New Frontiers in African Materials Science

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Lessons From the East

- The far east provides us with a vision of what is possible through science & technology
- The key to their success was the early recognition of the potential for engines, silicon technology and microelectronics (about 40 - 50 years ago)
- More recent example of success in the pharmaceutical industry e.g. Singapore
- So the real question today is – what is the “silicon” or “pharmaceutical” opportunity for Africa today?

Gazing Through My Crystal Ball!

- Predicting the long term future is difficult
- However the near future (5-15 years) may be somewhat easier to predict
- The following areas appear to be poised for significant growth in the near future
  - Biotechnology from biodiversity (from natural products to drugs and synthetic biology)
  - Nanotechnology (from energy to water purification)

The Needs of The Africa

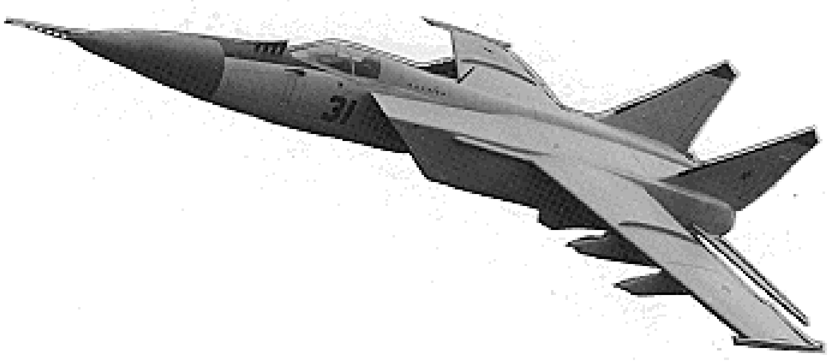
- However, the immediate needs of the Africa are more basic…and the frontiers alone not the simple answer
- People need food, shelter, energy, health, transportation, infrastructure and the ability to add value to resources (creative solutions needed)
- The most sustainable way to achieve these is by
  - Integrated collaborative research (from ideas to markets)
  - Educational initiatives (institutions, artisans, continuous education & knowledge/technology transfer)
  - Entrepreneurship with a focus on value addition

Materials – The Major Driver

- Materials have always been a major driver in technological change…
  - Alloys
  - Semiconductors
  - Polymers
  - …

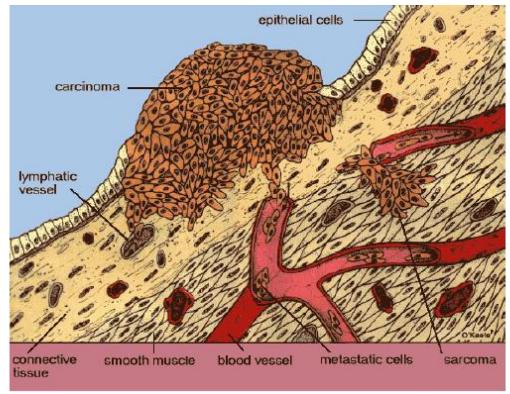
Hard materials

Soft materials



Systems-Based Interdisciplinary US/Africa Collaboration in Materials Research & Education

- Advanced Materials (Bio and Nano)
  - Targeting of disease
  - Alternative energy
- Societal Development
  - Affordable infrastructure e.g. recycling of agricultural & industrial waste
  - Value addition to minerals and natural products (Africa's silicon)



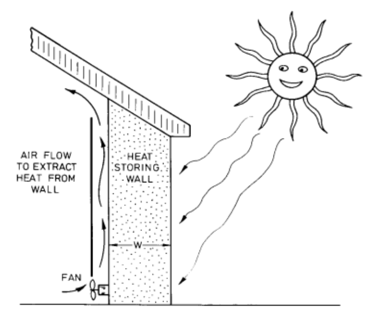
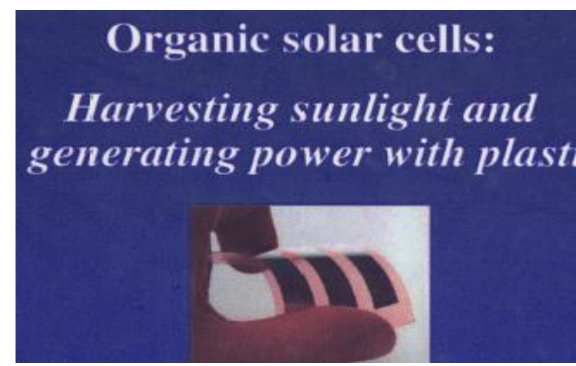
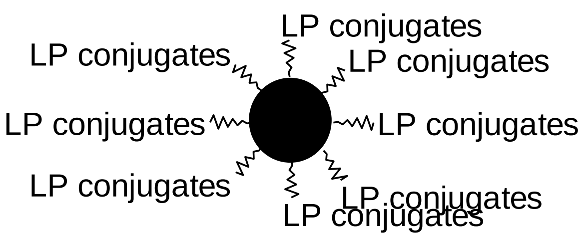


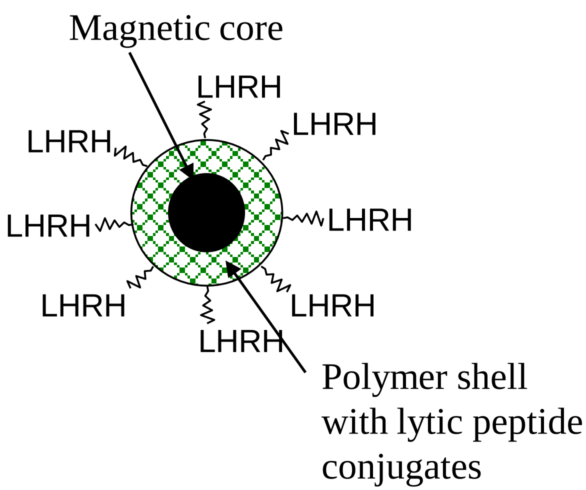
FIG. 6.32 A heat-storing wall. The sun shines on the outside during the day; heat is extracted from the inside at night. The heat diffusion time through the wall must be about 12 hours.

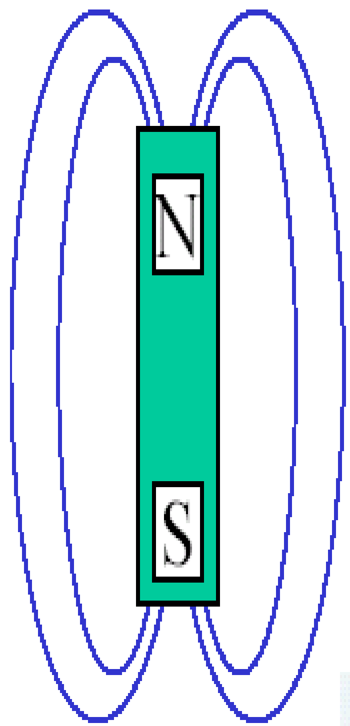


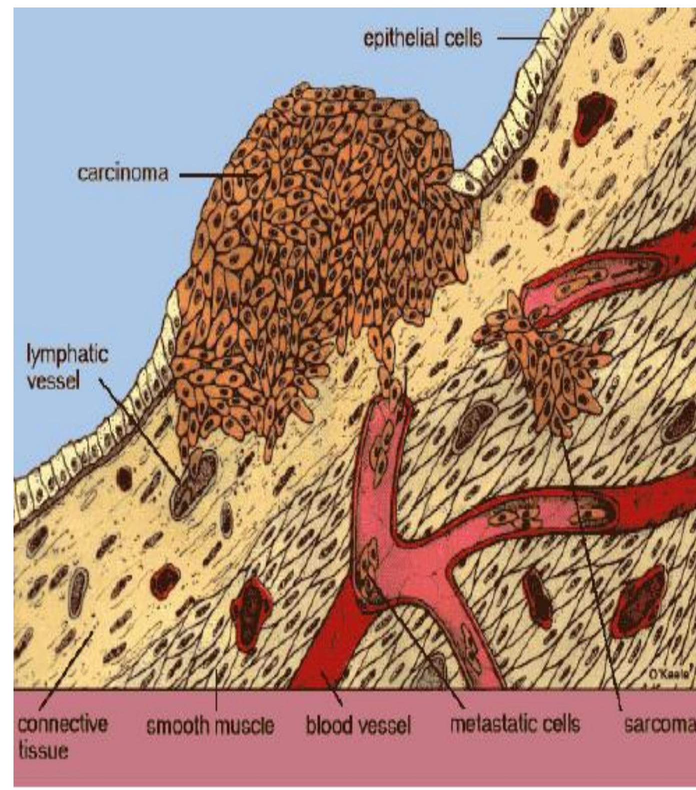
Our Approach to Early Cancer Detection and Treatment!

A novel use of magnetic fields and magnetic particles to deliver therapeutic drugs at the desired time in the correct dosage to the correct site in the human body.

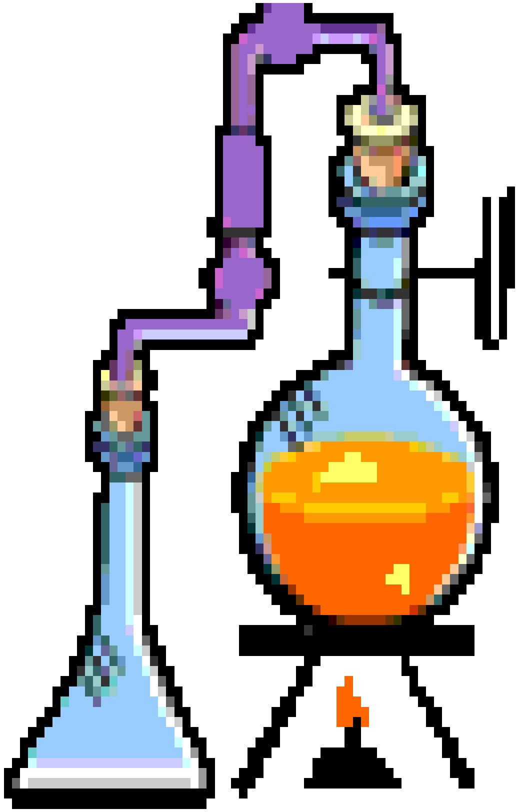






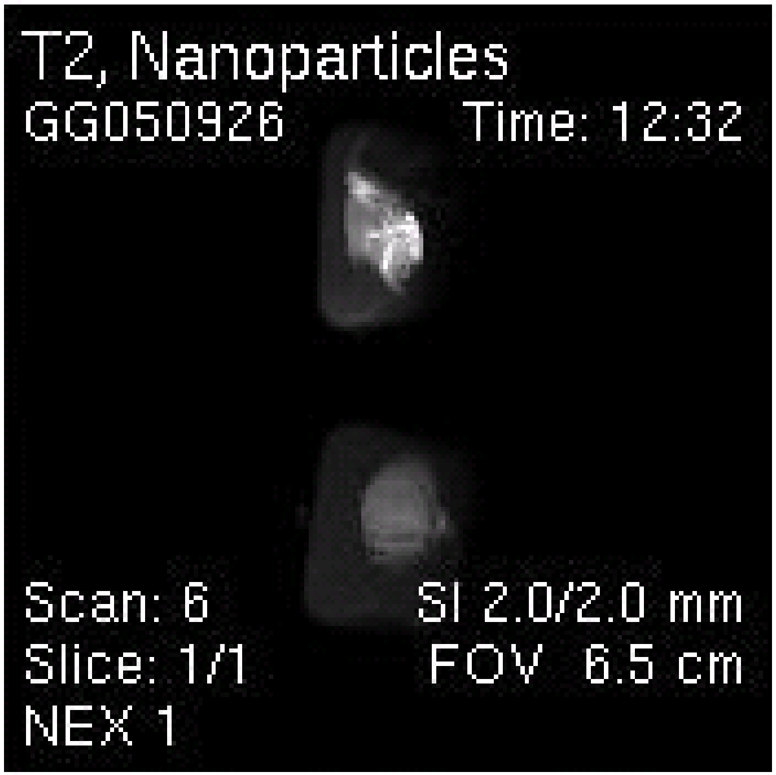


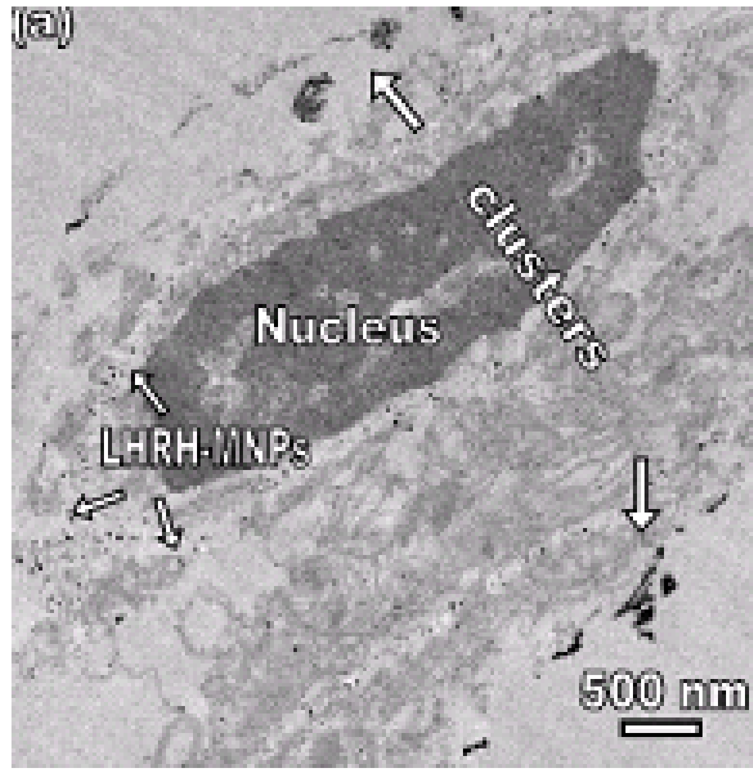
Wet Chemical Synthesis of Nano-particles



- Metallic, polymeric and metal-polymer Nano-particles using bottom-up approaches
- Novel Micro reactor technology for scale-up and controlled synthesis
- Synchrotron radiation based X-ray absorption Spectroscopic characterization
- Capability to attach bio-molecules

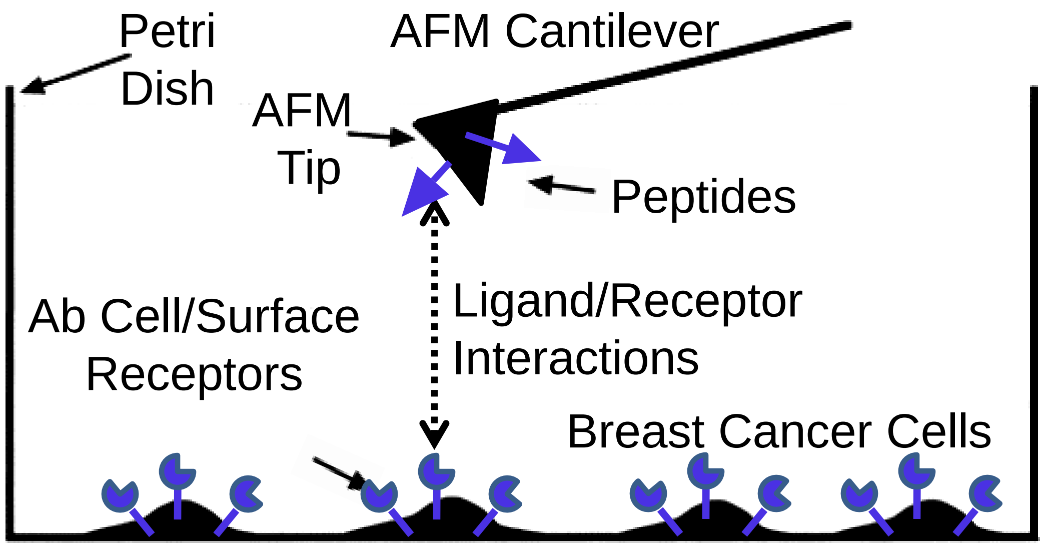
T2 Images of Tumors – Contrast Enhancement Due to LHRH-MNPs



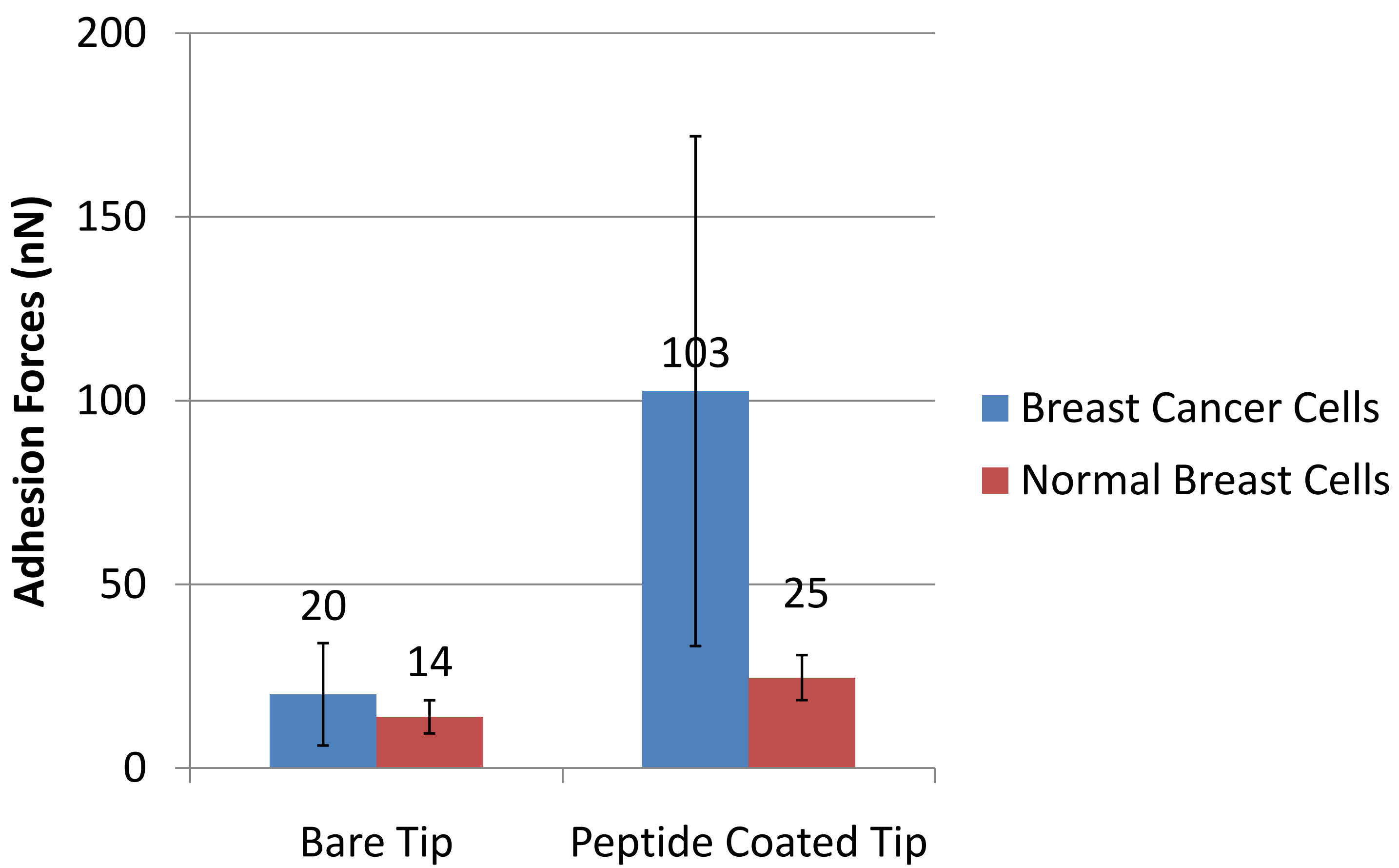


AFM Peptide Adhesion Studies

- AFM Tip (VeecoProbes) dip coated in LHRH peptide
- SEM used to verify success of coating
- AFM contact mode used to obtain force vs. deflection curves to quantity adhesion forces
  - Peptide vs. MDA-MB-231 and Hs578Bst
  - Bare tip vs. MDA-MB-231 and Hs578Bst



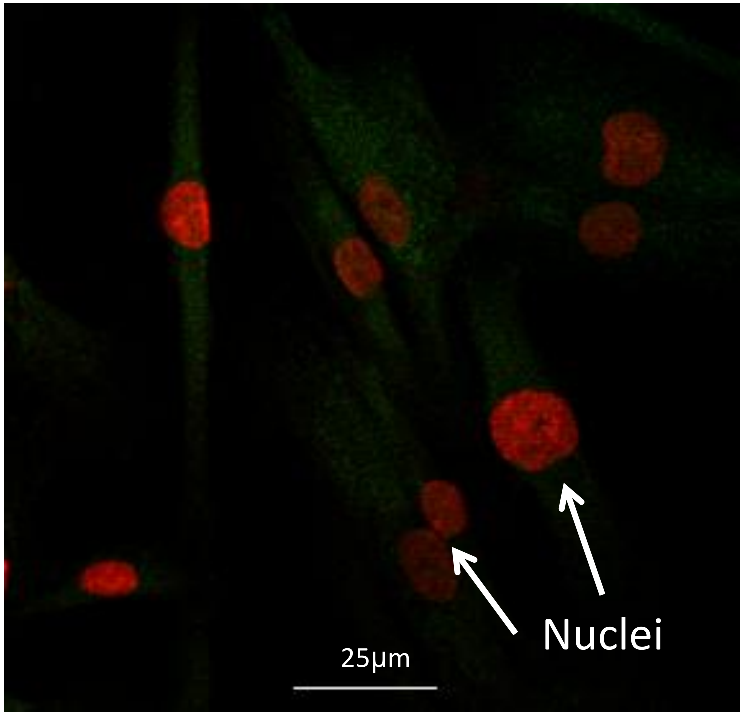
Comparisons with Prior Results: Adhesion with LHRH Peptide



