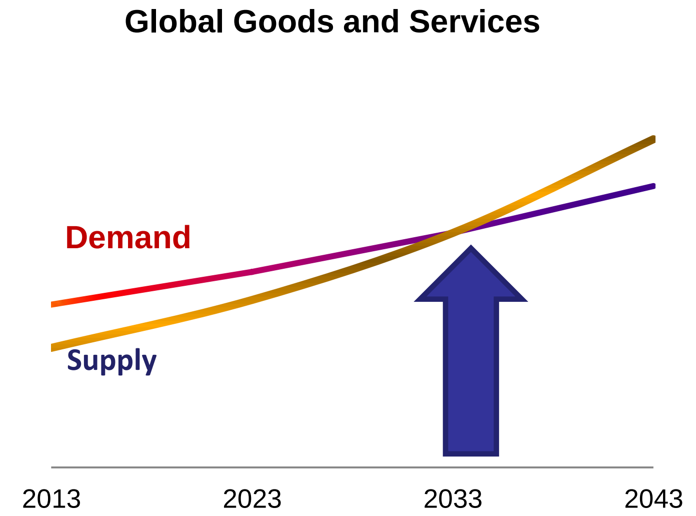
- **Abundance* movement forecasts elimination in one generation (20 to 30 years) of major global problems:**
  - Lack of food
  - Lack of medical care
  - Lack of clean water and air
  - Lack of energy



* http://www.abundancethebook.com/

- **Abundance forecasts the need for (among others) 45 trillion sensors, many not yet developed.**
- **Historical sensor development cycles from prototypes in academic labs to volume production were 30 years.**
  - Left to historical cycles, slow new sensor commercialization would delay the arrival of Abundance.
- **Trillion Sensors Movement encourages the acceleration of the new sensor development cycle.**

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Abundance* Enablers

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Exponential Technologies that Promise to Grow Into Large Markets Quickly

- Biotechnology and bioinformatics
- Medicine
- Nanomaterials and nanotechnology
- Networks and sensors (45 trillion networked sensors in 20 years).
- Digital manufacturing (3D printing) and infinite computing
- Computational systems
- Artificial intelligence
- Robotics

* http://www.abundancethebook.com/

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Bill Gates: No Poor Countries by 2035

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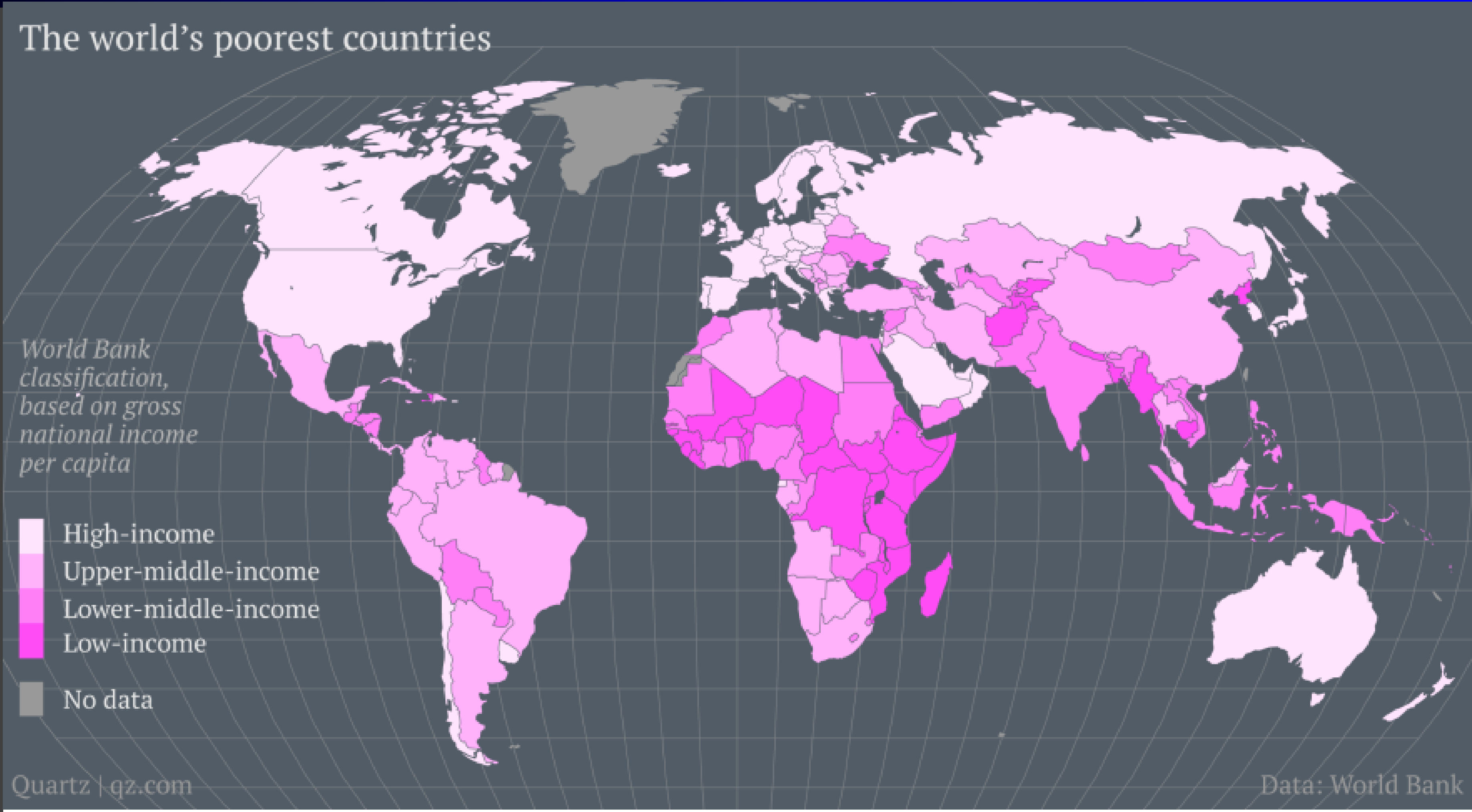

http://qz.com/168341/bill-gates-predicts-there-will-be-almost-no-poor-countries-by-2035/

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Engineering for the Public Good

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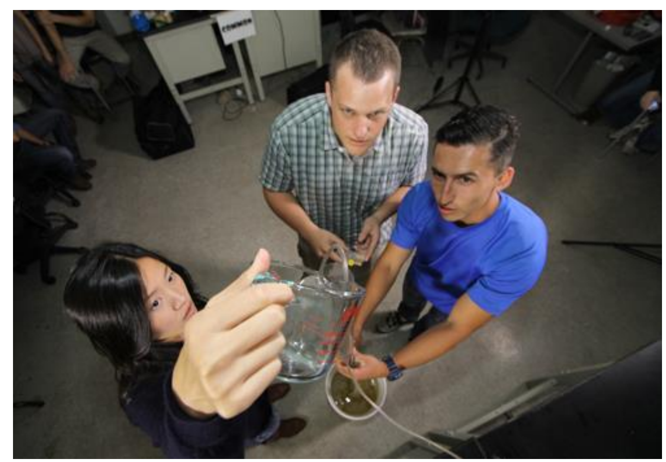
Medical Advances

Sustainable Energy Technologies

Transportation Safety



Solutions for Developing World

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Cluster Sensor Landslide Prediction

