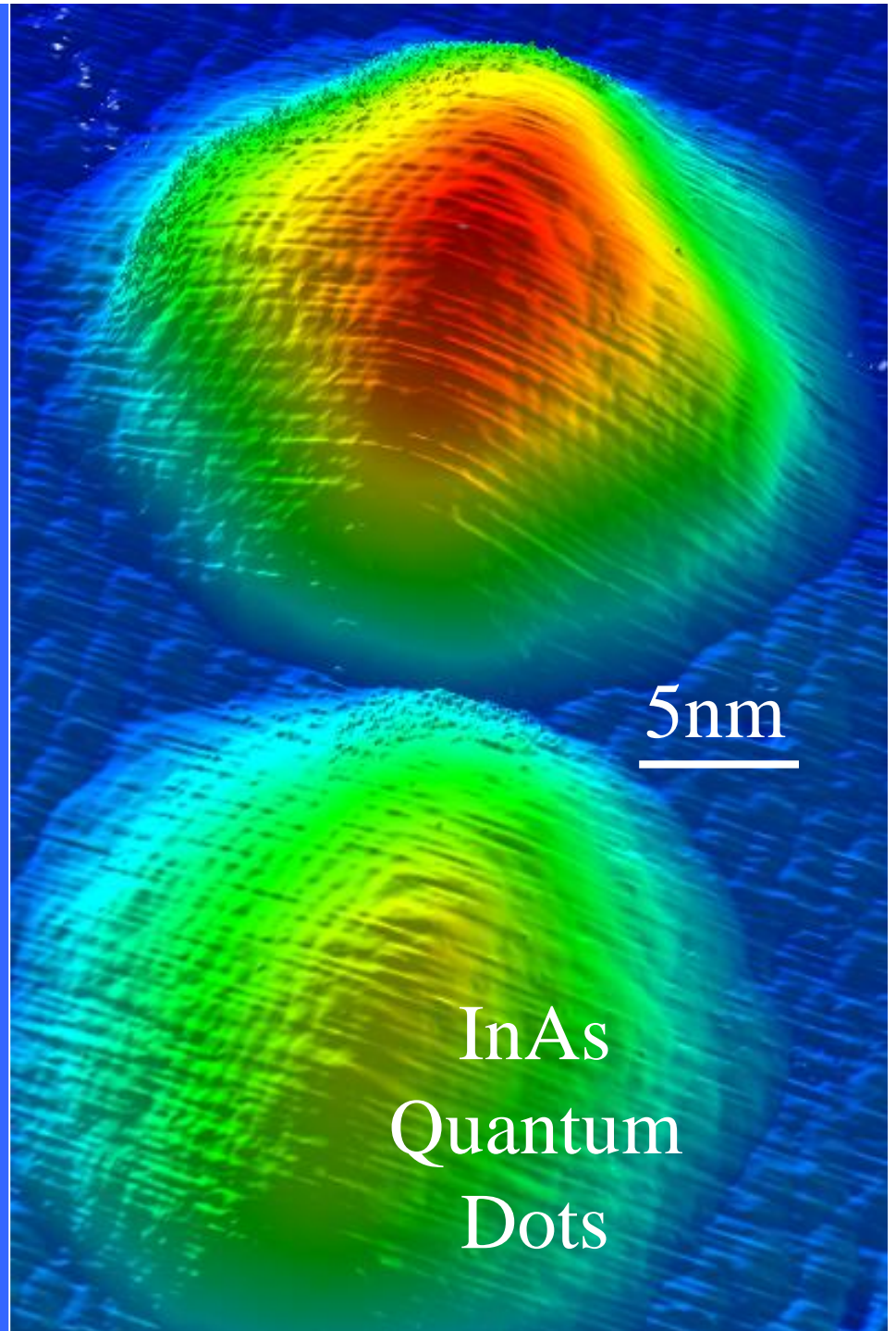


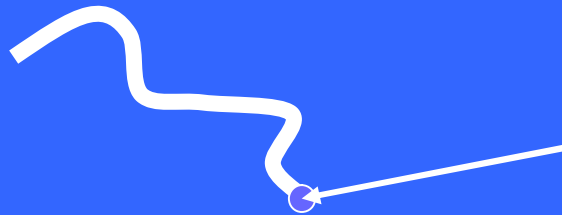
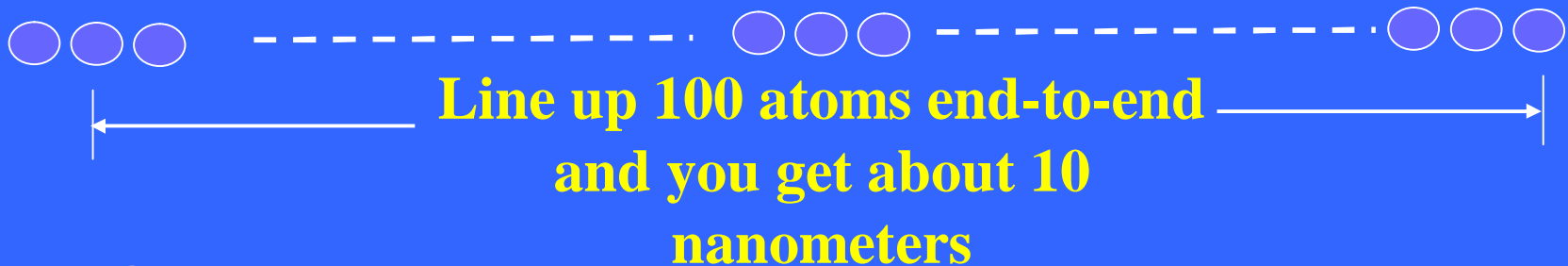
*Nanoscale  
Materials Inspires  
Innovation  
and  
Drives Economic  
Development*

*Greg Salamo  
&  
Alex Biris*



# What is Nanoscience ?

*The effort to understand and design structures at the nano size and seek their application*



Take the diameter of a hair and divide  
by 100,000 and you have a diameter of  
nanometer size



# Chemical Periodic Table

## Why are nanomaterials the driver of innovation?

<p>Atomic Weight ( ) indicates longest-lived isotope</p> <p>Acidity/Basicity<sup>2</sup> &amp; Crystal Structure<sup>3</sup></p> <p>Melting Point<sup>1</sup>, °C Boiling Point<sup>1</sup>, °C</p> <p>Density<sup>2</sup> (300 K), g/cm<sup>3</sup> for gases: g/L, 273.15 K, 1 atm</p> <p>Electronegativity</p>																		<p>Group Classifications<sup>4</sup></p> <p>Atomic Number</p> <p>Oxidation States bold indicates most stable state</p> <p>Symbol<sup>1</sup></p> <p>Electronic Configuration</p> <p>Name</p>																	
<p>1 IA 1 H 1.00794 Hydrogen</p>																		<p>2 IIA 4 He 4.002602 Helium</p>																	
<p>3 IIIA Li 6.941 Lithium</p>																		<p>4 IIIA Be 9.012182 Beryllium</p>																	
<p>11 IIIA Na 22.990 Sodium</p>																		<p>12 IIA Mg 24.305 Magnesium</p>																	
<p>19 K 39.0983 Potassium</p>																		<p>20 Ca 40.078 Calcium</p>																	
<p>21 Sc 44.955912 Scandium</p>																		<p>22 Ti 47.88 Titanium</p>																	
<p>23 V 50.9415 Vanadium</p>																		<p>24 Cr 51.9961 Chromium</p>																	
<p>25 Mn 54.938045 Manganese</p>																		<p>26 Fe 55.845 Iron</p>																	
<p>27 Co 58.933195 Cobalt</p>																		<p>28 Ni 58.6934 Nickel</p>																	
<p>29 Cu 63.546 Copper</p>																		<p>30 Zn 65.38 Zinc</p>																	
<p>31 Ga 69.723 Gallium</p>																		<p>32 Ge 72.64 Germanium</p>																	
<p>33 As 74.921595 Arsenic</p>																		<p>34 Se 78.96 Selenium</p>																	
<p>35 Br 79.904 Bromine</p>																		<p>36 Kr 83.80 Krypton</p>																	
<p>37 Rb 85.4678 Rubidium</p>																		<p>38 Sr 87.62 Strontium</p>																	
<p>39 Y 88.905848 Yttrium</p>																		<p>40 Zr 91.224 Zirconium</p>																	
<p>41 Nb 92.90638 Niobium</p>																		<p>42 Mo 95.94 Molybdenum</p>																	
<p>43 Tc 98.90625 Technetium</p>																		<p>44 Ru 101.07 Ruthenium</p>																	
<p>45 Rh 102.90550 Rhodium</p>																		<p>46 Pd 106.42 Palladium</p>																	
<p>47 Ag 107.8682 Silver</p>																		<p>48 Cd 112.411 Cadmium</p>																	
<p>49 In 114.818 Indium</p>																		<p>50 Sn 118.710 Tin</p>																	
<p>51 Sb 121.757 Antimony</p>																		<p>52 Te 127.60 Tellurium</p>																	
<p>53 I 126.90447 Iodine</p>																		<p>54 Xe 131.29 Xenon</p>																	
<p>55 Cs 132.90545 Cesium</p>																		<p>56 Ba 137.327 Barium</p>																	
<p>57 La 138.90483 Lanthanum</p>																		<p>58 Ce 140.12 Cerium</p>																	
<p>59 Pr 140.90768 Praseodymium</p>																		<p>60 Nd 144.24 Neodymium</p>																	
<p>61 Pm 144.91274 Promethium</p>																		<p>62 Sm 150.36 Samarium</p>																	
<p>63 Eu 151.964 Europium</p>																		<p>64 Gd 157.25 Gadolinium</p>																	
<p>65 Tb 158.92534 Terbium</p>																		<p>66 Dy 162.50 Dysprosium</p>																	
<p>67 Ho 164.93033 Holmium</p>																		<p>68 Er 167.26 Erbium</p>																	
<p>69 Tm 168.93421 Thulium</p>																		<p>70 Yb 173.054 Ytterbium</p>																	
<p>71 Lu 174.967 Lutetium</p>																		<p>72 Hf 178.49 Hafnium</p>																	
<p>73 Ta 180.94788 Tantalum</p>																		<p>74 W 183.84 Tungsten</p>																	
<p>75 Re 186.207 Rhenium</p>																		<p>76 Os 190.23 Osmium</p>																	
<p>77 Ir 192.22 Iridium</p>																		<p>78 Pt 195.084 Platinum</p>																	
<p>79 Au 196.966569 Gold</p>																		<p>80 Hg 200.59 Mercury</p>																	
<p>81 Tl 204.3833 Thallium</p>																		<p>82 Pb 207.2 Lead</p>																	
<p>83 Bi 208.980393 Bismuth</p>																		<p>84 Po 209 Polonium</p>																	
<p>85 At 210 Astatine</p>																		<p>86 Rn 222 Radon</p>																	
<p>87 Fr 223.0197 Francium</p>																		<p>88 Ra 226.0254 Radium</p>																	
<p>89 Ac 227.0278 Actinium</p>																		<p>90 Th 232.0377 Thorium</p>																	
<p>91 Pa 231.03626 Protactinium</p>																		<p>92 U 238.02891 Uranium</p>																	
<p>93 Np 237.04817 Neptunium</p>																		<p>94 Pu 244.06422 Plutonium</p>																	
<p>95 Am 243.06136 Americium</p>																		<p>96 Cm 247.07035 Curium</p>																	
<p>97 Bk 247.07035 Berkelium</p>																		<p>98 Cf 251.07887 Californium</p>																	
<p>99 Es 252.083 Einsteinium</p>																		<p>100 Fm 257.09331 Fermium</p>																	
<p>101 Md 258.10 Mendelevium</p>																		<p>102 No 259.10888 Nobelium</p>																	
<p>103 Lr 262.101 Lawrencium</p>																		<p>104 Unq Unquadium</p>																	
<p>105 Unp Unpentium</p>																		<p>106 Unh Unhexium</p>																	
<p>107 Uns Unseptium</p>																		<p>108 Uno Unoctium</p>																	
<p>109 Une Unennium</p>																		<p>110 Uub Unbinilium</p>																	

