An IMI Video Reproduction of Invited Lectures from the 17th University Glass Conference

The Biofunctionality of Glass (The Closet Biomaterial)

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17th University Conf. on Glass
PSU June 2005

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18th University Conference on Glass

- May 20-23 2007
- Rochester NY = Alfred
- Transport Phenomena in Glasses and Glass-Forming Melts
  - Electrical and Ionic Conductivity
  - Ion Exchange
  - Chemical Dissolution
  - Weathering
  - Gas Diffusion
  - Fining of Melts

75 Years of Glass at Alfred

hallmm@alfred.edu

http://engineering.alfred.edu/outreach/conf

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Outline

- Why Glass?
- Glass as an old biomaterial
- Glass as an accidental biomaterial
- Glass as a structural/repair material
- Glass as a Facilitator
- Glass as a Medicine
- What is not well understood
- Techniques that can be applied to understand what is not well understood
- Predicting the future

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Why Glass?

- Flexibility of Composition (just say no to stoichiometry)
- Flexibility of forming procedures leading to varied microstructures
- Flexibility of surface chemistry and surface engineering
- Can be even more bioactive than hydroxyapatite

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Driving Forces for New Biomaterials Development

- Fast Analysis and Diagnosis
- Preventative Medicine
- Minimally Invasive Treatments

Short Hospital Stays

Lower Health Care Costs

Higher Success Rates

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Barriers to New Biomaterials Development

- Length of time to market
- Expense of FDA process
- Litigation

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Glass as an Old Biomaterial

- Glass is not glass is not glass is not glass
- All glasses are not equal: some glasses are more equal than others
- Glass is not bioinert

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Degrees of Interaction

- "Bioinert"
  - shoved back in the closet
- Bioactive
  - bonds and sticks around a while
- Bioresorbable
  - does what it is meant to the dissappears

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Glass as an Accidental Biomaterial

- Fiberglass insulation
- Made to be bioresorbable but with reasonable durability
- High alumina fiberglass study

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Glass as a Structural Biomaterial:

- For many years the definition of biomaterial had to do with replacement parts: predominantly structural
- A-W glass ceramics Japan
- Fiberglass reinforced polymers (shape memory polymers and glass ionomer cements)
- Bulk Metallic Glasses

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Bioglass®

- Soda lime silica glass
- Bonds to bone and soft tissue
- More osteoconducive than hydroxyapatite
- Glass “turns on” genes
- Possible applications in prevention/remediation of osteoporosis

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Tissue Engineering

- Stem Cell Research
  - Non embryonic; harvested by transplanting a differentiated cell nucleus into an egg
  - The cells differentiate upon stimulus into specified cells
  - Regenerate tissue
  - Reduce the need for transplants

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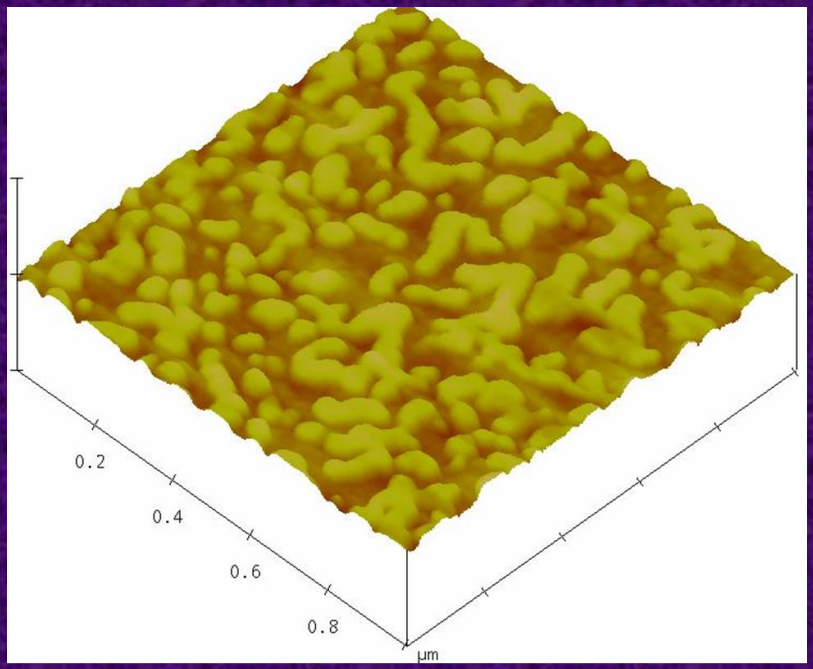
Engineered Porosity

- Sol-Gel/Sonogel Processing
- Spinodal Phase Separation+Leaching
- Composite Compact+Leaching
- Foaming