Confocal Staining for LHRH Receptors

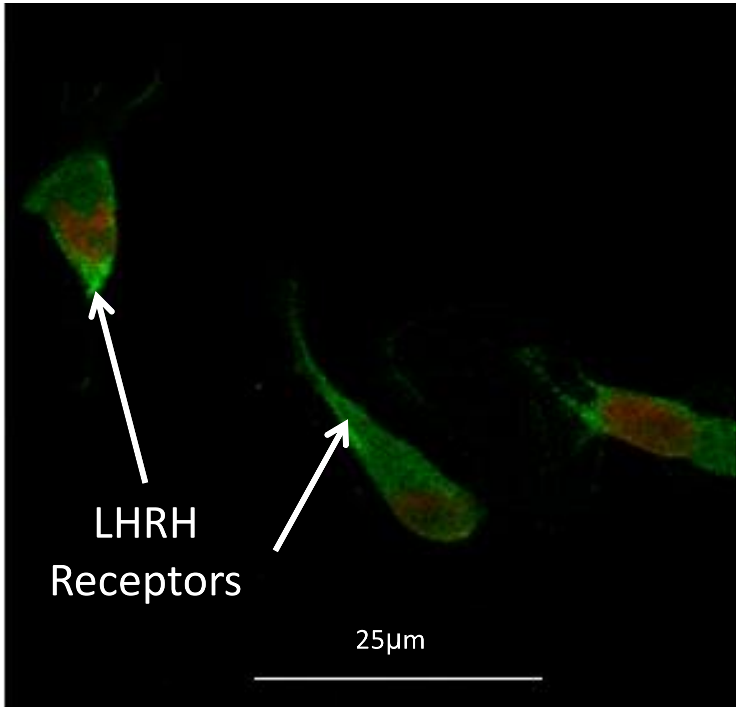
Normal Breast Cells

Hs578Bst



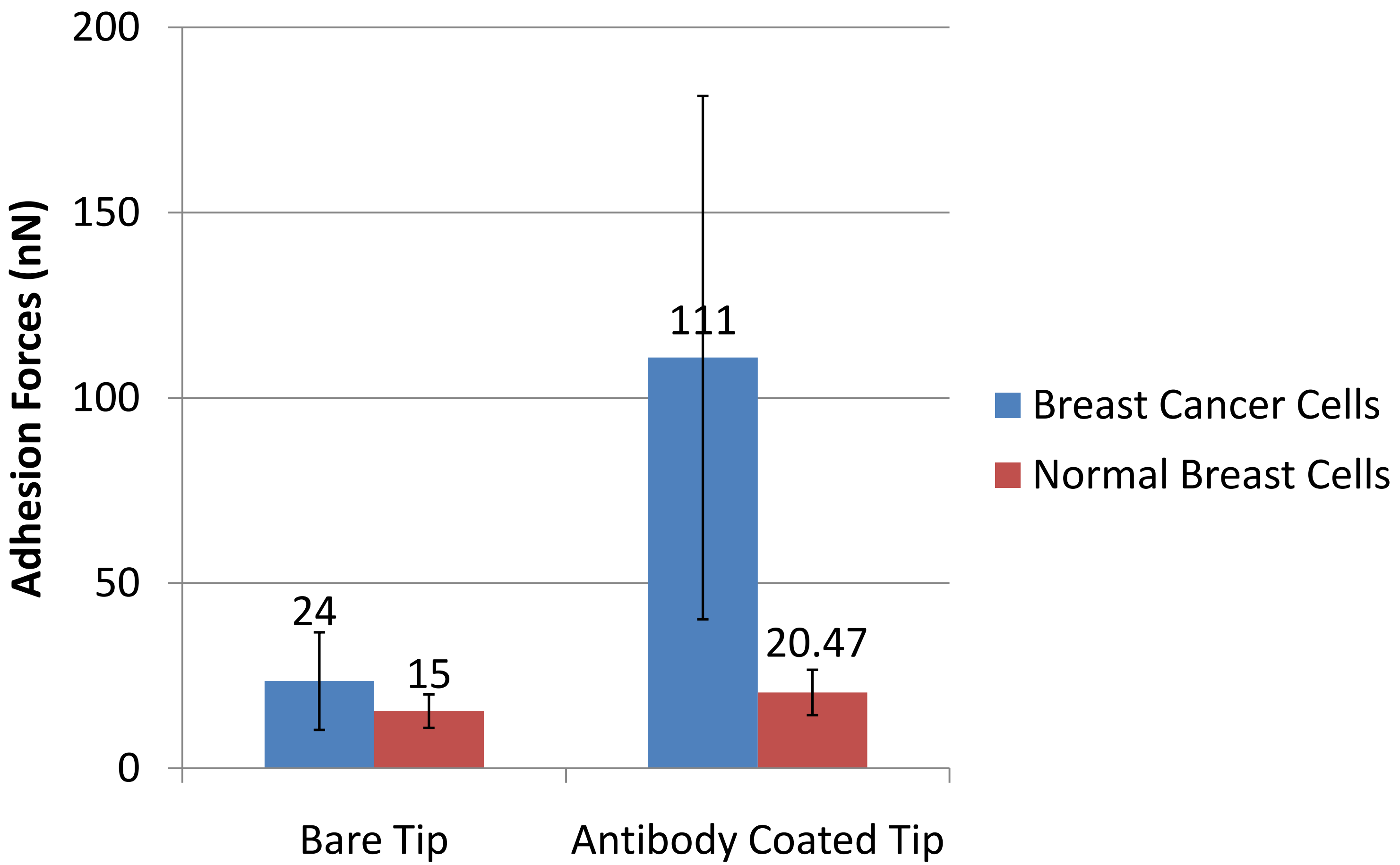
Breast Cancer Cells

MDA-MB-231



LHRH Receptors: *green*, Nuceli: *red*

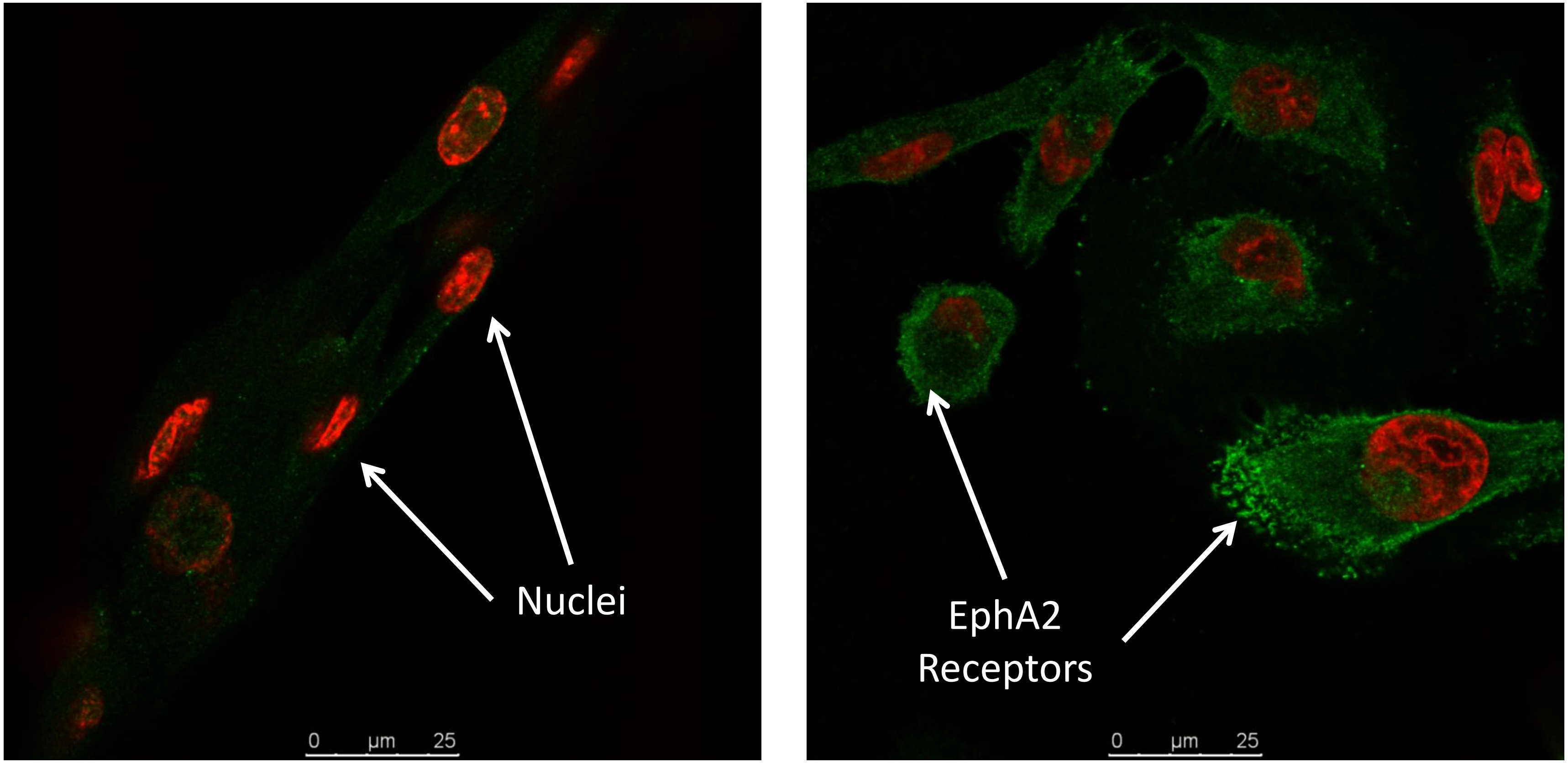
Cell/Ab Adhesion Force



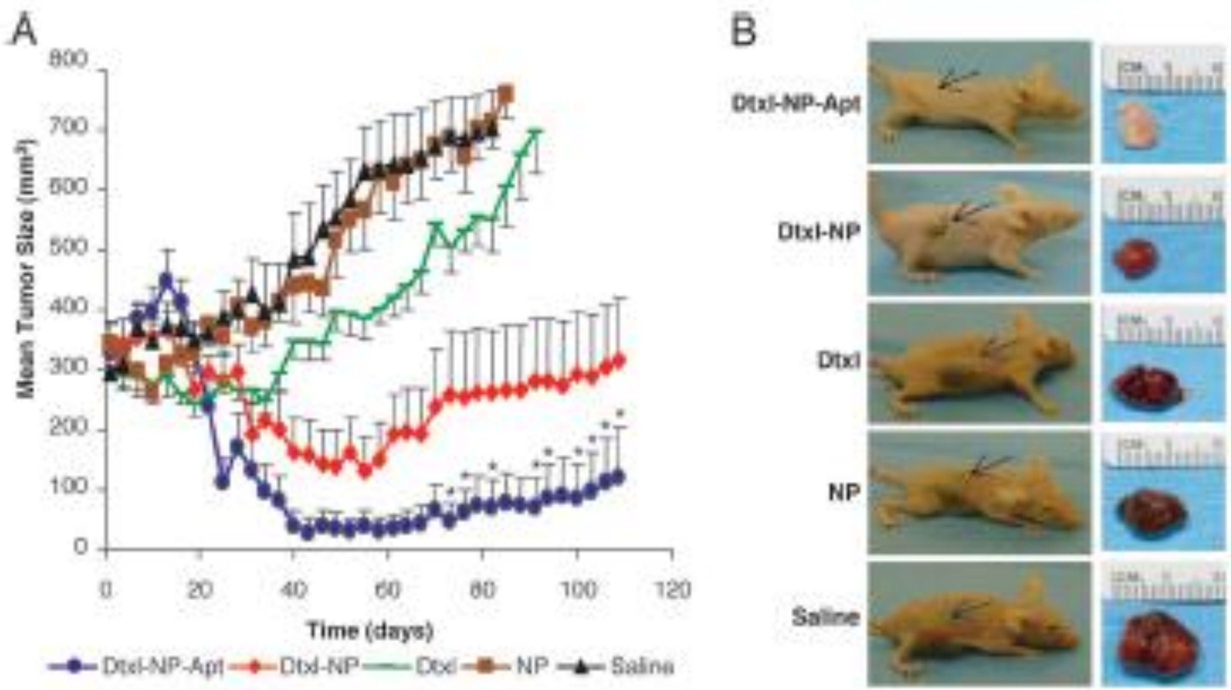
Confocal Staining for EphA2 Receptors

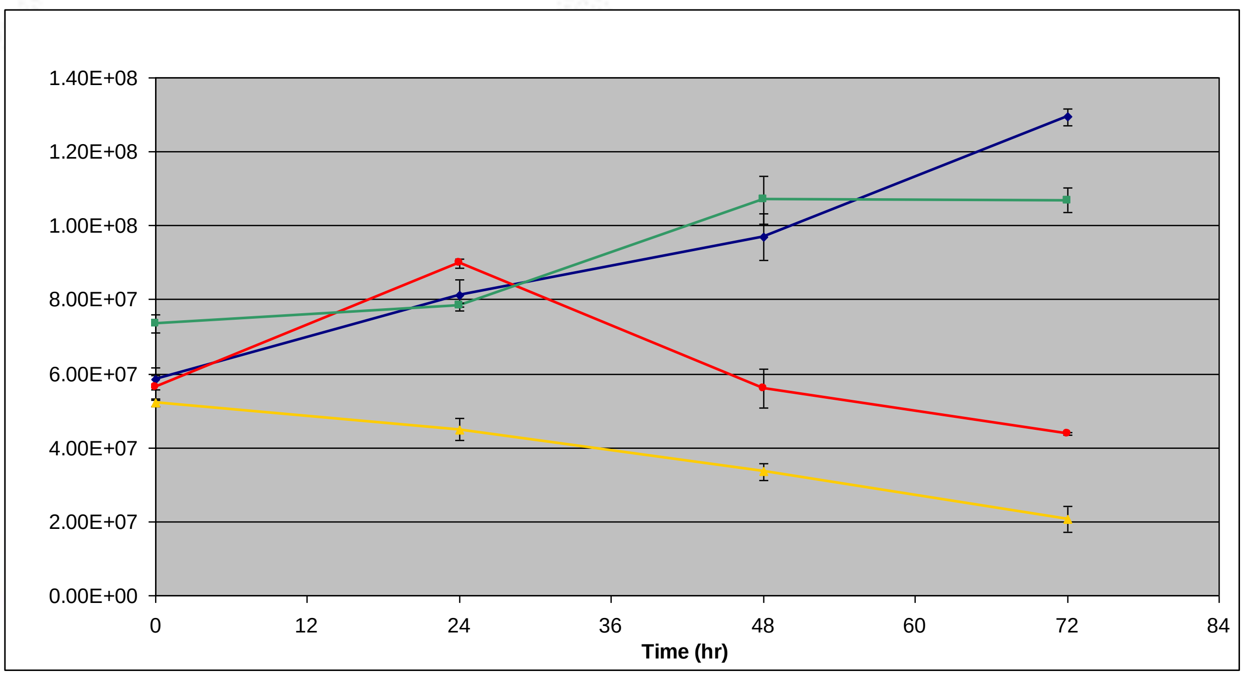
Normal Breast Cells
Hs578Bst

Breast Cancer Cells
MDA-MB-231



EphA2 Receptors: *green*, Nuceli: *red*





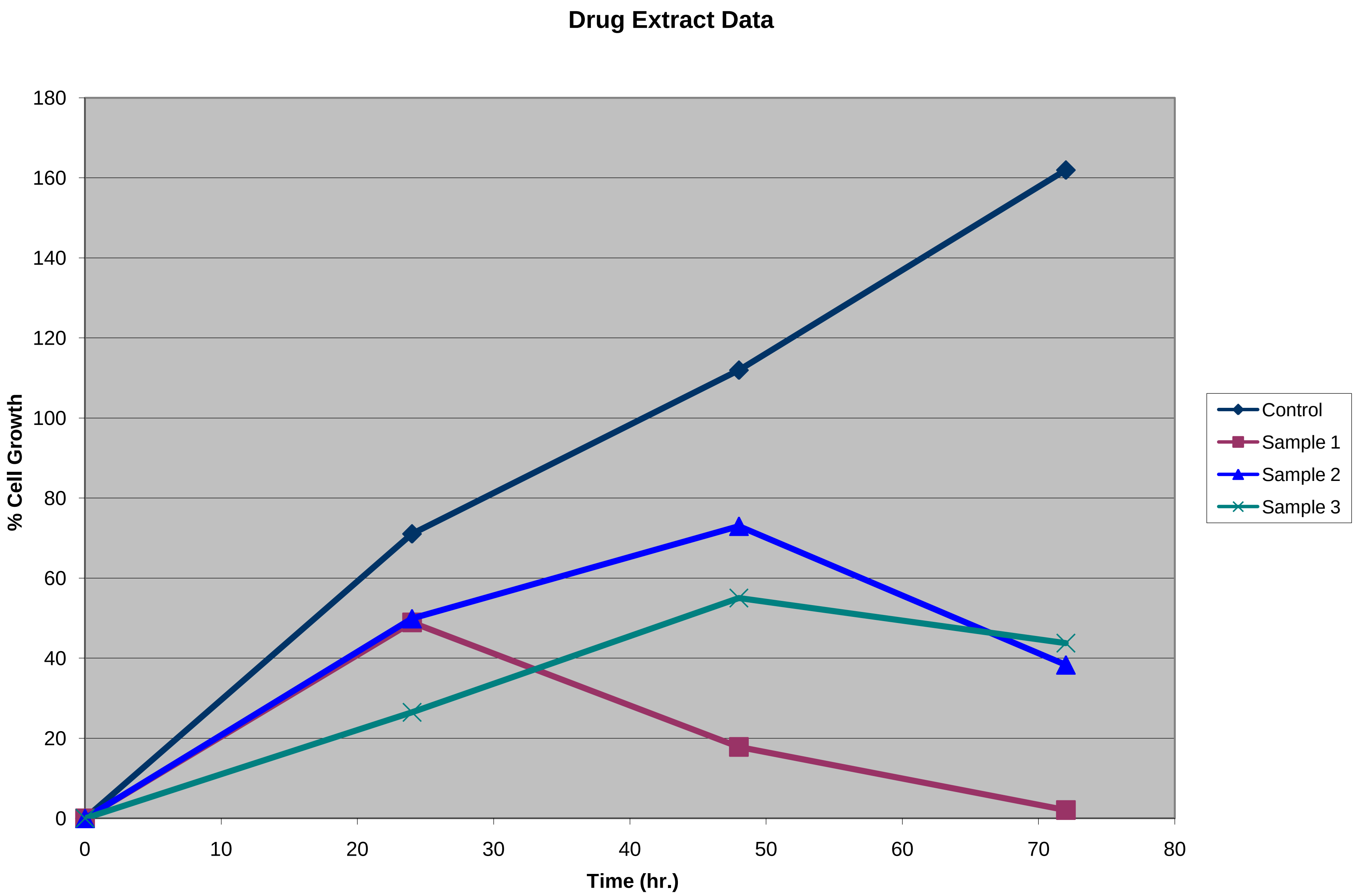
Tumor Reduction Due to Localized Drug Delivery