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140.115 82 Ce Cerium	140.90768 59 Pr Praseodymium	144.24 60 Nd Neodymium	144.91274 61 Pm Promethium	150.36 62 Sm Samarium	151.964 63 Eu Europium	157.25 64 Gd Gadolinium	158.92534 65 Tb Terbium	162.50 66 Dy Dysprosium	164.93033 67 Ho Holmium	167.26 68 Er Erbium	168.93421 69 Tm Thulium	173.054 70 Yb Ytterbium	174.967 71 Lu Lutetium
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CHEMICAL PERIODIC TABLE, 3rd Edition

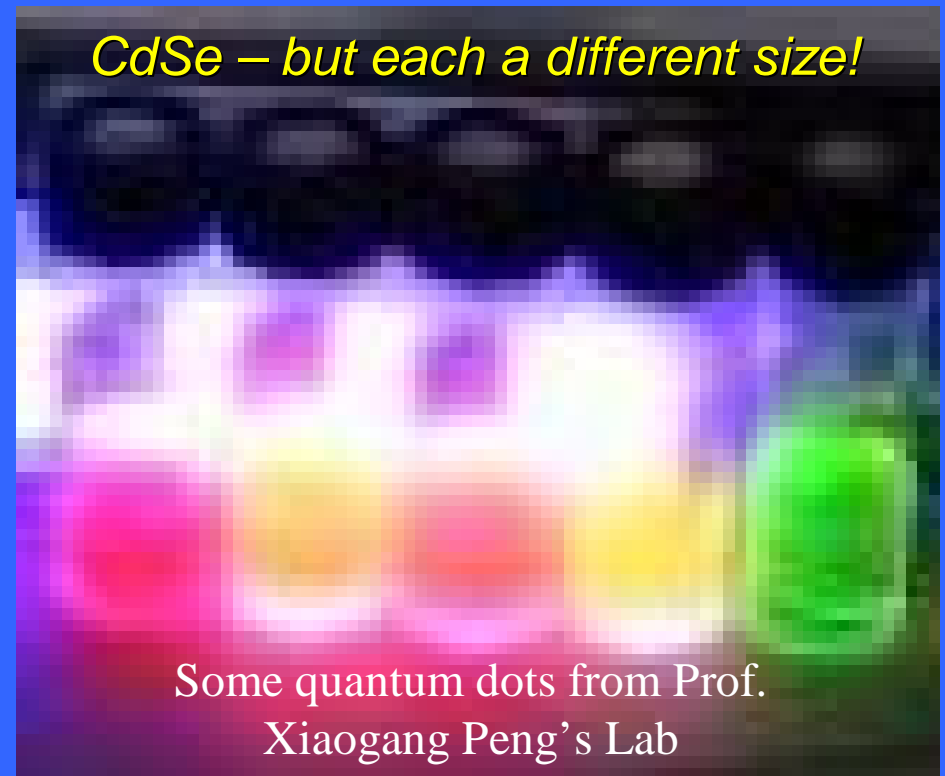
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ISBN 1-55180-065-5

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# Take Any Element in the Periodic Table

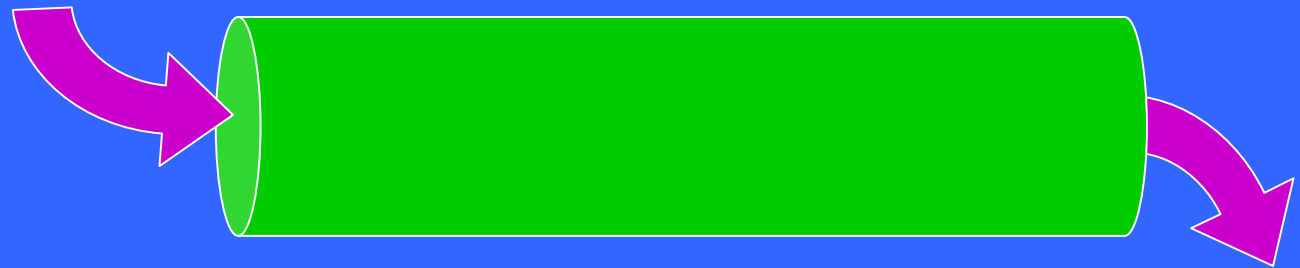
*It will have very different optical, electrical, or mechanical properties depending on its size!*



***Throughout history new materials  
inspired innovation***

# Why this Change in Behavior? New Rules When We Go Very Small

Easy to Cause Flow



If it's Small it is Difficult  
to Cause Flow



# Impact of Nanotechnology in

## Healthcare, Energy Efficiency, and Renewable Energy



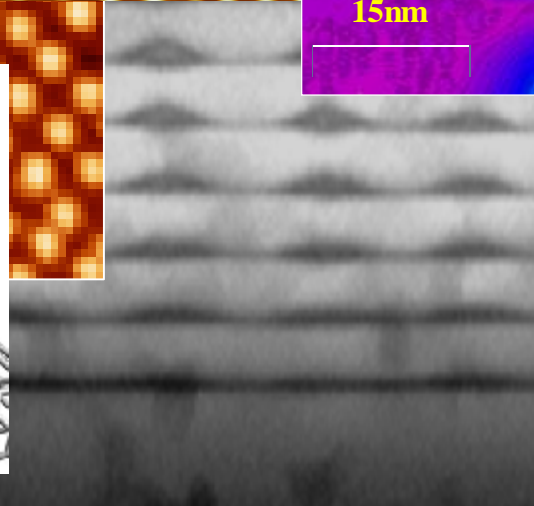
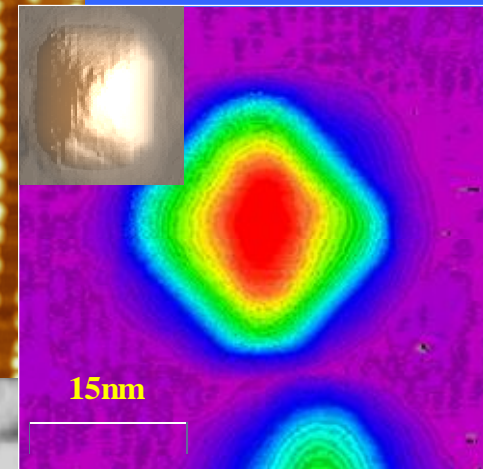
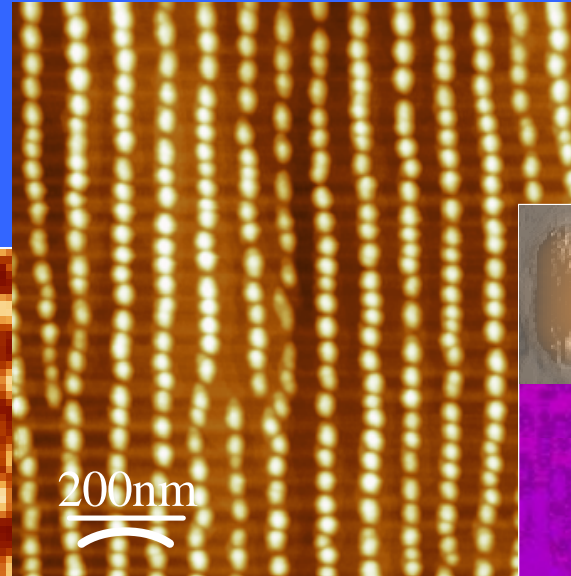
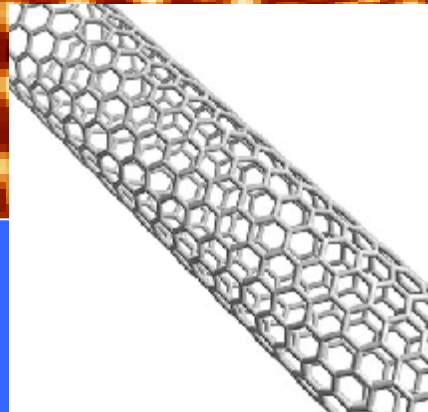
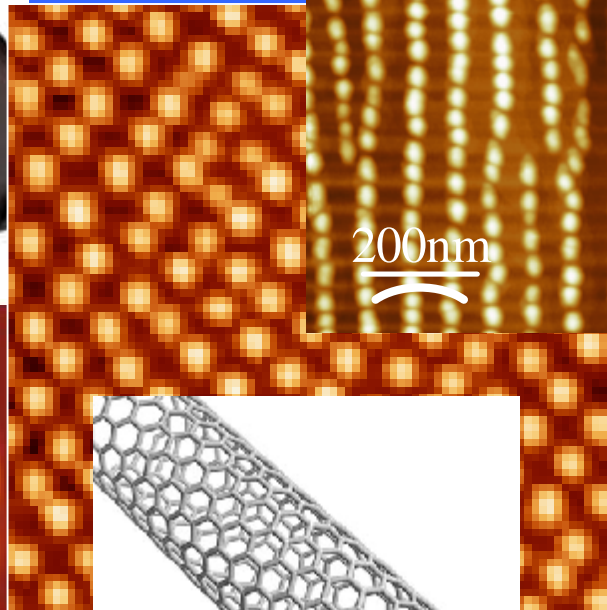
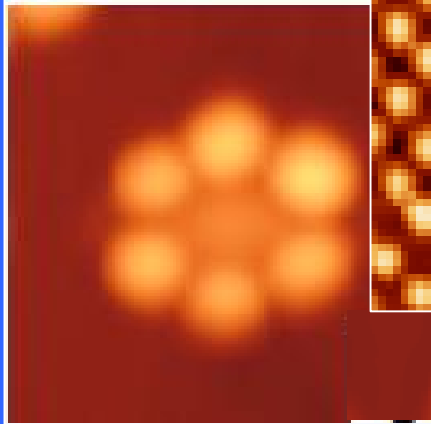