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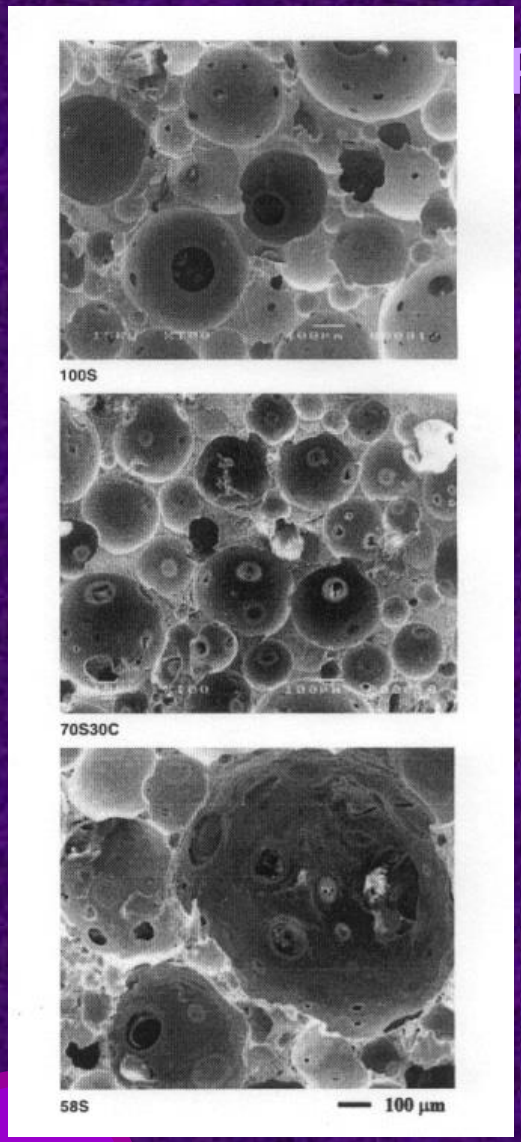
Porous Bioactive Glasses as Tissue Scaffolds



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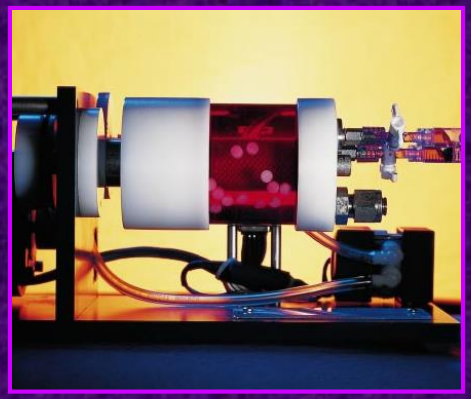

Bioreactor

Tissue

P. Sepulveda, J.R. Jones, and L.L. Hench, "Bioactive sol-gel foams for tissue repair," *Journal of Biomedical Materials Research*, 59 340-348 (2002).

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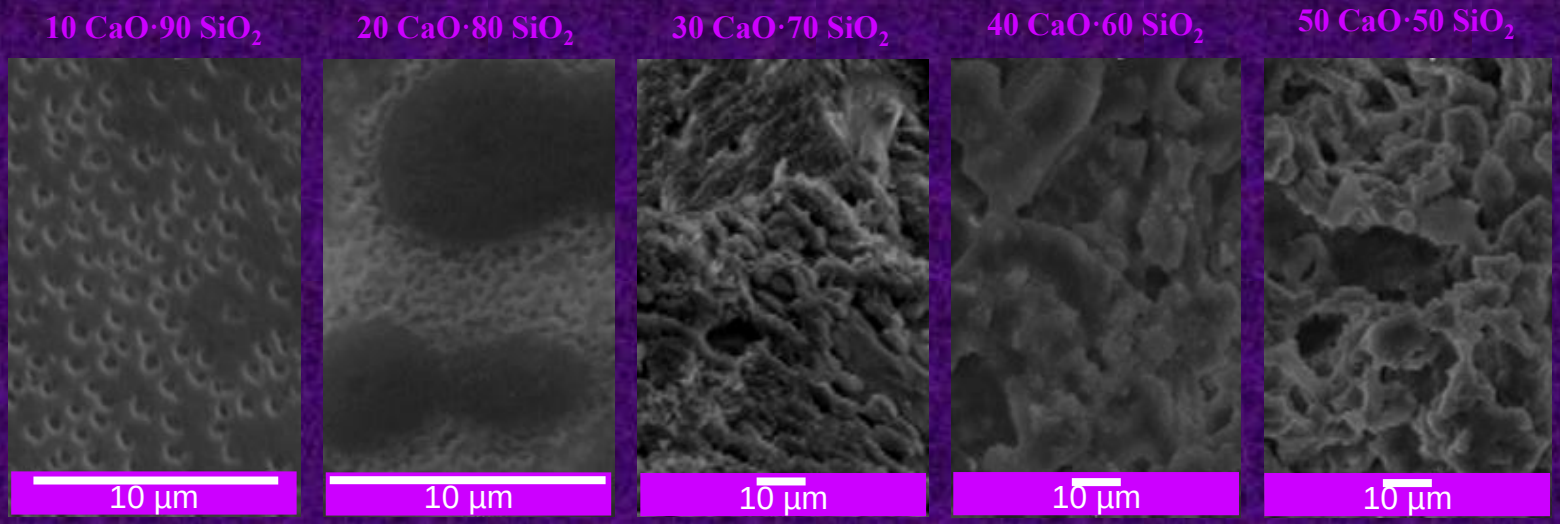
Foamed Calcium Silicates by Thermal Bloating of Xerogels



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Bioactive Material Applications

