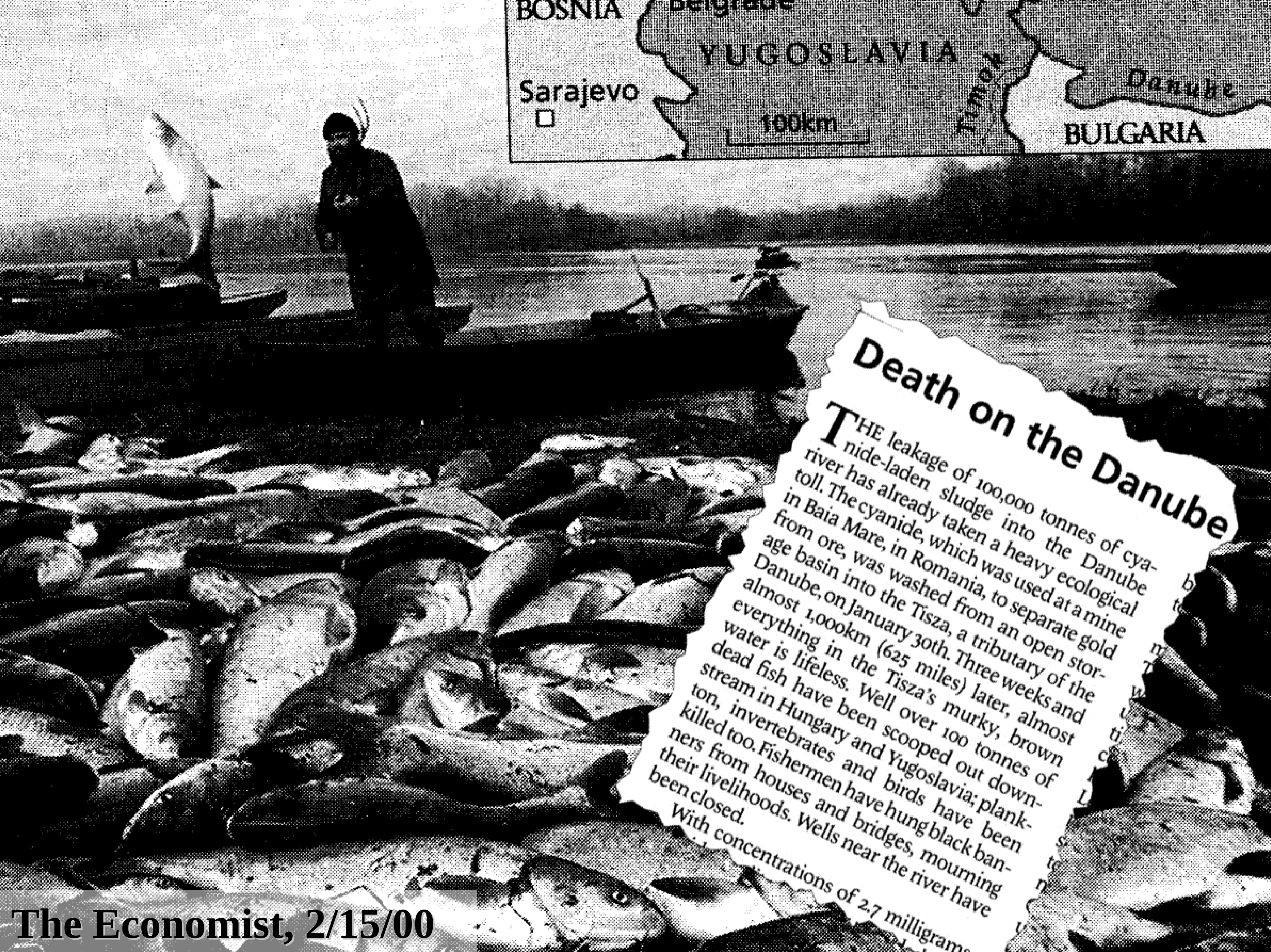


Death on the Danube

THE leakage of 100,000 tonnes of cyanide-laden sludge into the Danube river has already taken a heavy ecological toll. The cyanide, which was used at a mine in Baia Mare, in Romania, to separate gold from ore, was washed from an open storage basin into the Tisza, a tributary of the Danube, on January 30th. Three weeks and almost 1,000km (625 miles) later, almost everything in the Tisza's murky, brown water is lifeless. Well over 100 tonnes of dead fish have been scooped out downstream in Hungary and Yugoslavia; plankton, invertebrates and birds have been killed too. Fishermen have hung black banners from houses and bridges, mourning their livelihoods. Wells near the river have been closed.