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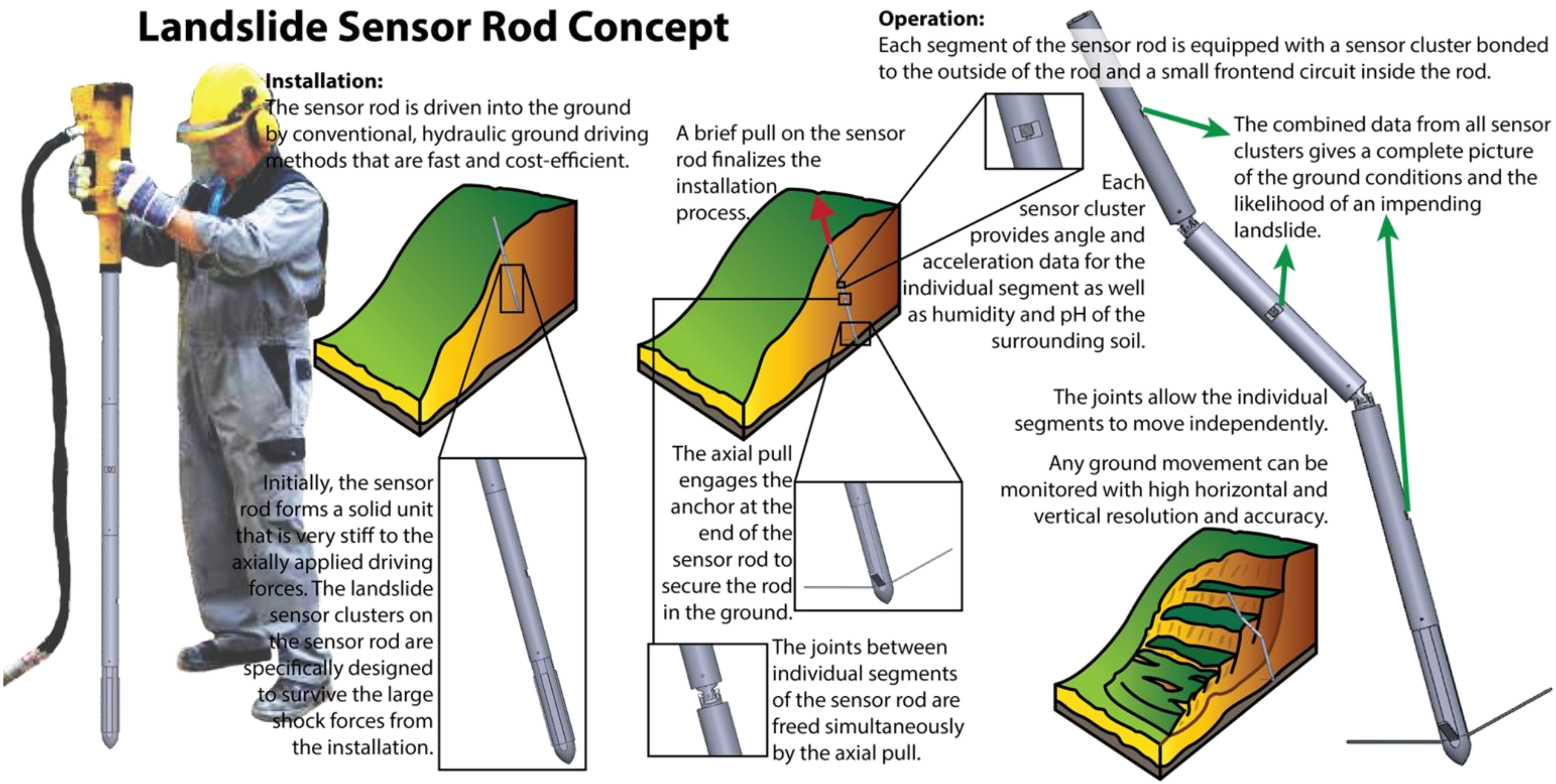

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Epidermal Electronics: Just a Tattoo?

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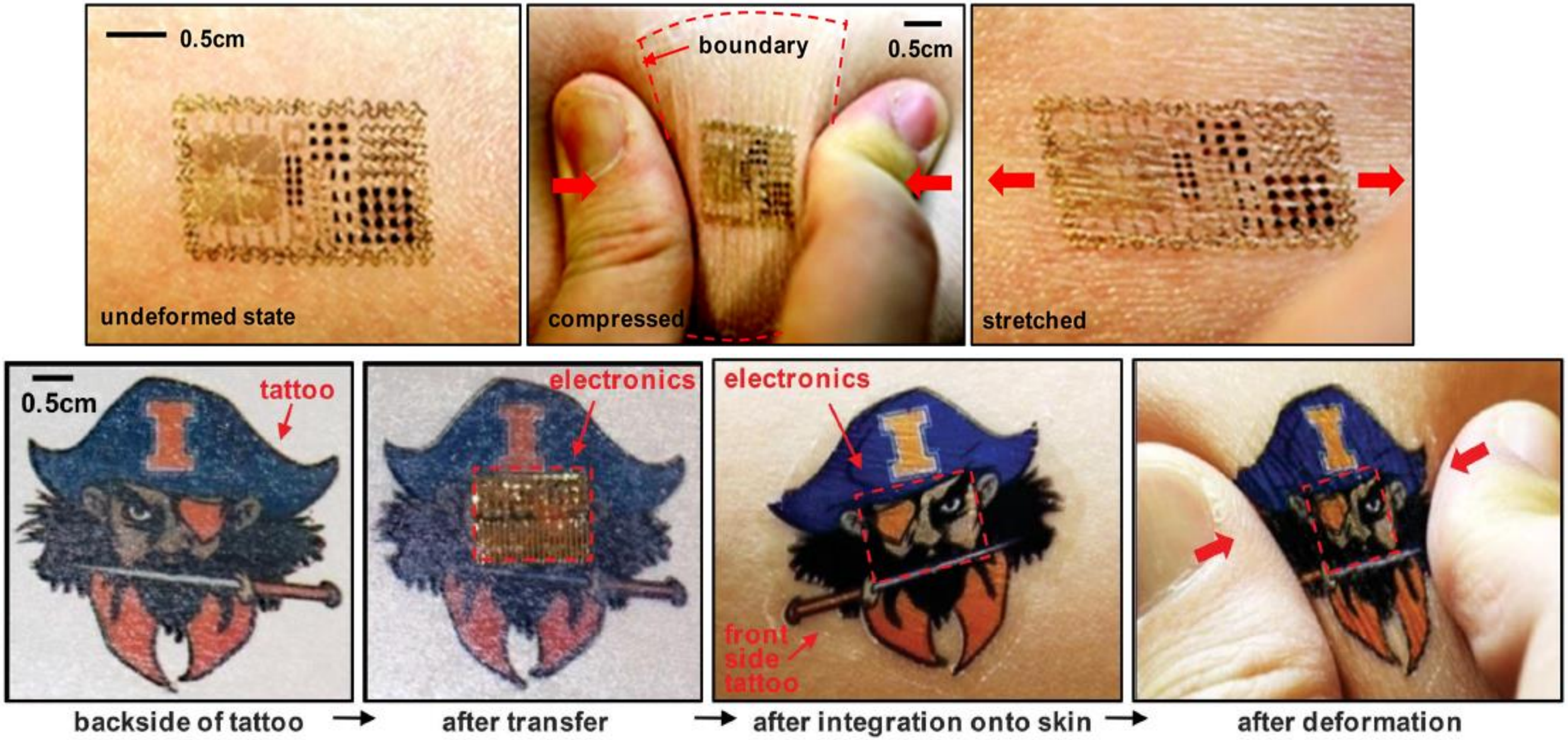
Todd P. Coleman, Ph.D.

Department of Bioengineering



Science, Aug 12, 2011.