- Bioglass and Bioglass-Like Compositions
  - Bone Filler
  - Composite Healing Plates
  - Adhesive for bone allografts
  - Dental Applications
  - Alternative therapies (see later)
  - Tissue Engineering

Glass as a Facilitator for Better Diagnostics, Sensing and Remediation

- Diagnostics Laboratory on a Chip and Microfluidics
- Multisensing fiber optic bundles
- Sol gel chemistry for encapsulation of Bioindicators
- Optical biopsy and imaging endoscopy
- Facilitating X-ray analysis

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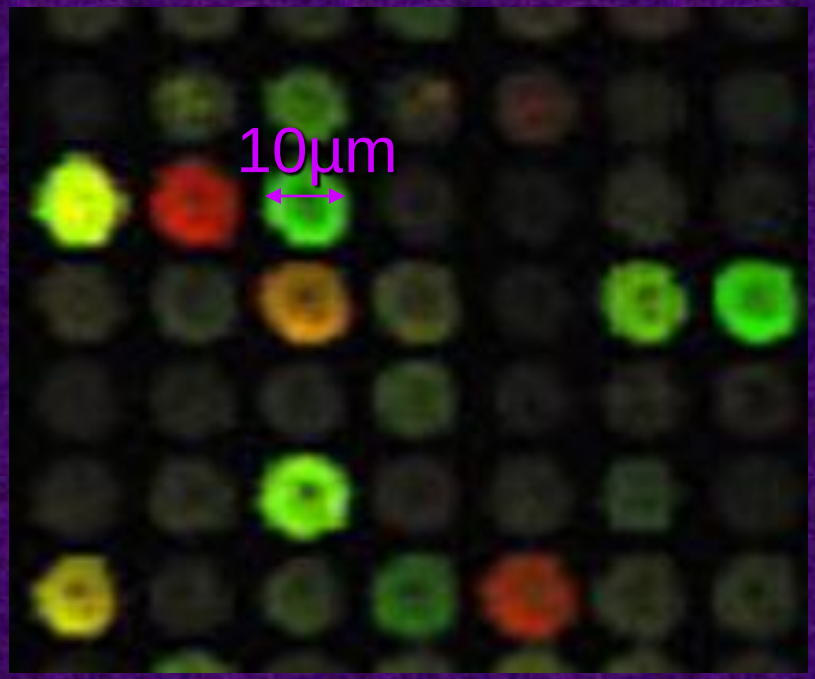
Fast Diagnostics

- Affymetrix
  - Glass Slide tagged with fluorescent antibodies
  - Inject sample and put into spectrometer



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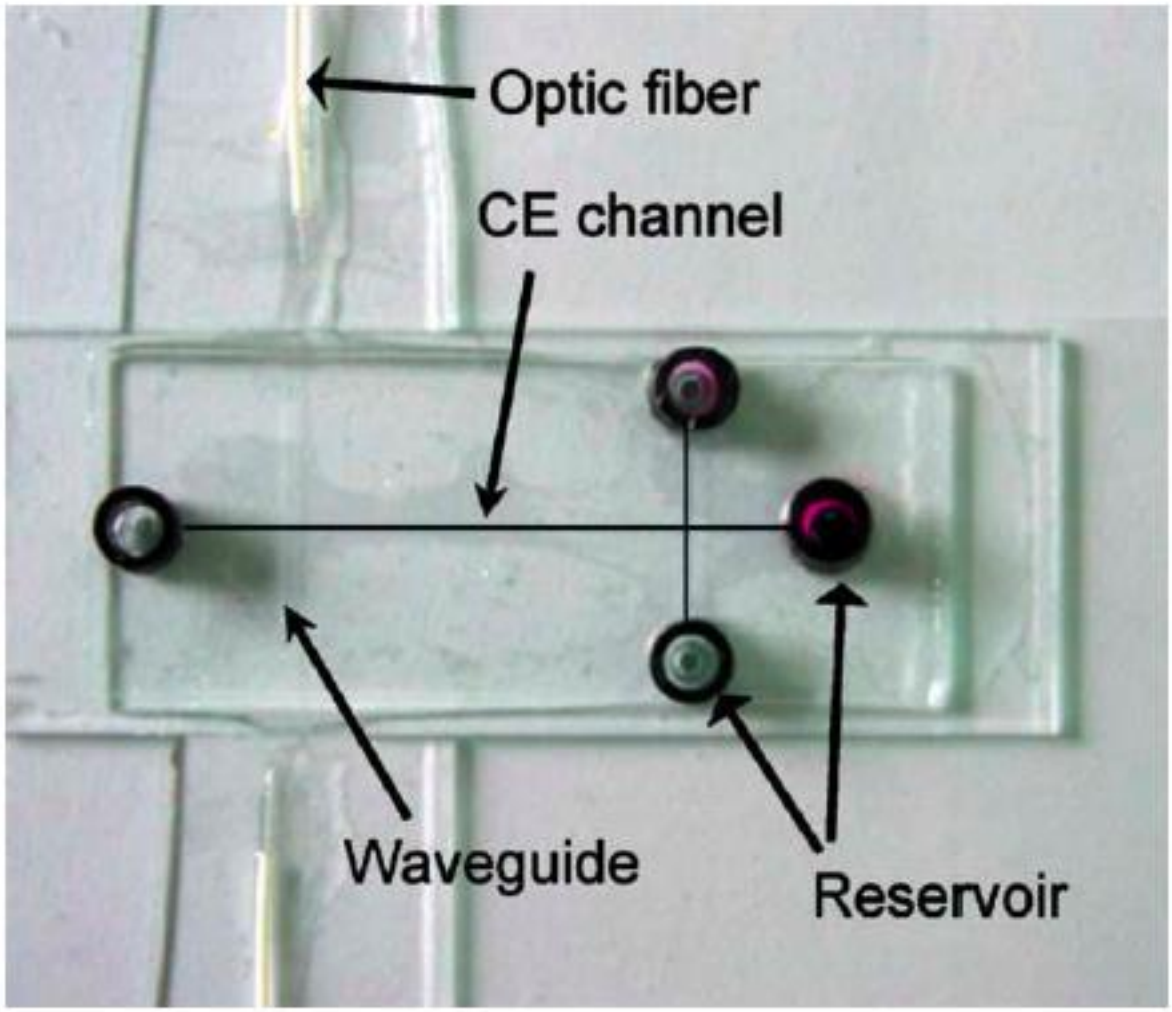

