Nanowires for Use in Medical and Biological Applications

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Materials 265
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Outline

- Biological Applications
  - Applying mechanical forces to cells
- Biotemplating
  - Aiding in the bone growth
- Biomolecule and Nanoparticle Transfer
  - Hydrophobic treatment of nanowire substrate
- Cancer detection
  - Recognition of cancer proteins

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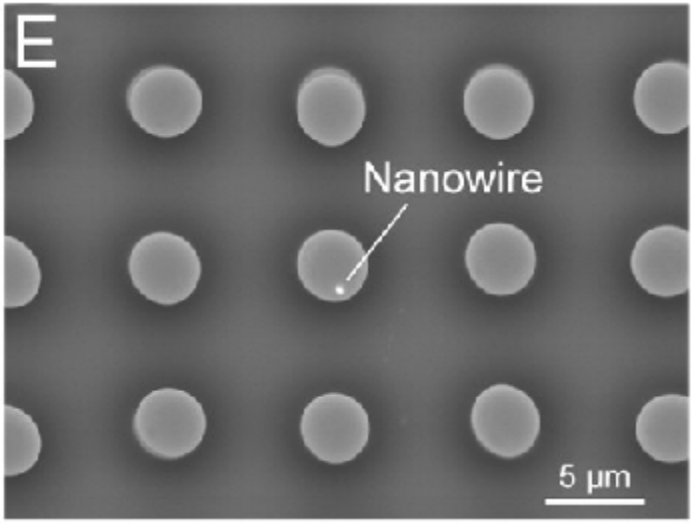
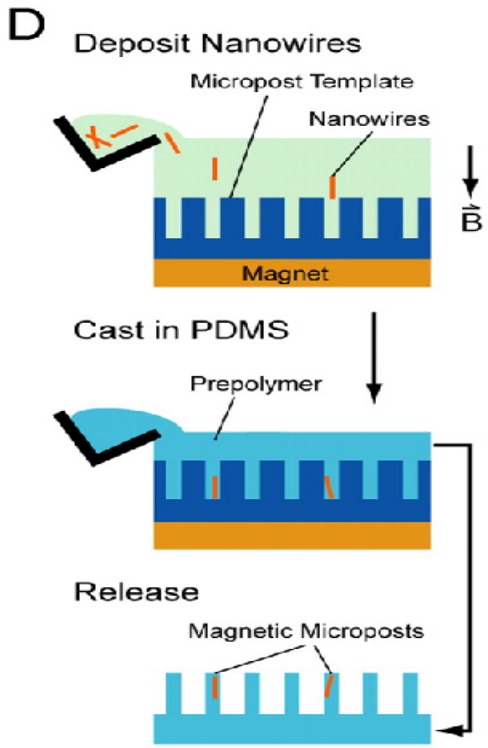
Application of Mechanical Force to Cells

- Cobalt nanowire formed by electrochemical deposition in alumina filter templates
  - 350 nm diameter and 5-7μm in length
- Inserted in microfabricated poly(dimethylsiloxane) (PDMS) posts
  - 3 μm in diameter and 10 μm in length
- Magnetic field applied to align nanowires





- Sniadecki, N.J.; Anguelouch, A.; Yang, M.T.; Lamb, C.M.; Liu, Z.; Kirschner, S.B.; Liu, Y.; Reich, D.H.; Chen, C.S.; *PNAS* **2007,** 104, 14553-14558

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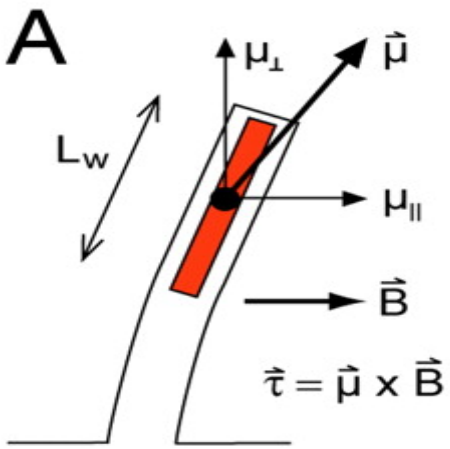
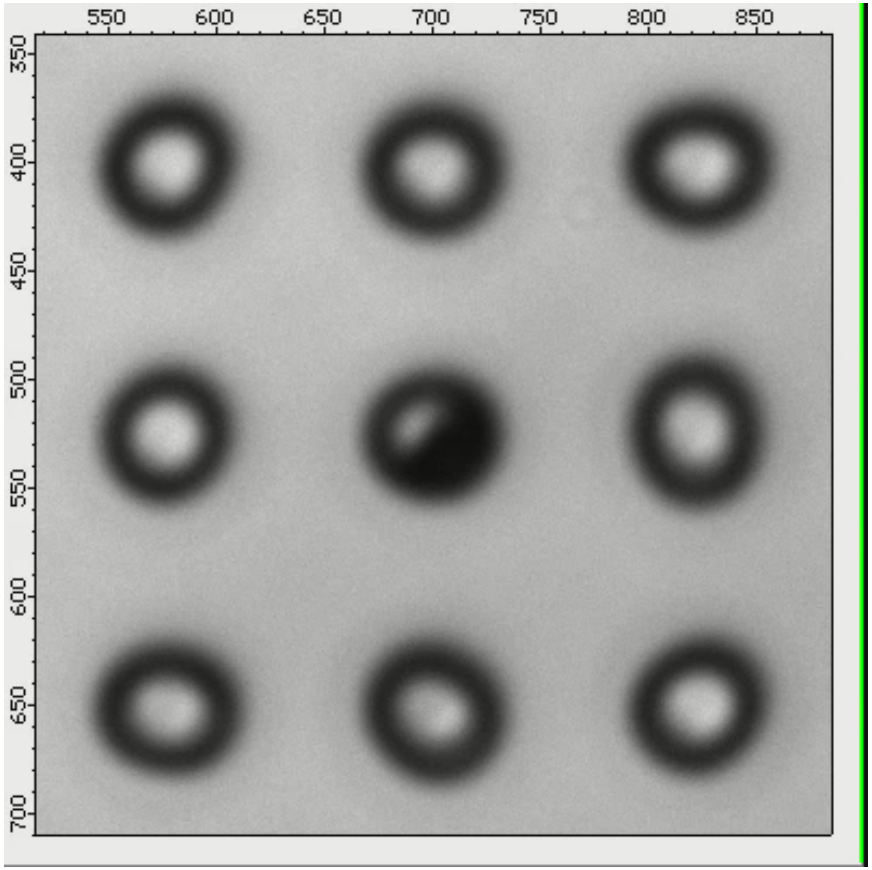
Application of Mechanical Force to Cells