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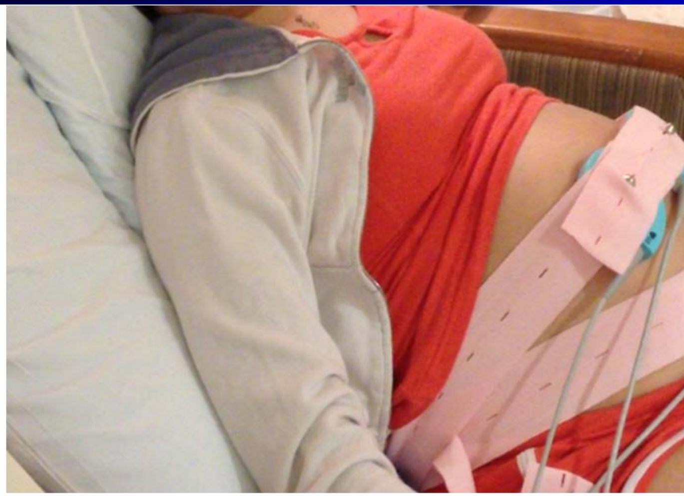
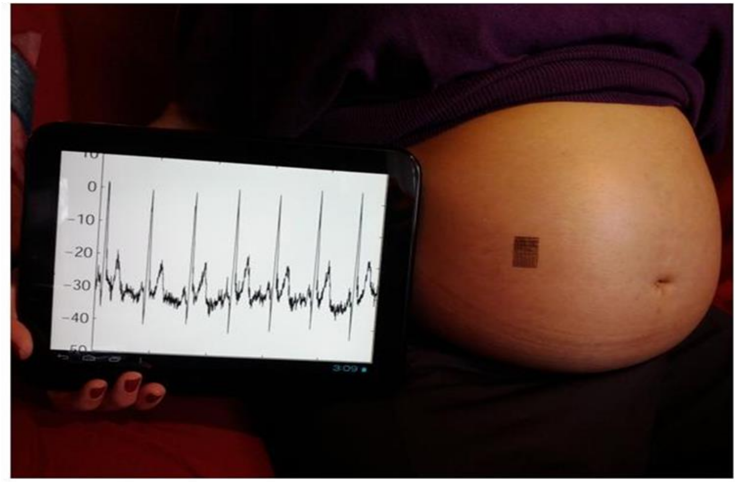
UCSD Center for Perinatal Health

UC San Diego Jacobs School of Engineering





old

new

Whole Body Wearable Sensors

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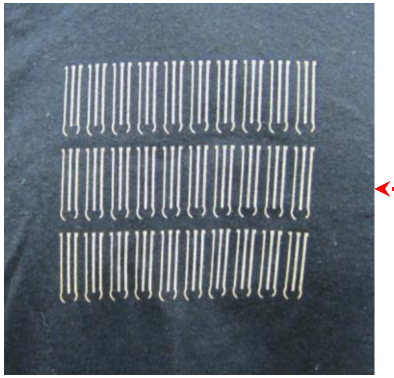
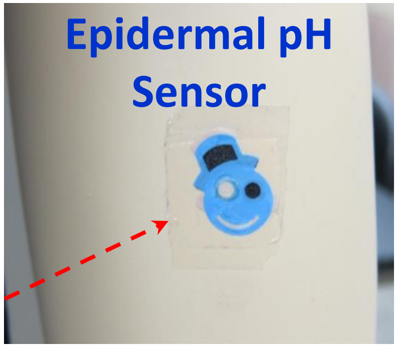
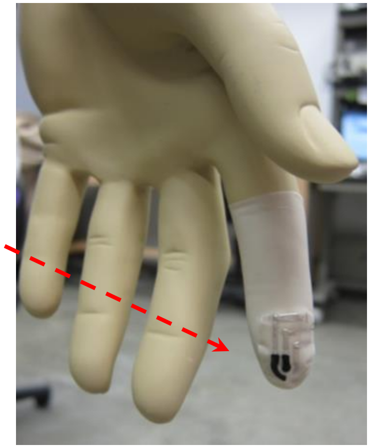
Fitness Textile Sensor



Metabolite Sensor with Electronics



Epidermal pH Sensor



Forensic Finger Sensor

Any-place All-day Non-Invasive Monitoring directly on the Skin or Textile:

Reduce health-care costs and enhancing the quality of life.

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The Problem: *Diabetes*

- Type 1 requires blood sampling, insulin injection
- Type 2 is related to obesity, inactivity, lifestyle

  -initially treatable with pills, weight control and exercise

  -requires blood sampling, may require insulin later

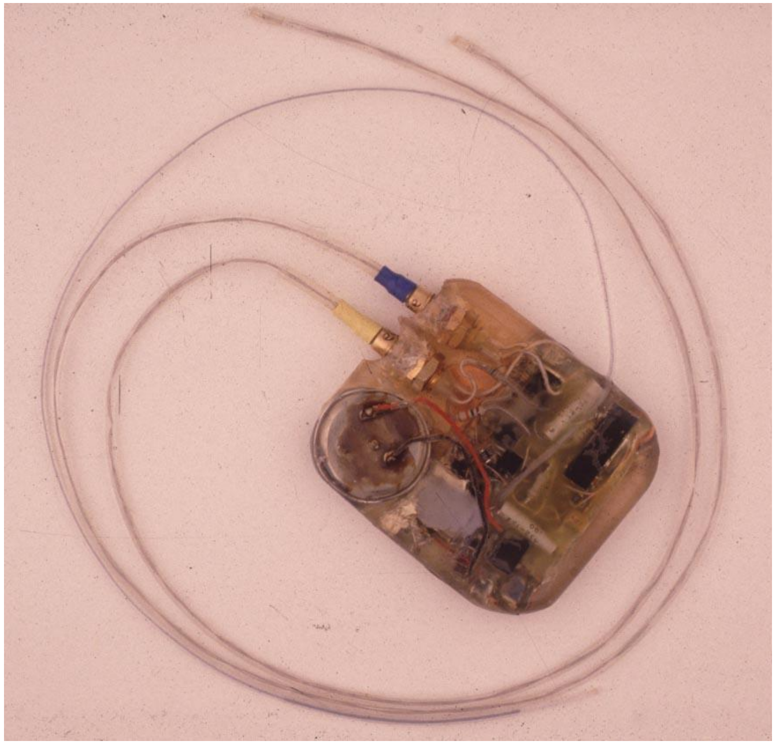
  -exacerbates many other medical conditions

  -growing at *epidemic rates*, <u>especially among youth</u>
- All treatments are related to blood glucose control
- US monetary costs: > $140 Billion/year
- Tremendous wastage of human resources
- New therapies are clearly needed

The Biosensors 2010

UC San Diego Jacobs School of Engineering

Dr. David Gough
Department of Bioengineering



(Reuters) - American bioengineers have demonstrated that an implanted glucose sensor with potential to transform the management of diabetes has passed a crucial test: the device they developed worked continuously in animals for over a year, without showing signs of "tissue encapsulation" seen in trials with other similar devices. 2010.

E4E Technology

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Land

Intelligent Camera Trap

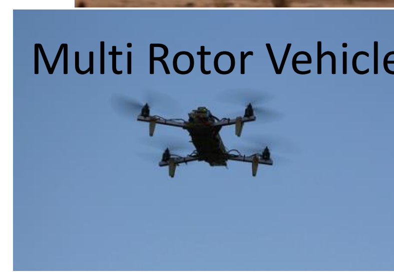
Terrestrial Vehicle

Air

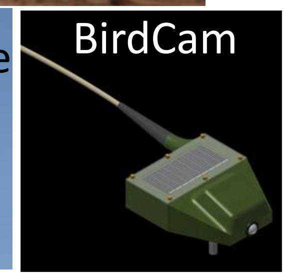
Stabilized Aerial Platform

Unmanned Aerial Vehicle

Multi Rotor Vehicle

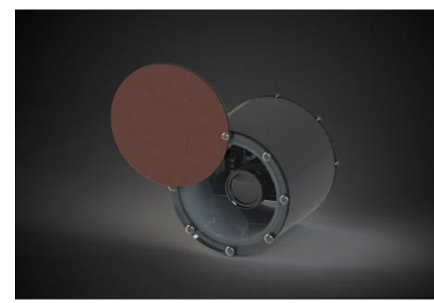


BirdCam



Sea

Stingray Autonomous Underwater Vehicle



CoralCam

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E4E Applications

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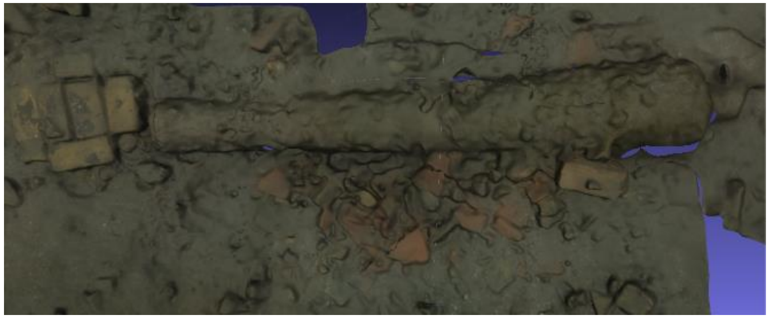
Whale Shark Monitoring