# State-of-the-Art Growth & Fabrication Facilities



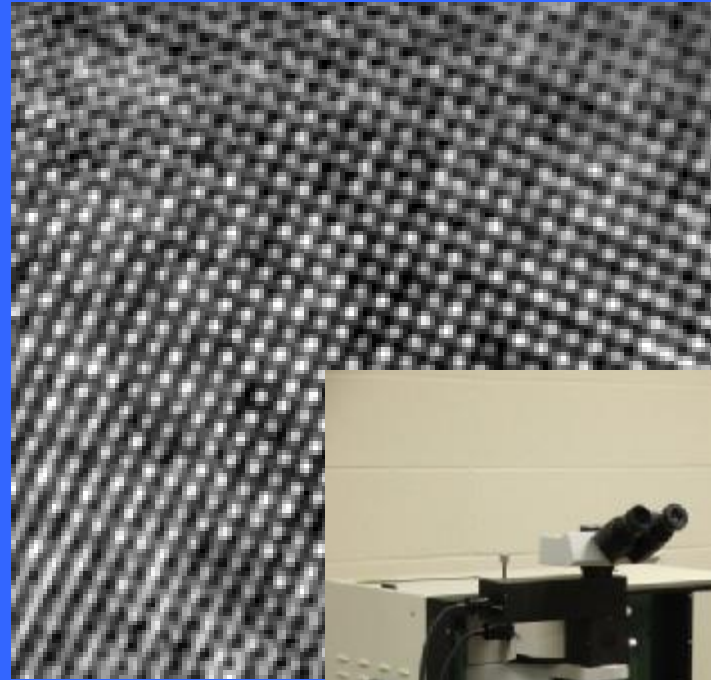


# Form Molecules or Chains or 3D arrays made of Nanoscale materials



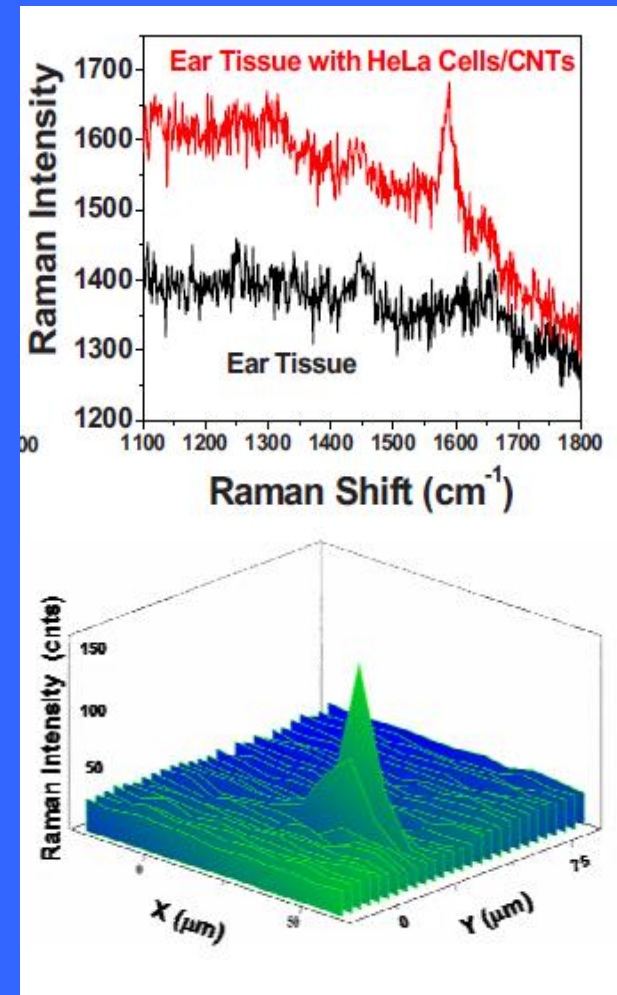
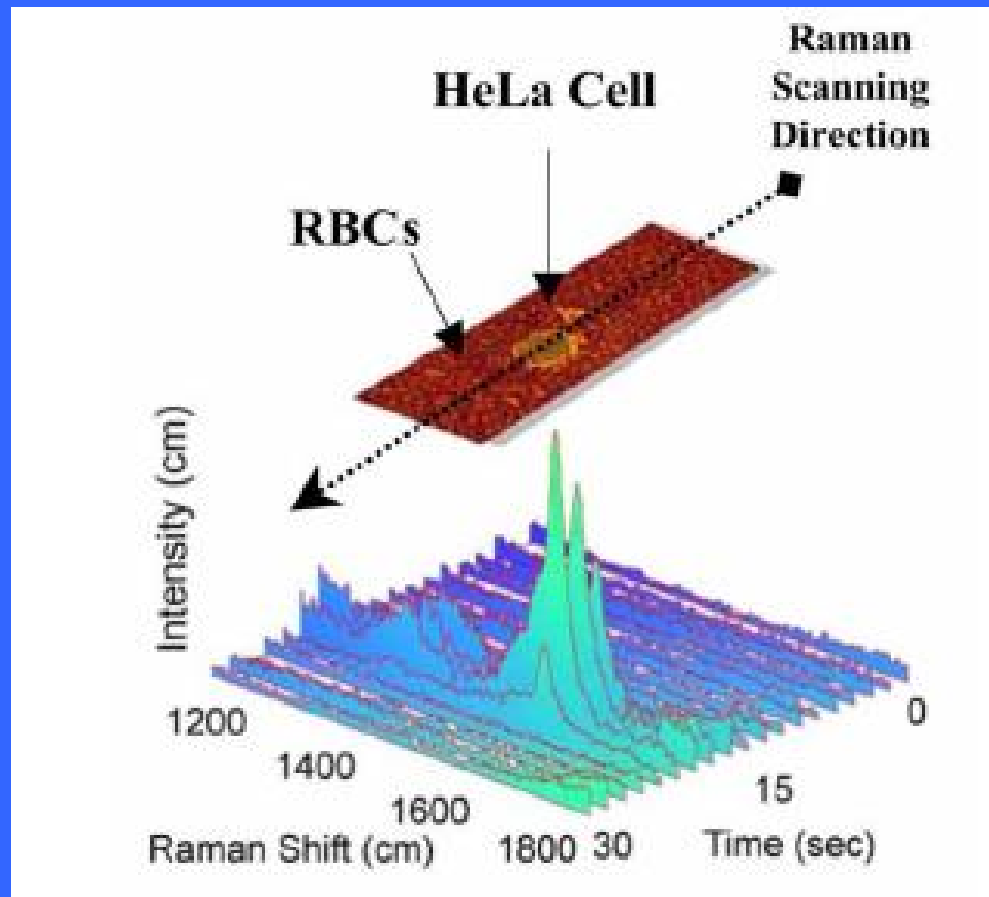


# State-of-the-art Nanoscale Materials Imaging Tools



FIB, STM; AFM; SEM, STM/SEM X-Ray; XPS; TEM, etc.