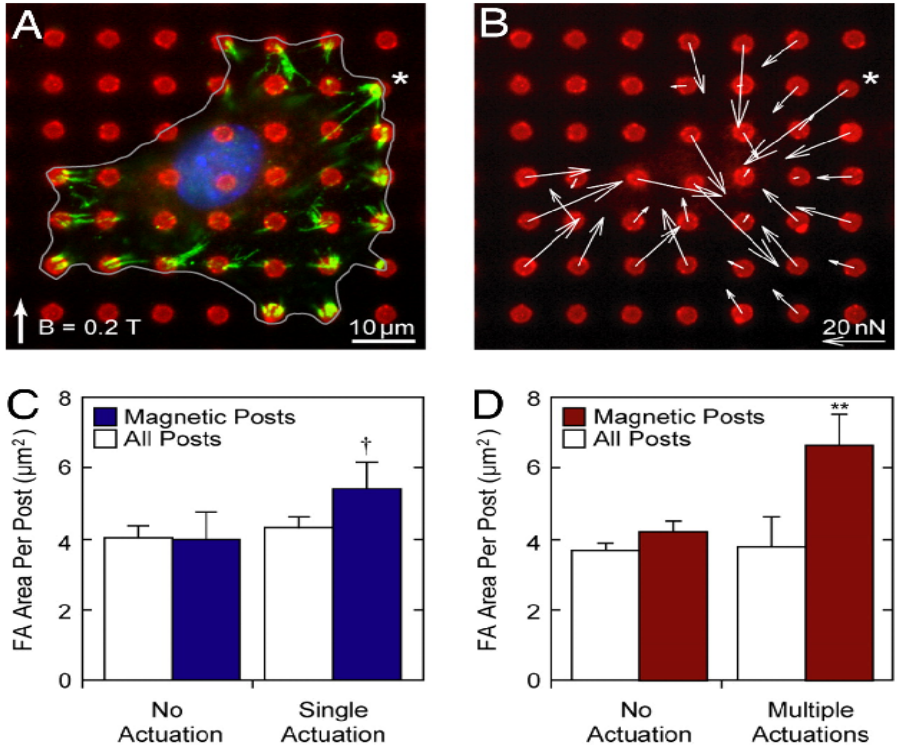
- Horizontal magnetic field applied by electromagnet on microscope stage
  - Cycled between -0.31 T and 0.31 T
- Deflection calculated by measuring the displacement of the centroid of the posts
  - 0.5-1 μm
- Displacement always the same direction magnetic moment of nanowire changes with the field





Application of Mechanical Force to Cells

- Measure cells response to externally applied mechanical force
  - Focal adhesions are proteins that respond to applied force, aid in locomotion, and may transmit information from the extracellular matrix to the cytoskeleton[1]
  - Traction force is the force applied by the cell to initiate locomotion or resist locomotion



Physiological Uses – Bone Biotemplating

- Current goal of orthopedic research is to design implants the induce controlled growth and help shorten healing times
- Silicon nanowires (SiNW) and bone material and protein structure are hypothesized to have compatible nanostructure
  - $Ca_3(PO_4)_2$ and protein molecules in extracellular matrix
- Will promote osteoblast differentiation and matrix production (stimulate growth and adhesion)

http://z.about.com/d/arthritis/1/0/L/C/kneexray.jpg

- Popat, K.C.; Daniels, R.H.; Bubrow, R.S.; Hardev, V.; Desai, A.T.; *J. Ortho. Research* **2006**, 619