Goal: Classify the worlds largest, yet illusive fish
Partner: Hubbs SeaWorld Research Institute

Habitat Restoration

Goal: Understand and track health of river valley
Partner: San Dieguito River Valley Conservatory

Underwater Archeology



Goal: 3D reconstructions of underwater archeological sites
Partner: Atlantic World Marine Archeology Research Institute

Protecting Vaquita

Goal: Conservation of worlds most endangered cetacean
Partner: San Dieguito River Valley Conservatory

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CitiSense: Air Quality via the Crowd

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- Mobile personal sensing approach to regional air quality monitoring
- Machine learning latent-variable analysis interpolates between sensors & predicts future conditions
- Two month-long user deployments in San Diego region
- Other contributions
  - End-to-end Hardware/software system design
  - Mobile power management
  - Interaction design for in-the-world sense-making
  - Observed new patterns of sense-making, behavior, attitudes, sharing

Griswold, Dasgupta, Krueger, Rosing (CSE), Patrick (SOM)

Retina Prosthesis –Vision Restoration

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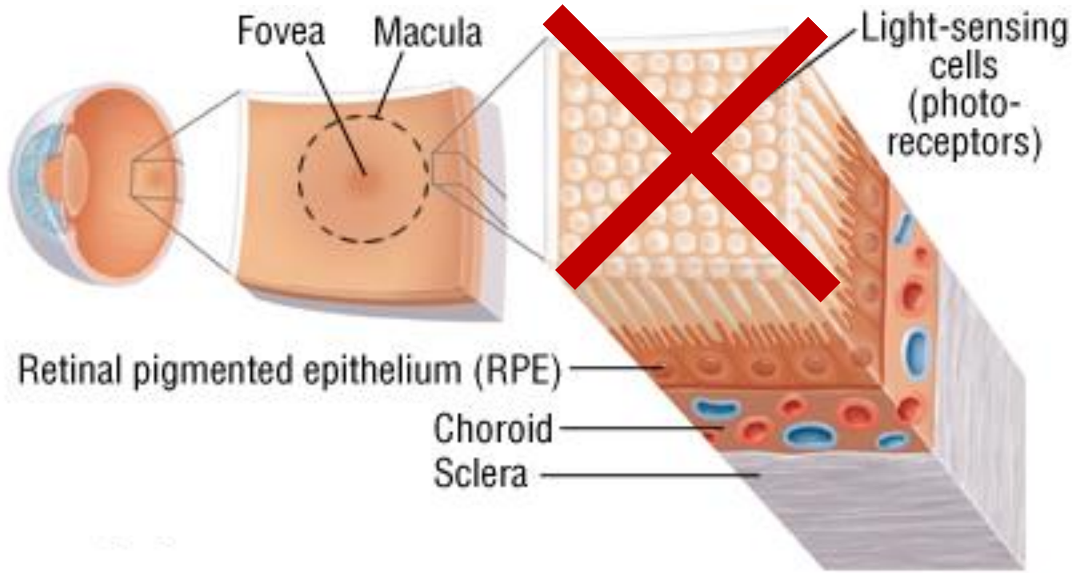
Objective: To restore vision from irreparable rod and cone damage related to various forms of degenerative retinal disorders such as Macular Degeneration.



Our Solution: To restore vision from ***implantation of photosensitive semiconductor nanowires*** serving the functions of photoreceptors to ***stimulate neural responses*** of ganglion cells that transmit image signals to the brain through the optical nerve.

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Implantable Nanowire Photoreceptors

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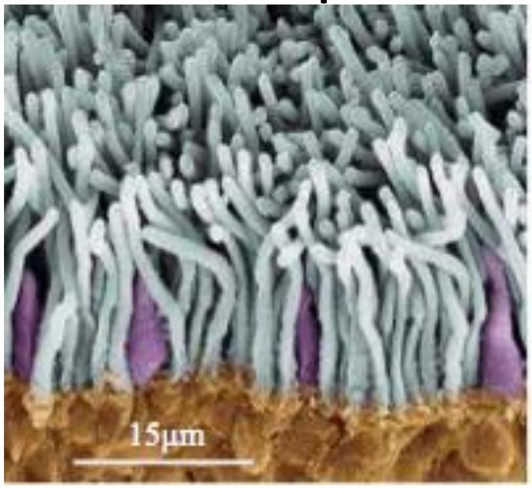
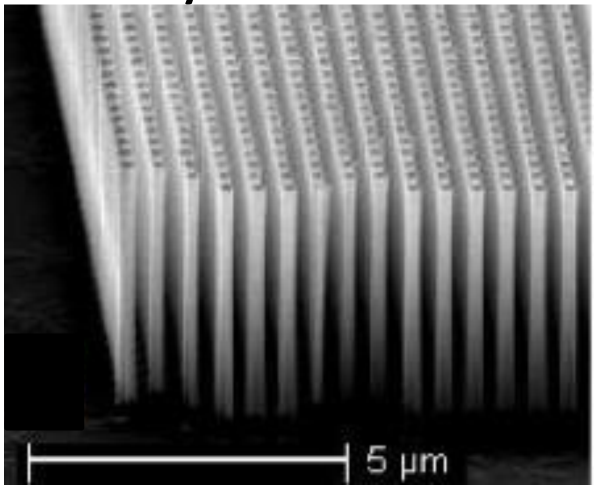
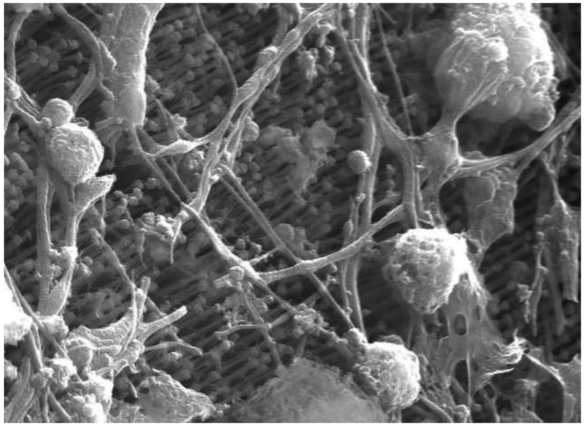
Human Photoreceptors in Combs



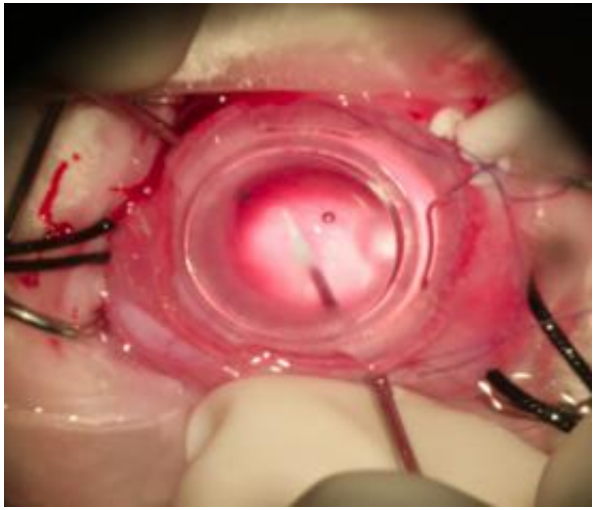
Arrays of Si nanowires



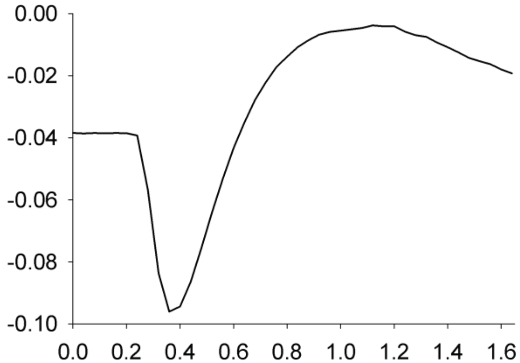
Human neurons on Si nanowires



Nanowire prosthesis in the eye



Stimulated neural signal by Si nanowires



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Syn Hollow Enzyme-Loaded nanoShell