Fig. 3. A micro CE chip after assembly. The separation channel is 40 mm long and the buried optical waveguide is placed 30 mm away from the intersection channel. Etched optic fiber is inserted into the waveguide channel to connect the waveguide to a PMT optical sensor.

Fast Diagnostics

- Illumina
  - Fiber Bundle with etched wells
  - Fluorescent tagged beads
  - Pattern of light determines antibody presence

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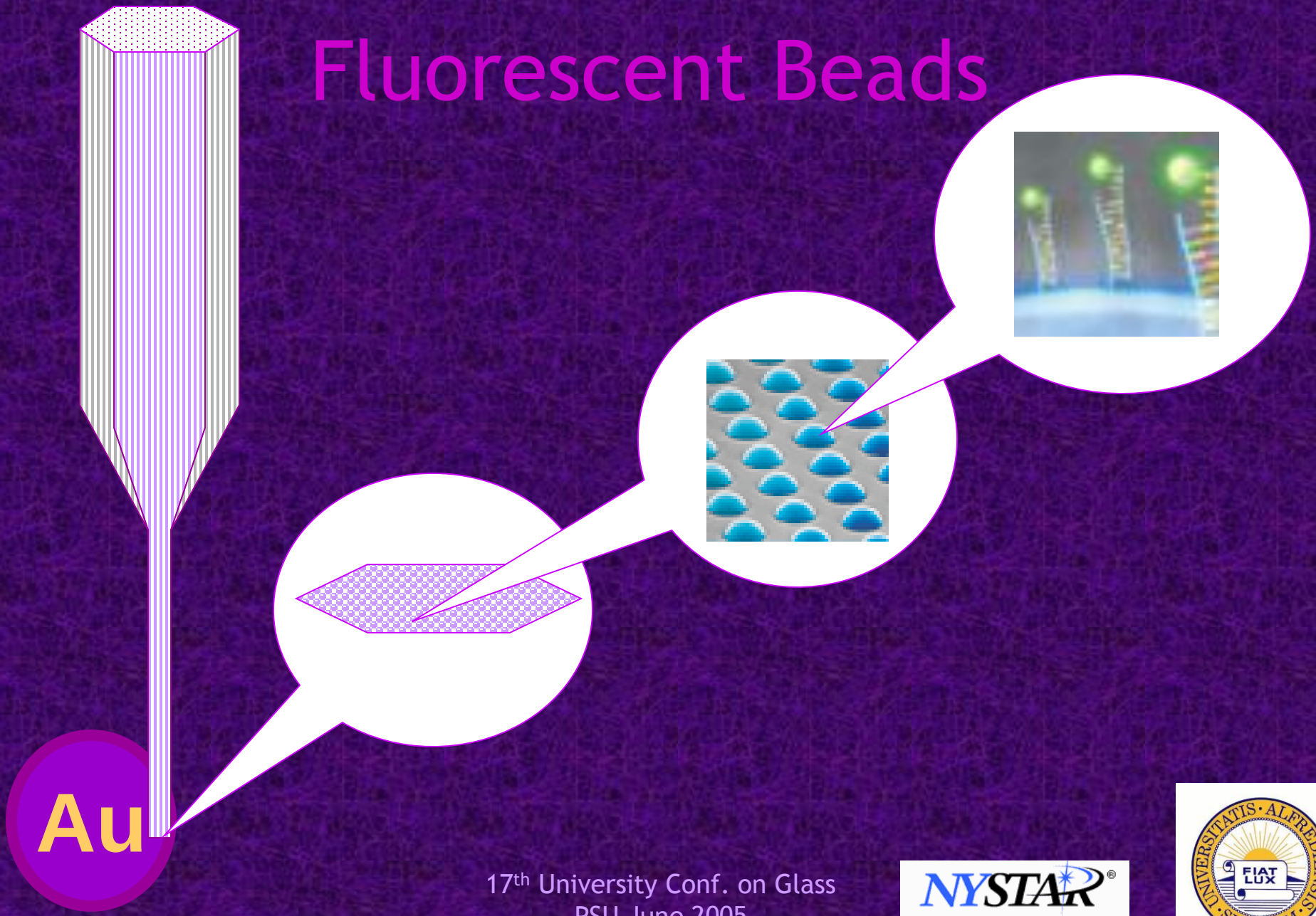
Fluorescent Beads