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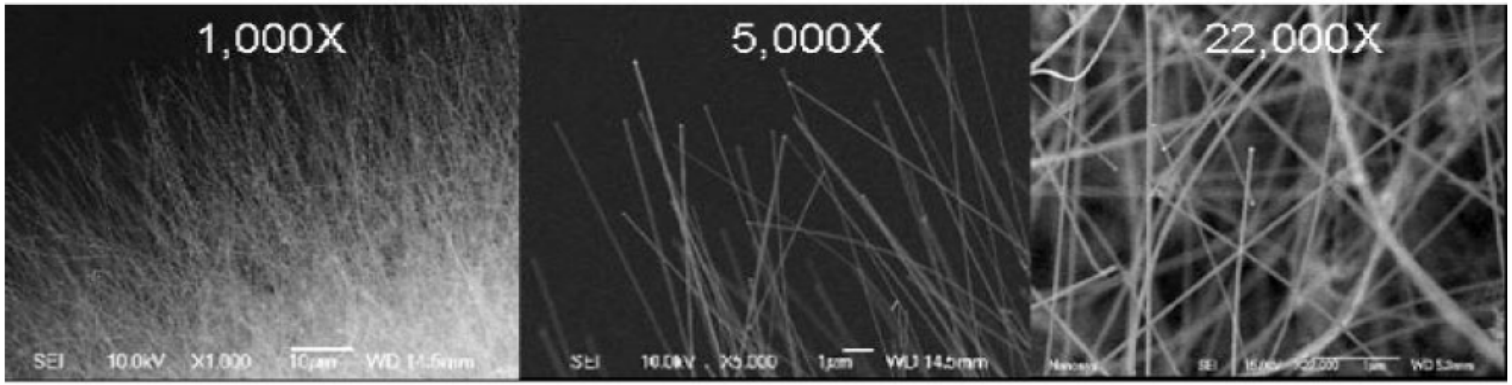
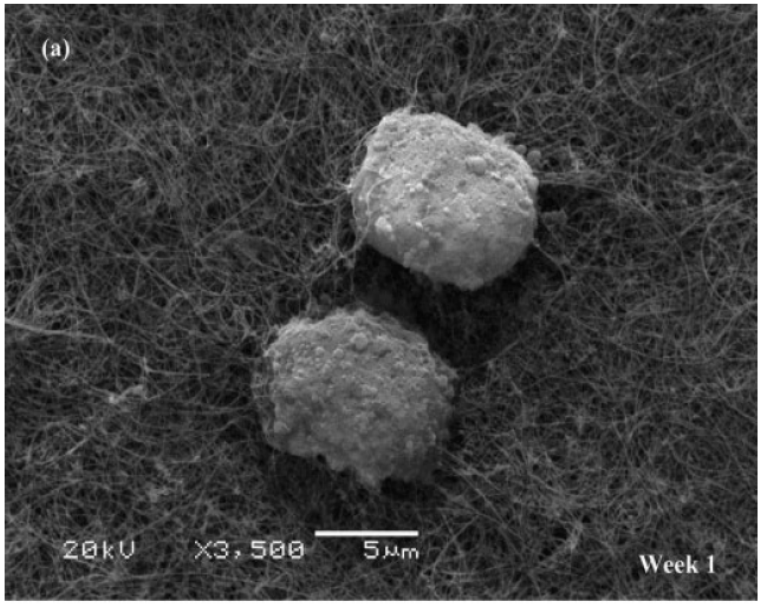
Bone Biotemplating

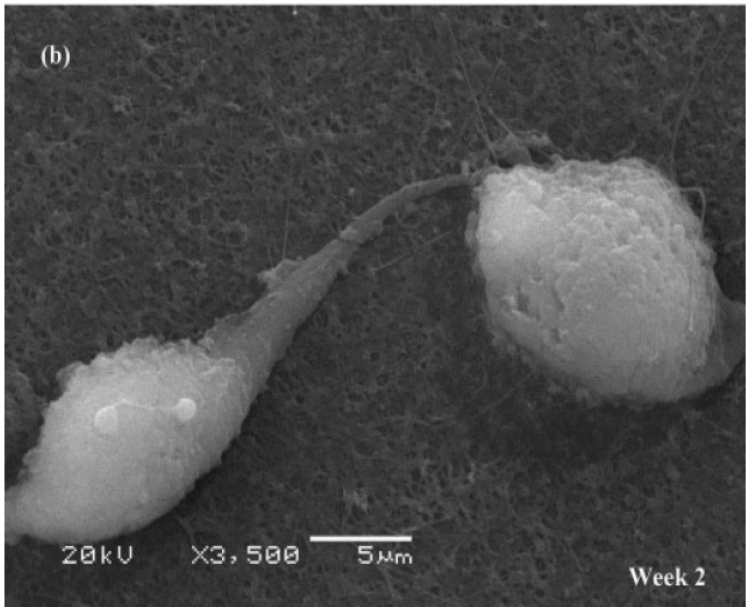
- Fabricated using 40nm gold colloid deposited on poly-l-lysine coated fused silica
- Placed in furnace at 480 °C with SiH_4 gas, which decomposes on the gold
- Silicon forms a eutectic residue from which the nanowire precipitates
  - Diameter defined by size of gold particle
- Density varied by density of colloid and reaction time in furnace
  - Low density
  - High density long
  - High density short