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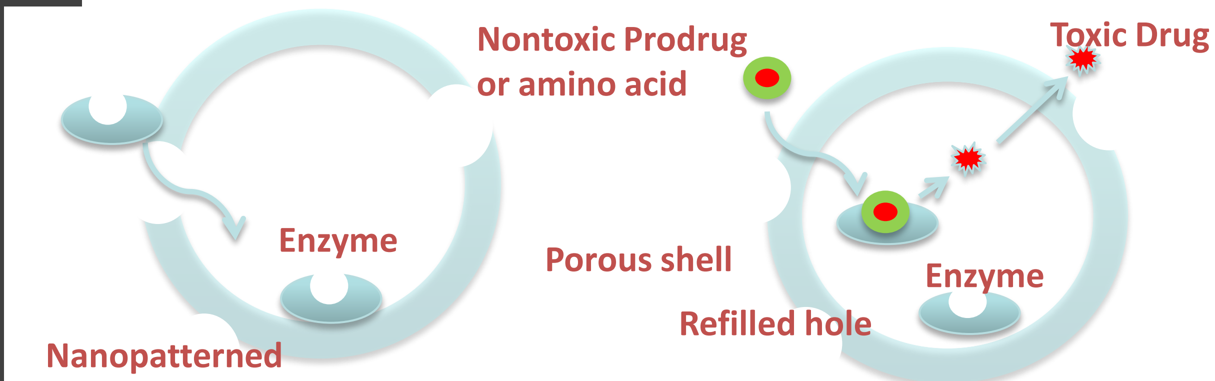
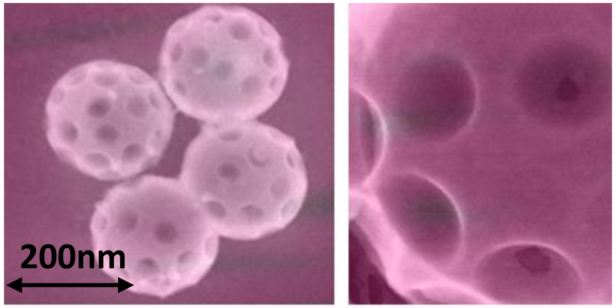
Inanc Ortac and Sadik Esener (NanoEngineering & MCC)

- **Enzymes enable powerful therapies against cancer: they can revolutionize selectivity of chemotherapy or starve cancer by depleting tumor nutrients (Licensed to Devacell Inc.)**
- **However, most therapeutic enzymes are unstable and from non-human origin therefore immunogenic**
- **Dual porosity SHELS platform offers an engineered nanotechnology solution**

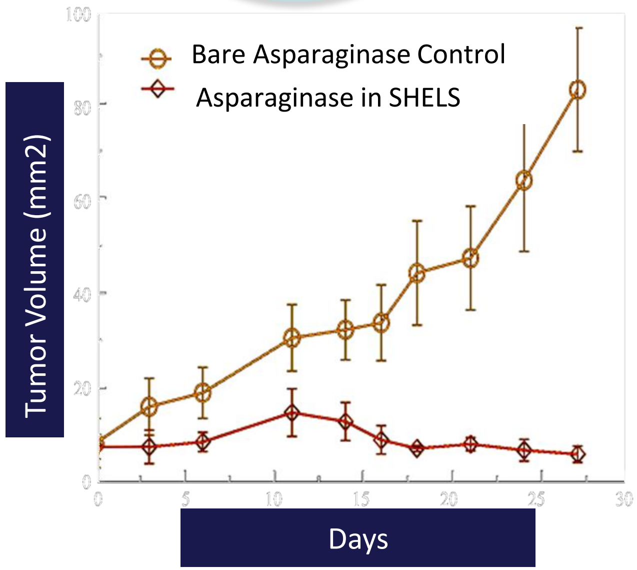




Fabricated SHELS

Engineered nano-teabag:

Encapsulated enzyme is larger than the nanopores but smaller than patterned holes. Pro-Drug, drug and amino acid molecules are small enough to pass through the porous shell and cleaved by the enzyme. Hole refilling chemistry does not affect enzyme function



In Vivo Proof of concept:

Pancreatic tumor cannot grow when IM injected, asparaginase loaded SHELS distant from tumor depletes serum asparagine (Left). Encapsulated asparaginase achieve systemic aminoacid depletion in the presence of neutralizing antibodies while bare enzyme completely fails

Nano Letters January 2014

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Toxin Nanosponge

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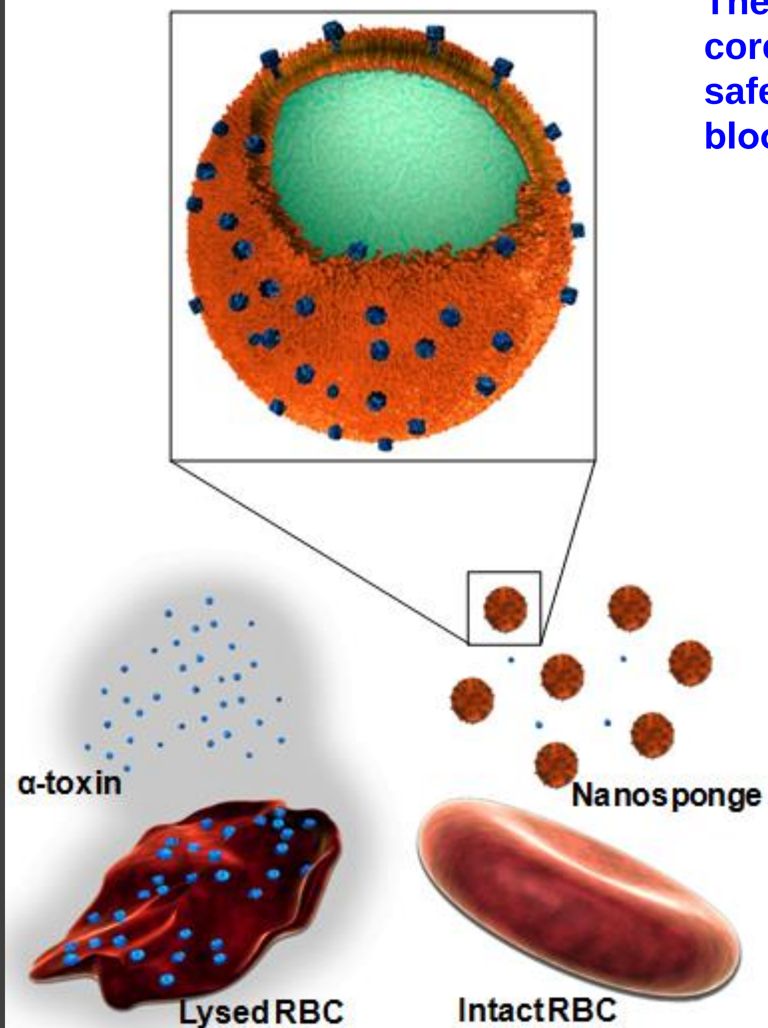
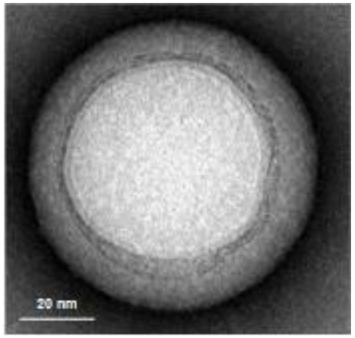
The nanosponge is a biocompatible particle made of a polymer core wrapped in a red blood cell membrane. It is capable of safely removing a broad class of dangerous toxins from the bloodstream regardless of the toxin's molecular structure.