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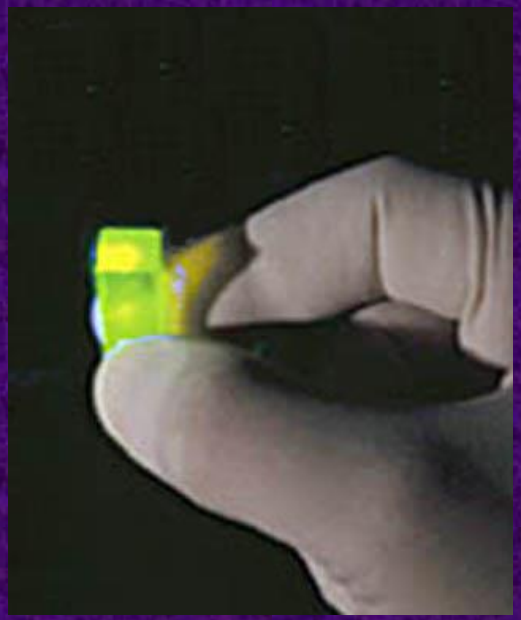
Luciferin Based Sensing

- Luciferin + ATP + O_2 $\xrightarrow{Mg2+\ Luciferase}$ Oxyluciferin + AMP + PP
- Oxyluciferin* $\longrightarrow$ Oxyluciferin + $h\nu$
- Hence in the presence of ATP and oxygen luciferin gives light
- ATP is the energy carrier for cells and is prevalent during bacterial activity
- Encapsulation in a sol gel matrix to immobilize and perhaps put onto a fiber optic sensor



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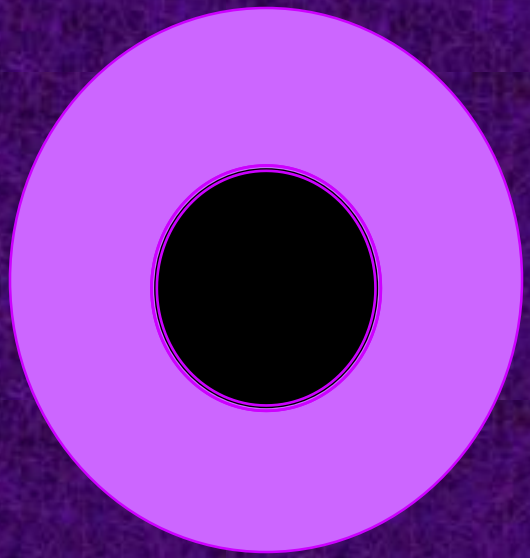
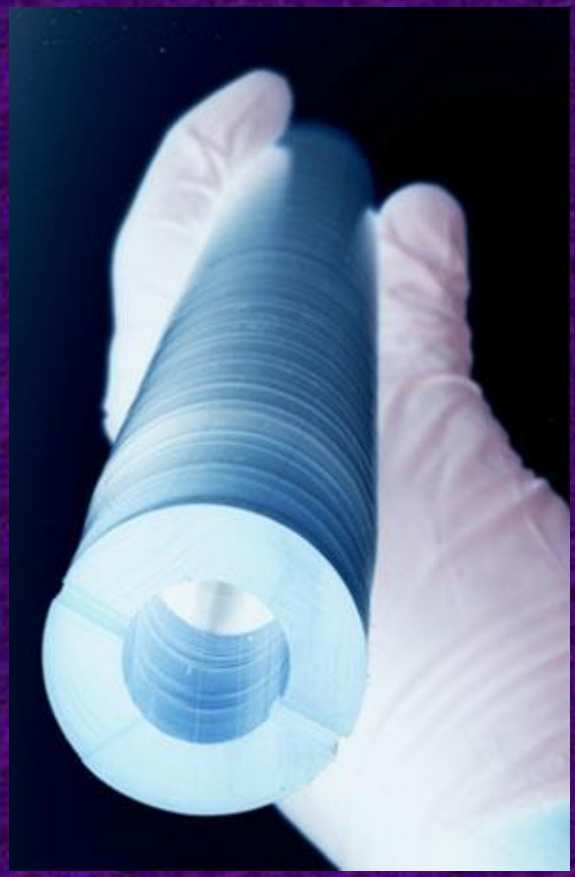
Optical Fibers

- Imaging
  - Bundles
- Remediation
  - CO_2 laser light delivery
  - Omniguide
  - Photonic Bandgap
  - 510K