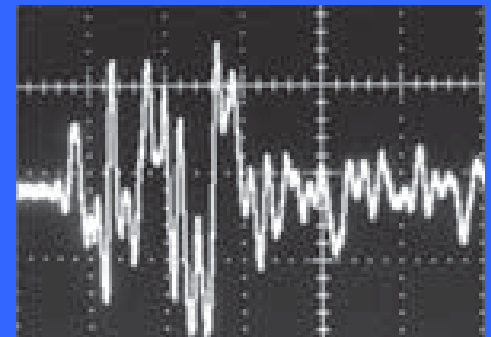
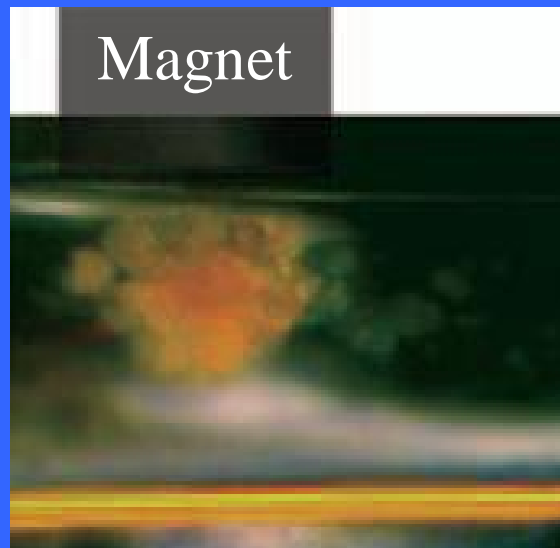
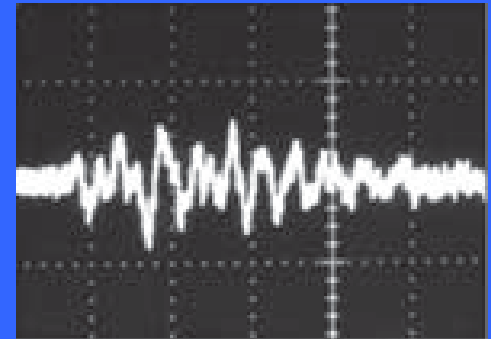
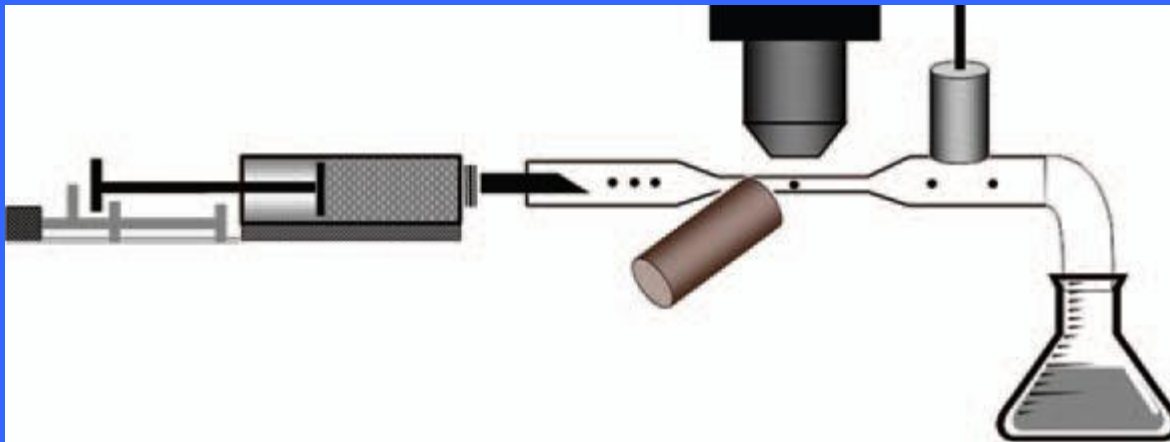
# Healthcare: Cancer Cell Detection in Blood/Ear Tissue (Zharov – Biris)



**What is new here – Detection of a Single Cell in Blood**

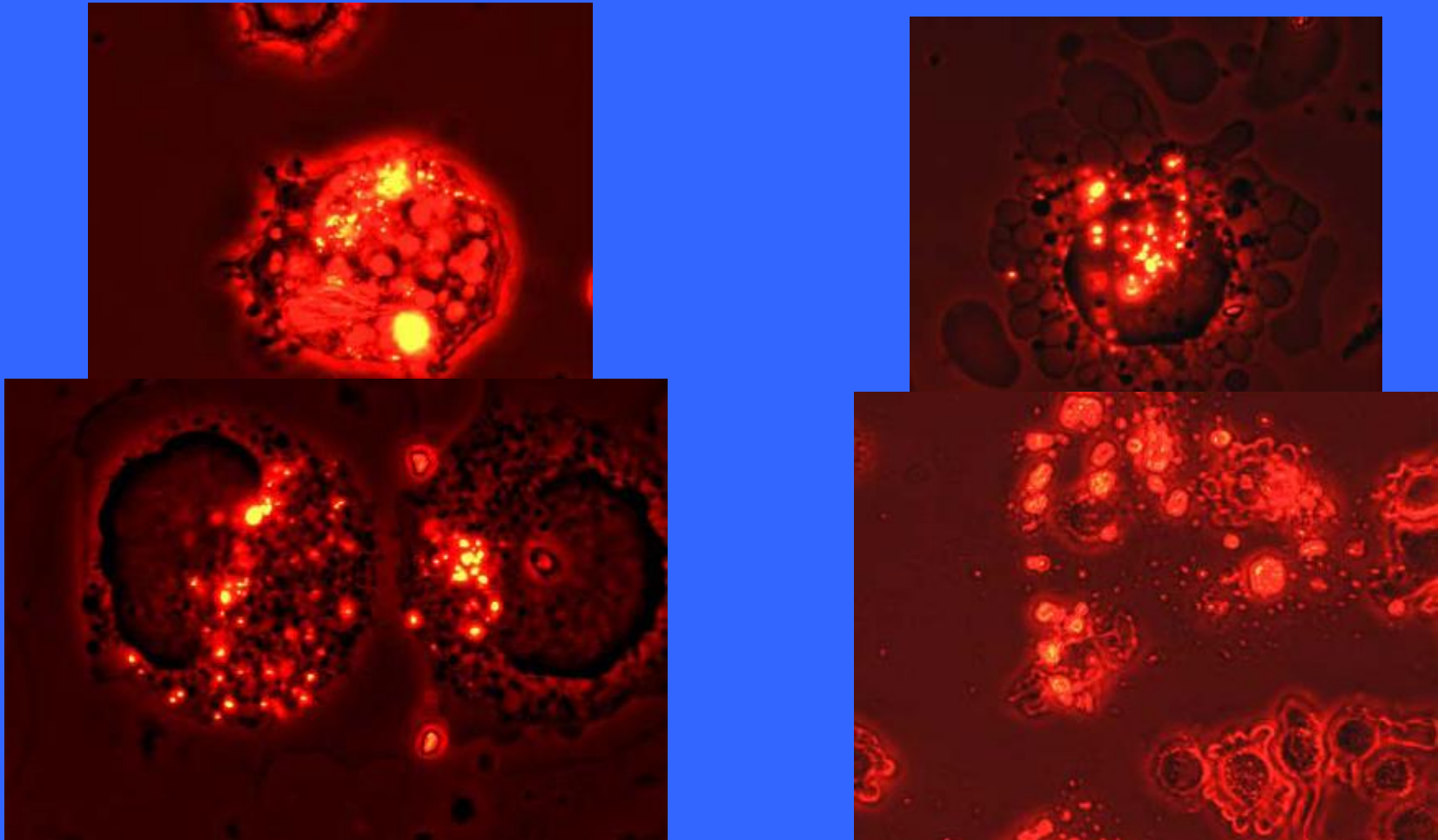
# Healthcare: In Vivo Magnetic Enrichment & Photoacoustic Detection of Circulating Tumor Cells

(Zhang and Kim)





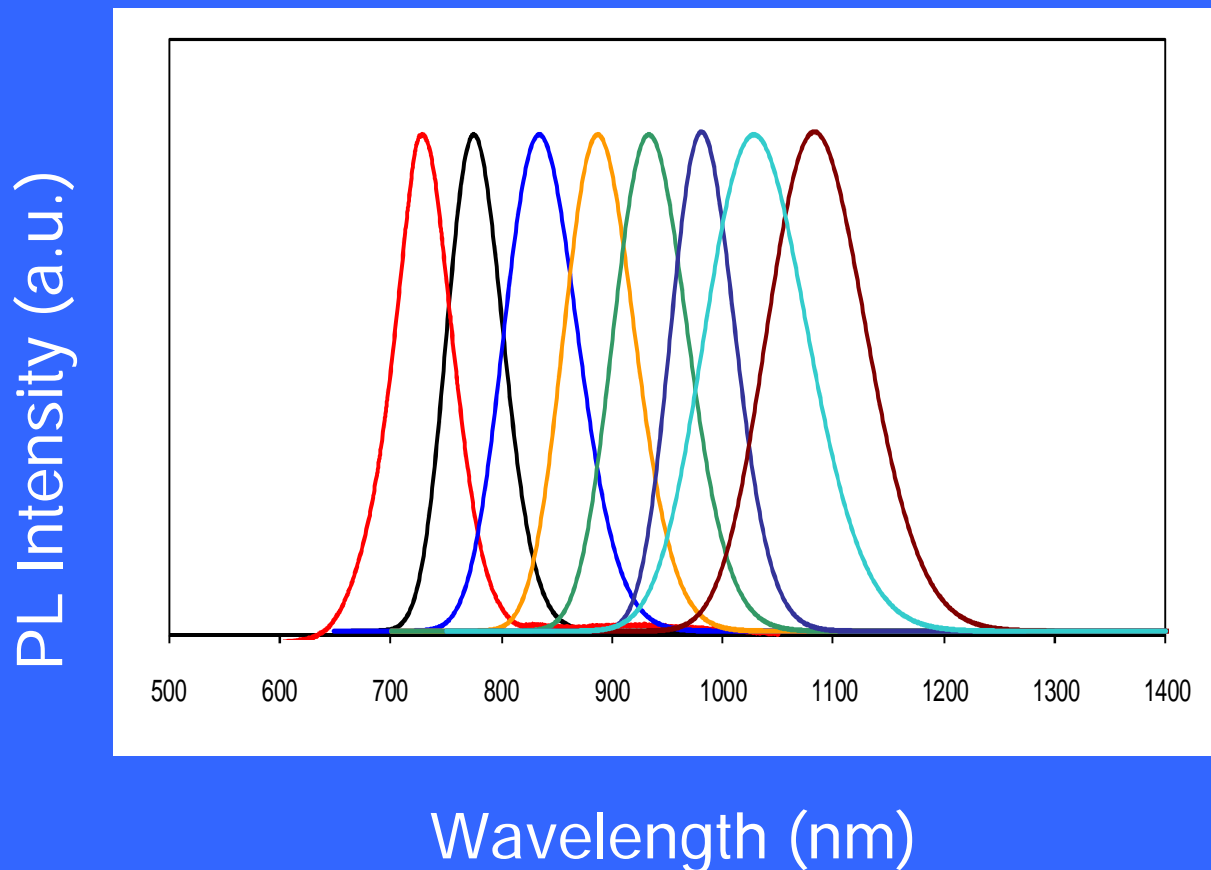
# Healthcare: Optical-Magnetic Nanoparticles for Cancer Treatment (Biris)