Bone Biotemplating

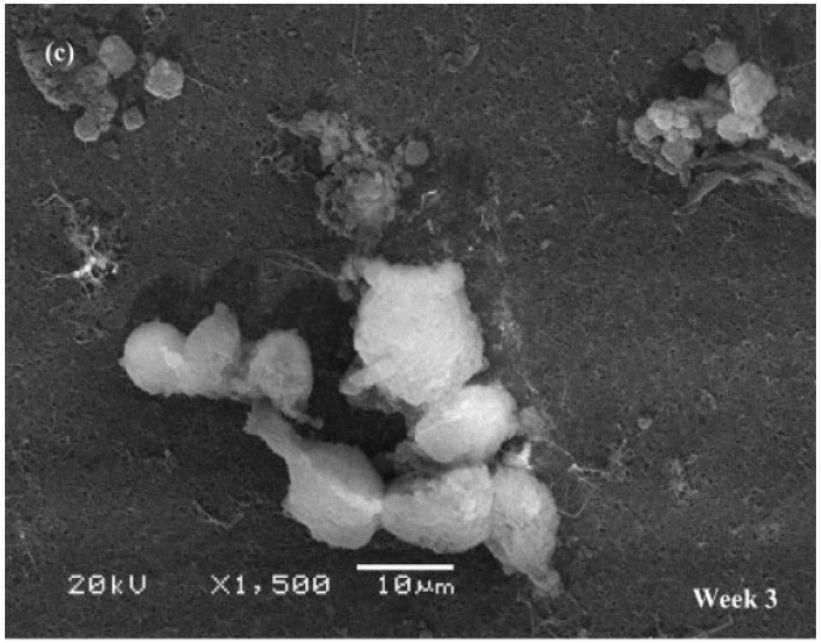
- Well plates were filled with sterilized SiNW, fetal osteoblasts (50,000/well), and nutrient solution
- Controls of fused silica, polystyrene, and latex were used
- Results measured by calcium concentration, XPS, and SEM

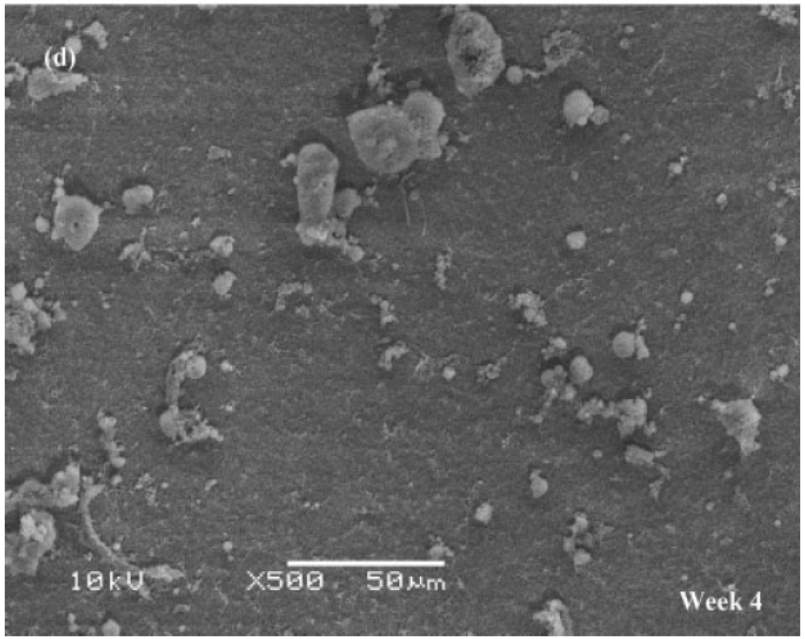




Bone Biotemplating – Methods and Results

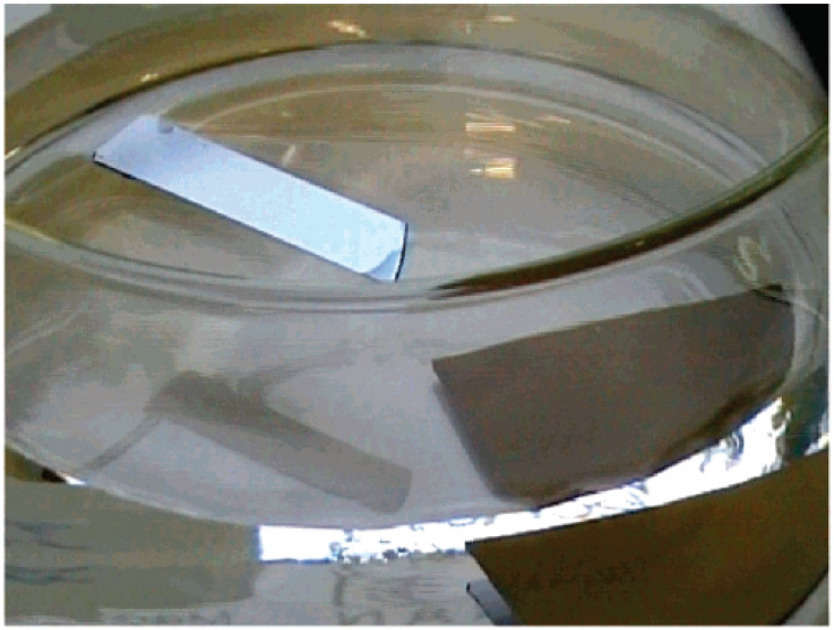
- SiNW showed much better osteoblast performance than control materials
- May be used to coat implants in future to aid to strengthen the bone implant interface