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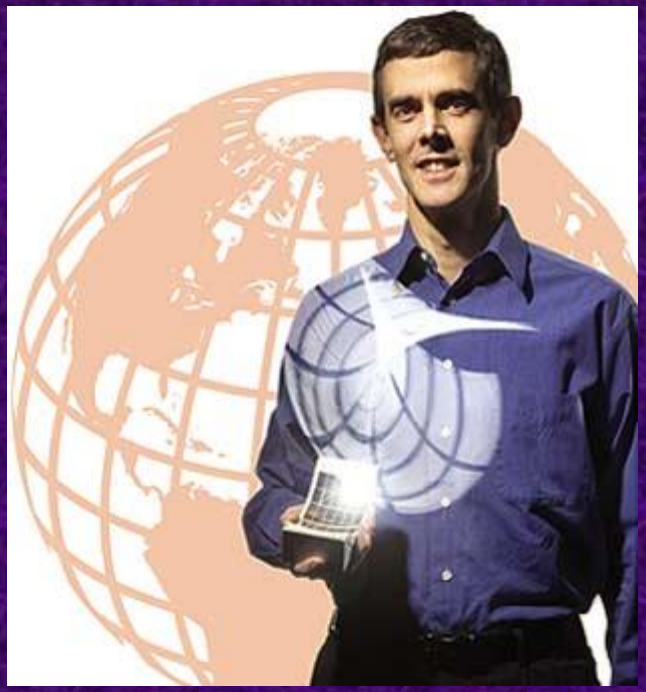
X-rays and EUV

- Glass Capilliary Converters
  - Guiding
  - Focusing
  - Polarization Analysis
- High resolution X-ray imaging



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Alternative Glass-Based Therapies

- Cancer
  - In situ radiotherapy
  - In situ Gene Therapy
  - ▫In situ Heat Therapy
- Light Therapies
  - Laser surgery glass delivery systems
  - Photodynamic therapy glass delivery systems

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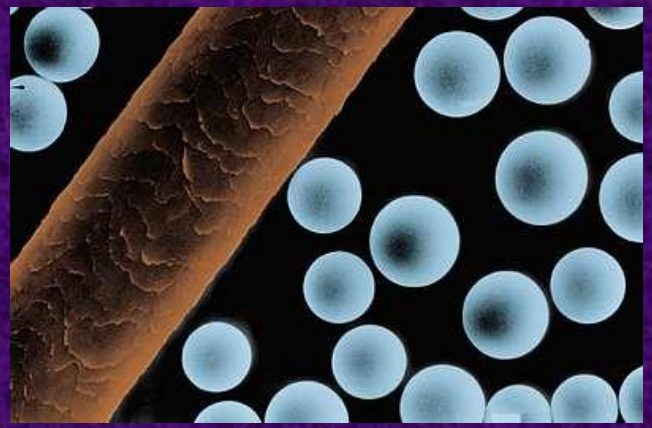
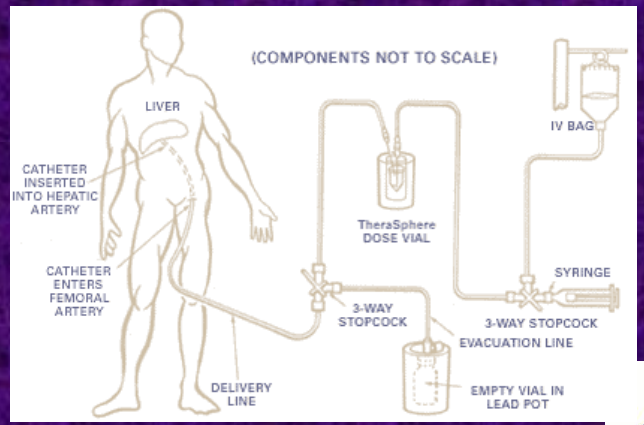
In-situ Radiotherapy

- Inject into bloodstream, concentrate at malignancy
- 5-7 times the dose that can be given externally (typically 15000 rads to liver)
- Little/no discomfort. 1 day in hospital
- Glass remains after radioactivity has decayed
- No leakage/release of radioactivity