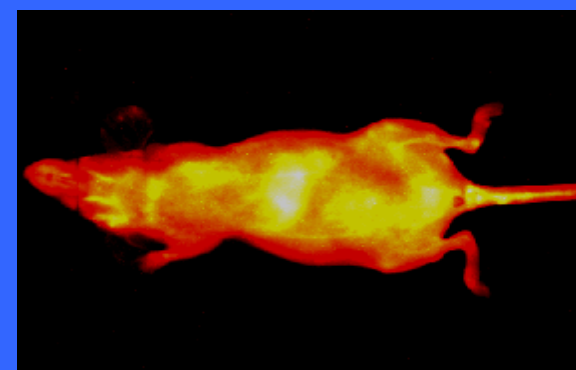
**What is new here: Exploding Cells under RF**

# Healthcare: Imaging Through Tissue

## InAs/InP/ZnSe Q-dots (Peng)



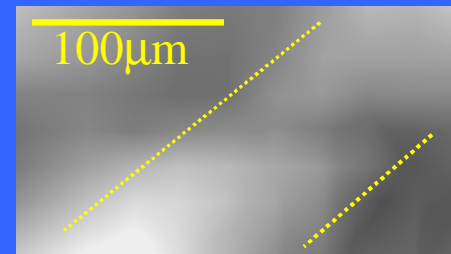
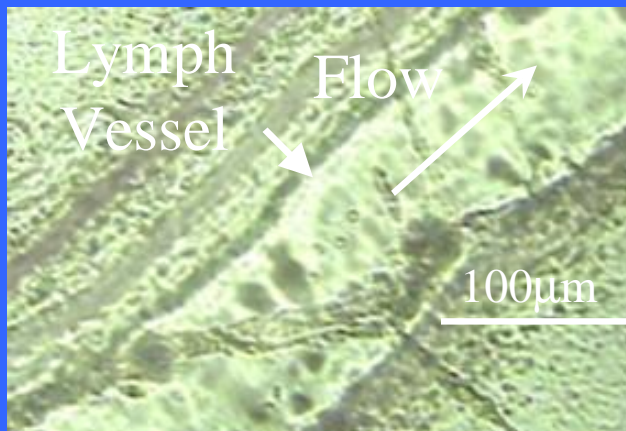
*What is new here – flexible Infra-red emission*



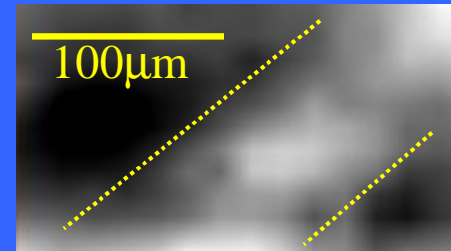
InAs dots  
(NIR) *in vivo*  
imaging

# Healthcare: Uptake and Clearing of CNTs by Lymph Vessel (Zharov & Biris)

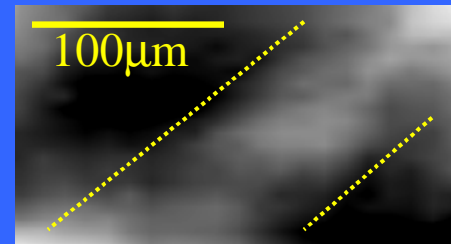
## Raman Analysis



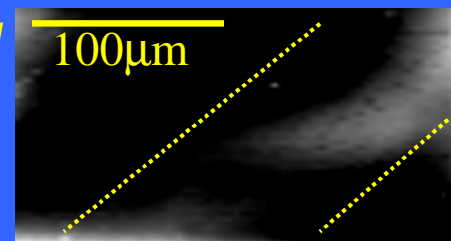
Time – 2 min



Time – 12 min

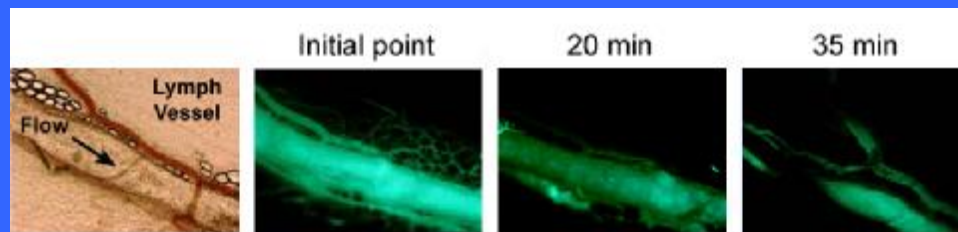


Time – 22 min



Time – 32 min

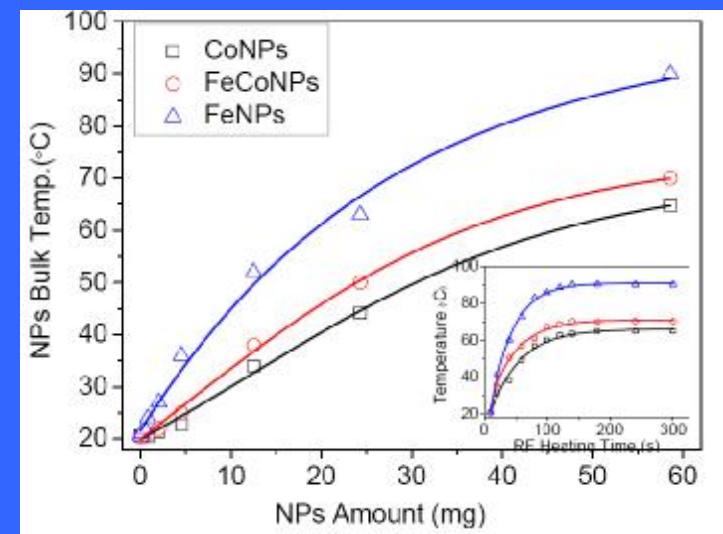
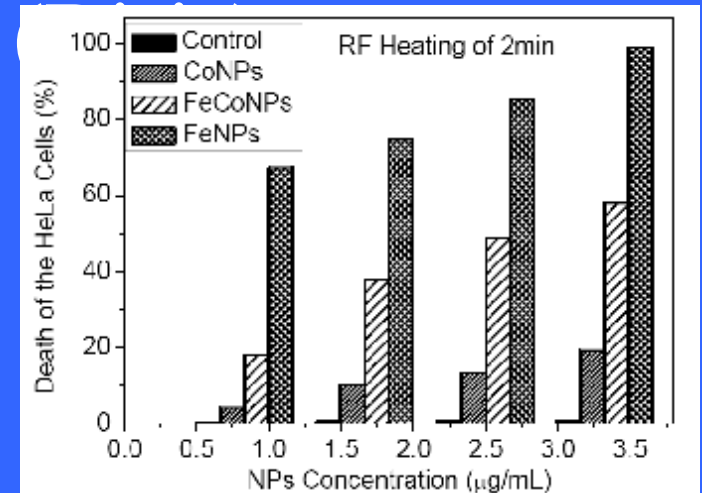
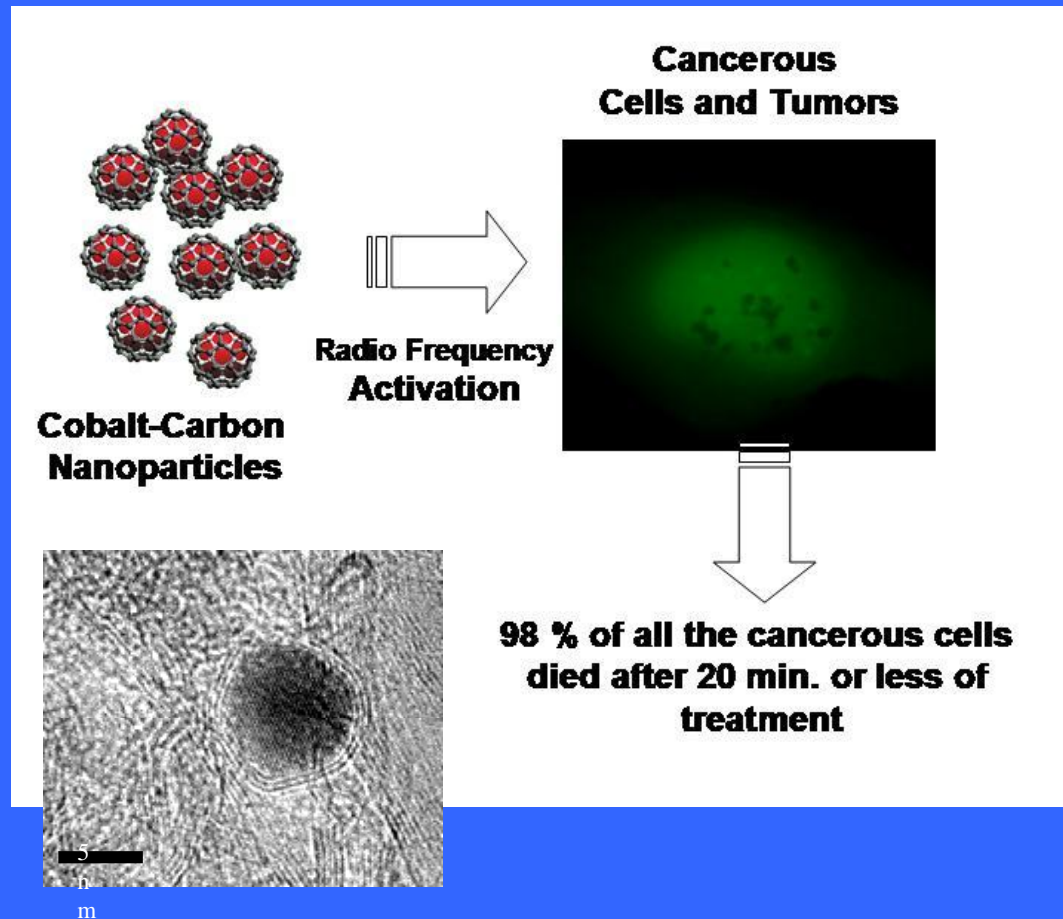
## Fluorescent Dye Analysis