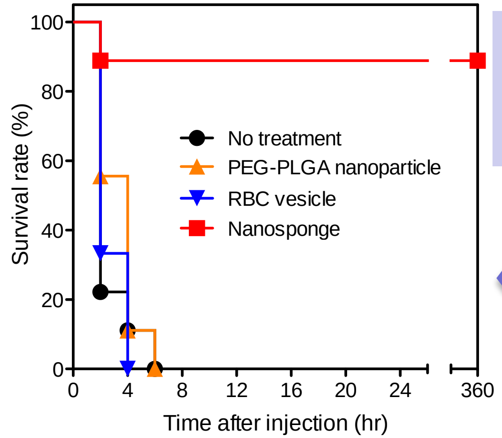


Physical Structure

RBCs + α-toxin

RBCs + α-toxin & nanosponge

In vitro test-tube hemolytic assay (effectively protects RBCs)



In vivo bloodstream detoxification (89% survival from lethal doses of toxins)

Nature Nanotechnology 2013, *8*, 336-340 (Liangfang Zhang Laboratory).

Printable Nanoelectronics

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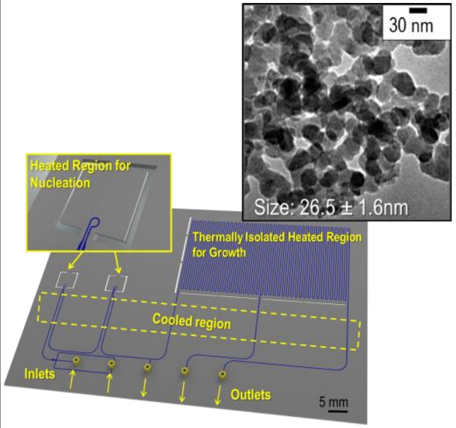
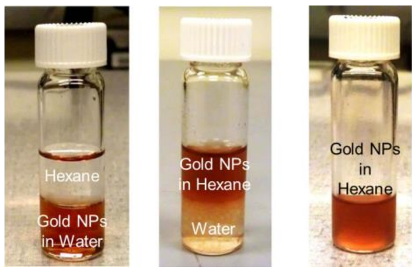
Quality nanoparticle (NP) generation via microreactors

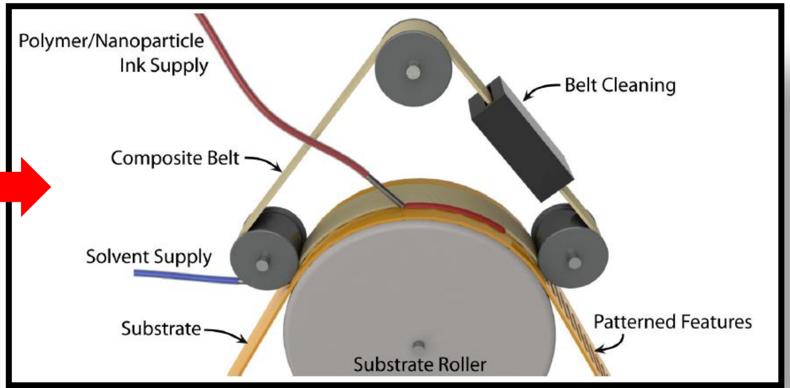


Generation of Ink
(choose solvent, ligands, etc.)

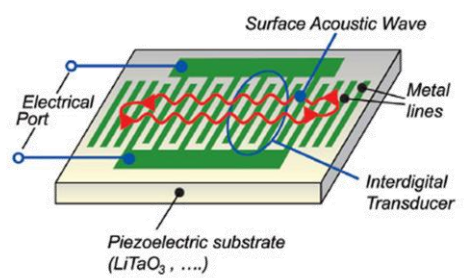


Phase Transfer

Nanoprinting

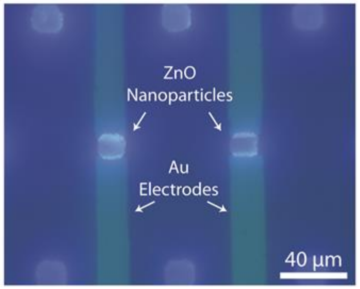


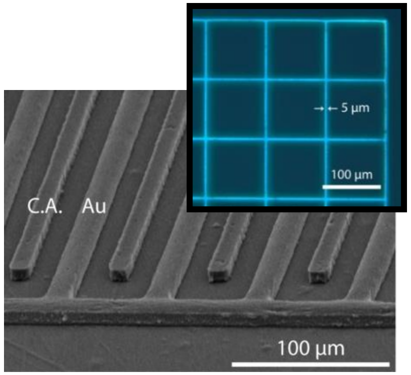
Several Applications



MEMS SAW Devices

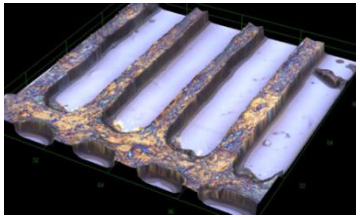
UV Sensors





Biosensors

Organic Electronics



E. Erdem, et al., Small, 2013, in press
M. Demko, et al., ACS Nano, 2012

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Next Wave: Advective Nanoprinting

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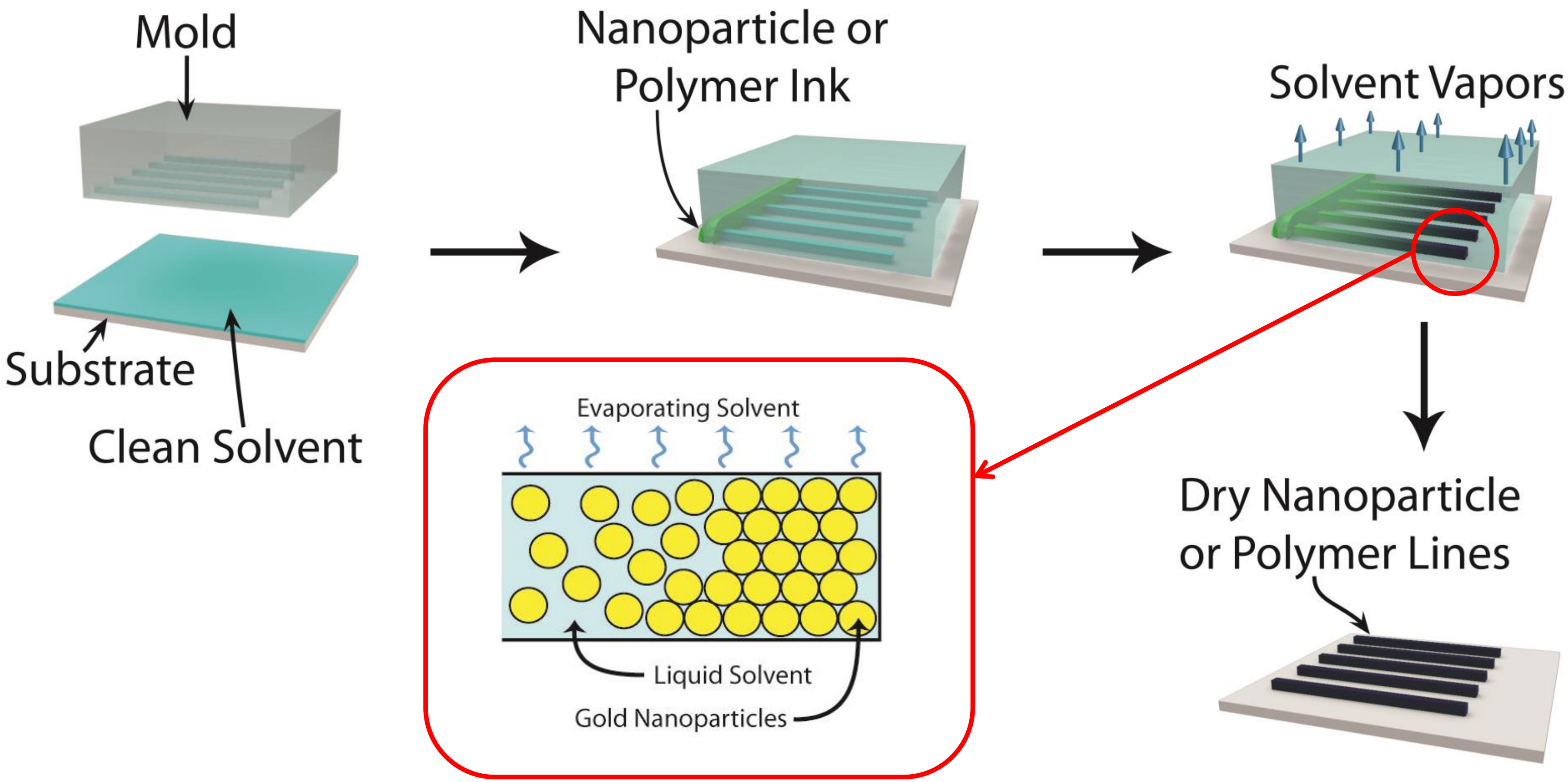
Multiple Layers	Resolution: 250 nm	Alignment: 100 nm	Throughput: Moderate