1997 Scholes Lecture Delbert E. Day





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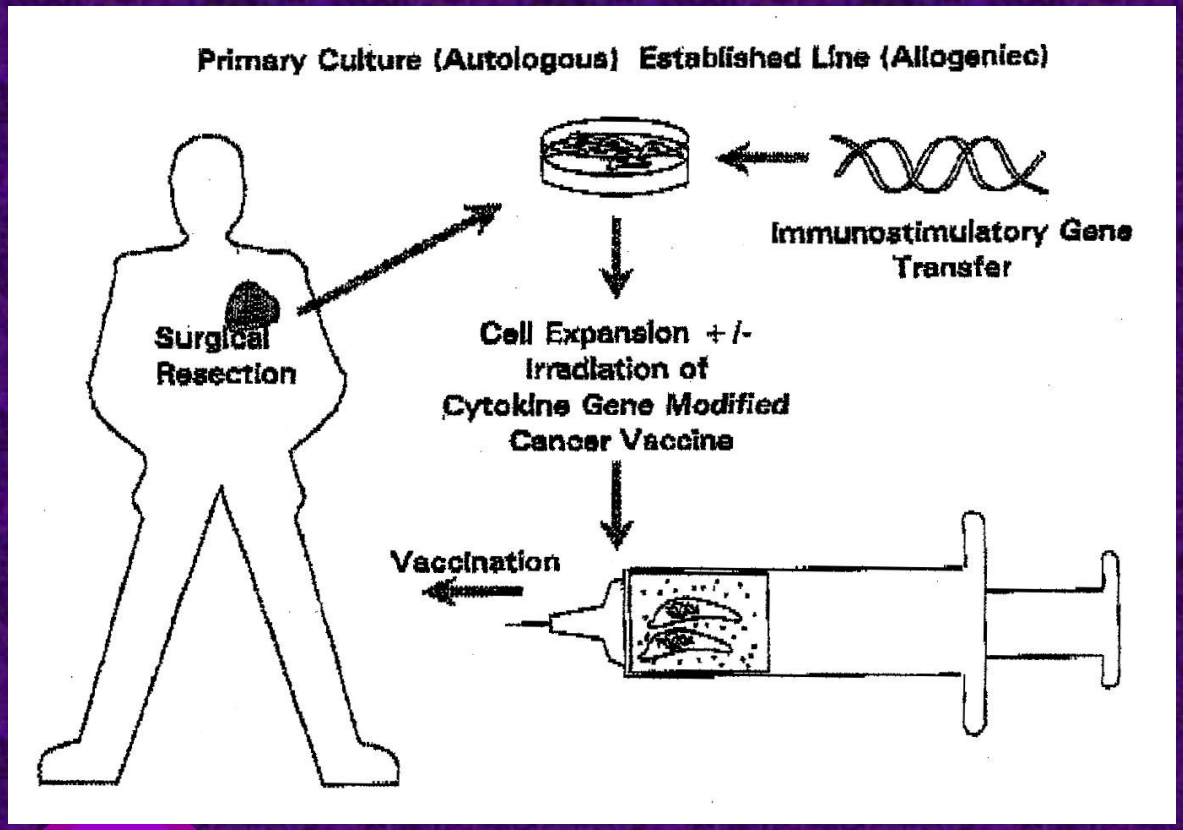
Ex Vivo Gene Therapy



Cytokine Gene-Transduced Tumor Vaccine Strategy[6]

ADVANTAGES of porous glass device:

* Keep modified cells localized to tumor area
* Continually supply modified cells to tumor area
* Collect tumor cells
* Inhibit cancer cell migration/metastasis

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Magnetic Hysteresis Hyperthermia

- Hypethermia known cancer treatment:
  - induced erysipelas
  - hot baths
  - inhaled hot gases
  - microwave
  - ultrasonics
  - Bioactive glass ceramics

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Magnetic Hysteresis Hyperthermia

- Glass-ceramic invented at Corning by Joe Panzarino
- Contains microscopic ferromagnetic crystals which exhibit hysteresis on exposure to oscillating magnetic field
- Malignant tumors susceptible to temperatures in excess of 43°C, healthy tissue not damaged below 46°C
- Glass is bioresorbable

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What is not Well-Understood

- Very little is known about how biological species really interact with glass: return to fundamentals
  - Kinetics of Bioglass® reactions inorganic reactions
  - Energy of reactions of molecules with glass
- What happens to molecules once attached?
- How can we use molecular modeling and model biomolecules to work out what's happening?

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How Does this Help New Functionality?

- You can't build bridges without knowing the limitations of your building materials
- You can't find out about your materials by building bridges out of it
- Sometimes new functionality comes from detailed investigations (c.f Viagra)

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Some Techniques That Might Help

- CFM
- Modeling
- Microcalorimetry

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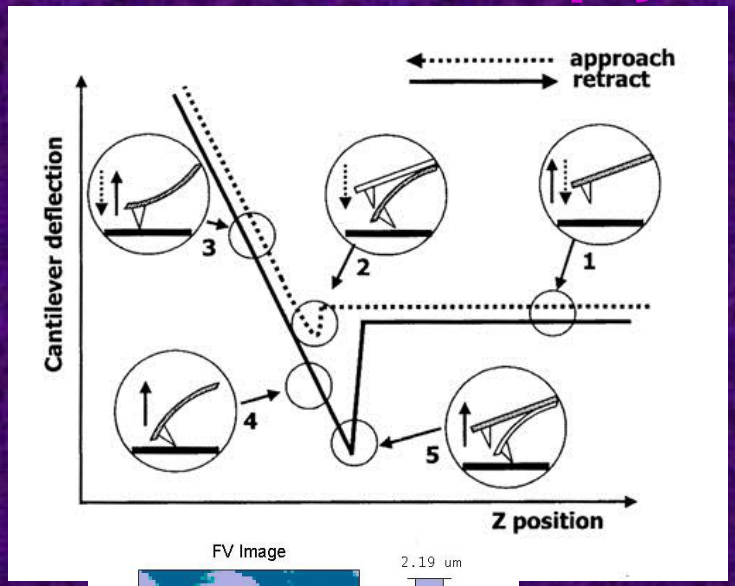
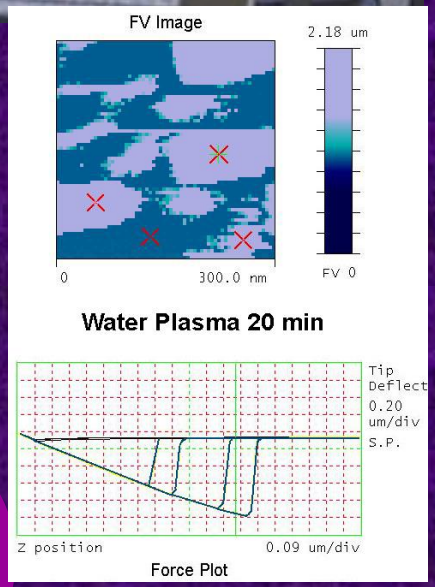
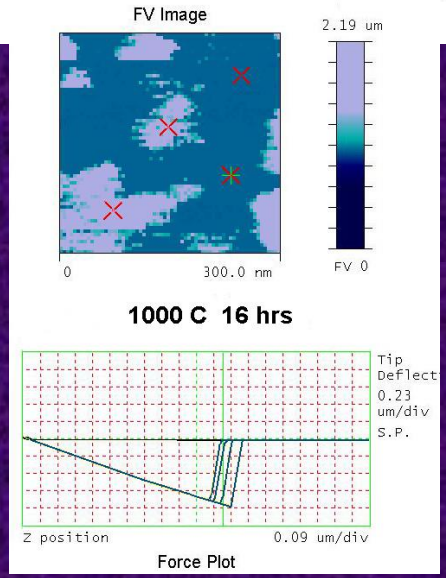
Chemical Force Microscopy