**What is new here – CNT enter and propagate in Lymphatic**

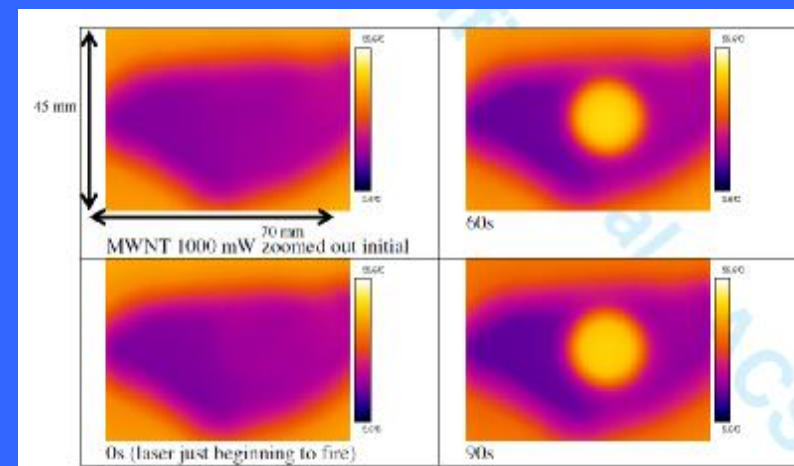
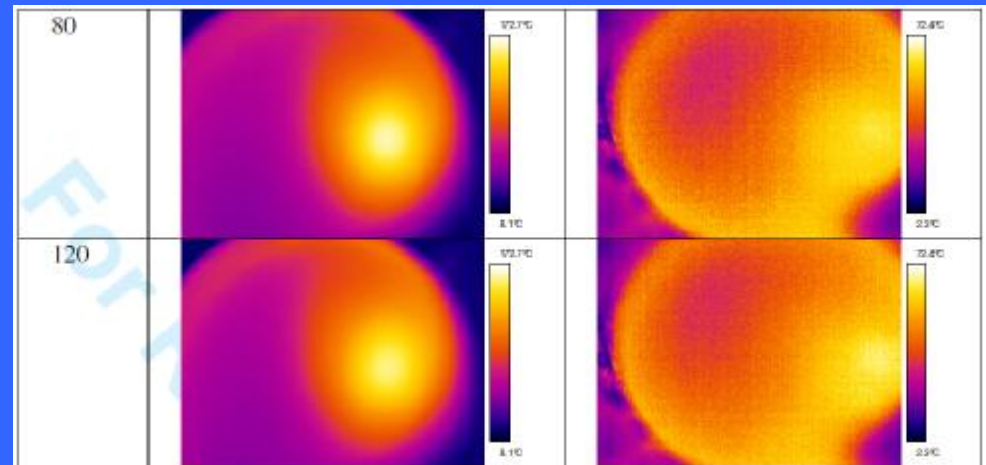
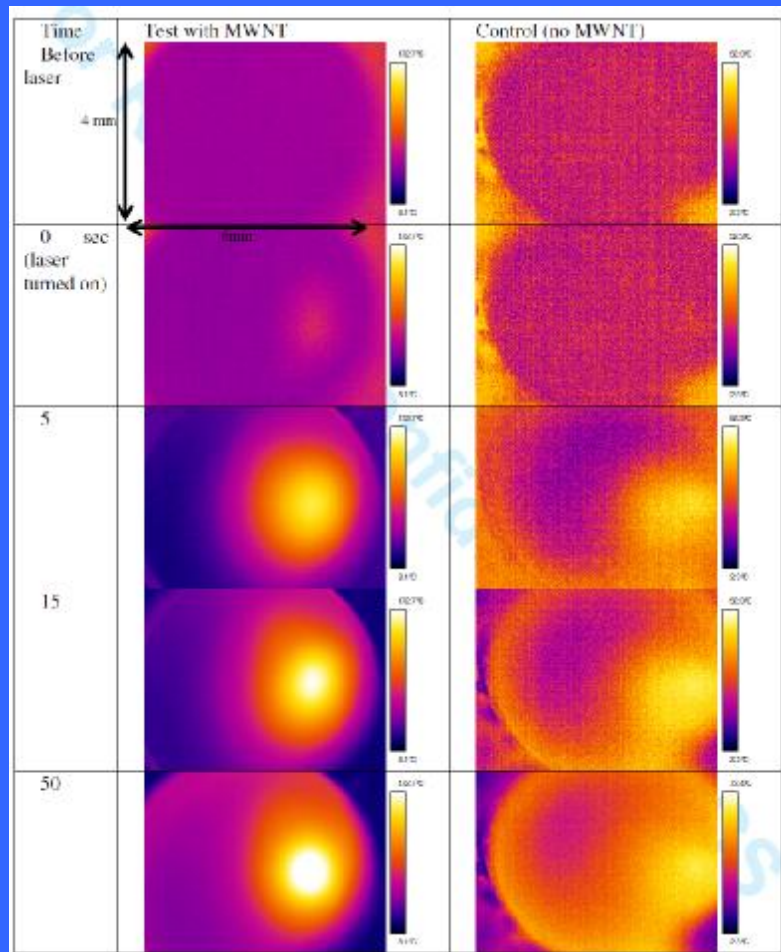


# Healthcare: Graphitic Coated Magnetic Nanoparticles for Heating Cancer Cells with Radio Frequency



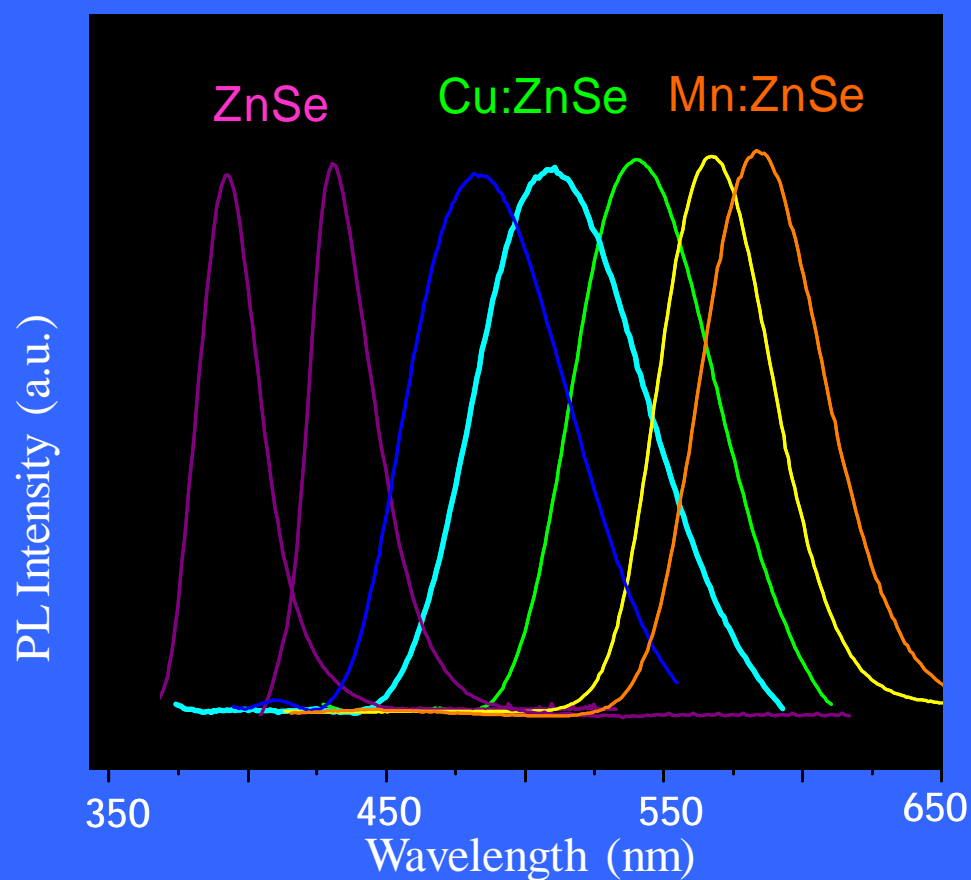
**What is new here – Heating Cancer Cells with Radio Waves**