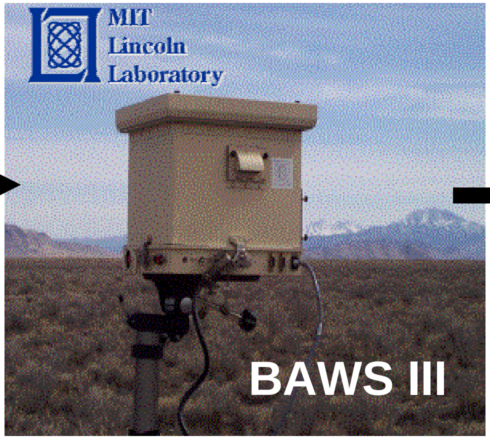
With concentrations of 2.7 milligrams

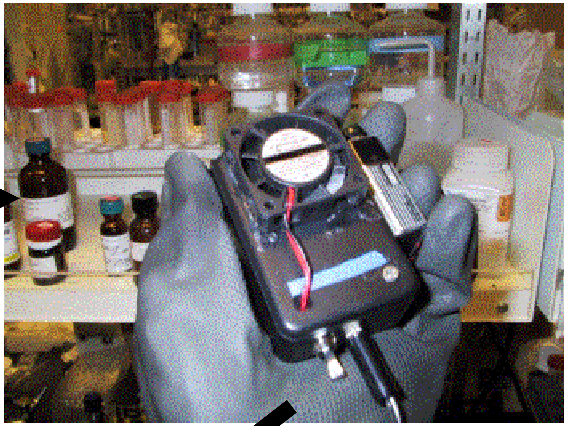
The Economist, 2/15/00

University of California San Diego

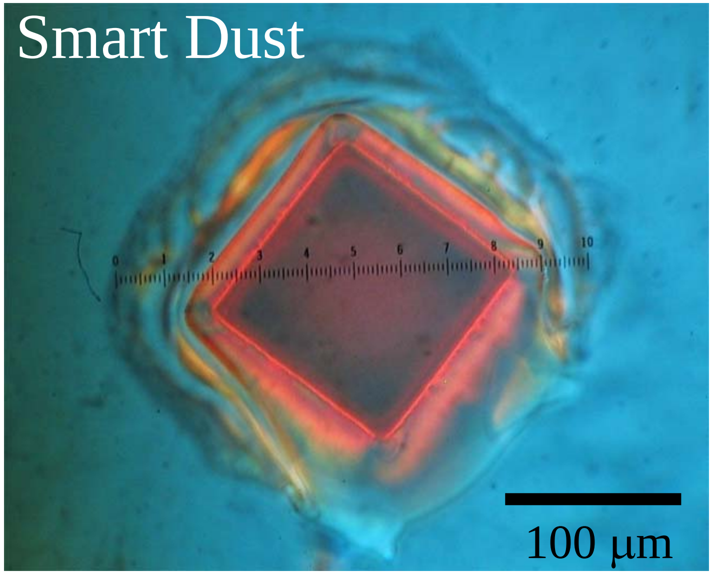
Why Nanotechnology?

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R829619





Sensors:
Small
Cheap
Low Power
Highly distributed



Nature Materials **2002**, *1*, 39-41.

Nanosensors ("Smart Dust")

This research is funded by
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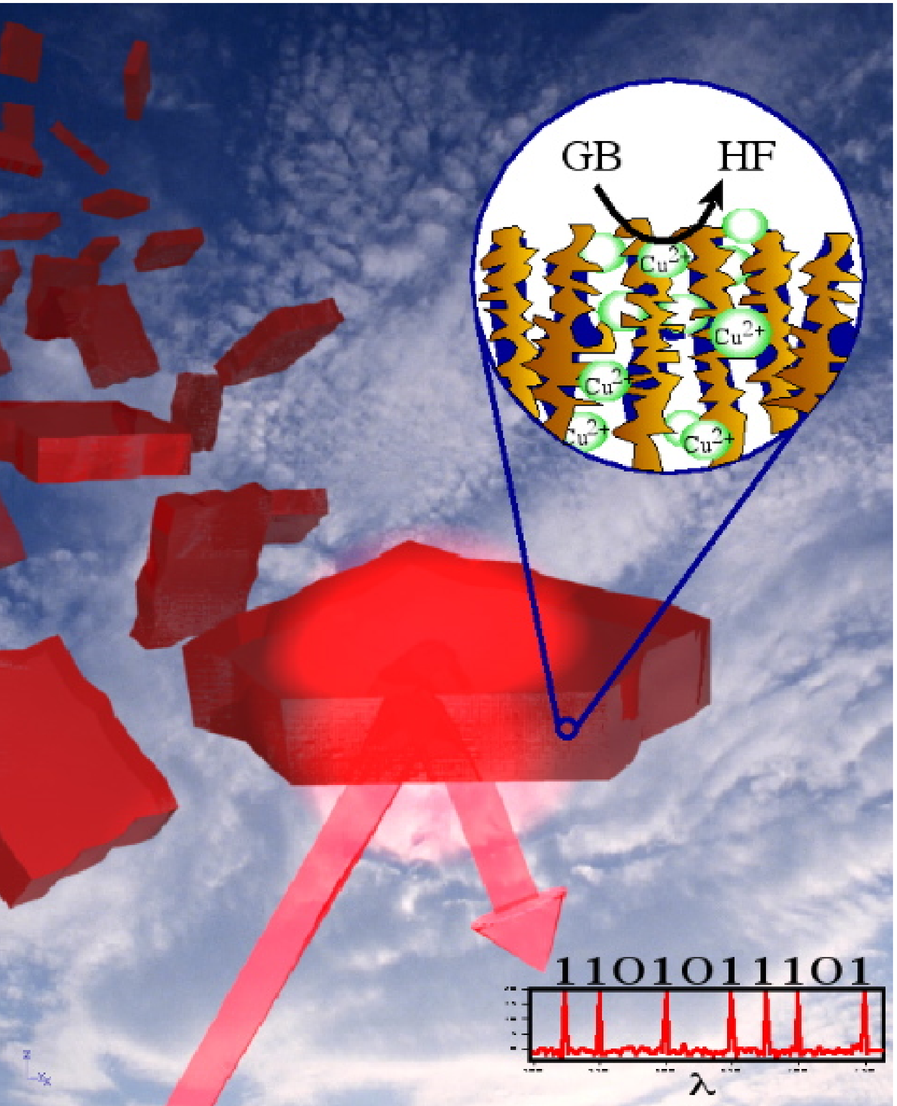
Grant # R829619

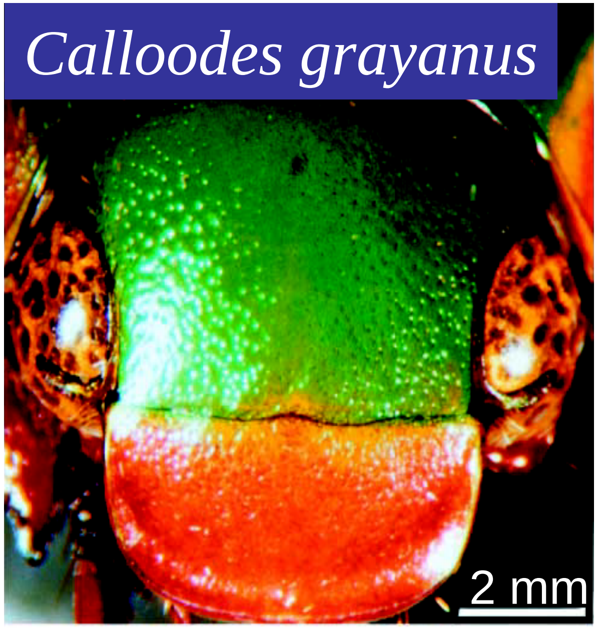
What functionalities can be incorporated into a grain of sand?