Work of Langer et al., 2006

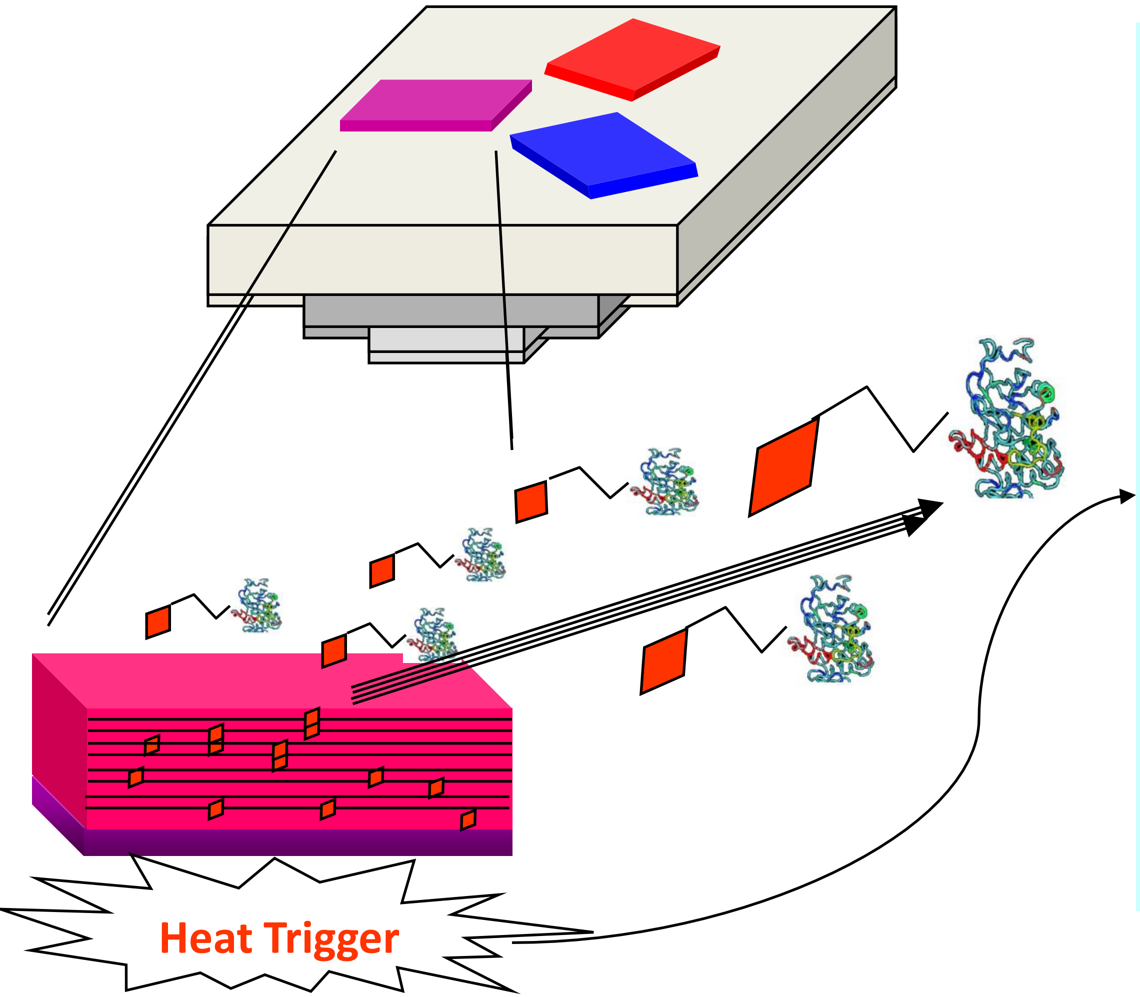
USAMI goal is to use materials science approaches to explore ways of shrinking the tumor size to zero

The other goal is to use localized delivery to reduce the side effects of chemotherapy

Collaboration with Prud'homme

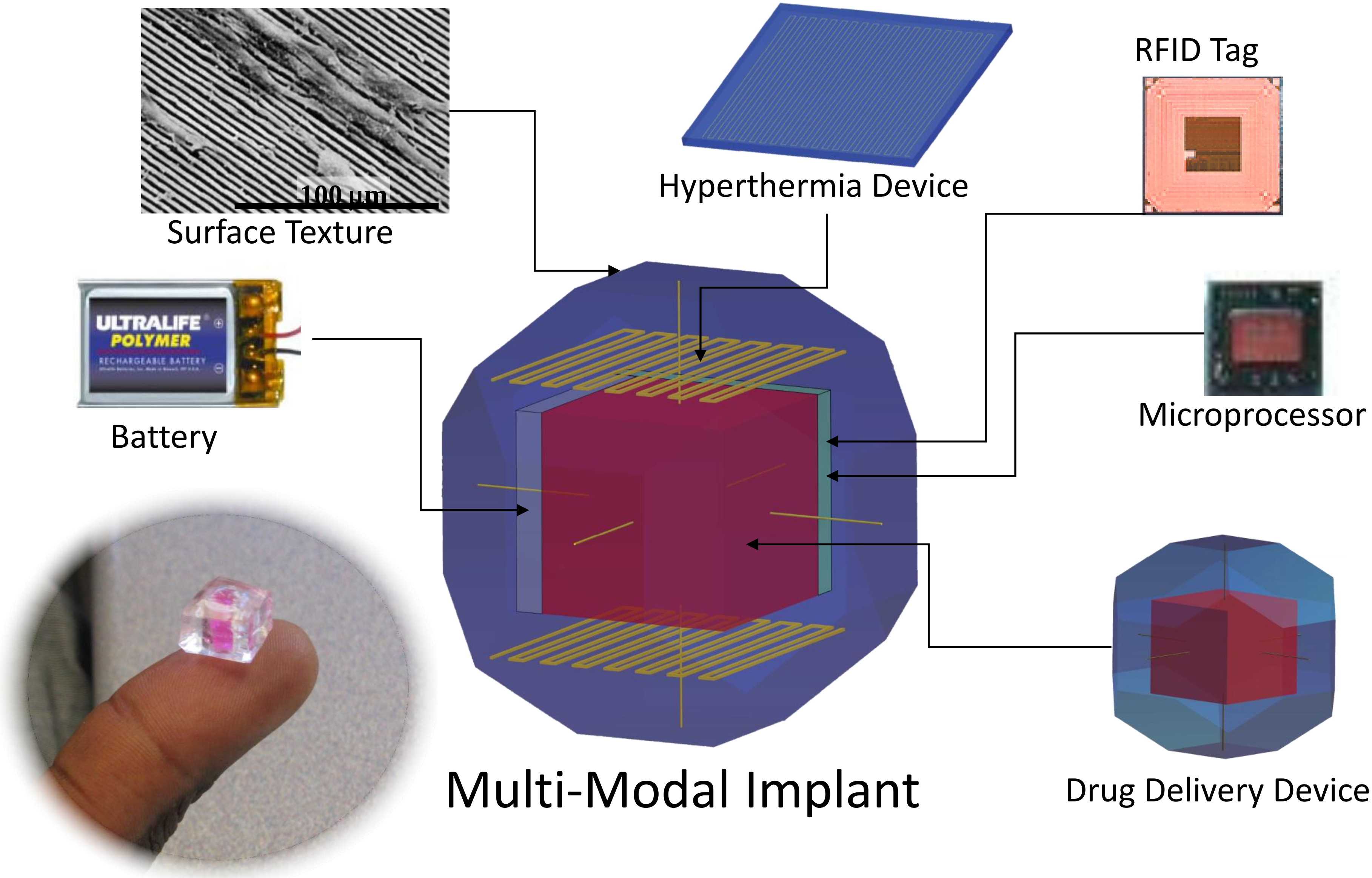

Drug Extract Data
180
160
140
120
100
80
60
40
20
0
% Cell Growth
0
10
20
30
40
50
60
70
80
Time (hr.)
Control
Sample 1
Sample 2
Sample 3

Drug Delivery by Resistive Heating

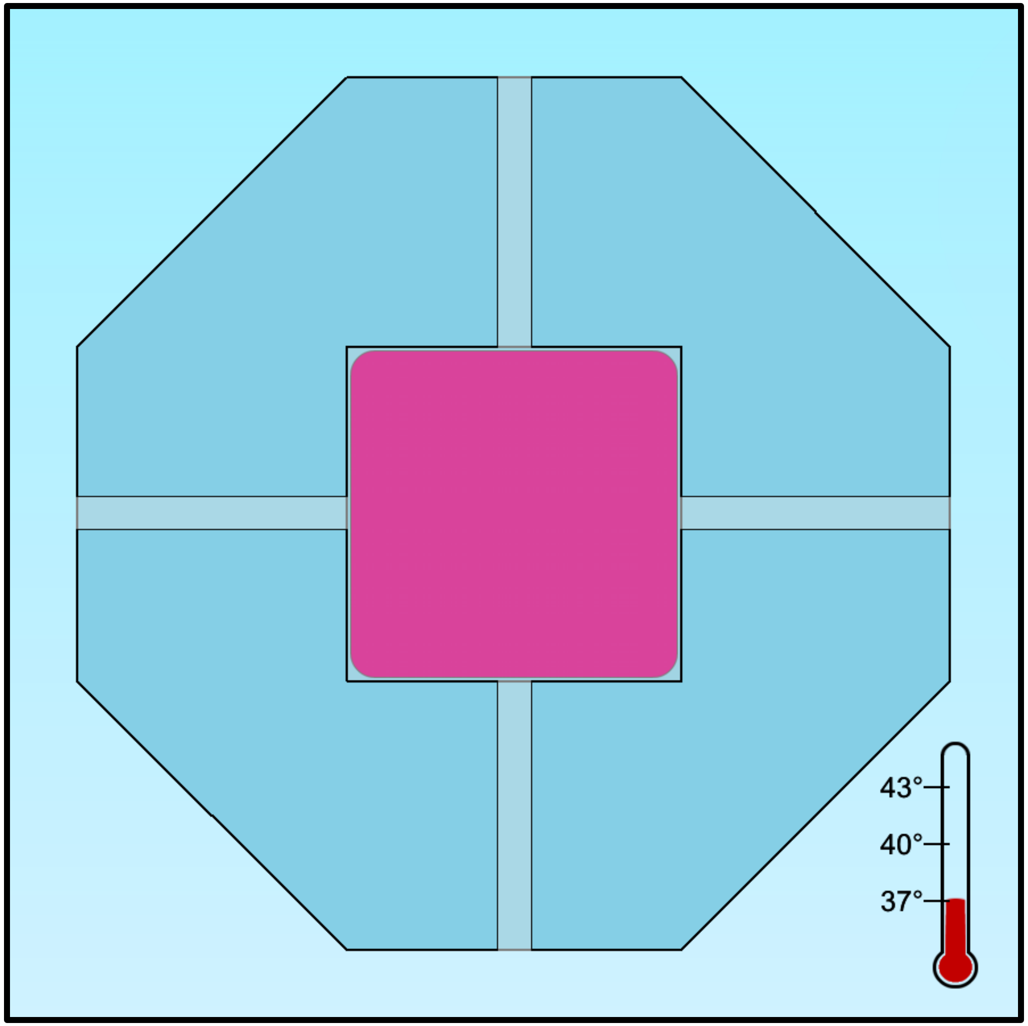


- Hydrogels sit on metallic plates
- Current running through plates heat plates
- Temperature controlled by current
- Current controlled by open/closed switch programming

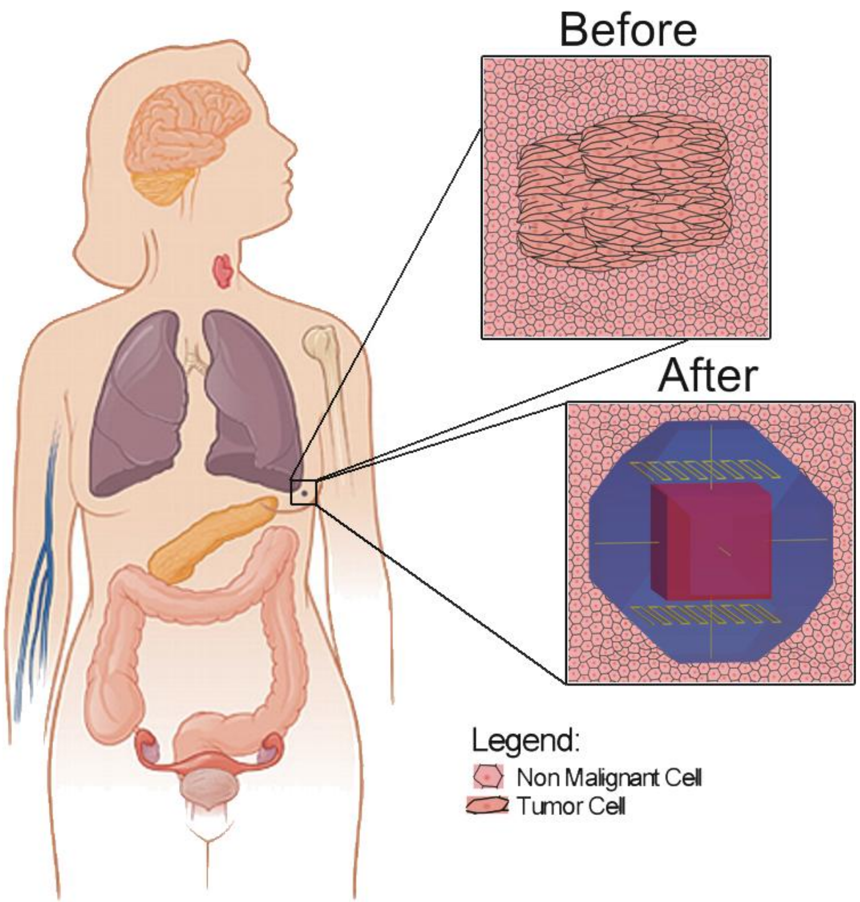
The Innovation



Multi-Modal Solution



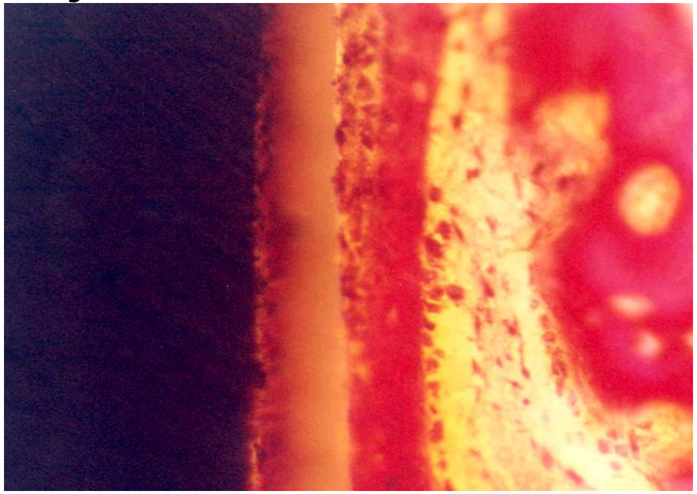
The device is designed to be implanted at the site of solid tumors after removal by surgery.

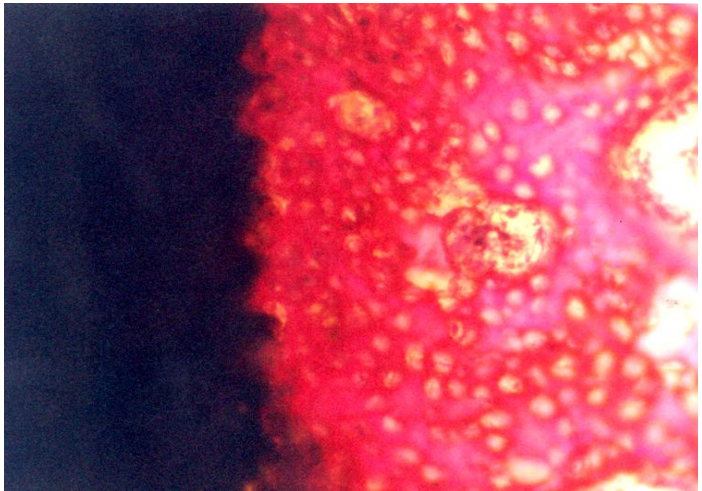


Osteogenic Titanium Biomedical Systems – Laser Textured RGD-Coated Ti Screws

- Laser texture + RGD

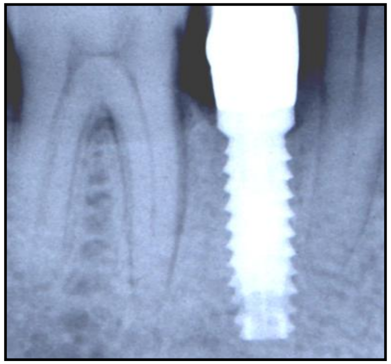
Fasasi, Chen, Alkhodary, Beye, Bly, Schwartz, Saad, Marei

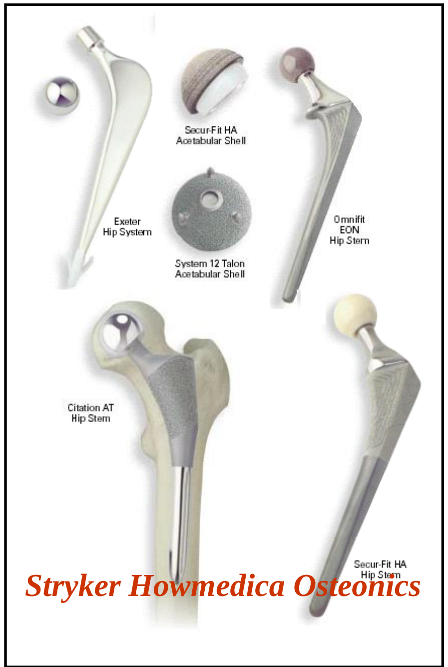




Implant Innovations, Inc.