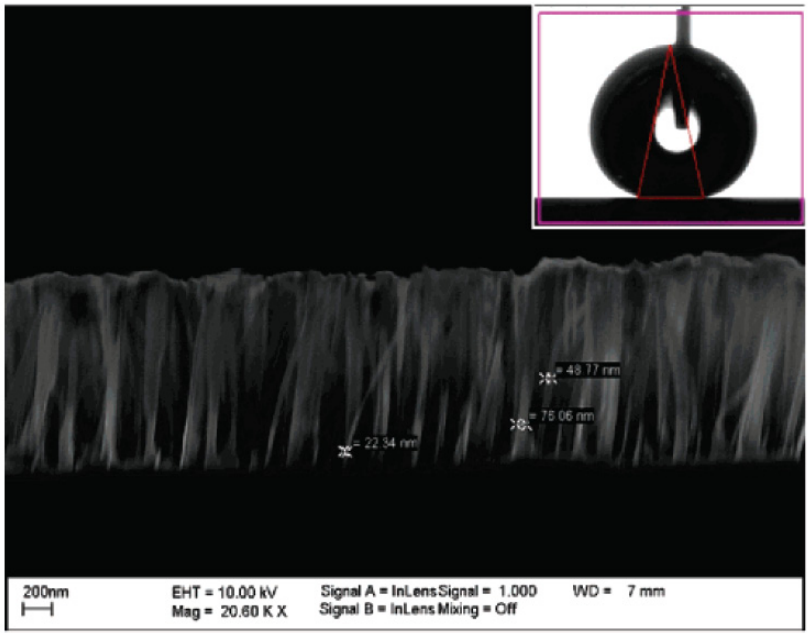




Patterned Hydrophobicity on Surfaces

- SiNW fabricated using VLS method or by chemical etching of crystalline silicon in $AgNO_3$/HF solution
- Nanowires are then treated with silicon a oxide layer (hydrophilic) or octadecyltrichlorosilane (hydrophobic)

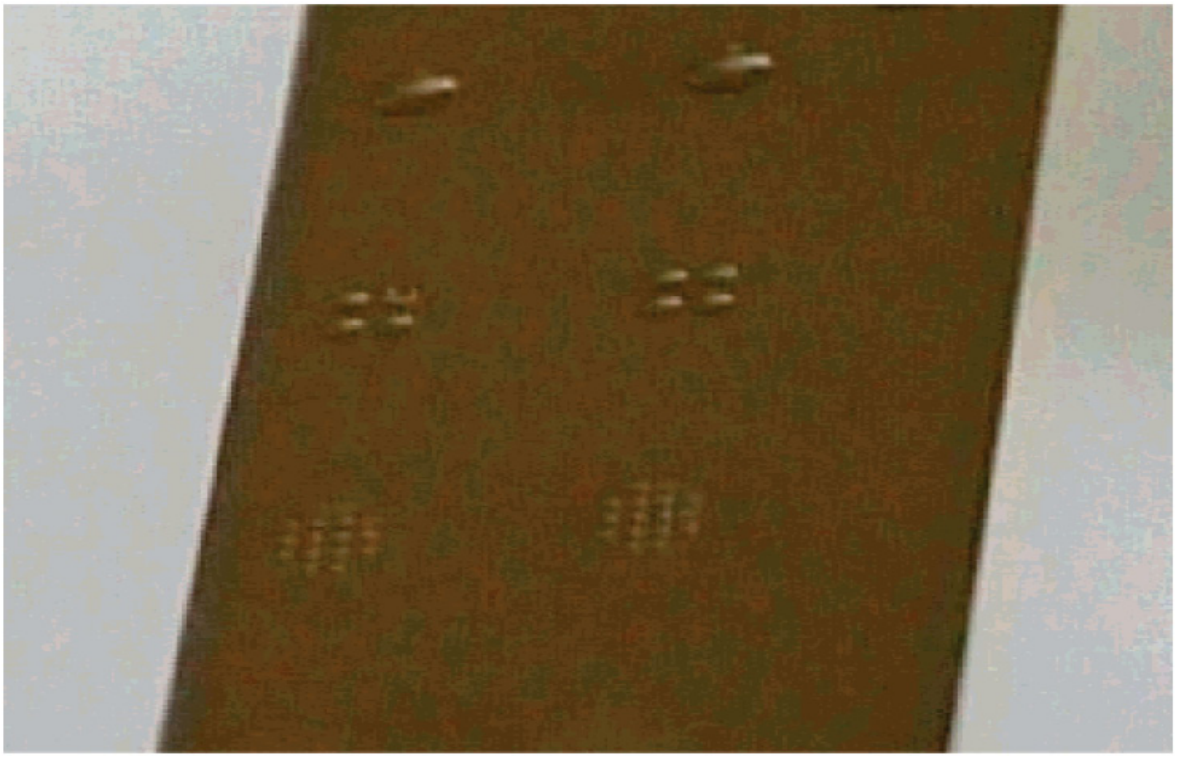




- Piret, G.; Coffinier, Y.; Roux, C.; Melnyk,O.; Boukherroub, R.; *Langmuir* **2008,** 24, 1670