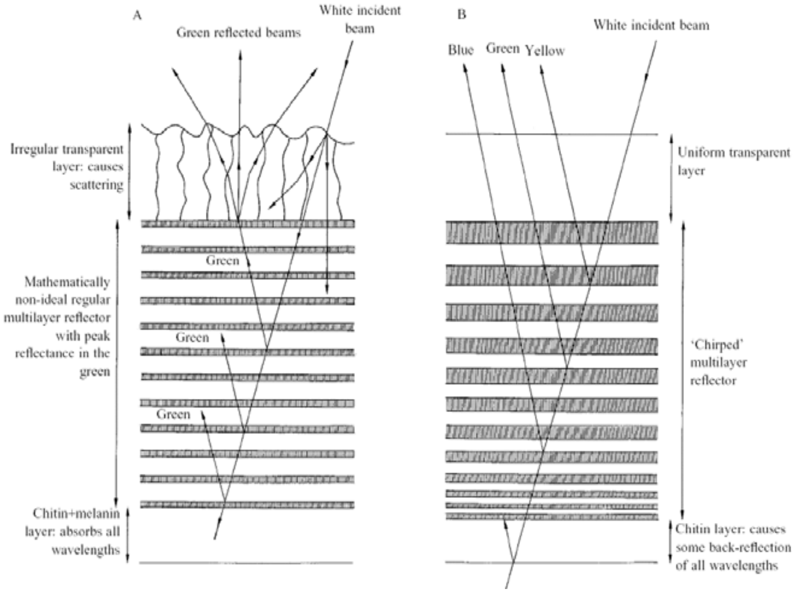


- Filtration
- Sample concentration
- Chemical sensing
- Biological sensing
- Environmental stability
- Internal referencing/drift correction
- Remote identification
- Remote interrogation (>100 m)
- Remotely triggered chemical processing
- Targeted motion
- Collective behavior (swarming)

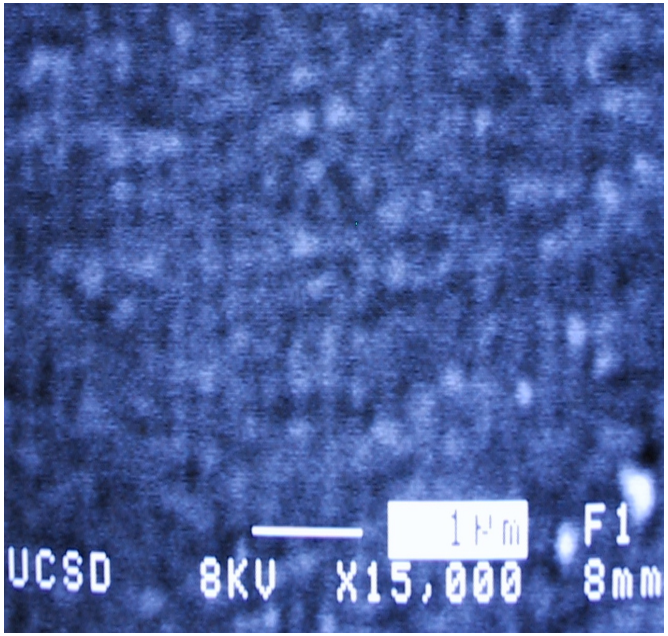
Photonic Crystals

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program Grant # R829619





PARKER, A. R., et.al., J. Exper. Biol. **1998** *201*, 1307-1313.



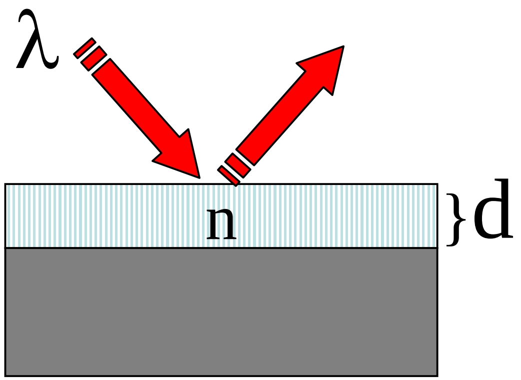
1 µm

University of California San Diego

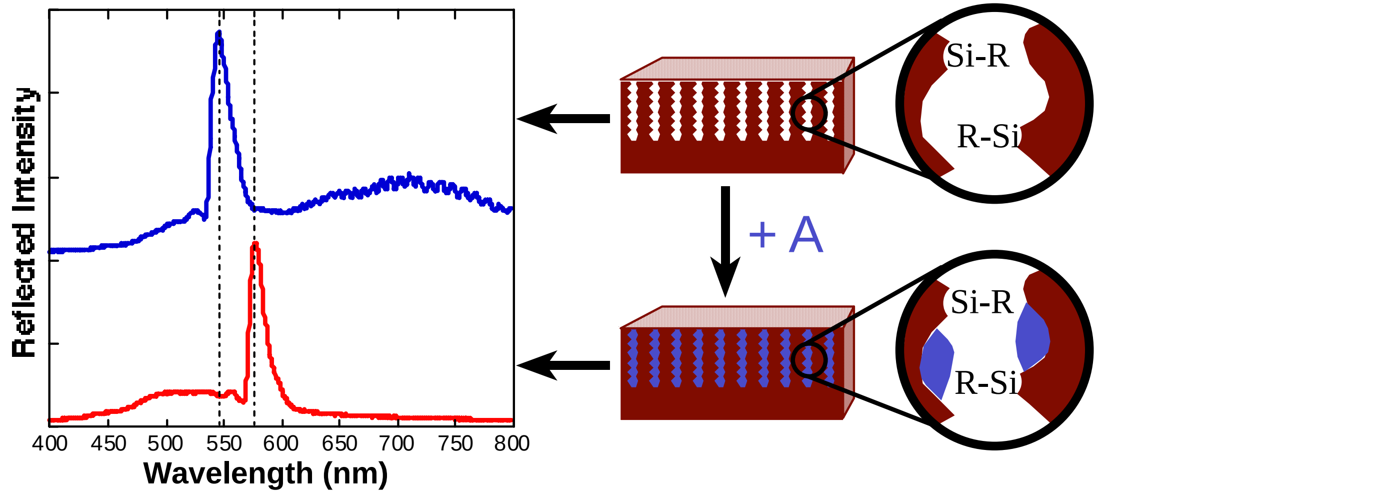
This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program Grant # R829619

Chemical Sensing with a Si Photonic Crystal

QuickTime™ and a MPEG-4 Video decompressor are needed to see this picture.



$$I = 4I_0 \cos^2\left(2\pi \bullet \frac{nd}{\lambda}\right)$$



University of California San Diego

Amplified Vapor Sensing in Microporous Media

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R829619

Capillary condensation: Liquids spontaneously condense from vapor into cracks and pores as bulk liquid.