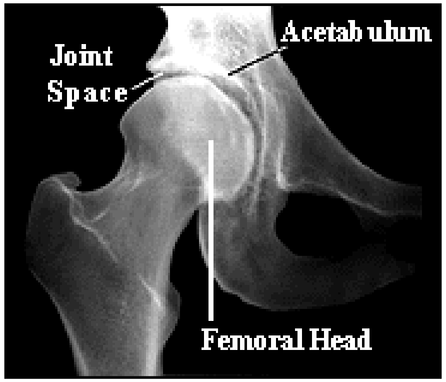
Dental Implants



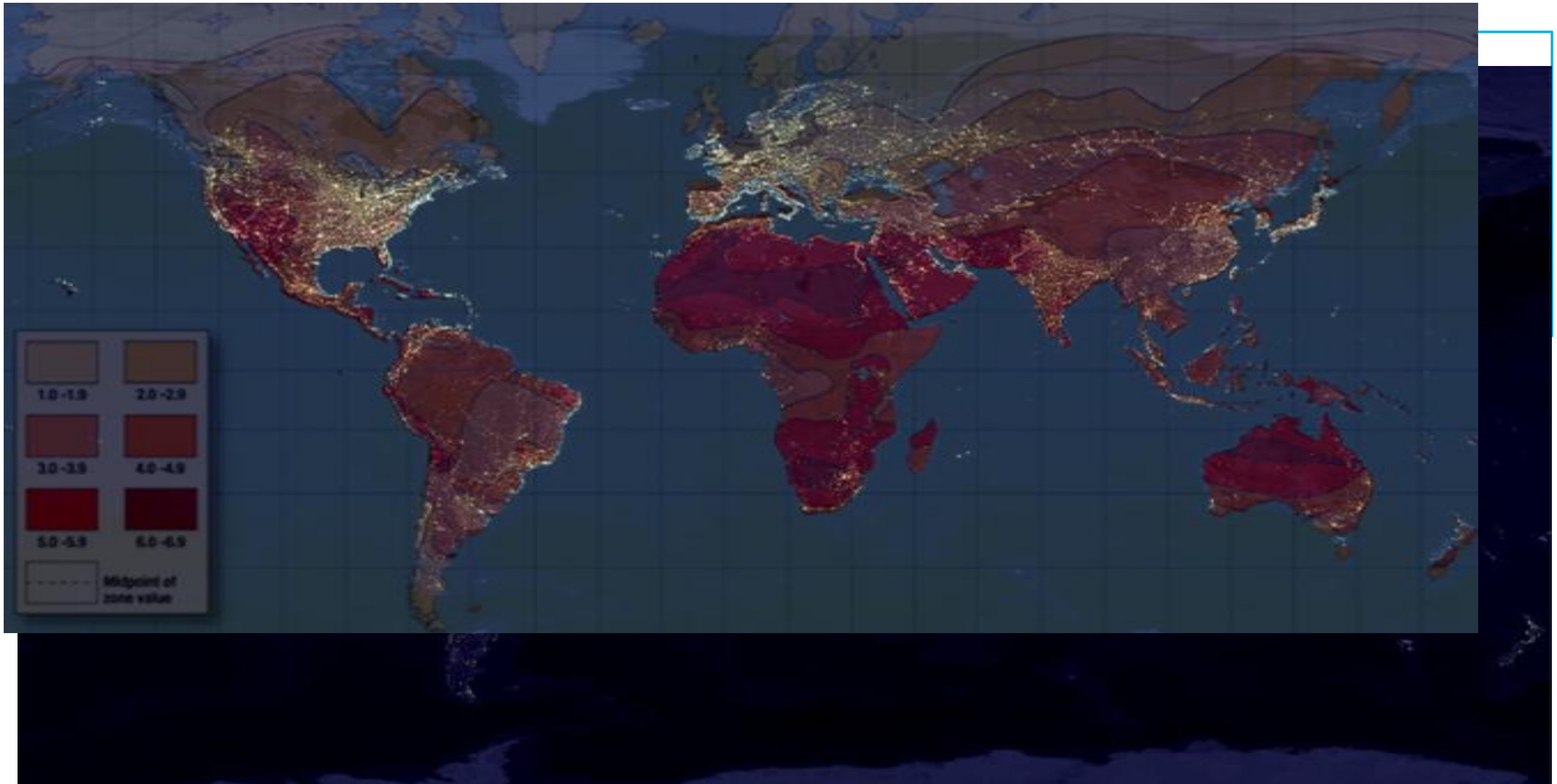


Stryker Howmedica Osteonics

Hip Implants



Motivating Technological Independence in Africa: Solar Energy



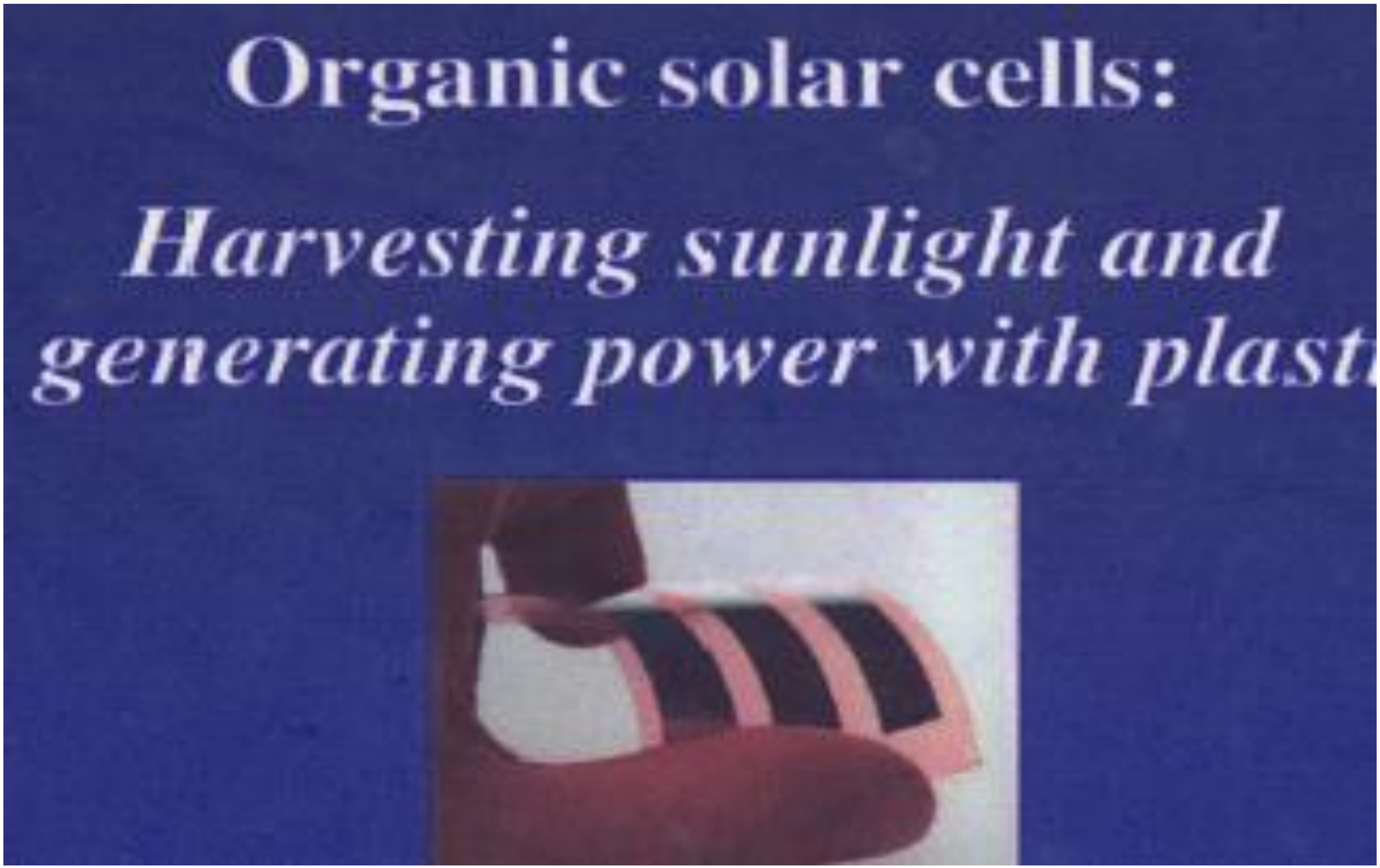
Map of Possibilities

Map of the World at Night

Organic Electronics Initiative

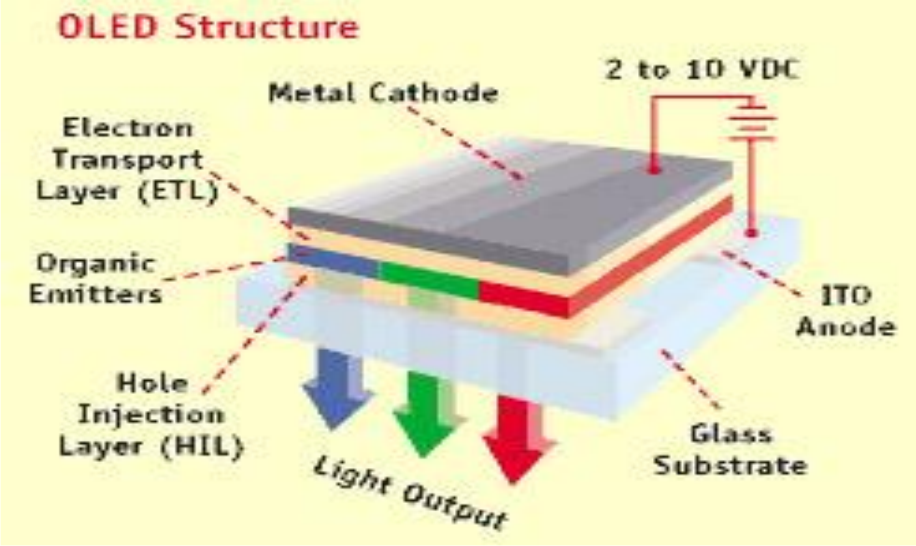
- This section of the talk presents an overview of ongoing work in organic electronics in an ongoing US/Africa Collaboration
- The objective is to develop a US/African effort similar to the US/Korea and US/Taiwan effort in silicon electronics
- Research with divesrse backgrounds
- African partners include
  - Ethiopia – Admassie, Mammo, Admassie, Workalemahu
  - Nigeria – Adewoye, Babatope, Eleruja, Kana
  - Senegal – Sakho, Beye

Flexible Devices



Introduction to OLEDS

- OLED = Organic Light Emitting Device

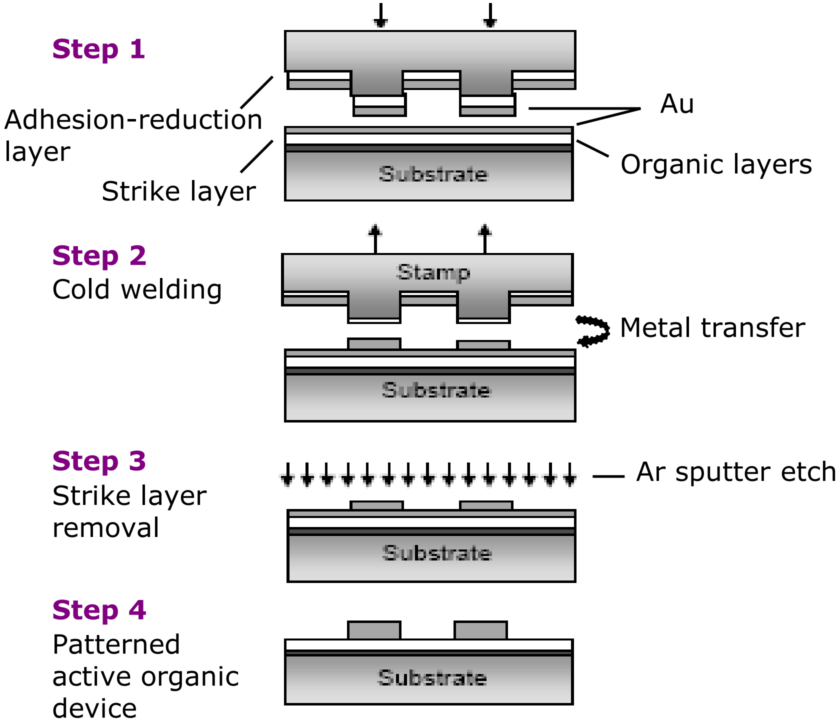


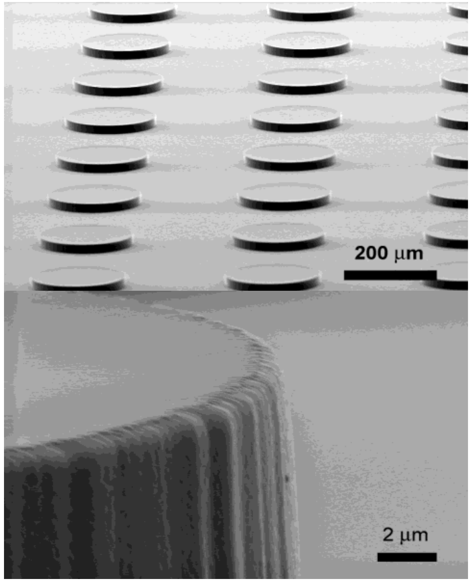
- The advantages of OLEDs:
  - Large viewing angle
  - Increased brightness and contrast
  - Low power consumption
  - …

http://www.kodak.com/

Cold Welding for OLED Fabrication

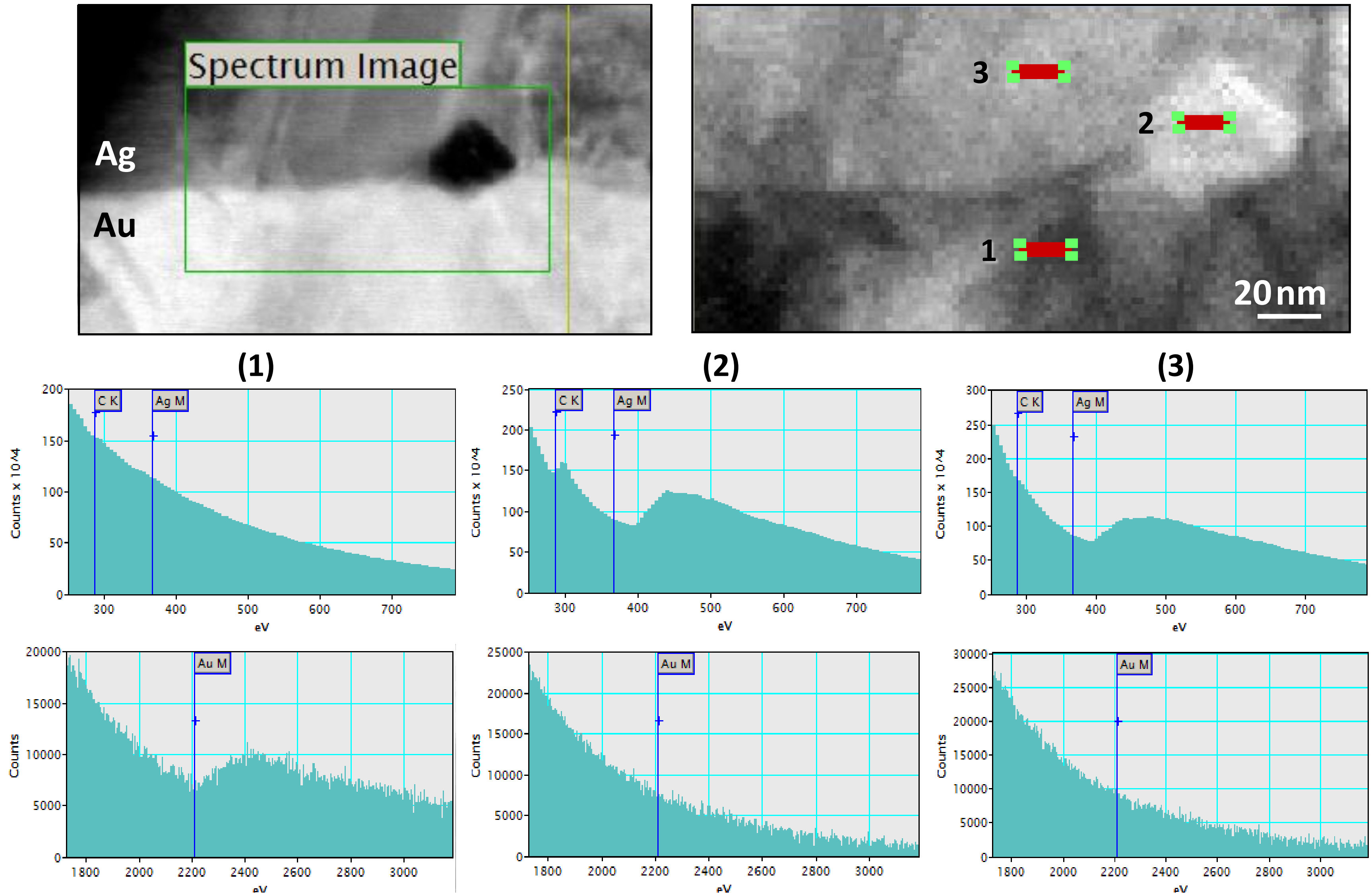
- Patterning of the OLED electrodes is difficult by photolithography since the organic material degrades in conventional solvents or high temperature
- Nano- and micro-patterning can be realized by inducing cold-welding between a metal coating on the stamp and the metal layer on the organic film





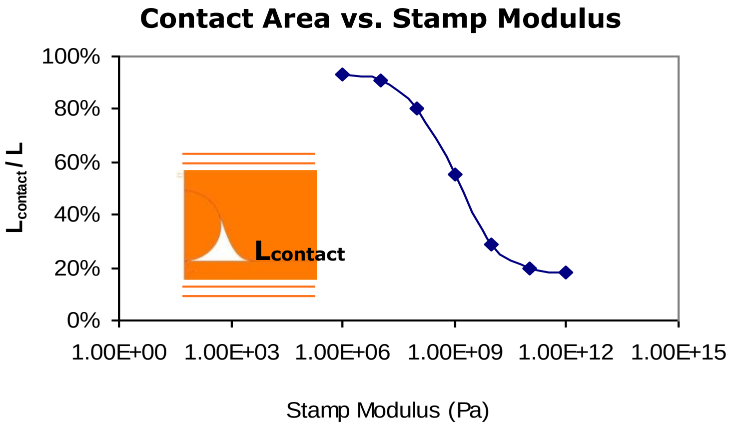
--- Kim, Forrest, *Adv. Mater*. (2003)

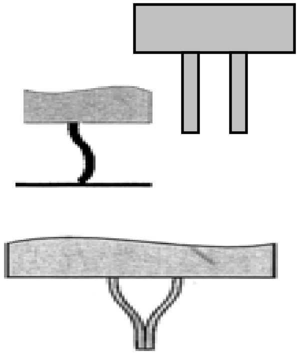
Electron Energy Loss Spectra of Au-Ag Interface



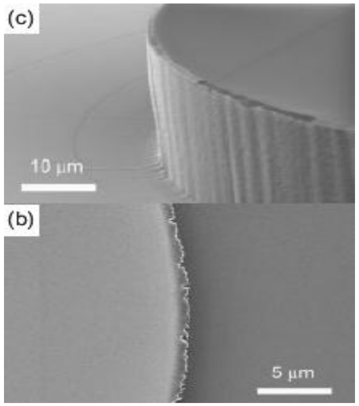
Comparison of EELS collected from various locations across the Au-Ag cold-welded interface. It shows there is a clear increase in both carbon and Ag peaks in position 2.

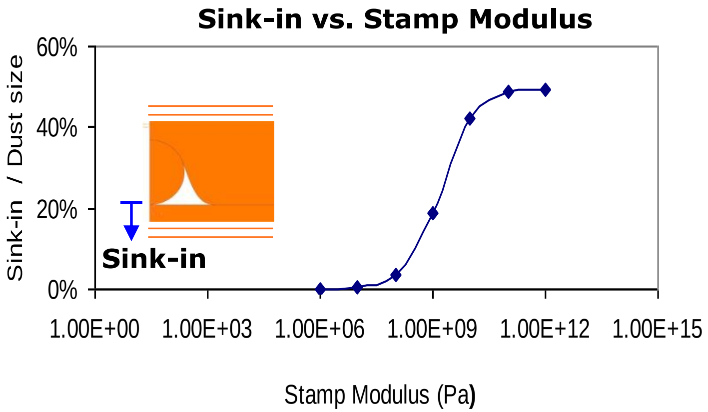
Stamp Modulus Design





---C. Hui, et al. (2002)

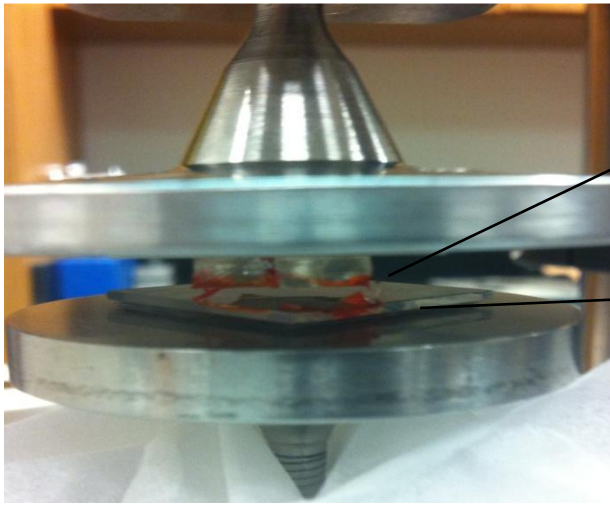




---400KN, 1µm dust

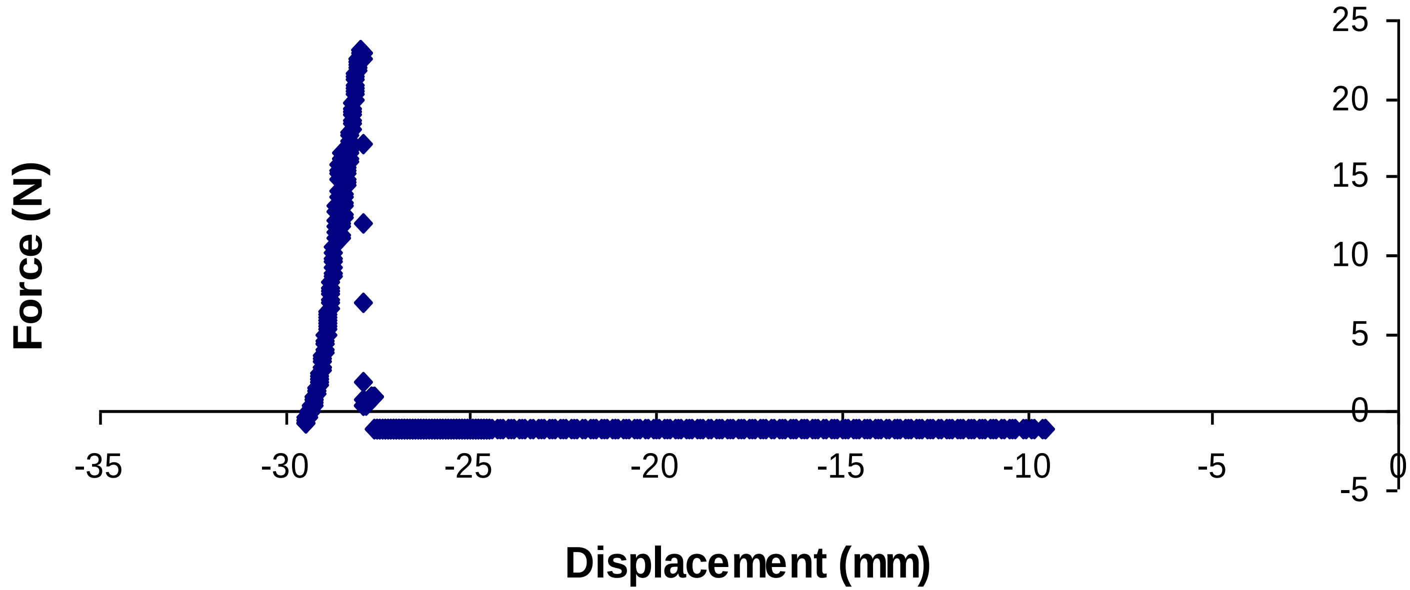
- Advantages of soft stamps: flexibility & low damage
- Disadvantages of soft stamps:
  - Dimensional instability problems
  - Stamp edge rounding
- Trade-off in design:
  - Low modulus vs. high modulus stamp