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Key Advantages

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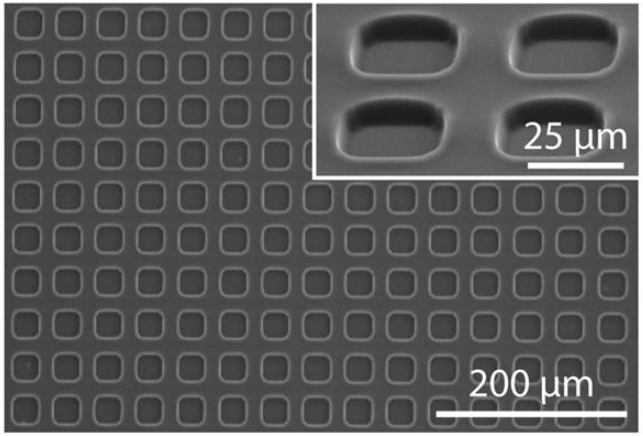
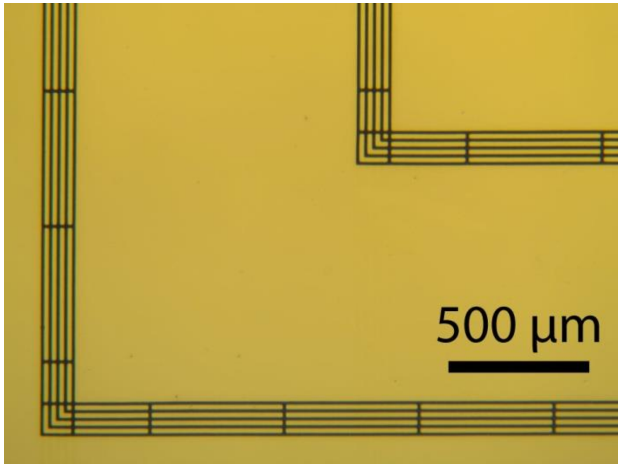
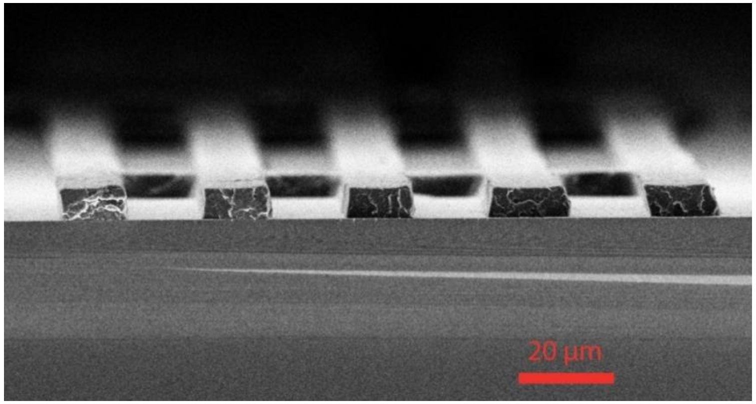


Cellulose Acetate on Polyimide



Gold Nanoparticles on Glass

Large Area
No Residual Layer

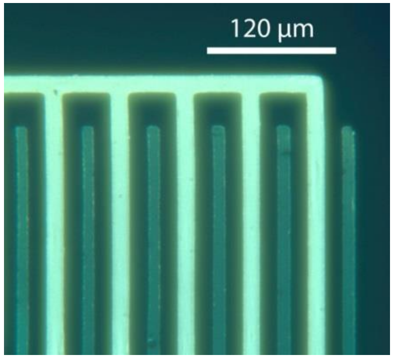


PMMA on Silicon

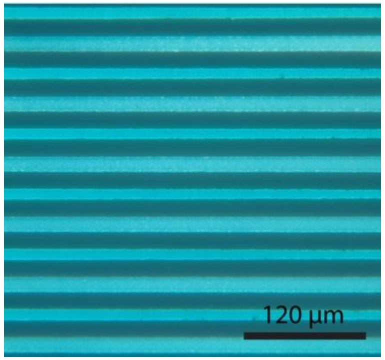
With Each Print:
High Aspect Ratio
High Geometry Fidelity
Tall Features in Single Shot

M. Demko, et al., Langmuir, 2010

Additional Advantages



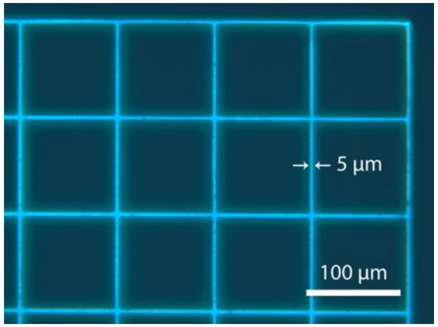
Cellulose Acetate
and ABS



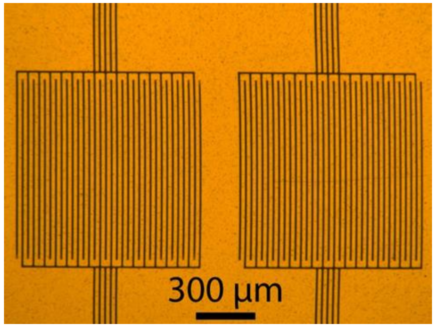
Cellulose Acetate
and PMMA

Multiple Materials Printed Concurrently

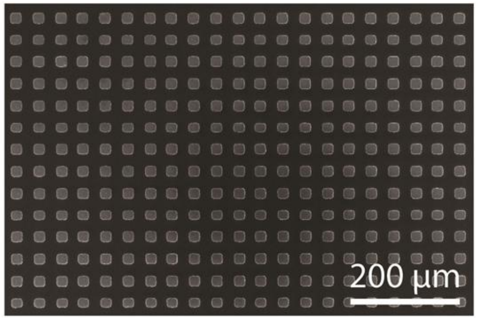
Chitosan on *Glass*



Gold Nanoparticles on *Polyimide*



Zinc Oxide Nanoparticles on *Silicon*



Compatible with Large Number of Different Substrates

M. Demko, et al., APL, 2011

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Benefits of Higher Local Rigidity