Schematic of a PS sample

Kelvin Equation:

$$k_B T \ln\left(\frac{P}{P_s}\right) = \gamma V_m \left(\frac{1}{R_K}\right)$$

Surface energy (γ)

Molar volume of the liquid (V_m)

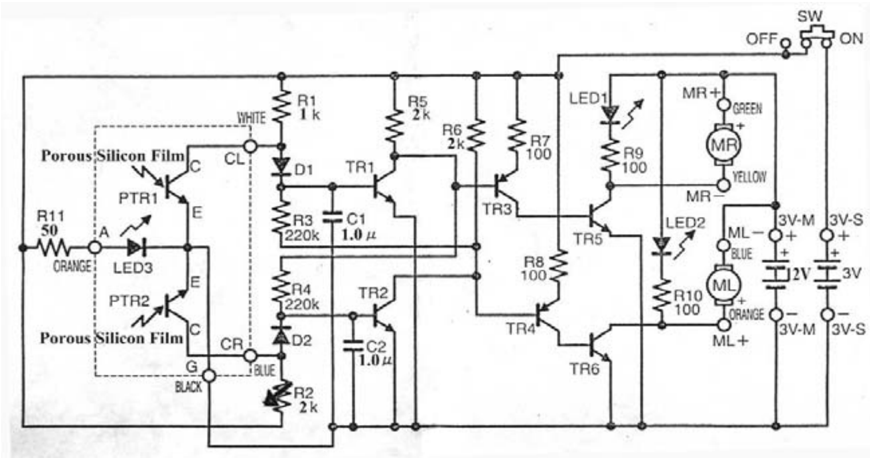
Effective pore radius (R_K)

Gao, J.; Gao, T.; Sailor, M. J., *Appl. Phys. Lett.*, **77**, 901-3 (2000).

University of California San Diego

Robotic platform integrating “smart dust” photonic crystal VOC sensors

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R829619



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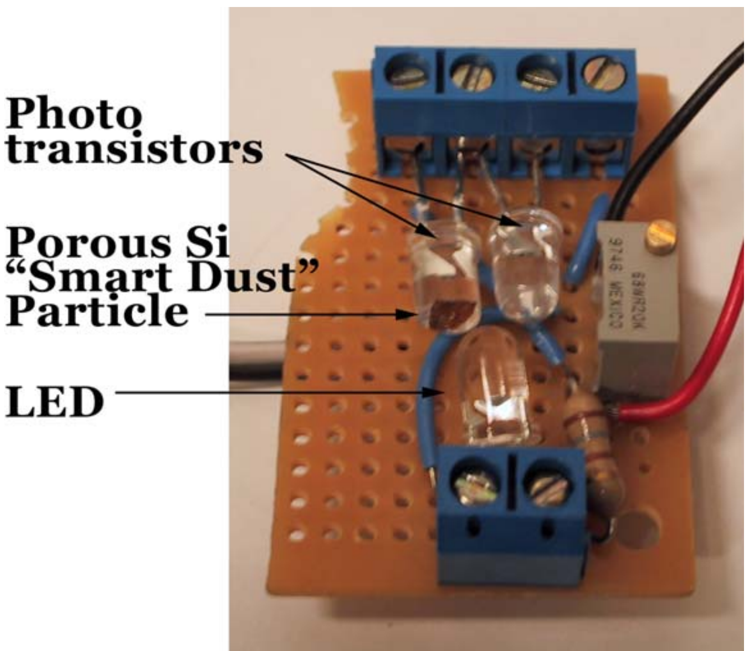


The robot follows a chemical track by sensing light transmitted through a chemically responsive photonic crystal. The robot uses two phototransistors, each covered with a porous silicon film as the chemical detector. Each sensor closes a circuit to one of the two drive motors when it detects a chemical vapor. The circuit memorizes which side the chemical it is on and activates the motor on the opposite side, steering the robot towards the chemical.