Adhesion test for pre-laminated sample

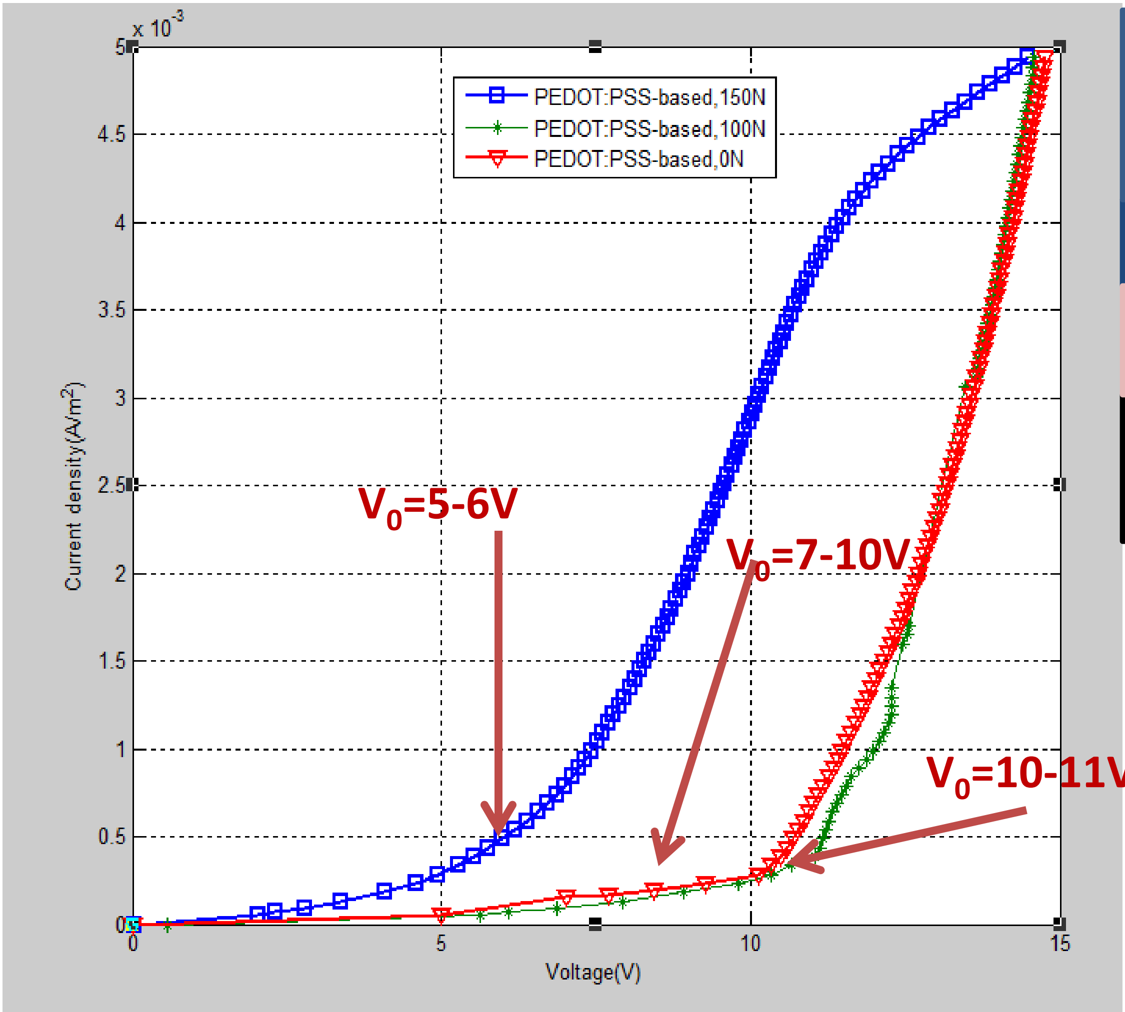


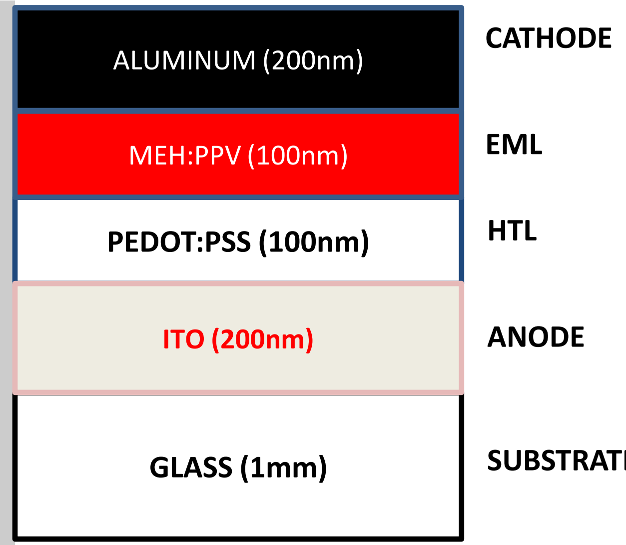
Double-sided tape on the upper mold

MEH-PPV pre-laminated onto PEDOT:PSS



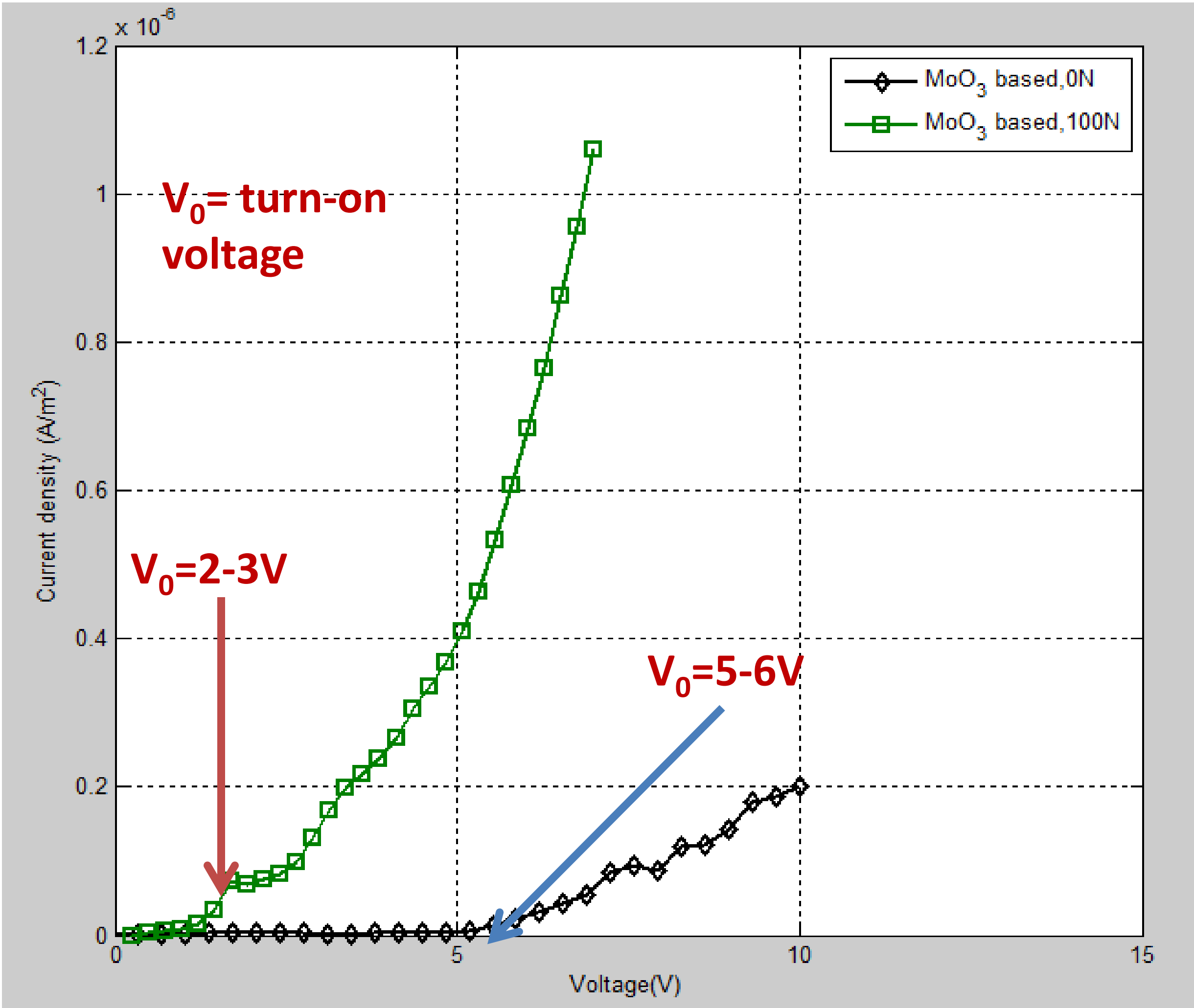
J-V CHARACTERISTICS

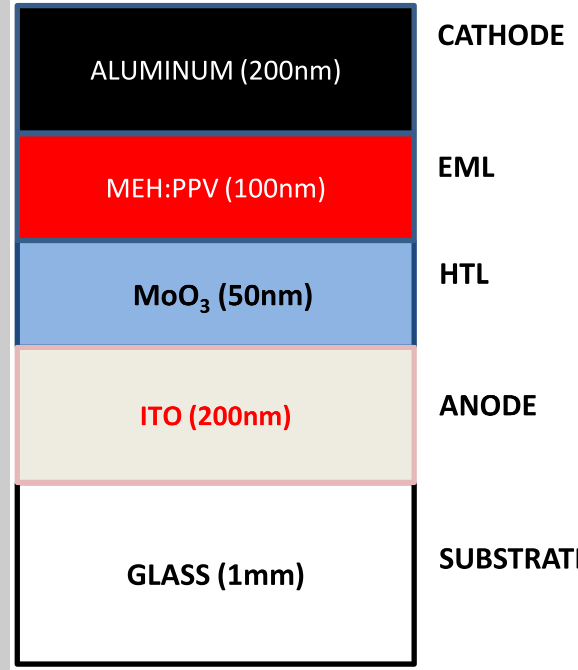


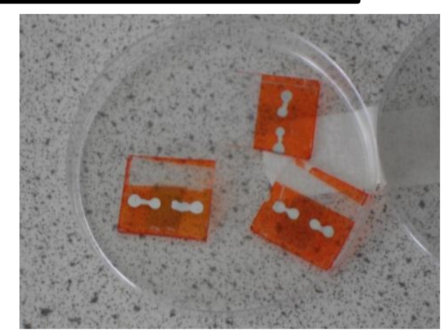


J-V plots for PEDOT:PSS -based device treated with 0N ,100Nand 150N loads compared

J-V CHARACTERISTICS

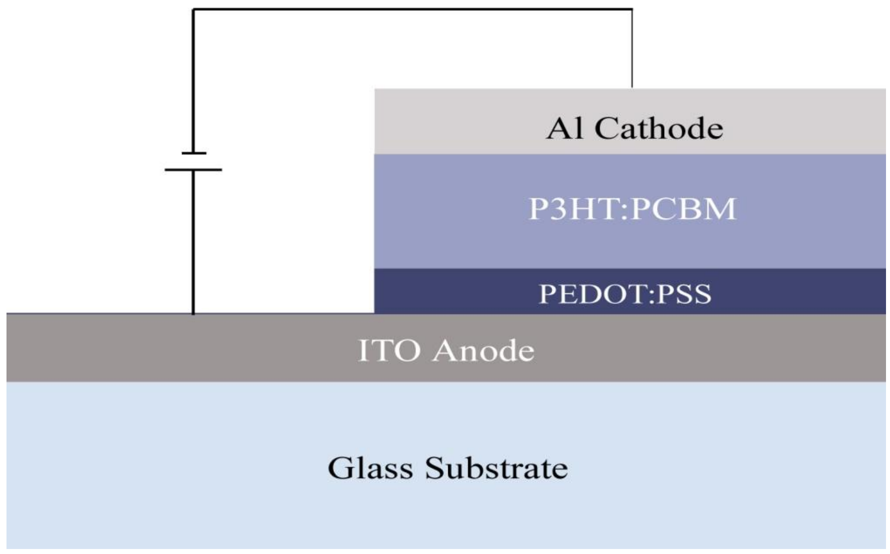


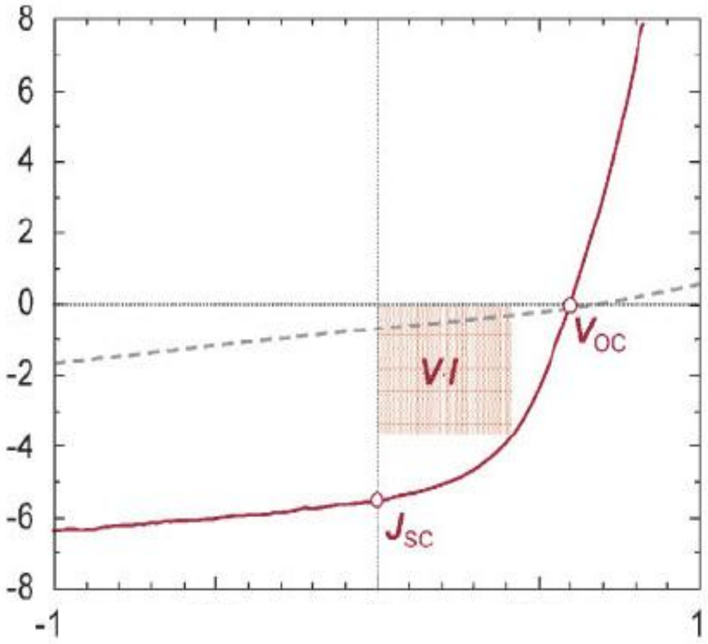


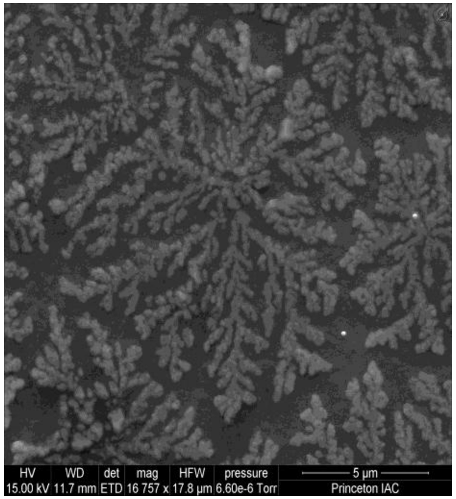


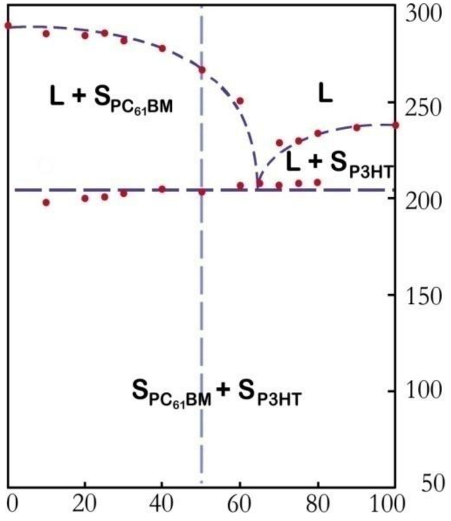
J-V plots for MoO_3 -based device treated with 0N and 100N loads compared

Typical I-V Curves for Solar Cells





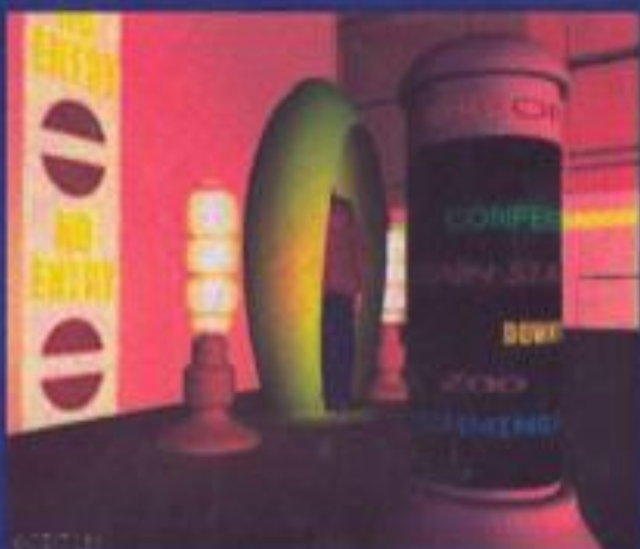




Integrated Systems and E-Textiles …

- Consumer applications (smartcards) will pave the way for large area PV systems (industrial coating technologies)

- Full plastic integrated systems containing solar cells, transistors and LEDs



The Need For a Manufacturing Initiative

- Quite clearly manufacturing issues are not too far ahead….e.g. NASENI plant in Abuja
- Africa’s goal should be to develop low cost manufacturing capability
- However strategy should not wait for organic electronics to mature
- The sandwich structure for solar cells and OLEDs is the same
- The only real difference is what is in the sandwich
- Should start with silicon and grow to organic and carbon-based electronics

Porous Ceramics For Water Filtration

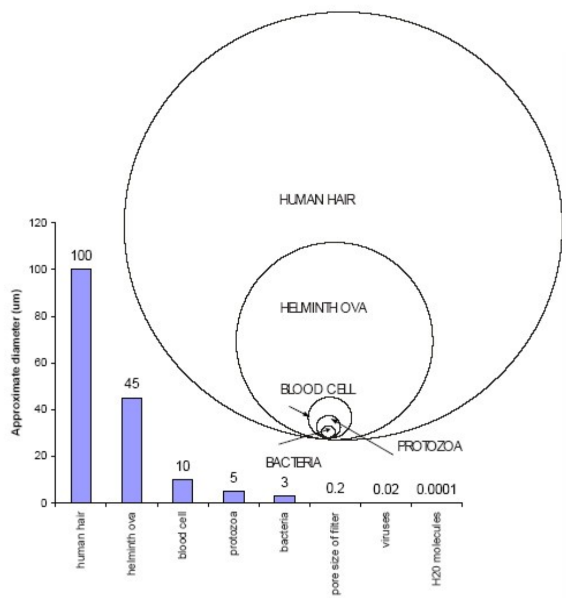
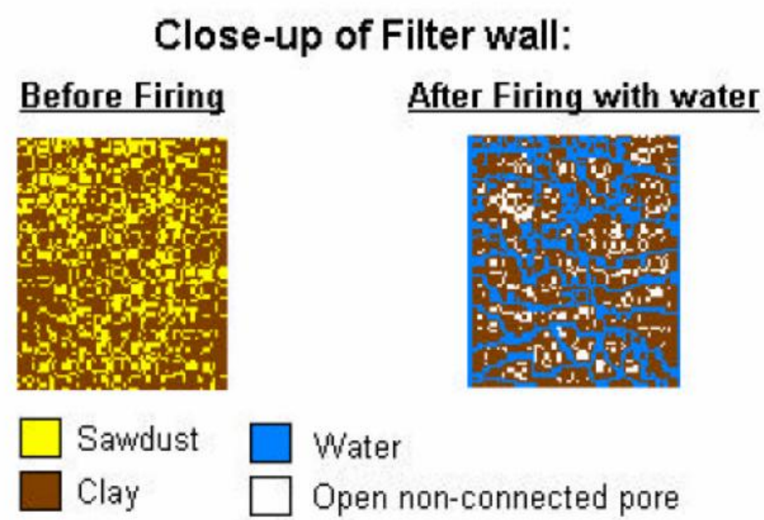
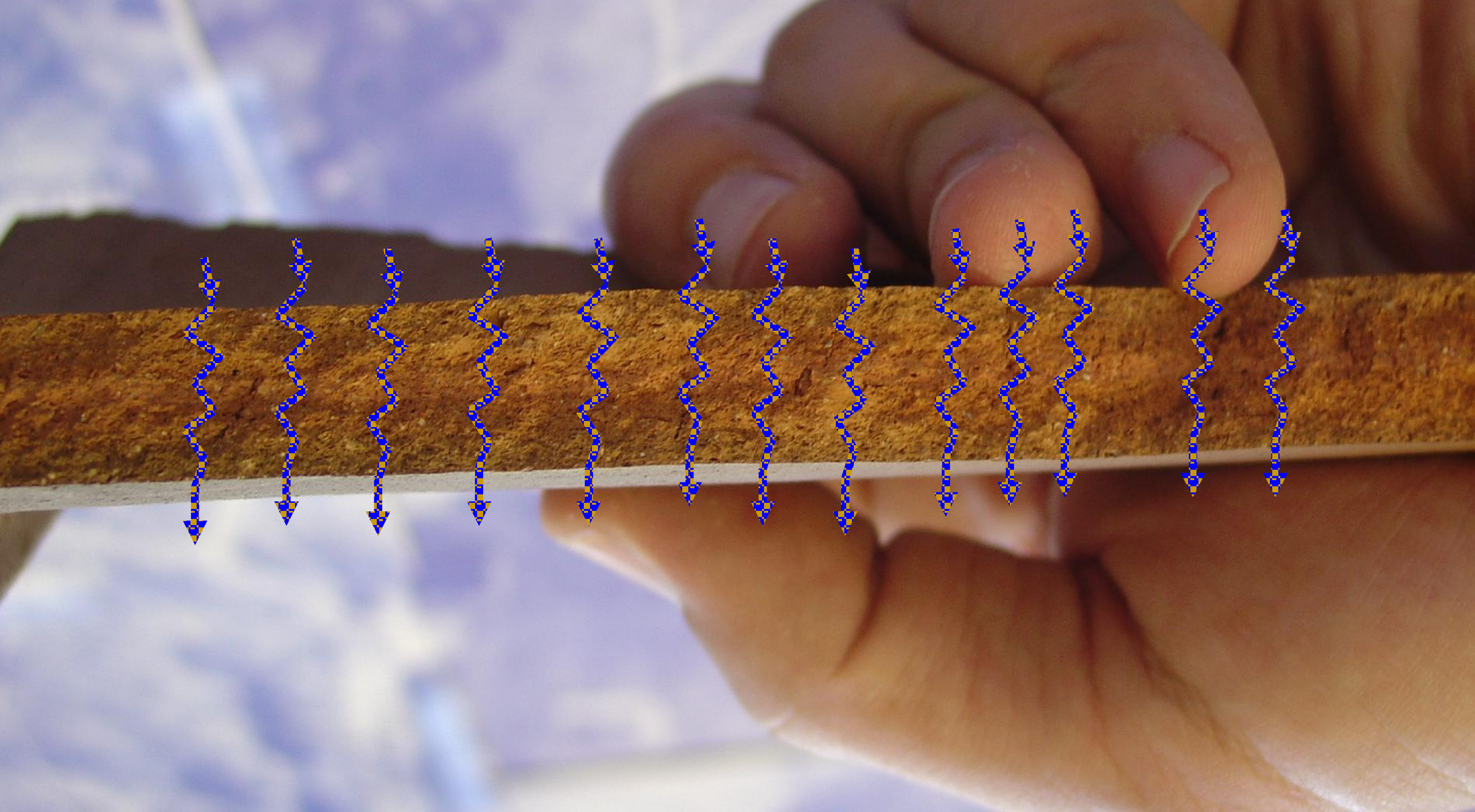