# Healthcare: In Vivo Nano-Thermolysis of Biological Tissues under Near-Infrared Laser Radiation (Biris & Boldor)

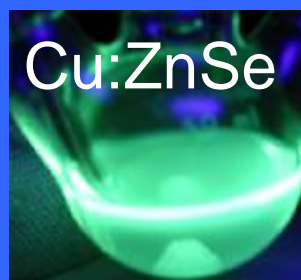
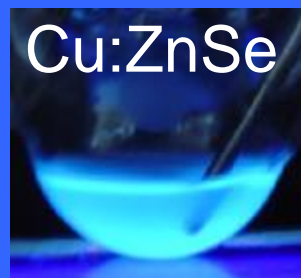


**What is new here – Localized Thermal heating-Cancer Tissue**

# Energy Efficiency Nanoscale Materials (Peng)



*What is new here – absorption /emission do not overlap & flexible emission*



NN Labs –  
our spin-off  
company



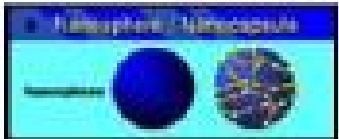
# Energy Efficiency: Nanoscale Materials to Reduce Friction (Malshe)

*Novel Nano-Bio Materials that reduce friction in mechanical systems*

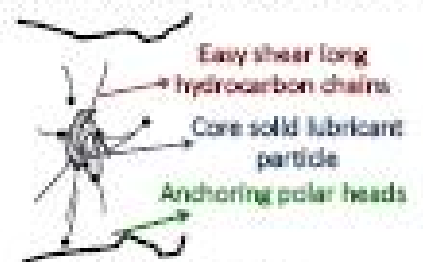
NanoGlide®




**NanoMech™**  
Innovative engineering design for active nanoparticles




MoS<sub>2</sub> and Canola oil was chosen to make controlled additives



Easy shear long hydrocarbon chains  
Core solid lubricant particle  
Anchoring polar heads



A triglyceride molecule  
Carboxylic acid and Carboxylate ions



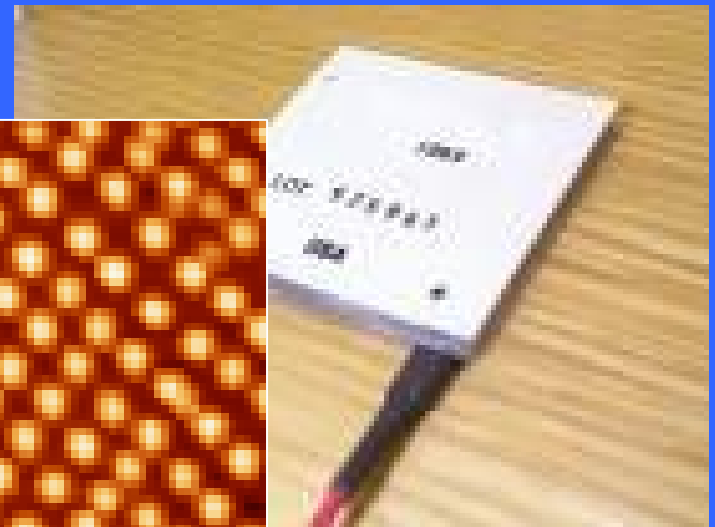
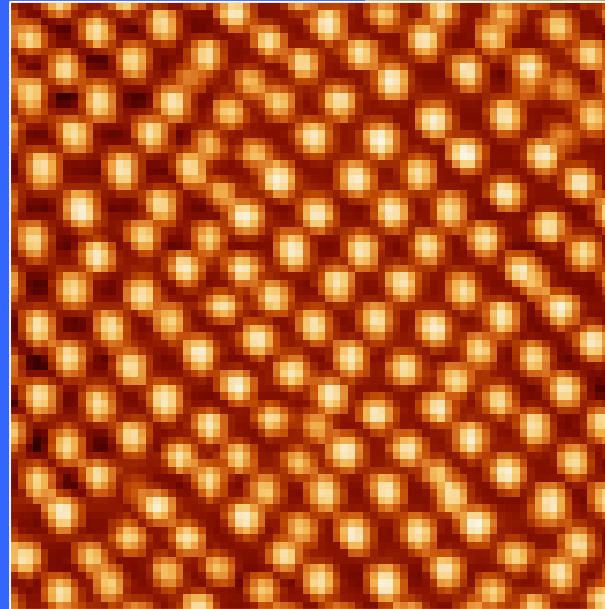
Schematic of the inorganic-organic

Patent: Malshe, A.P. and Varma, A., (2005), Nanoparticle Additives and Methods for Making and Using the Same, International Application No. PCT/US05/00506.  
\* Google Images

*What is new here – lowers friction better than anything else*

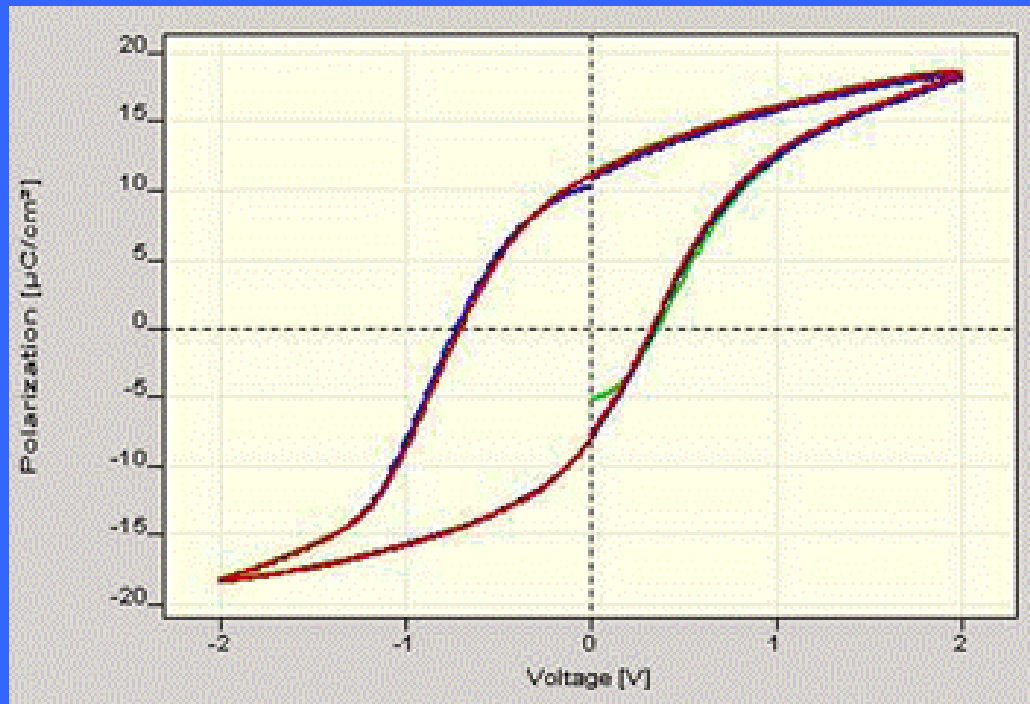
# Energy Efficiency: Nanoscale Materials with Large Thermo to Electric Conversion (Tchakhalian & Salamo)

*Devices that can  
convert wasted heat  
to electricity*

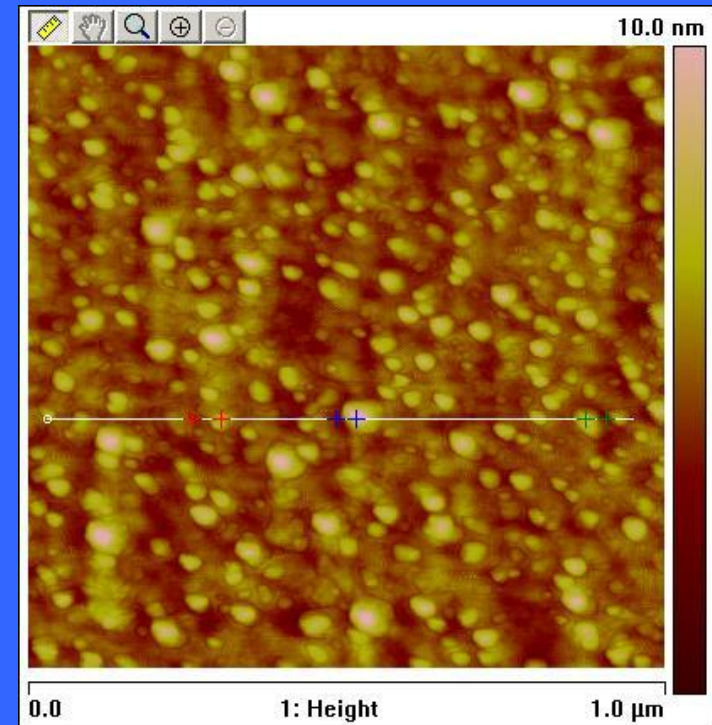


*What is new here: Current Figure of merit is about  $ZT \sim 1$ .  
Our nanoscale oxide material is already about 1.5 and has  
potential to reach 3*