Michael J. Sailor, UCSD http://chem-faculty.ucsd.edu/sailor/

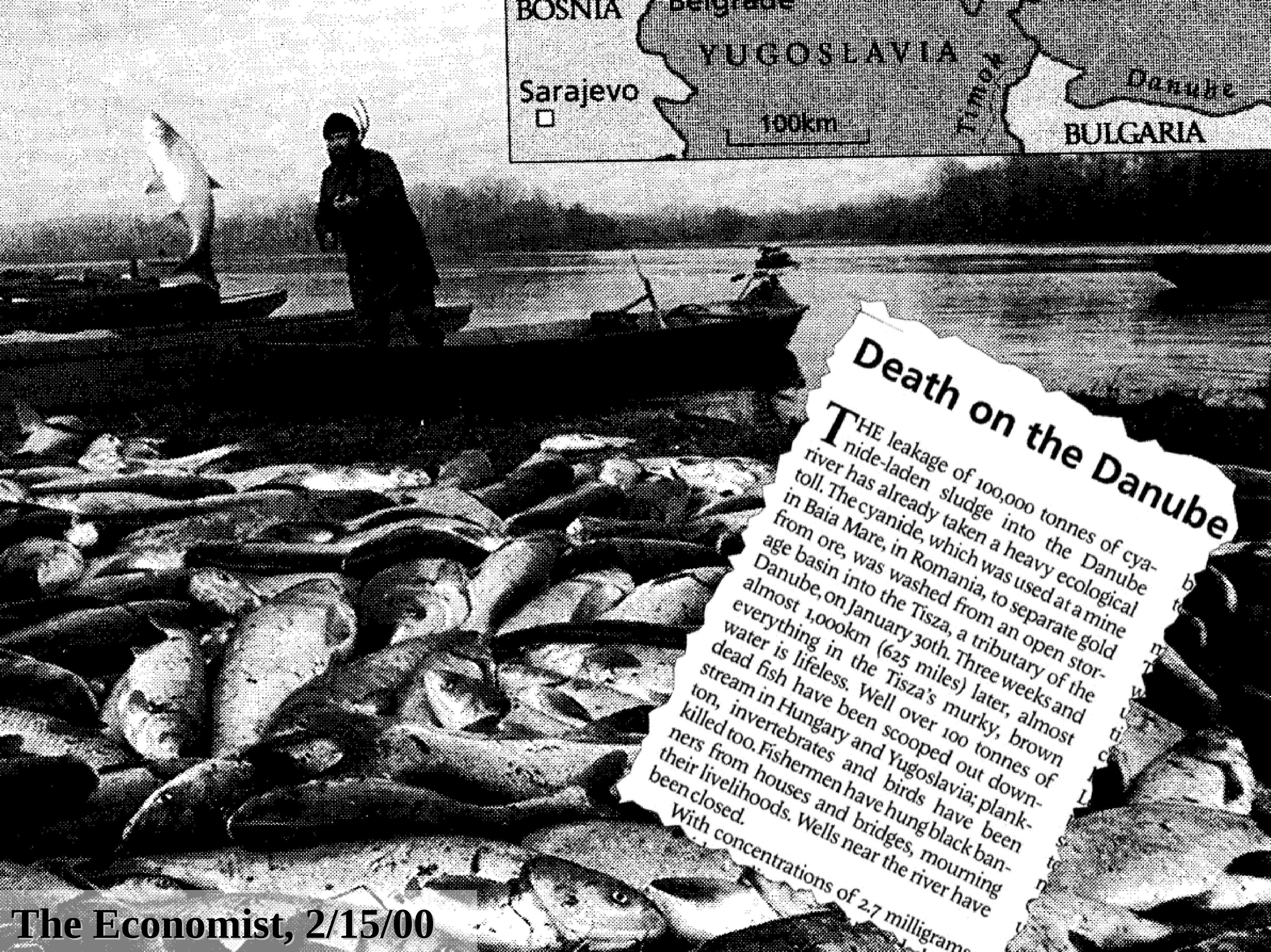
University of California San Diego

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program Grant # R829619

Smart Dust
Kris Pister, UCB

"The Smart Dust project is probing microfabrication technology's limitations to determine whether an autonomous sensing, computing, and communication system can be packed into a cubic millimeter mote (a small particle or speck) to form the basis of integrated, massively distributed sensor networks."

-*Computer*, **34**, 44-51 (2001).



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With concentrations of 2.7 milligrams

The Economist, 2/15/00

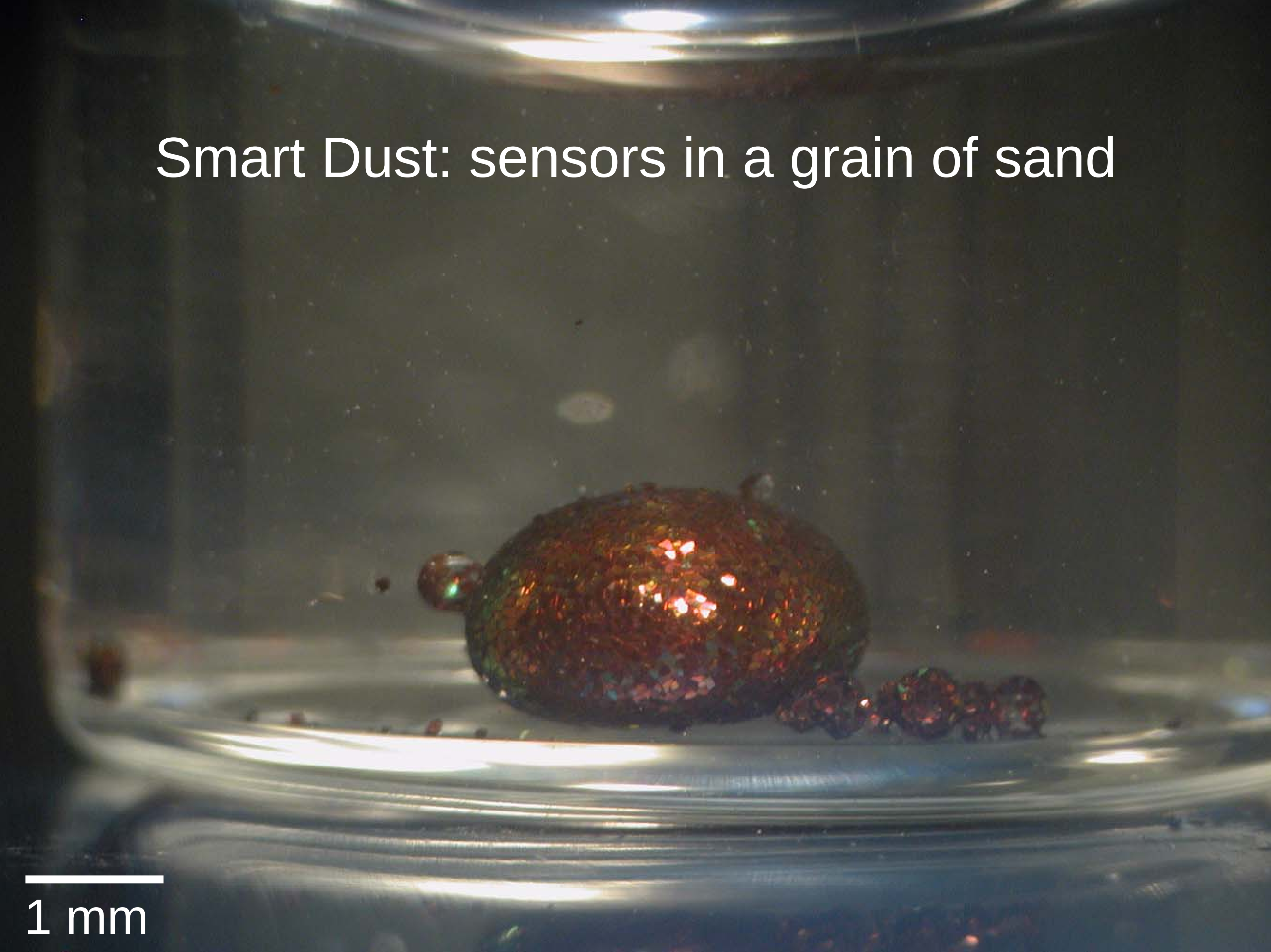
Field trials with Smart Dust at SMER

Santa Margarita Ecological Reserve (SMER) , San Diego county CA

In Aug 2002, we performed the first field trials of porous Si “smart dust” and small wireless chip-based systems for detection of environmental pollutants. The field trials were performed in the Santa Margarita Ecological Reserve, over 24 hours, and involved two undergraduates, two high school students, a graduate student, and a post-doc. A simulant (ethanol) was successfully detected from a distance of 25 meters.