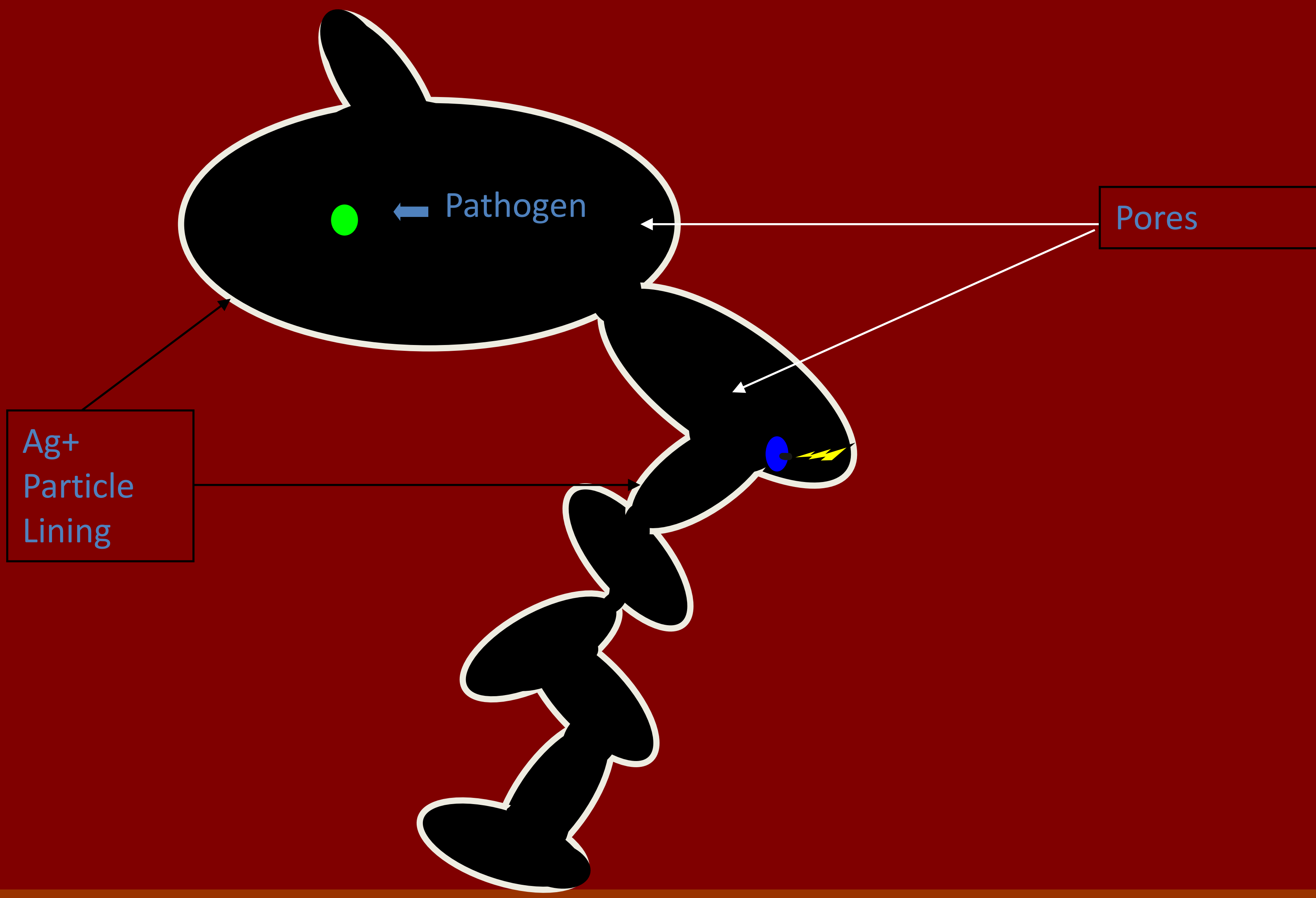
Figure 2. Comparison of relative sizes of various contaminants in water. Based on these, the pore size of the ceramic filter, at 0.2μm, would be about the size of a full stop on this page.



Cross-Section



Interactions With Ag Coating



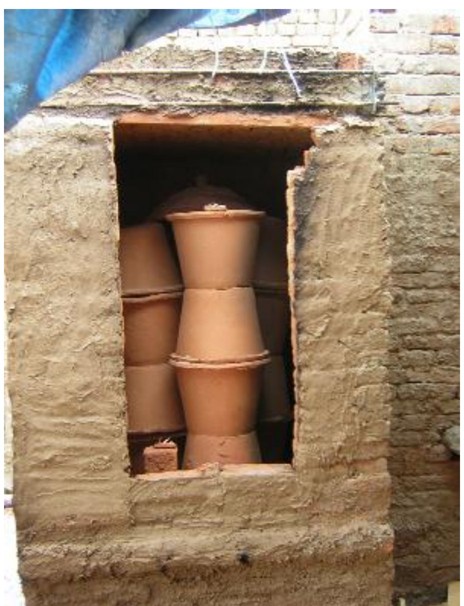
E. coli Filtration Tests of Non-Coated Ceramic Water Filters

Volume Fraction Clay:Sawdust	Test 1	Test 2	Average ± Range
45:55	99.97	99.85	99.91 ± 0.06
50:50	99.99	99.93	99.96 ± 0.03
55:45	99.52	99.84	99.68 ± 0.16
65:35	99.99	99.99	99.99 ± 0.00

Filter Processing - From Ideas to Markets







Filtron - Ceramic Water Filter Start-Up in Nigeria

Ron Rivera and Staff at The Staff at Filtron Nigeria in Abeokuta, Nigeria

US and African materials researchers have collaborated with Potters For Peace in the establishment of a start-up (Filtron Nigeria)

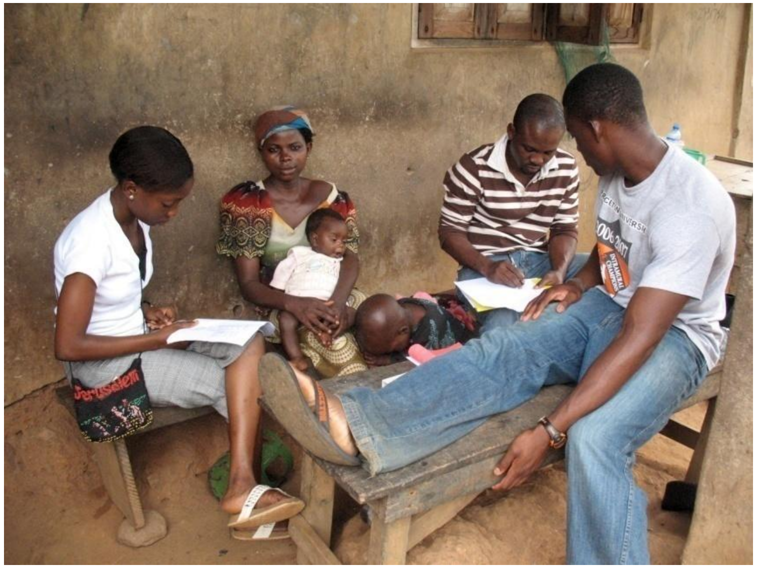
Filtron makes point-of-use ceramic filters that are fabricated from locally available clays and biodiversity such as wood chips and rice husks

The production activities are also integrated with research efforts on the effects of porous structure on ceramic water filtration

The group has produced filters for distribution to people in rural and urban areas

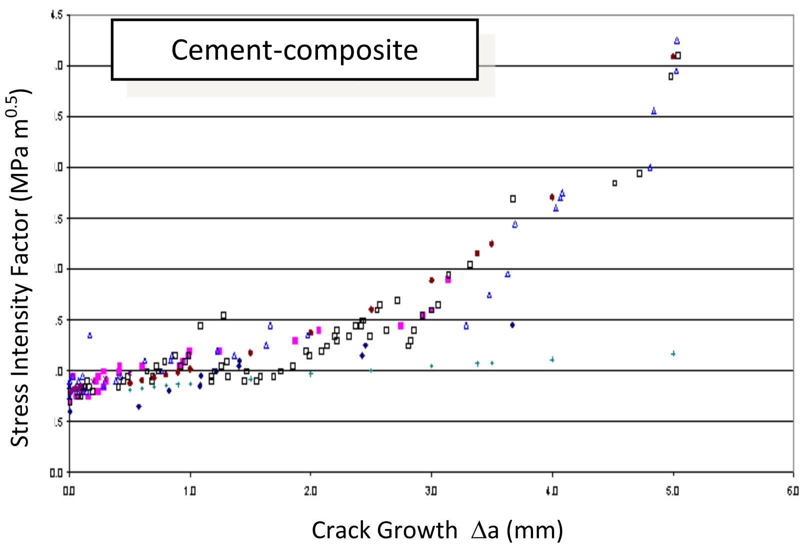
The impact of filter use has also been explored in the rural village of Eweje

Impact: Eweje Village

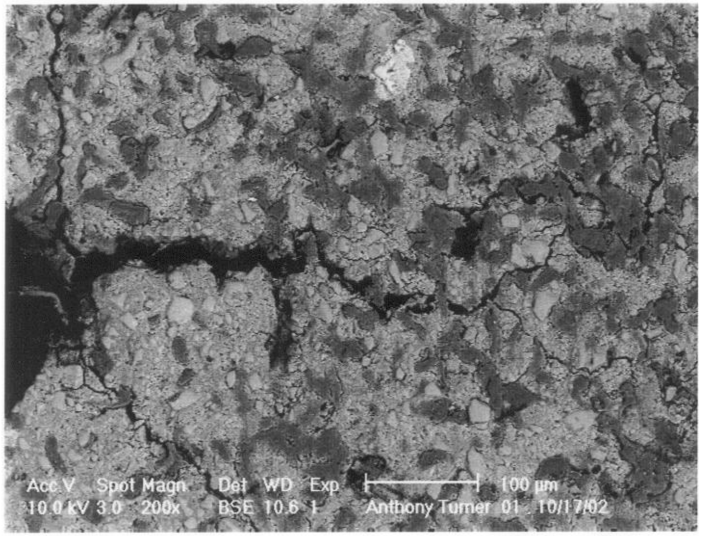


Alternative Eco-Friendly Materials

- All countries have industrial and agricultural wastes that can be combined with earth or cement based materials to make building elements
- Examples include straw-reinforced earth, cementitious composites reinforced with natural fibers and polymers reinforced with wood chips
- Such reinforcement gives rise to toughening by crack bridging which increases durability and earthquake resistance of homes and roads

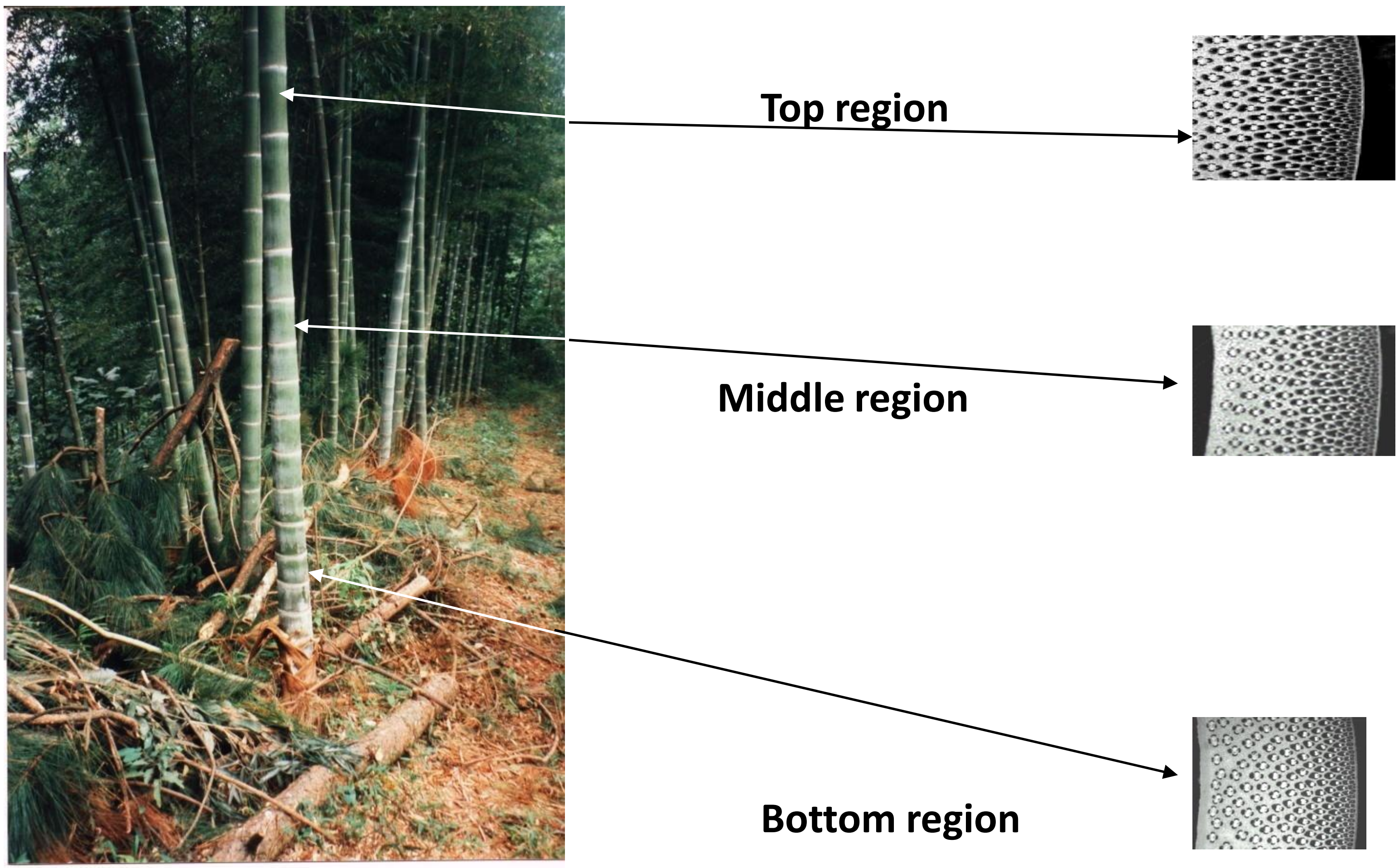


Resistance-curve behavior in natural fiber composites

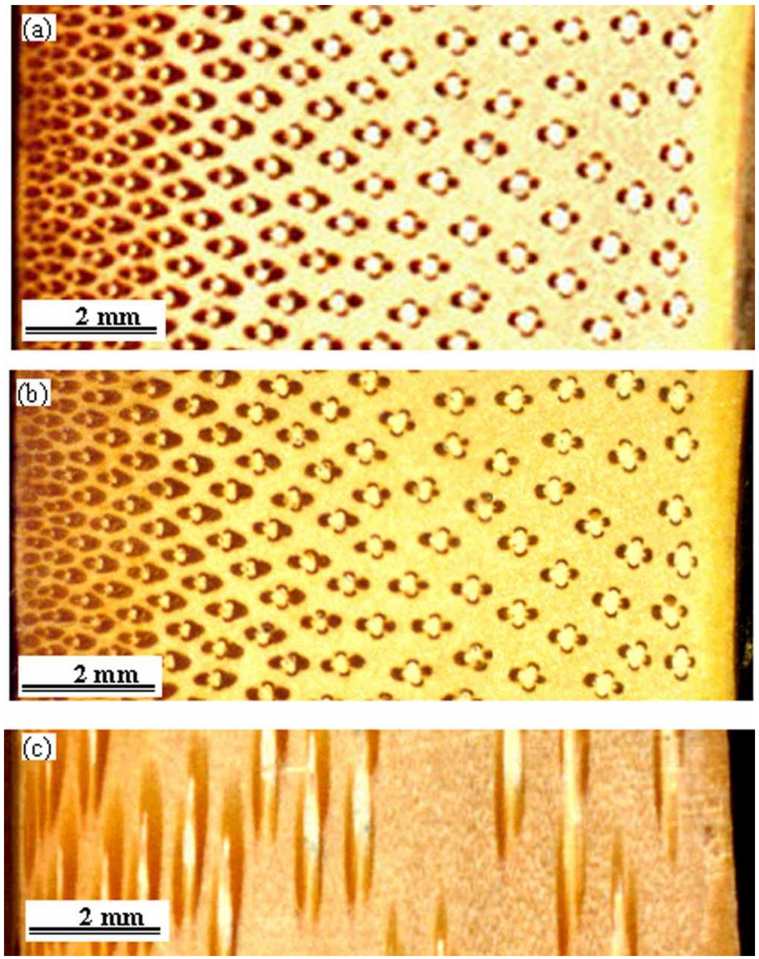


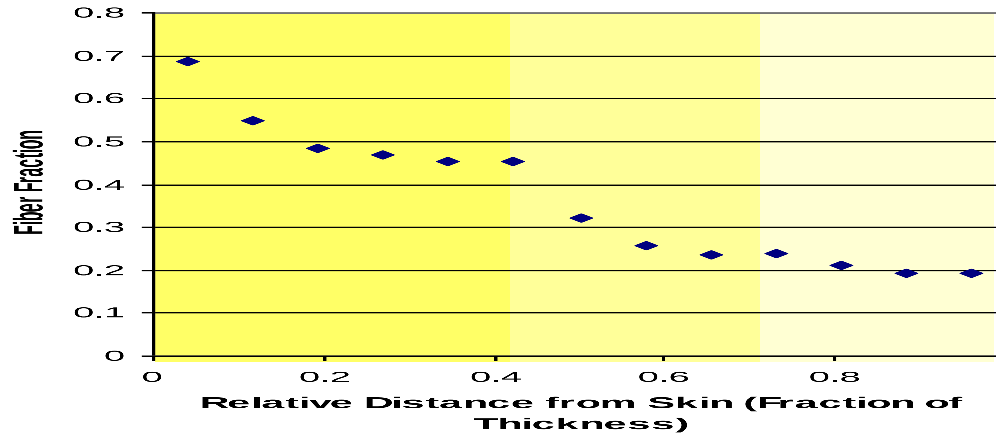
Backscattered electron image showing cracks and composite bridges. Fibers are seen in dark gray

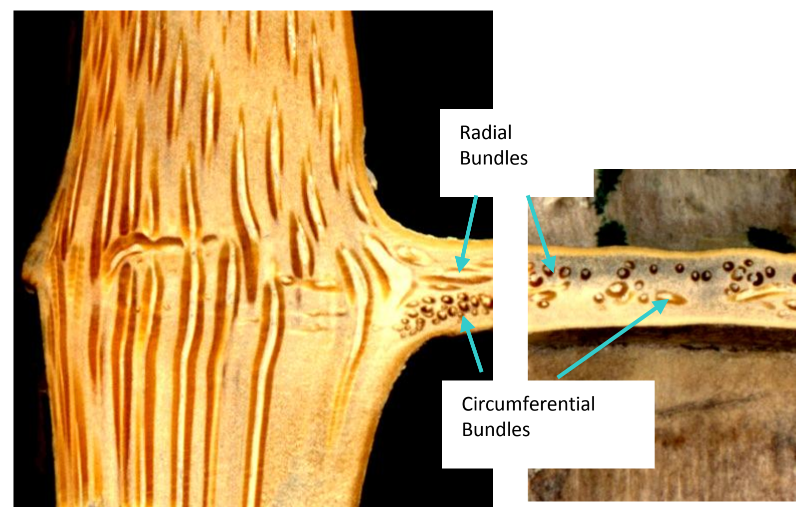
Bamboo as an Intelligent Material - Plantation of Moso Culm and FGM Cross Section



Scanned Images of Functionally Graded and Intelligently Adapted Bamboo Structures