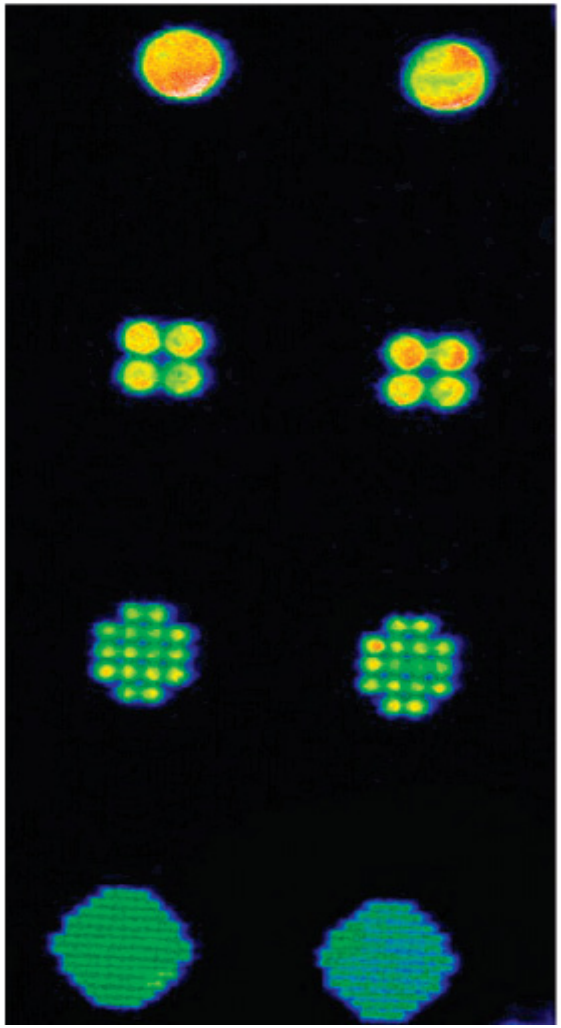
Patterned Hydrophobicity on Surfaces

- Nanowires substrate patterned using optical lithography
  - Patterns between 100 μm to 1 mm in diameter
- Water droplets are self confined in hydrophilic region



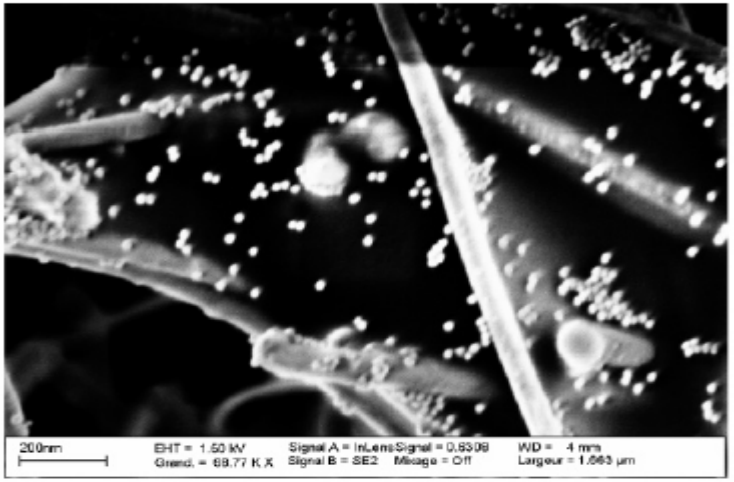
Patterned Hydrophobicity on Surfaces

- Transfer of molecules, peptides, and nanoparticles was tested using substrate
  - Surface exposed to rhodamine labeled strivectin and was observed for fluorescence
  - No evidence of protein absorbance on surface



Patterned Hydrophobicity on Surfaces

- Substrate treated with aminopropyltriethoxysilane
  - Favors NH_2 interactions with colloidal gold
  - Homogeneous distribution of nanoparticles on SiNW



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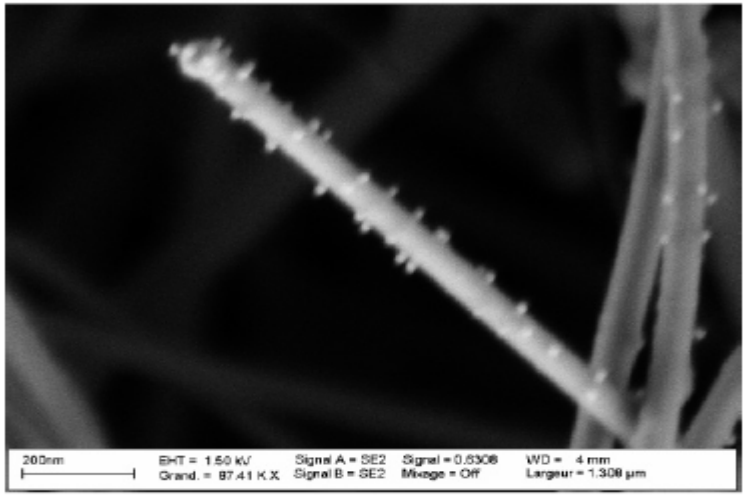
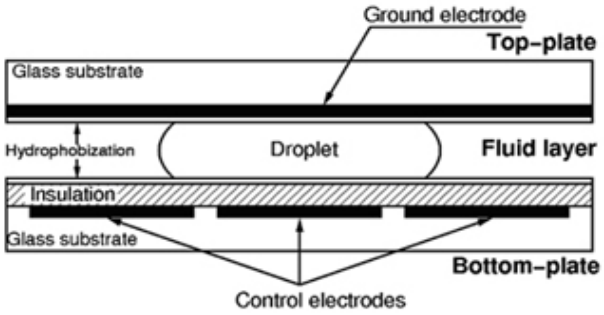
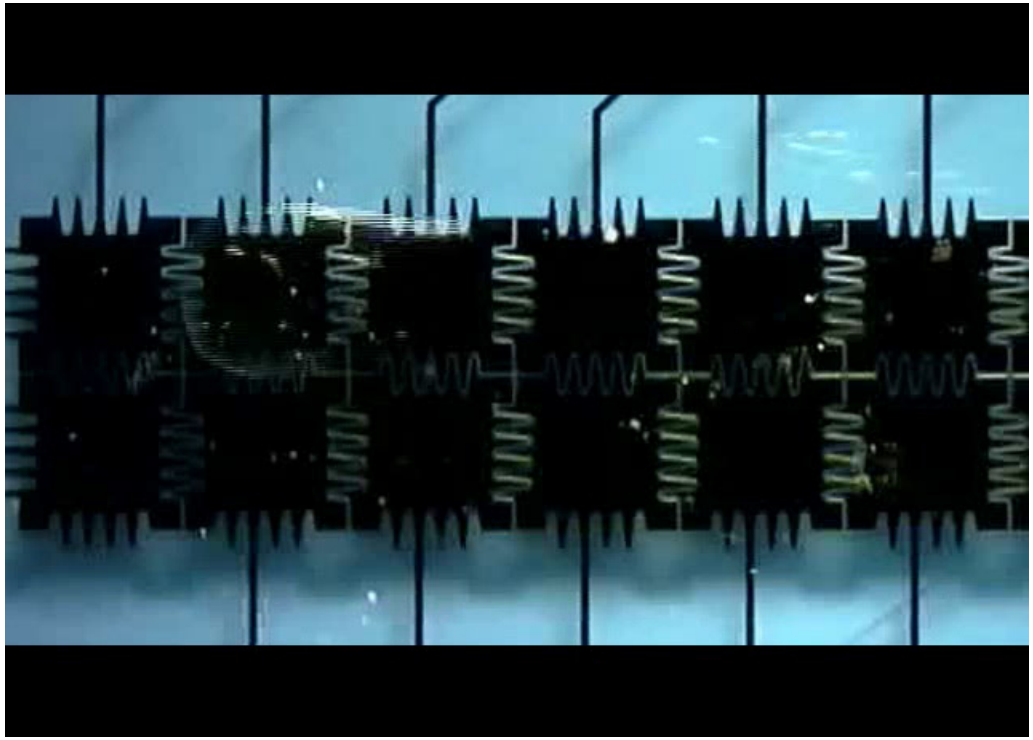