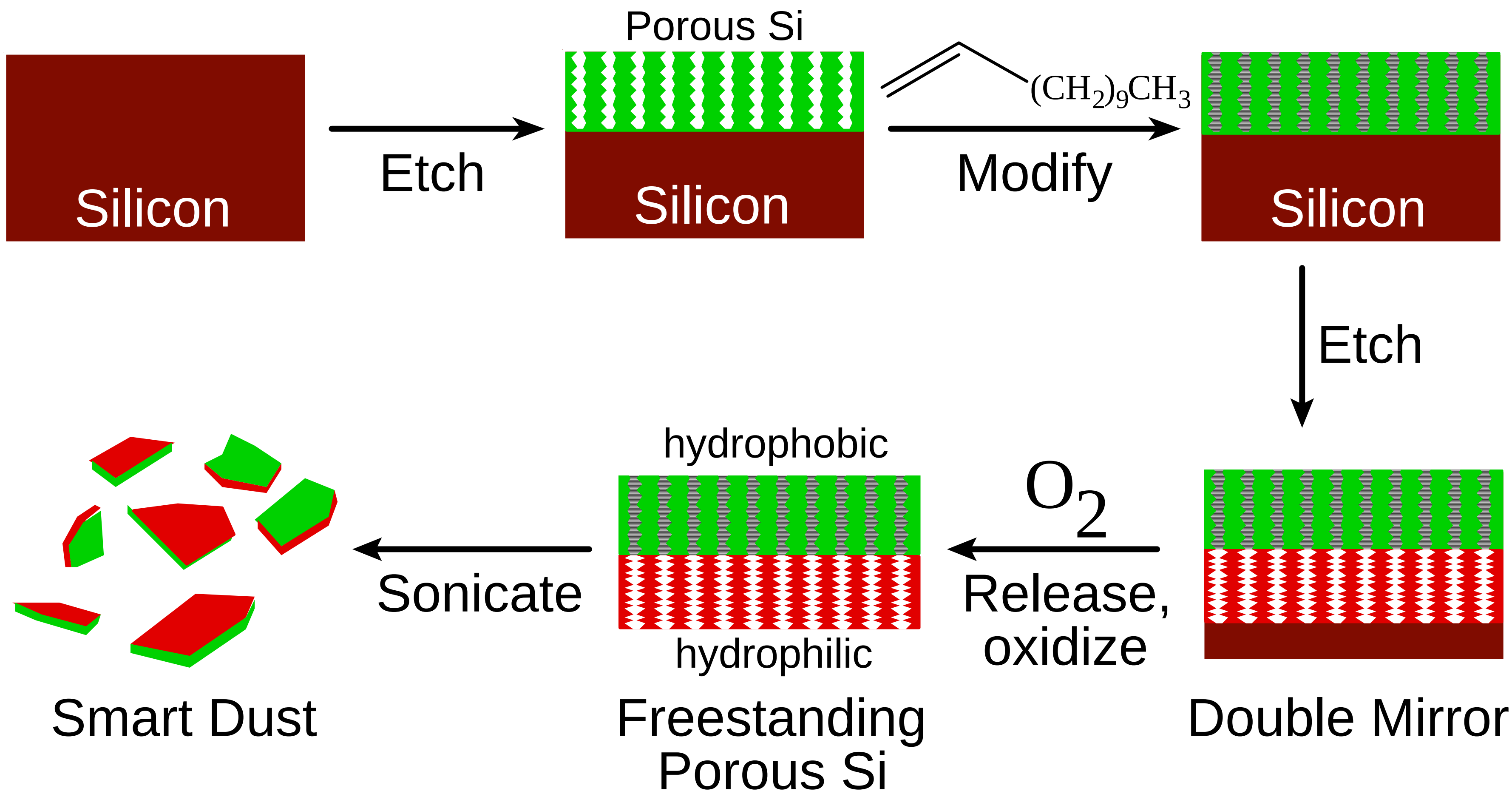
From left: Jamie Link (UCSD Grad), Pat Wang (Torrey Pines HS), Jason Dorvee (UCSD Undergrad), Frederique Cunin (UCSD Post-doc), Prof. Mike Sailor, Stephanie Tsai (Torrey Pines HS) at the entrance to SMER.

Jason Dorvee (UCSD Undergrad) doses smart dust sample with simulant vapor, assisted by Dr. Frederique Cunin (UCSD Post-doc)