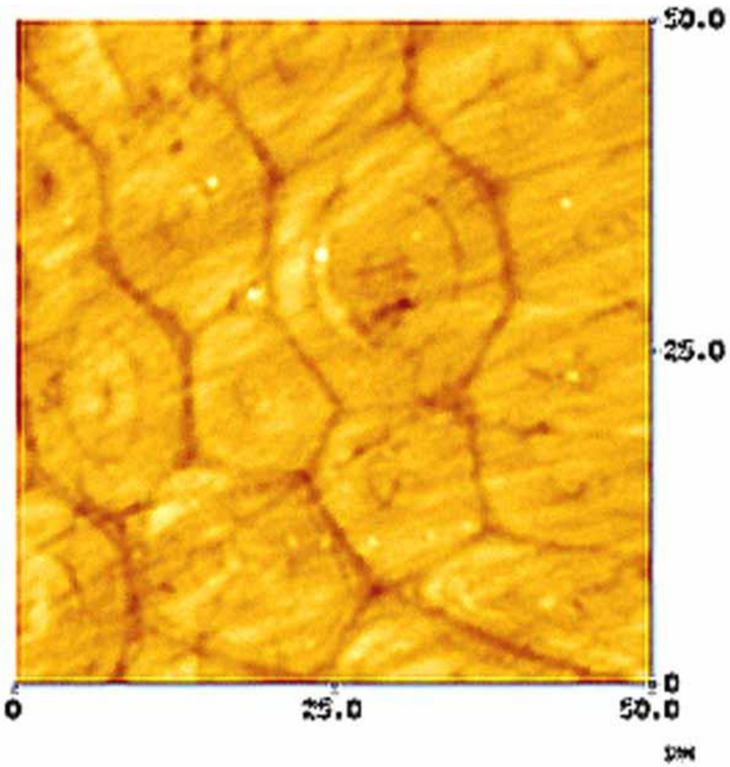




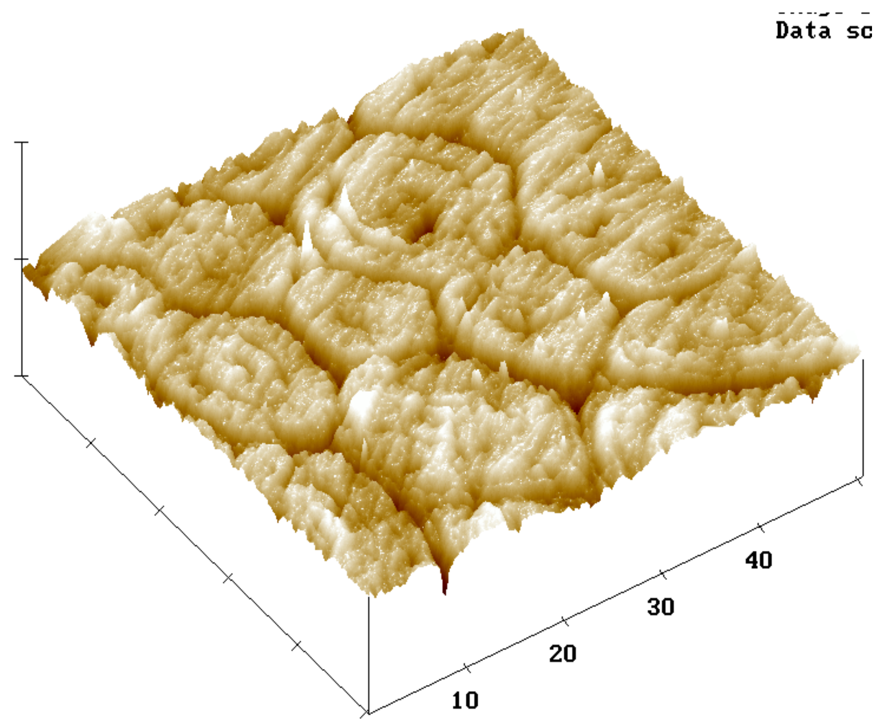
(a) L-R Cross section of the culm wall

(b) L-C Cross section of the diaphragm

AFM Scans of the Fiber Bundles

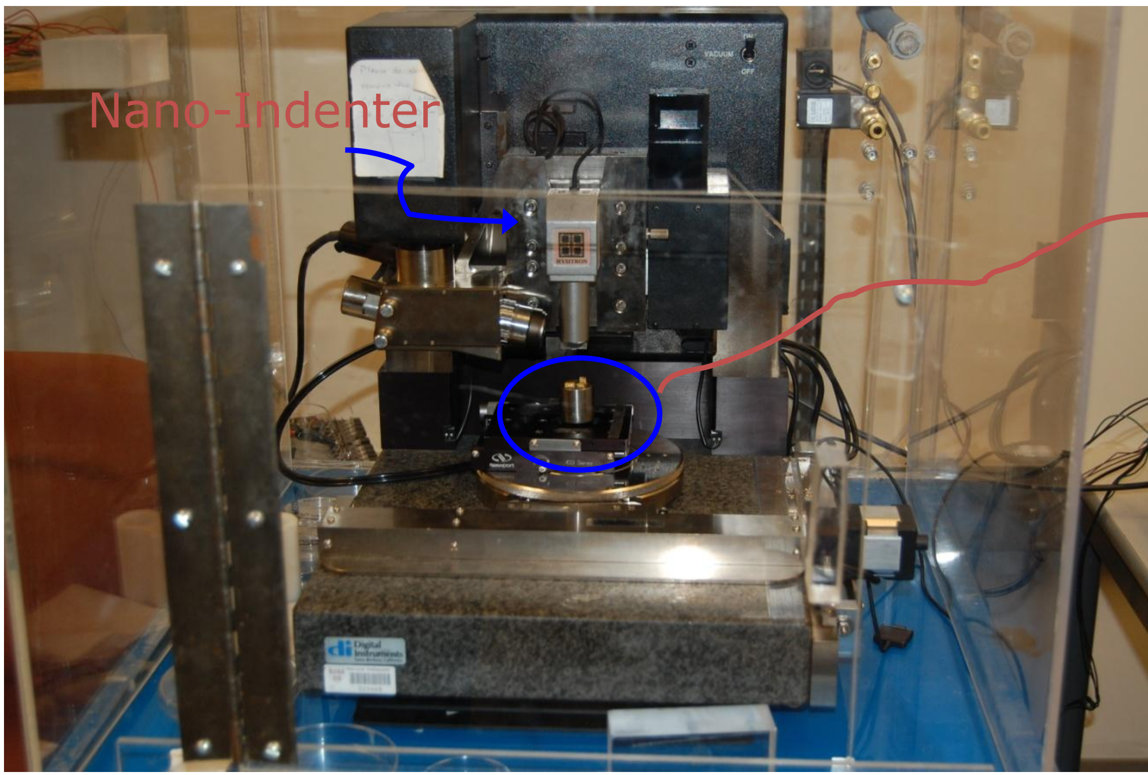


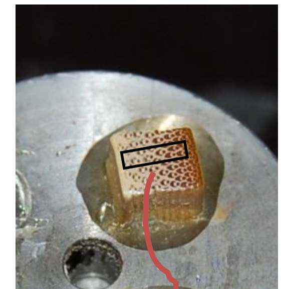
(a) Surface of vascular bundles in 2-D image

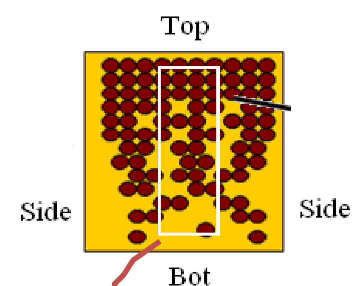


(b) Surface of vascular bundles in 3-D image

Elastic Modulus Study

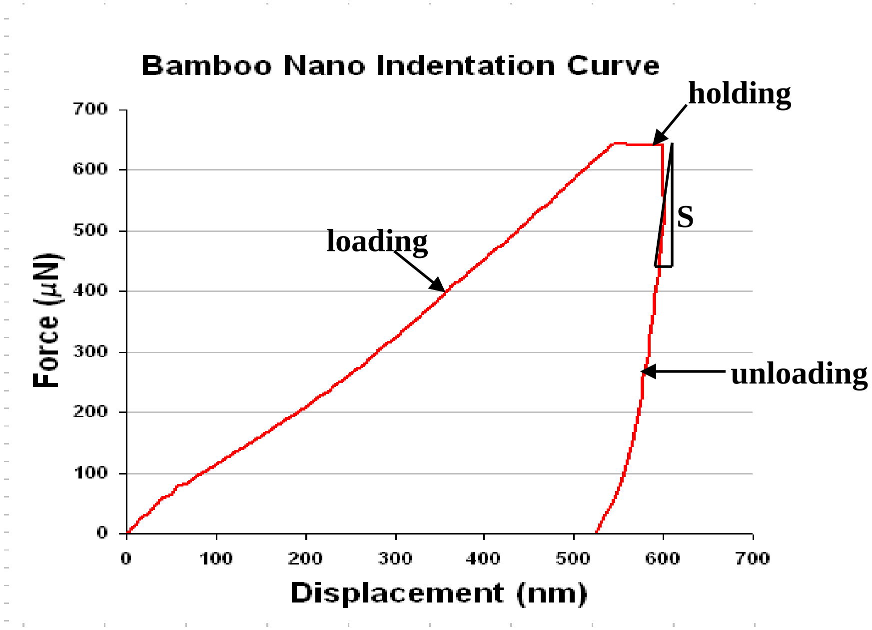


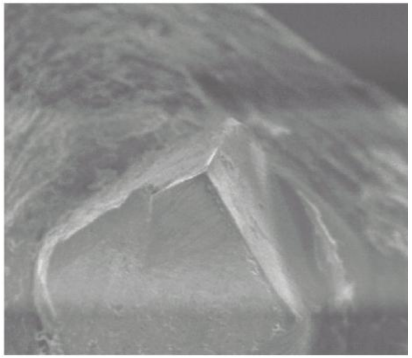




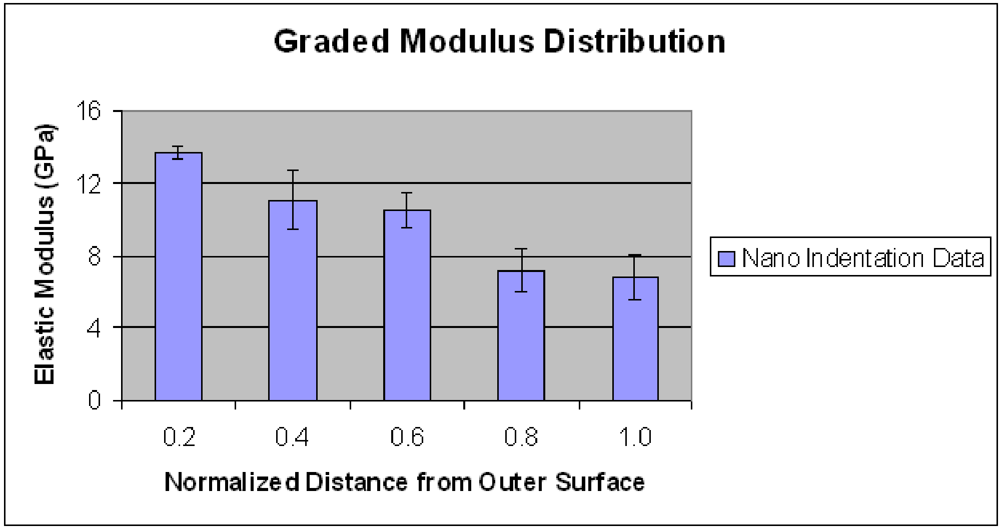
Nano-indentation Matrix
900 μm in width for 10 columns
4000 μm in length for 5 rows

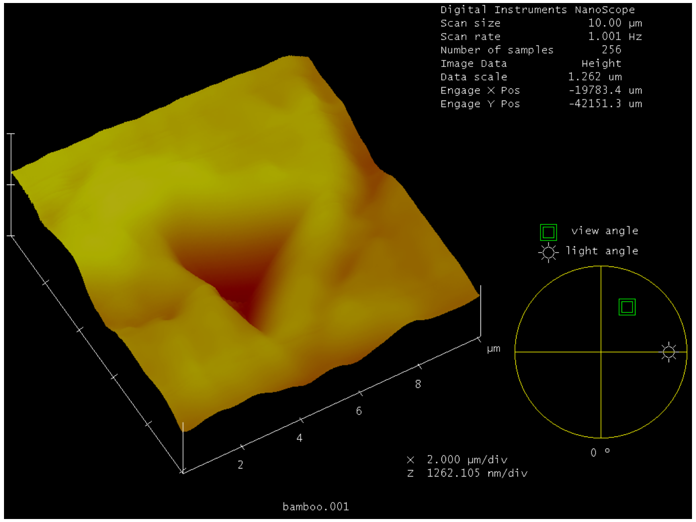
Functionally Graded Material



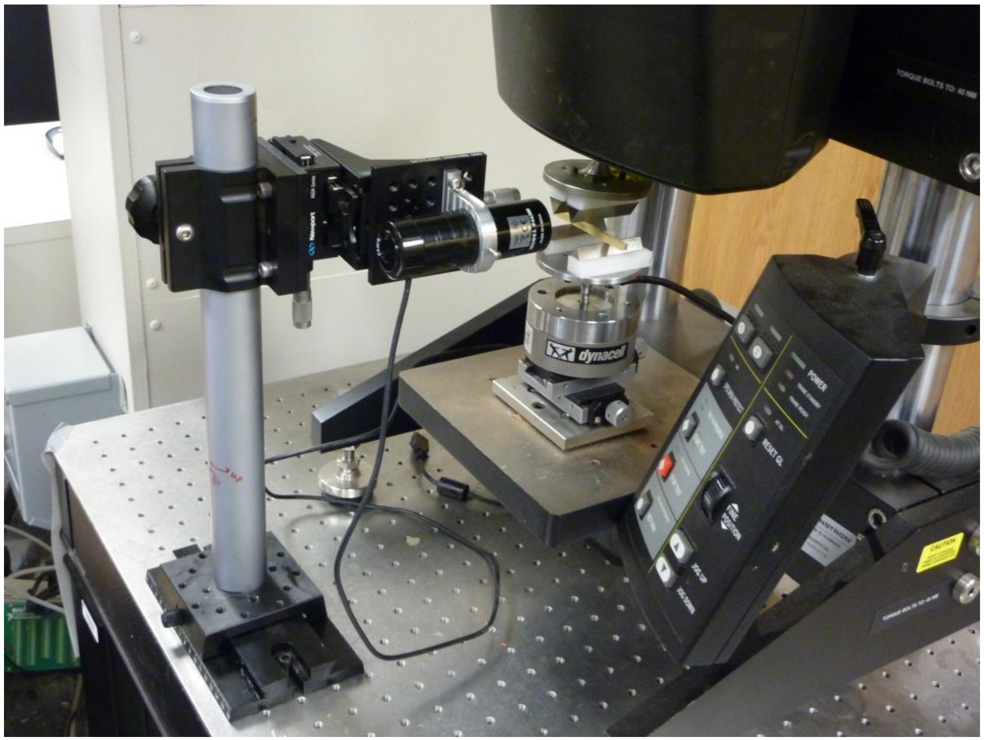


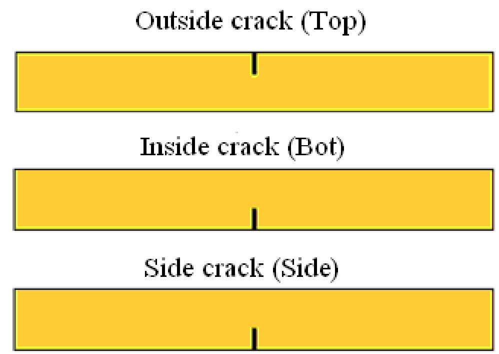
Cube-corner

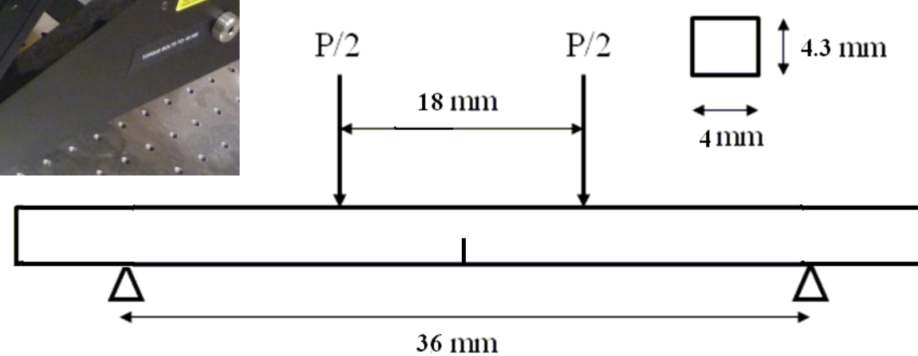




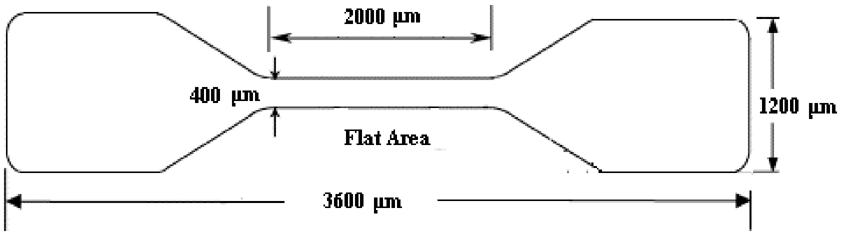
Fracture Experiments

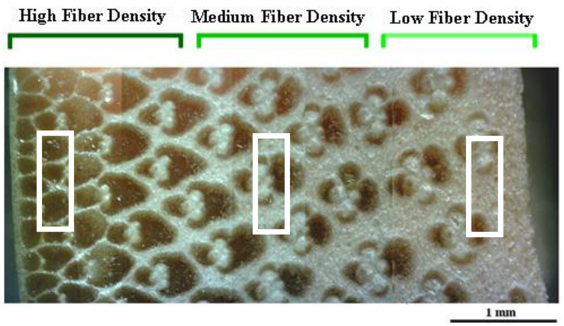


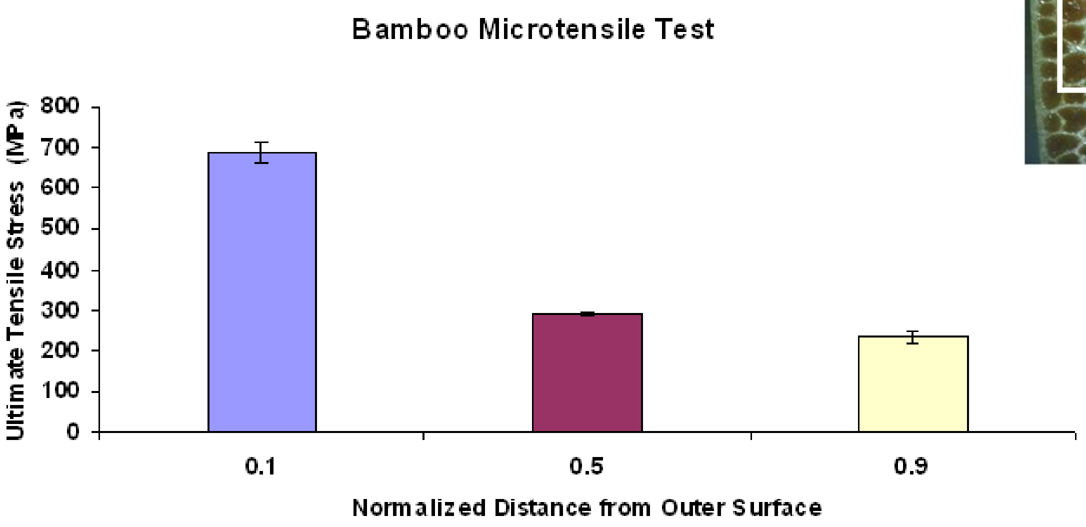




Microfiber Testing of Layers

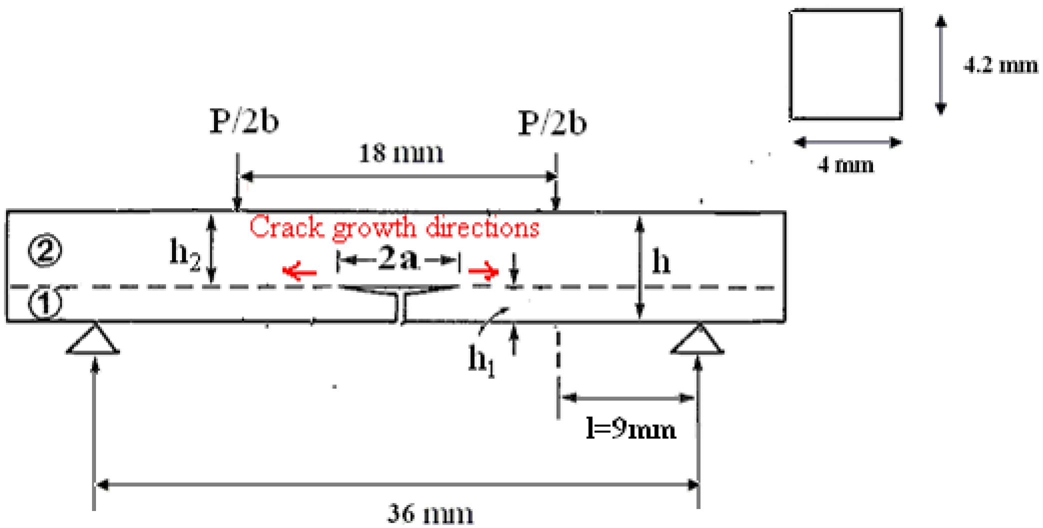






Analytical Fracture Mechanics Solutions

P.G. Charalambides, J. Lund , A. G. Evans and R. M. McMeeking (1989)



$$\mathcal{G}_{ss} = \frac{M^2\,(1-\nu_2^2)}{2E_2}\left(\frac{1}{I_2} - \frac{\lambda}{I_c}\right)$$