Patterned Hydrophobicity on Surfaces

- Materials can be used for single cell transfer,digital microfluidic devices, and self cleaning devices





http://microfluidics.ee.duke.edu//

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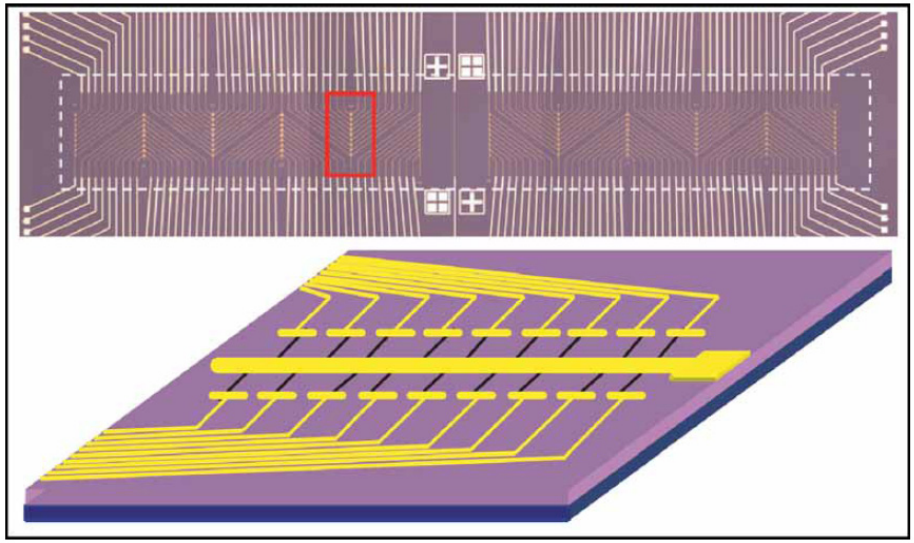
Cancer Detection

- SiNW arrays synthesized by chemical vapor deposition using 20 nm gold particle and silane gas
- Nanowires doped with either diborane (p-type) or phosphine (n-type)
- Treated with desired antibody
- Showed response on the fM scale (change in conductance)
- Achieved multiplexed detection
  - Recognition of multiple cancer proteins
  - Prevention of false positives



- Zheng, G.; Patolsky, F.; Cuil, Y.; Wang, W.; Lieber, C.m.; *Nat. Biotech* **2005**, 23, 1294