Smart Dust: sensors in a grain of sand
1 mm

Synthesis of bilayered 1-D photonic crystals

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R829619

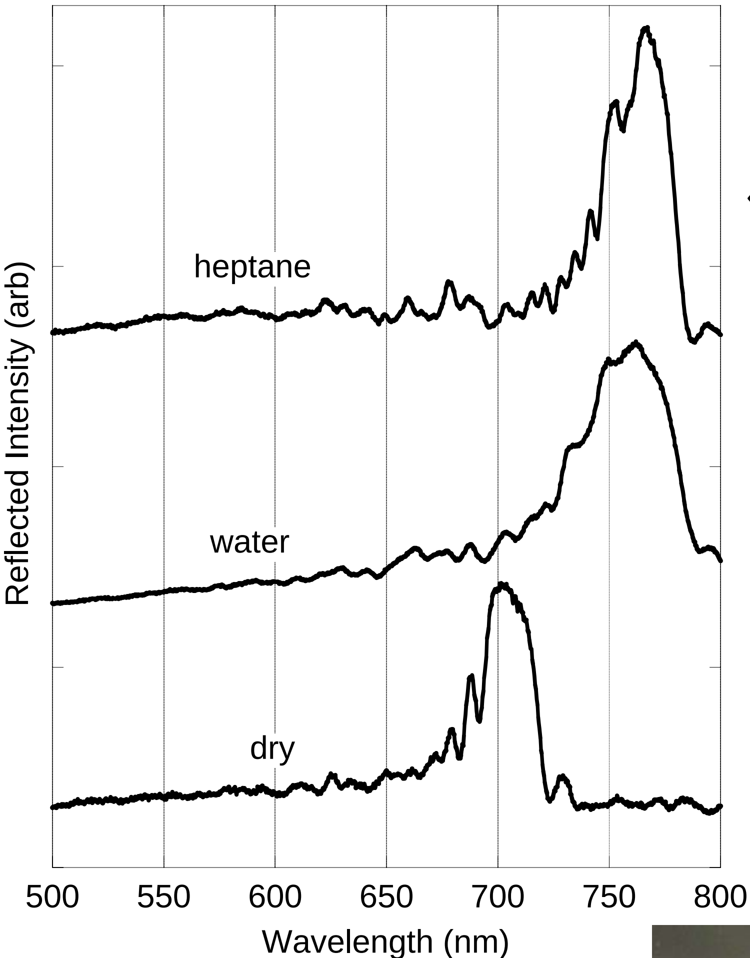


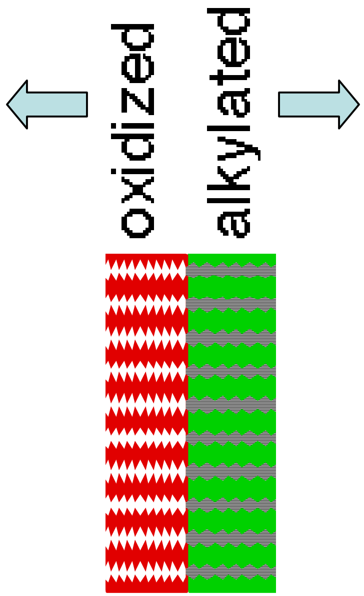
Link, J. R. and Sailor, M. J., *Proc. Nat. Acad. Sci.* **2003**, *100*, 10607-10610.