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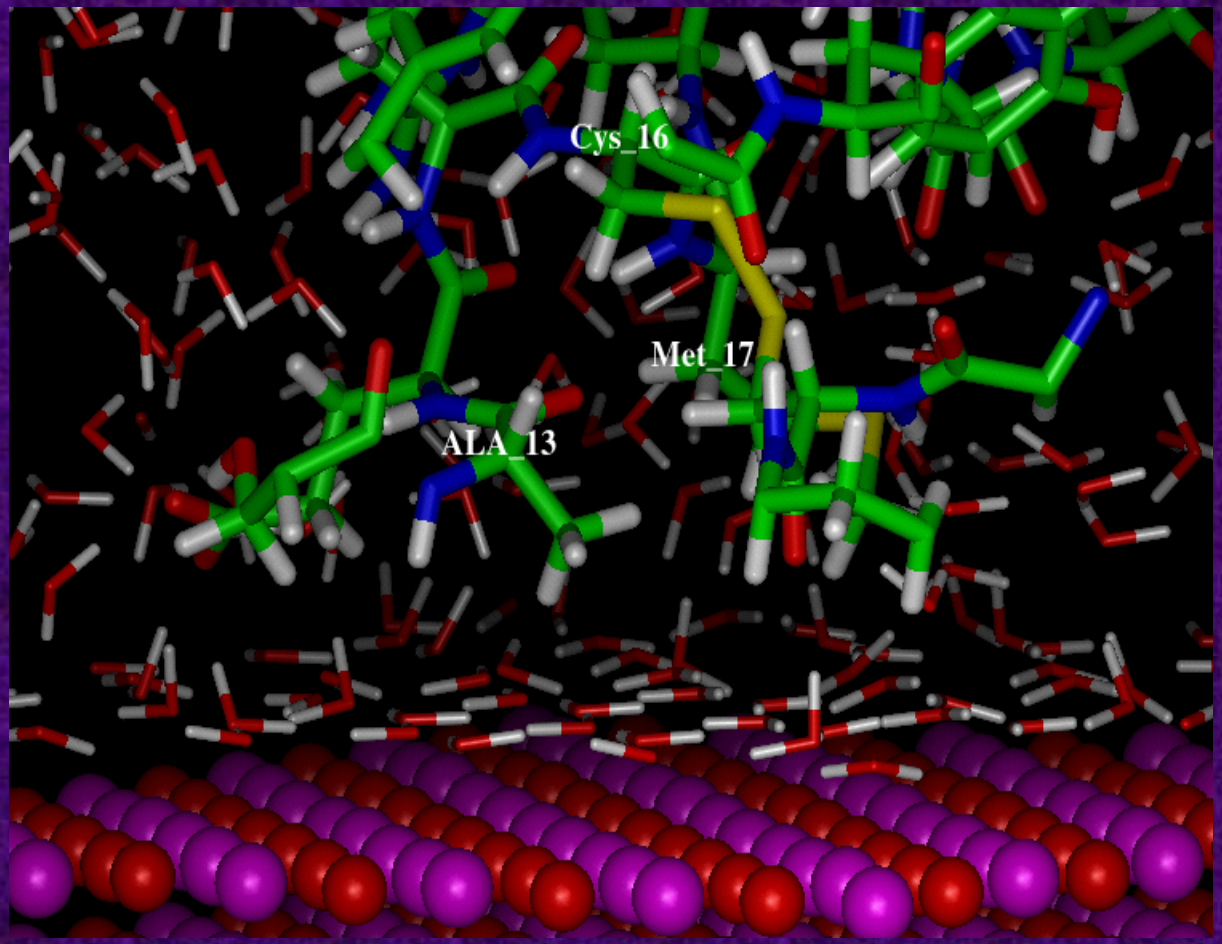
Modeling



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Microcalorimetry

- Interaction between solids and liquids
- High surface area needed
- Direct adhesion

Predicting the Future

- As light plays a larger role in medicine and biotechnology so will glass
- As we understand more about inorganic reactions in biological systems there will be more opportunities
- There is a whole world of light based sensor/actuator opportunities to restore motor movement

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