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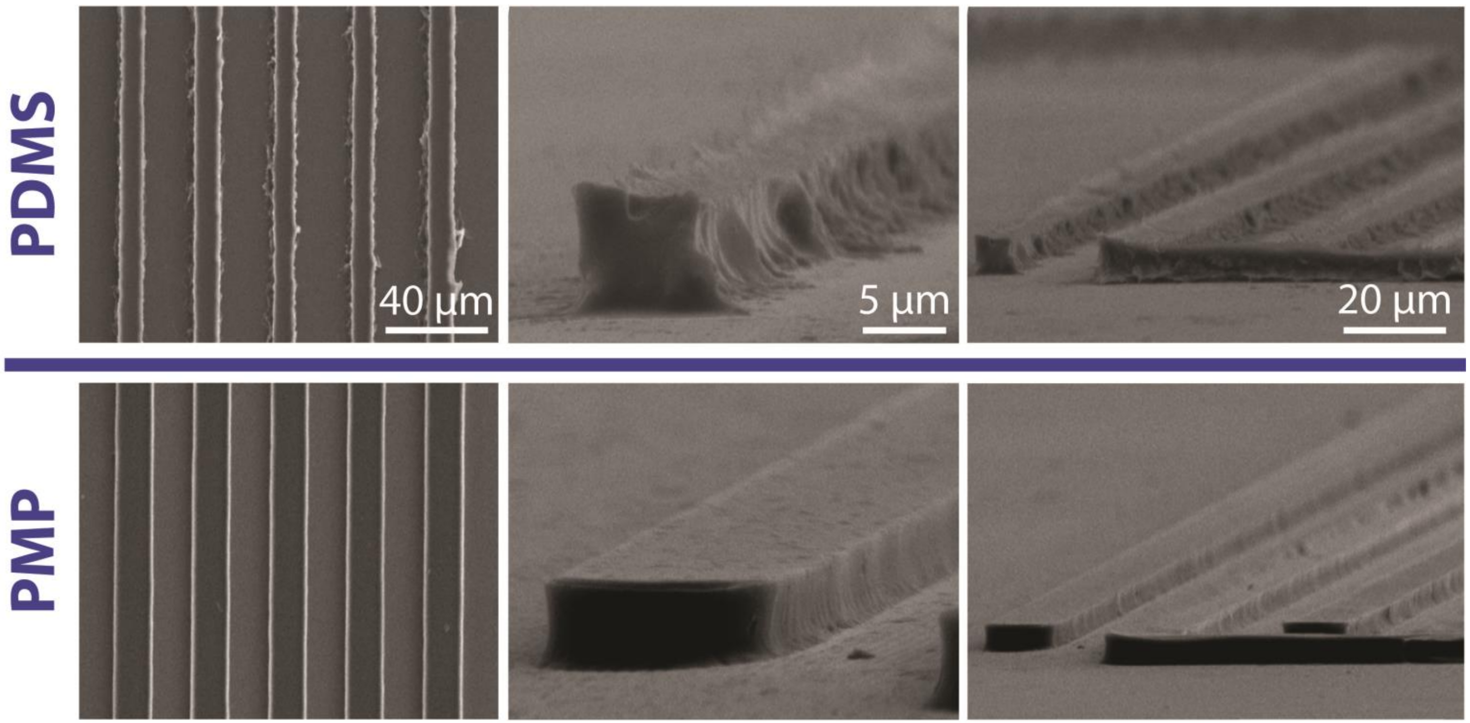

Micro-scale Patterns of Cellulose Acetate on Silicon

M. Demko, et al., ACS Nano, 2012

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3D Bioprinting for Tissue Engineering

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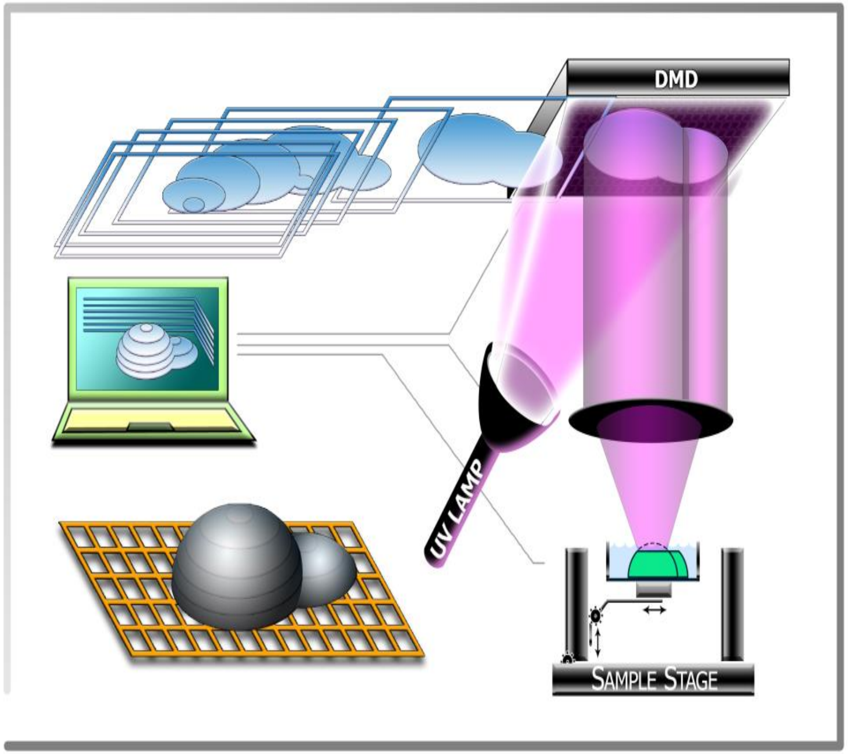
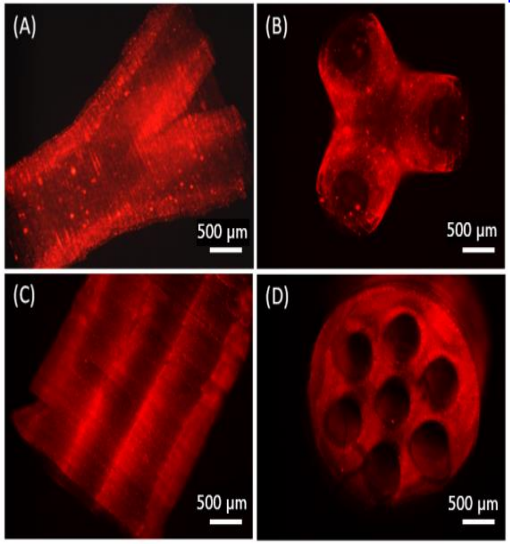
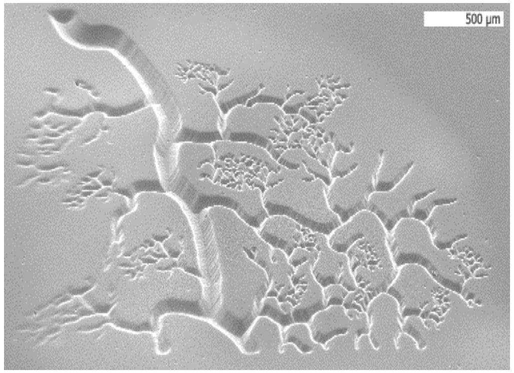




3D-printed biomimetic conduits for repairing spinal cord injury



3D-printing of vascular-like hydrogel in 1 sec

- Develop 3D bioprinting techniques integrating biomaterials/nanomaterials, optics, and stem cells
- Create patient-specific live tissues for repairing heart, liver, eye, and spinal cord injury.
- S. Chen - NanoEngineering

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Invitation to San Diego

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www.JacobsSchool.ucsd.edu/re

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Invitation to San Diego

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The TSensors Summits (www.TSensorsSummit.org) are a forum for the world's sensor visionaries to present their views on which sensor applications (TApps), sensor types and manufacturing platforms have the potential to fuel market growth to the trillions of units within a decade. Such forecasted explosion will be a continuation of consumer sensor growth from 10 million units in 2007 (iPhone introduction) to almost 10 billion devices in 2013.

Co-Chairs of TSensors Summit, San Diego:

- Albert P. Pisano, Dean of UC San Diego Jacobs School of Engineering
- Dr. Janusz Bryzek, originator and Chair of TSensors Summit movement

Register Here

Participation limited to 400 registrants. All TSensor Summits have reached full capacity, please register early.

Pricing: Early (until April 15): $695 Standard (April 16 – October 15): $795 Late (October 16 – November 11): $895

Contact Bette Cooper at bcooper@tsensorssummit.org, 650-714-1570. For more information and to add your e-mail address to our distribution list please go to www.tsensorssummit.org and click on "Join Our Email List".

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Conclusion

Thank You!

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