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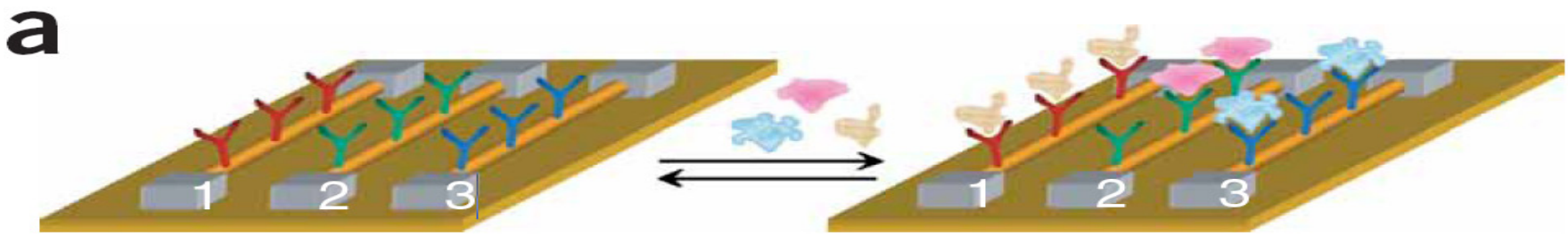
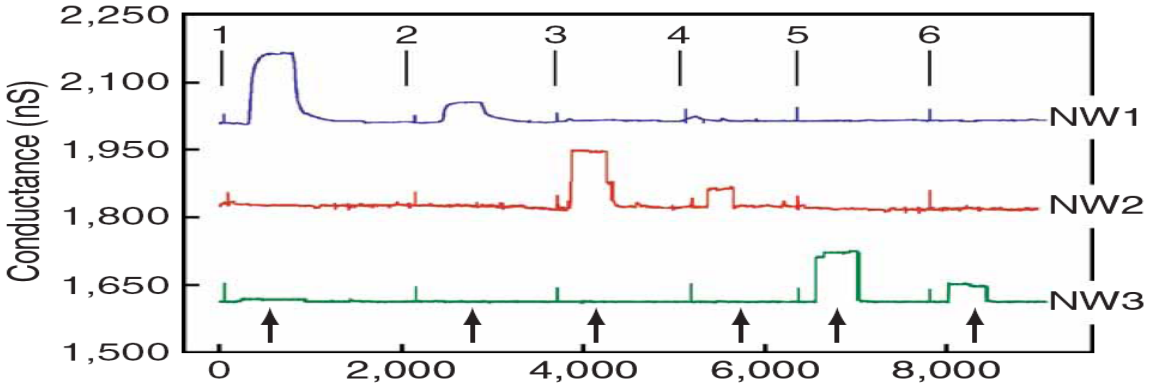
Cancer Detection

- Able to detect both cancer proteins and telomerase
  - Telomerase has been found in 80% of all human cancers
  - Good secondary identifier

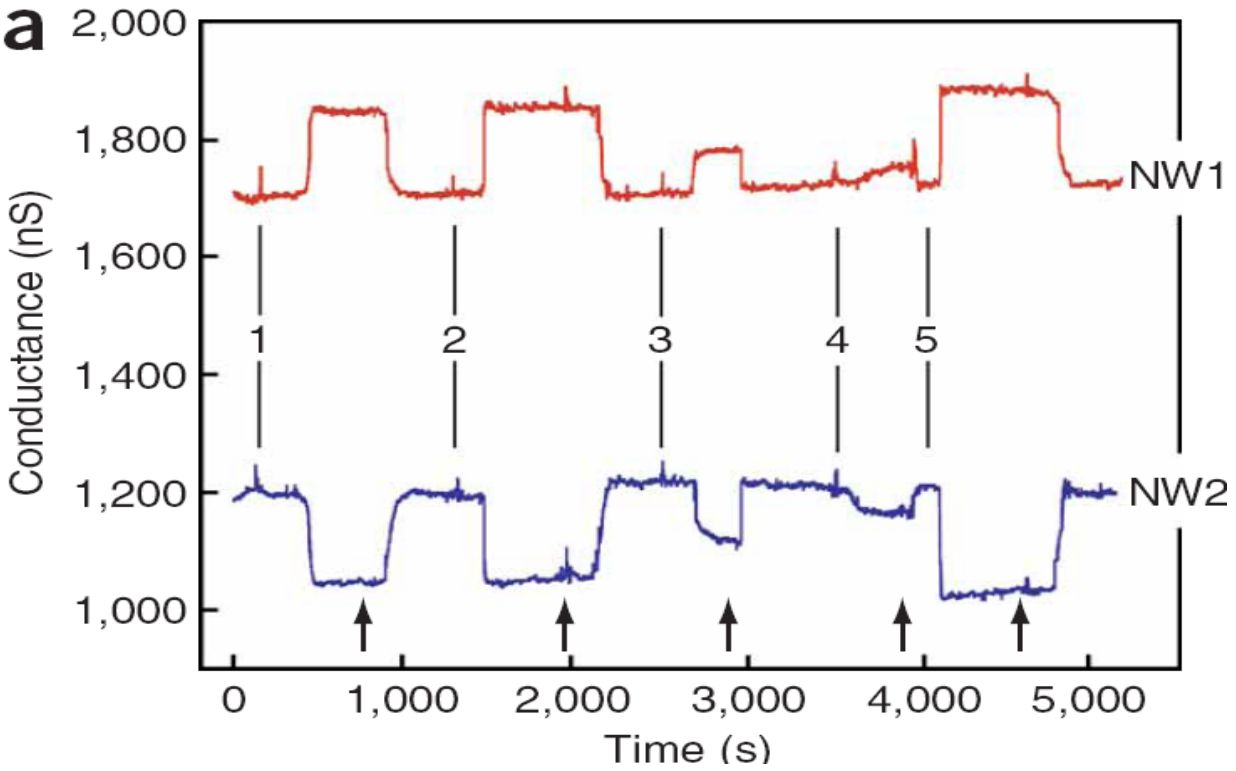


- Change in conductance indicates positive identification



Cancer Detection

- Prevention of false positive is achieved through coating both p-type and n-type on nanowires
  - Negatively charge antibodies result in a positive increase in conductance on p-type and a decrease in n-type



Any Questions?

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