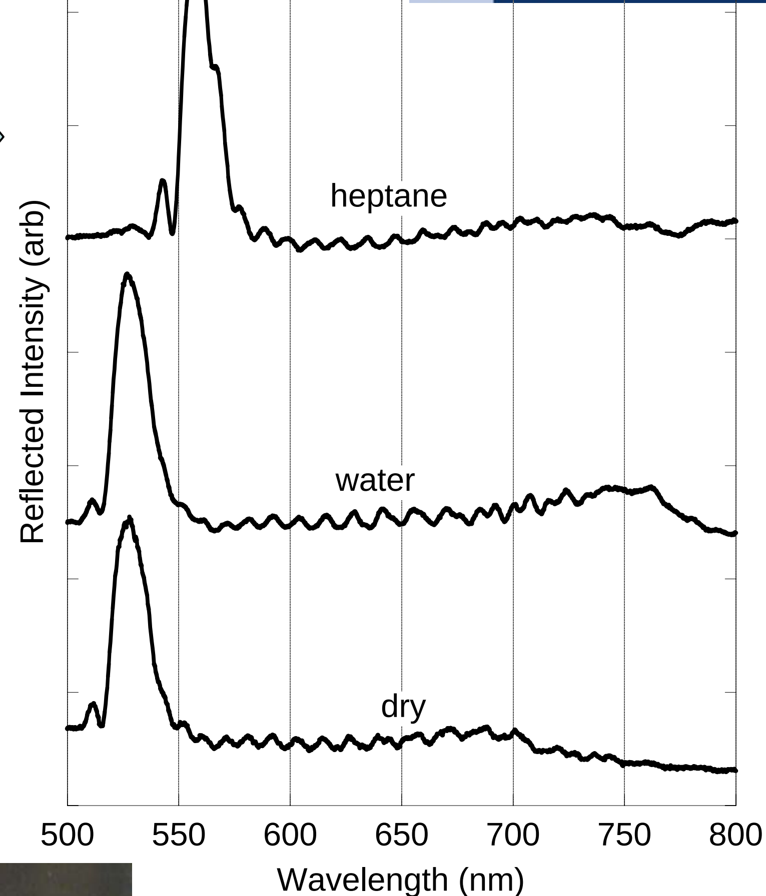
University of California San Diego

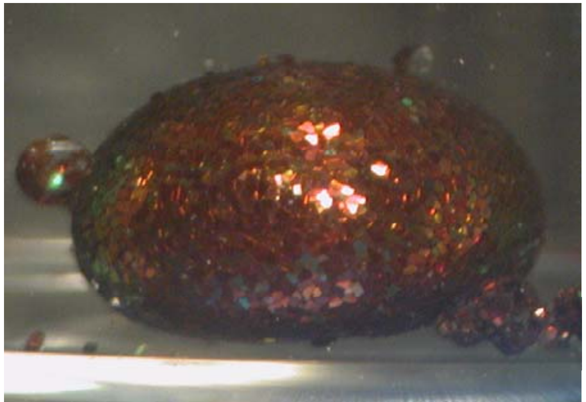
Self-Assembling Smart Dust Sensors

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R829619









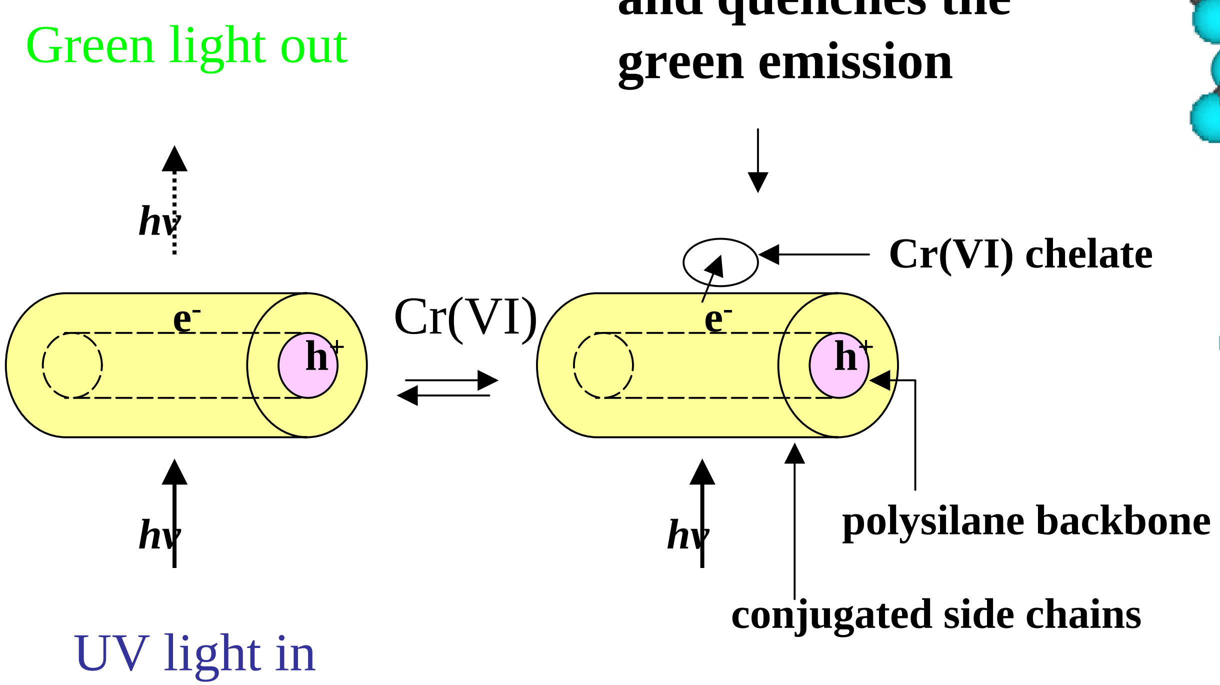
Bilayered rugate at CH_2Cl_2/water interface

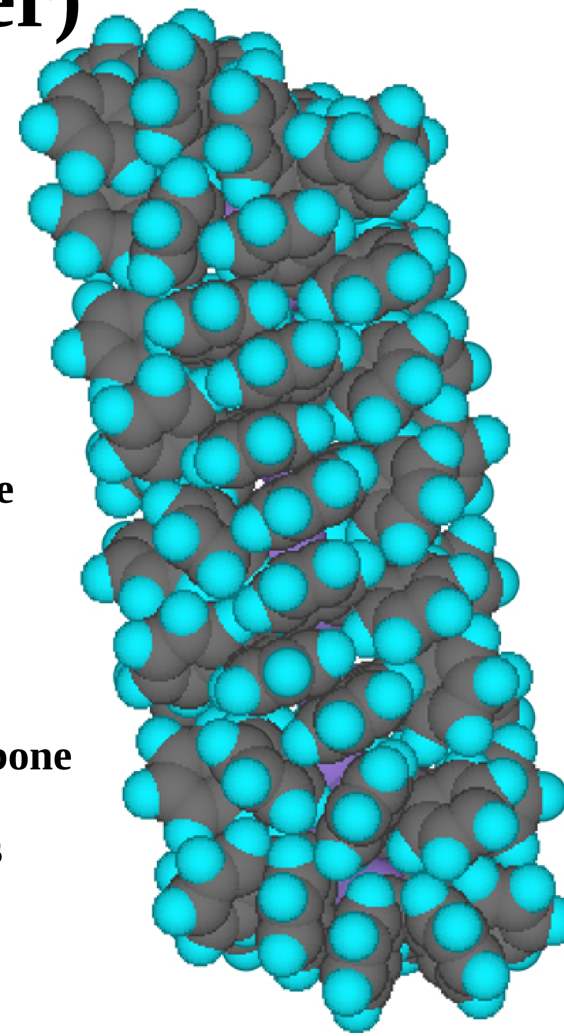
University of California San Diego

Specificity: Fluorescent molecular wires for detection of Cr(VI) in water (with W. C. Trogler)

This research is funded by U.S. EPA - Science To Achieve Results (STAR) Program Grant # R829619

Cr(VI) accepts the excited electron and quenches the green emission





University of California
San Diego

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R829619

Chromate Sensing with Silole-amine Nanoparticulate

Monomer | Nanoaggregate | 0.5ppm Cr^{VI} | 1ppm Cr^{VI}

William Trogler, Sarah Toal

University of California San Diego

Nanoextraction

This research is funded by
U.S. EPA - Science To Achieve Results (STAR) Program
Grant # R829619

Water

acetone →

Porous Si photonic crystal

Hydrosilylated Porous Si filmimmersed in water traps hydrophobic liquids.

- Hydrophobic liquids are trapped in hydrophobic porous Si matrix.
- Pollutants can be extracted and concentrated in this film for subsequent detection.

University of California San Diego

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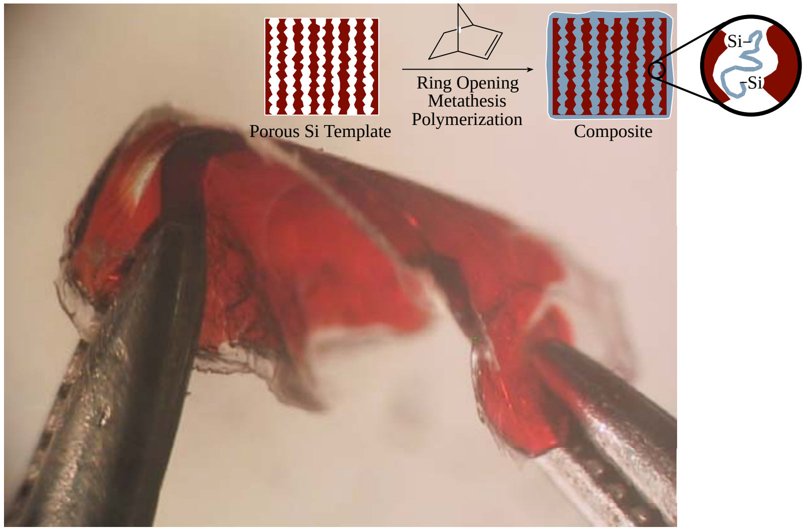
Application areas



Crosslinked Porous Si/polynorbornene composite film held between two pairs of tweezers, showing the mechanical stability of the materials.

- Chem/Bio detection in distributed sensor networks: buildings (HVAC), environment (air and water pollution monitoring), and public spaces (homeland security). Provide higher selectivity and sensitivity at lower cost, reduced power requirements.
- Medical implants, monitoring.
- High throughput screening for drug discovery, genomic sequencing.