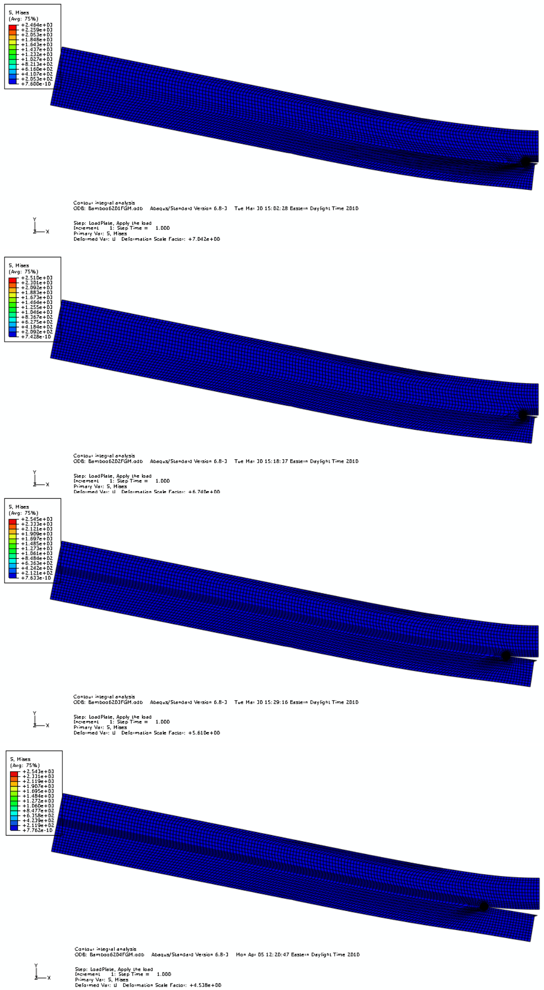
Where $M = Pl/2b$

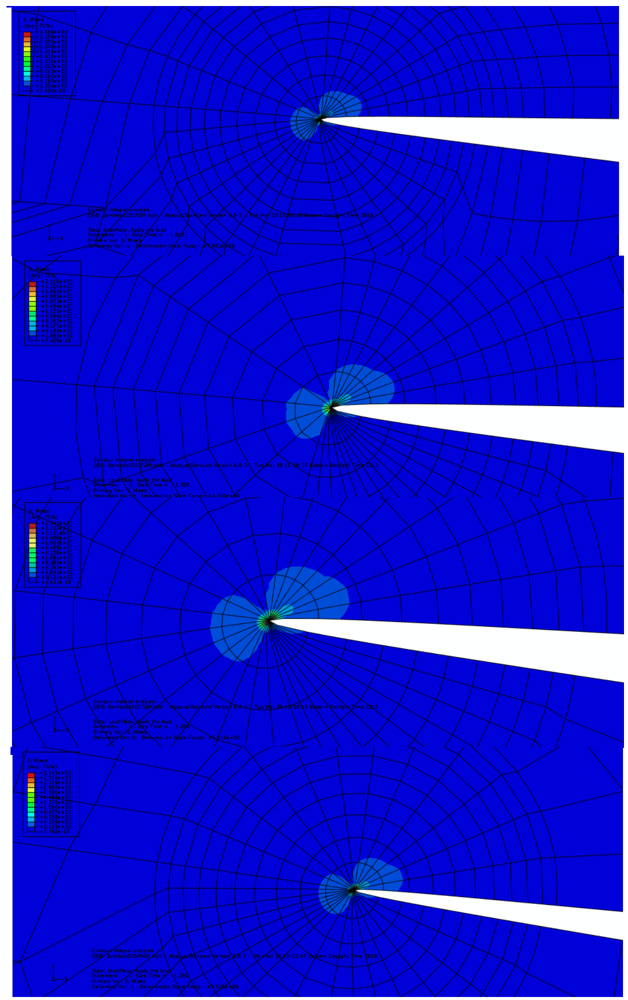
$$\lambda = E_2(1-\nu_1^2)/E_1(1-\nu_2^2)$$

$$I_c = h_1^3/12 + \lambda h_2^3/12 + \lambda h_1 h_2\ (h_1+h_2)^2/4(h_1+\lambda h_2)$$

and $I_2 = h_2^3/12$

FEM Modeling for FGM Beam





Crack Bridging Models

Small Scale Bridging Models (Budiansky, Evans and Amazigo)

$$K_c = K_m + \Delta K_{ssb} = K_m + \left(\frac{2}{\pi}\right)^{0.5} \alpha V_f \int_0^L \frac{\sigma_f}{x^{0.5}} dx$$

where

σ_f Flexural Stress

V_f Fiber Volume Fraction

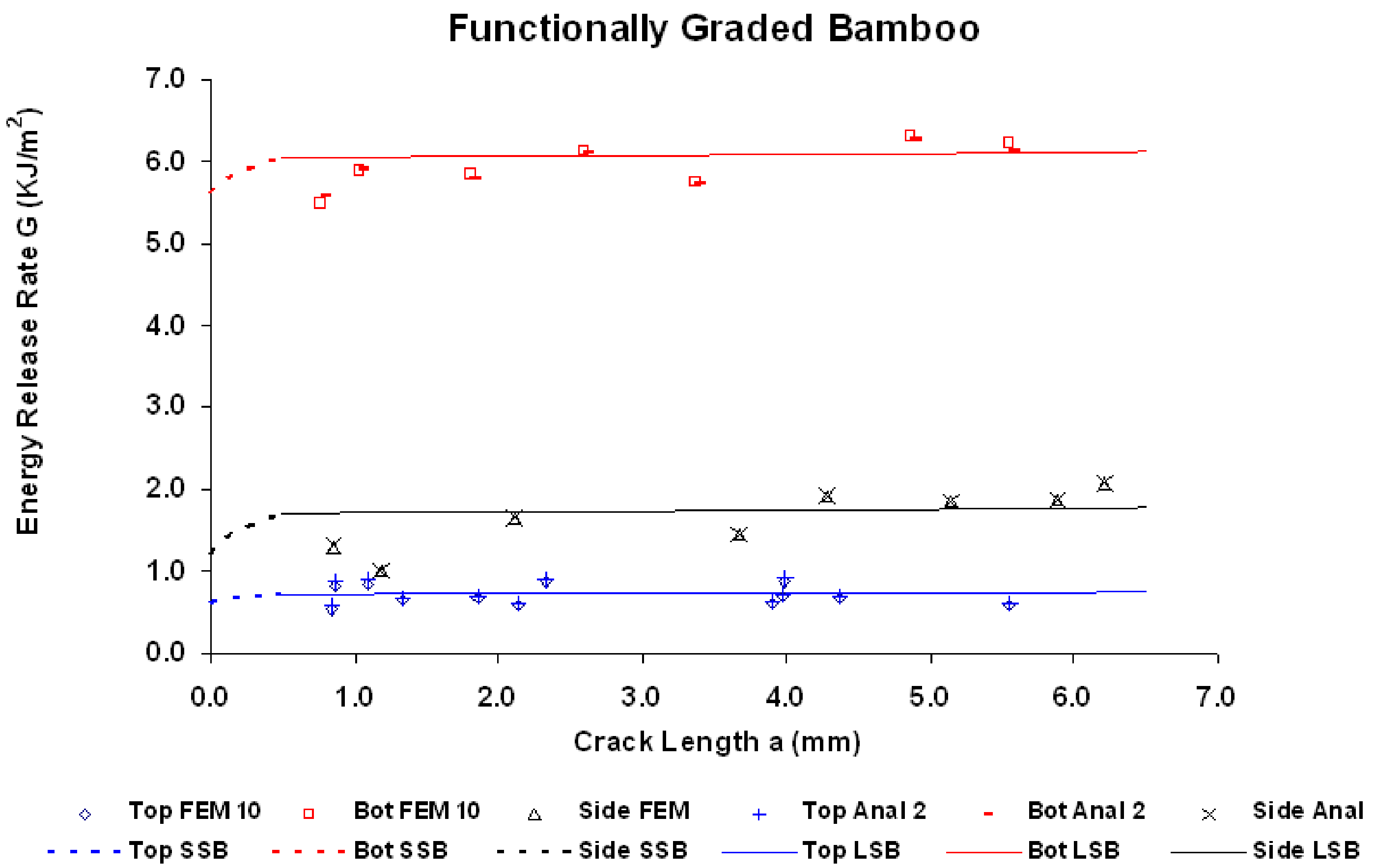
Large Scale Bridging Models (Fett and Munz, Bloyer et al.)

$$\Delta K_{ssb} = V_f \int_L \alpha \sigma_f h(a,x) dx$$

where

$$h(a,x) = \sqrt{\frac{2}{\pi a}} \frac{1}{\sqrt{1-\frac{x}{a}}} \left(1 + \sum_{v,\mu} \frac{A_{v\mu}\left(\frac{a}{W}\right)}{\left(1-\frac{a}{W}\right)} \left(1-\frac{x}{a}\right)^{v+1} \right)$$

Comparison

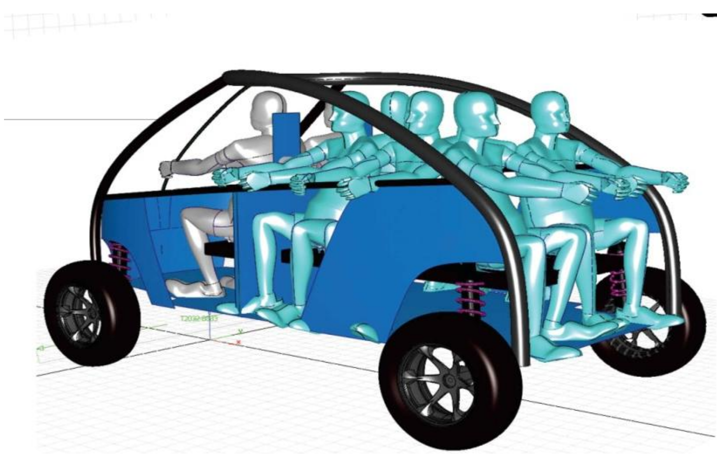

Functionally Graded Bamboo
Energy Release Rate G (KJ/m^2)
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
0.0
1.0
2.0
3.0
4.0
5.0
6.0
7.0
Crack Length a (mm)
Top FEM 10
Bot FEM 10
Side FEM
Top Anal 2
Bot Anal 2
Side Anal
Top SSB
Bot SSB
Side SSB
Top LSB
Bot LSB
Side LSB

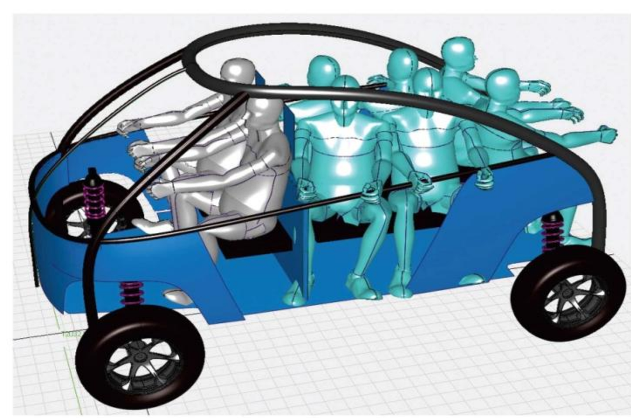
Bamboo Frame Bicycle

Nick Frey, Will Watts, Douglas Wolf, Tom Yersak
Ezekiel Odeh

Conceptual Design of The African Bamboo Car

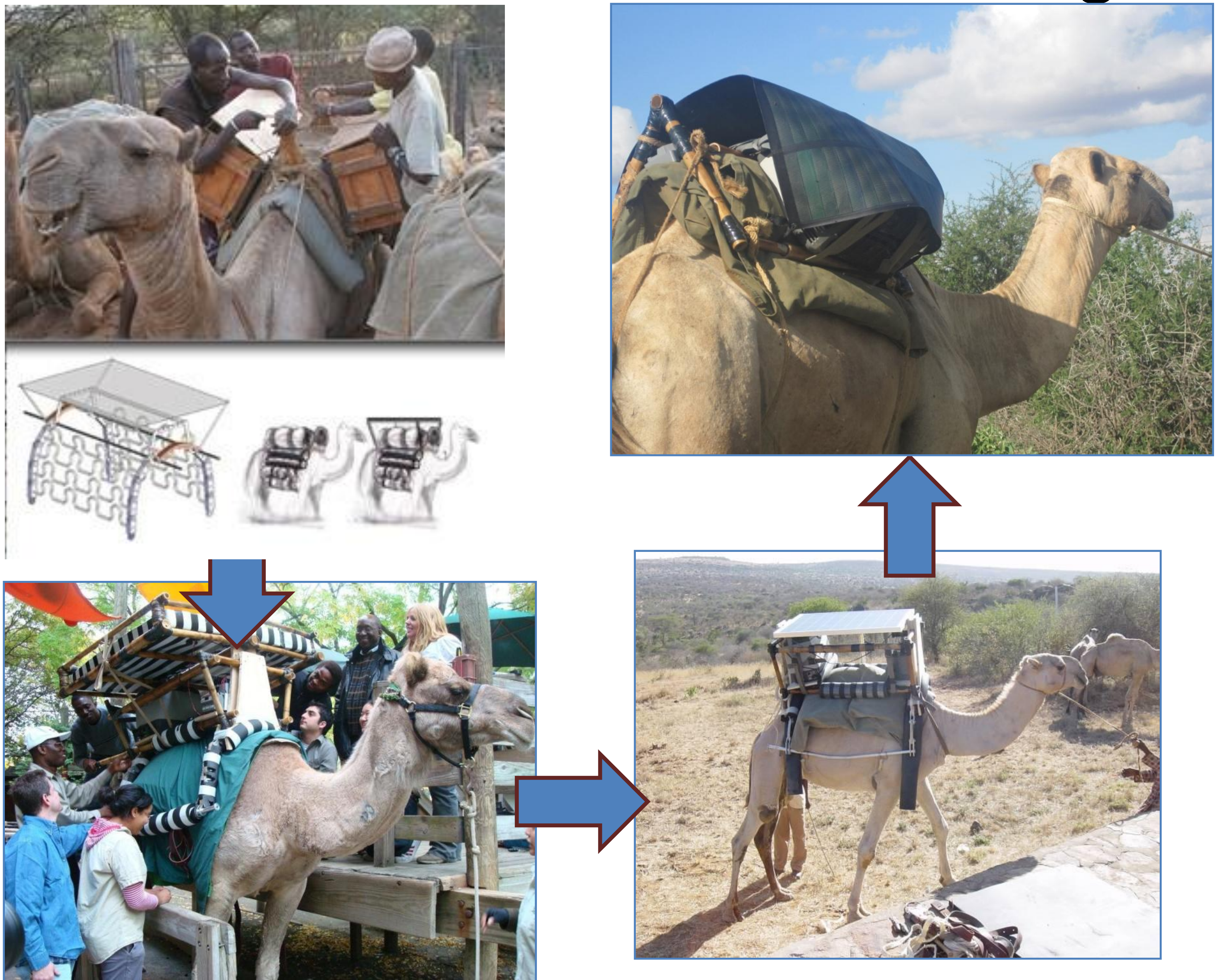
- Basic people mover concept – easy to construct
- Bamboo, leather and wood can be used
- Adaptable design for cargo and luggage space





Designer / Patrick Kiruki / K-Project

Evolution of Camel Solar Design



The Need for a Manufacturing Initiative

- African manufacturing initiative needed to ensure that Africa benefits from ongoing research
- Global manufacturing e.g. bamboo bicycles, solar cells
- Possible to develop collaborations between the US and Africa in these areas
  - Biomedical innovation
  - Natural products innovation
  - Solar cell/LED manufacturing
  - Bamboo bicycles
- The idea is to add value to human and natural resources through integrated education, research and innovation

The Role of Networks

- The key is to use networks as catalysts for economic development **e.g. RISE Networks such as AMSEN**
- Their potential has already been demonstrated recently by Africans in the **movie, spare parts, banking and religion industries**
- Similar networks are possible in the “knowledge” industry by forming networks that link
  - Africa to Africa
  - the international/diaspora to Africa e.g. ARIST
- However the span of activities must range from ideas to markets…

African Renaissance Institutes of Science and Technology (ARISTs)

- ARISTs are interdisciplinary centers of excellence (partnerships and networks) that are being created at existing African universities, research institutes and companies
- Initial focus on training the next generation of teachers and innovators e.g. 2iE, NASENI, KWASU etc
- The goal is to promote economic development through interdisciplinary research and education within networks (www.arist-edu.org)
- Networks are building bridges and developing solutions to Africa's problems
  - Health
  - Agriculture
  - Water
  - Energy
  - Value addition (materials and natural resources)
- Potential to link RISE, AMSEN and AIST initiatives

The Pan-African AIST/NMI Flower Model

Burkina Faso
Center for water and environmental engineering

Nigeria
AIST campus in Abuja and RISE HQ in Africa

Tanzania
AIST campus in Arusha

Nigeria
Center for offshore petroleum engineering (G2i)

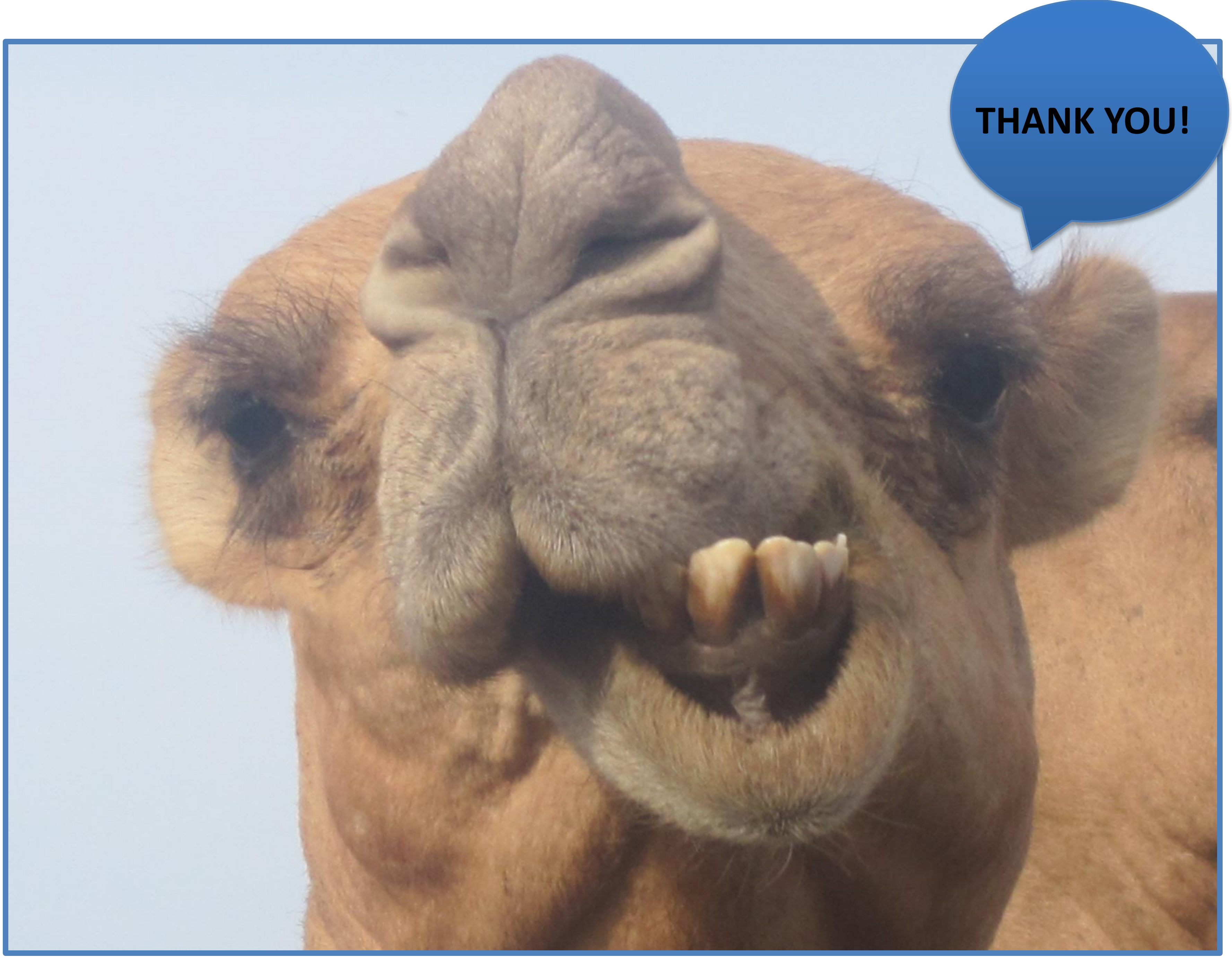
South Africa
Center for applied mathematics (partnering with the existing African Institute for Mathematical Sciences)

Building Synergies Through Networks and Centers

- There is the potential to build synergies by developing collaborations between
  - centers and networks e.g. AUST and RISE or AUST and AMSEN (PASMAT)
  - Networks and networks e.g. AMSEN and AMRS
  - ARIST to engage the African Adiaspora and international scientists
- There is also the potential to develop US/Africa collaborations such as USAMI
  - Student/faculty exchange visits to Princeton and other US universities
  - Access to specialty equipment e.g. synchrotron sources at Brook Haven National Lab
  - Innovation programs to go from ideas to markets

Summary and Concluding Remarks

- This talk presents some examples of recent collaborations between African and international scientists in the area of materials science for development – holistic approach needed
- The contributions of African scientists were highlighted in the areas of biomaterials, organic electronics and eco-materials & materials for water purification
- RISE, AMSEN, The AUST Abuja and the African Materials Network have a key role to play in harnessing the potential of Africa – need to build on the PASMAT experience
- This could be done in partnership with other African universities – with a focus on capacity development, collaborative research and innovation
- We welcome your involvement in these programs that could lead to a new generation of “African lions” with networks as the engines……


THANK YOU!