# Energy Efficiency: Nanoscale Ferroelectrics (Bellaiche & Salamo)



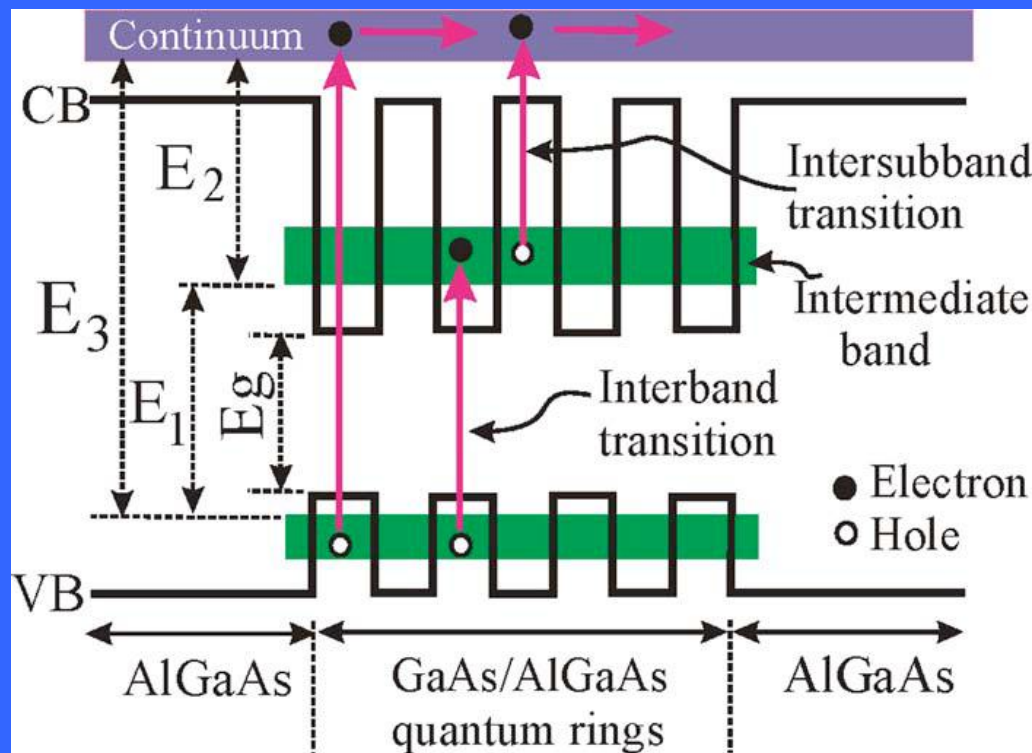
Hysteresis (Memory Element)



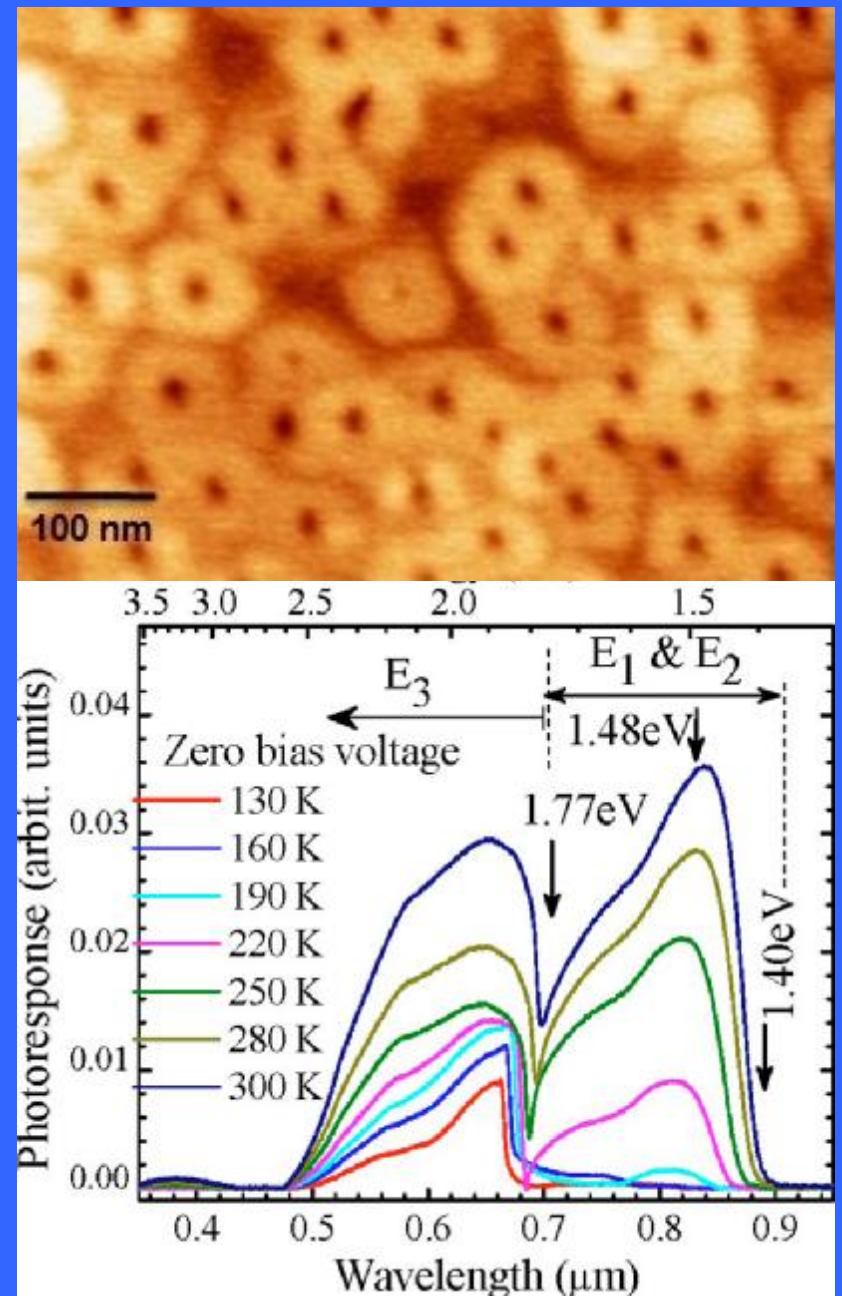
BaTiO<sub>3</sub> Dots

*What is new here –ferroelectric quantum dots form 10,000 times smaller memory*

# Renewable Energy: Novel Solar Cell Nanomaterial (Manasreh & Salamo)



*What is new here – board band absorption for high efficiency*





# Impact in nanoscale materials and application

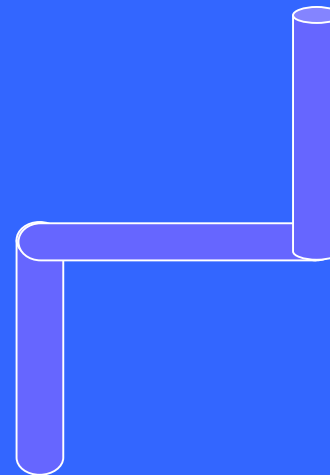
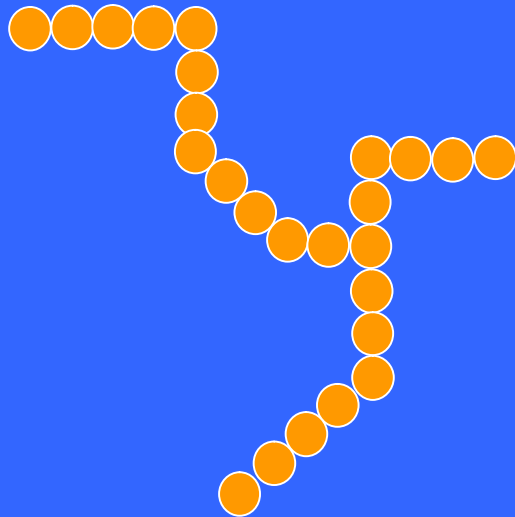
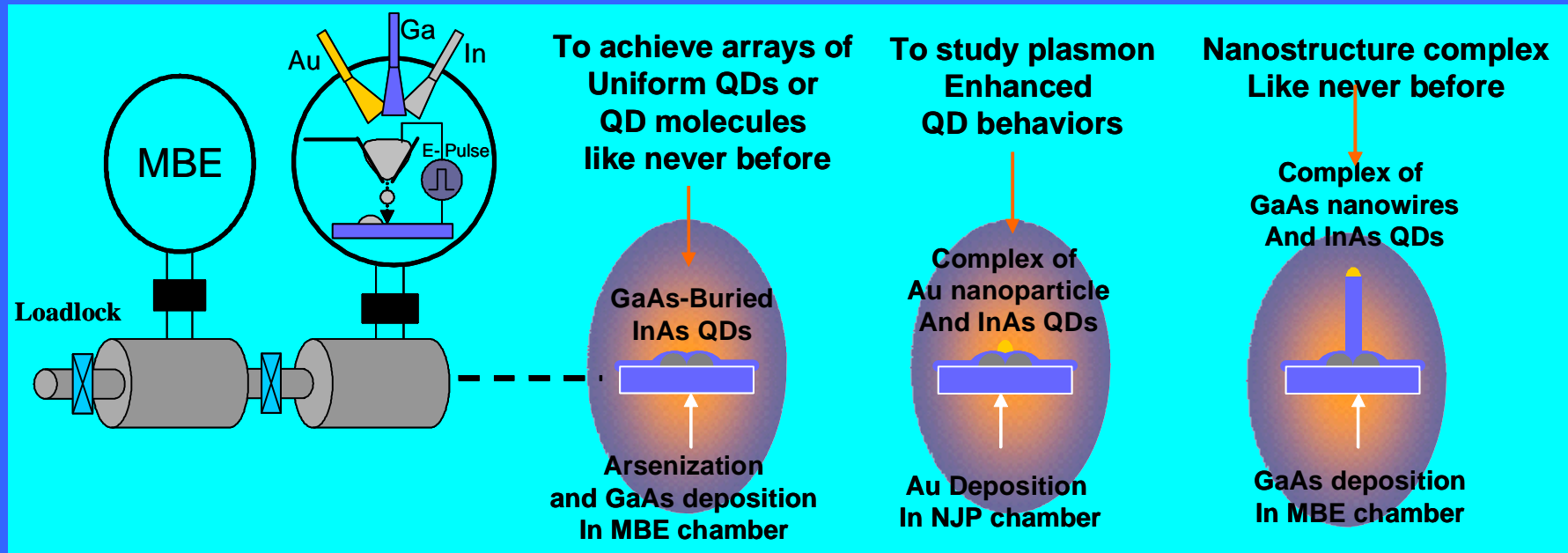
## Evidenced by:

- *(NSF) Materials Research Science and Engineering Center (MRSEC)*
- *6 spin-off companies with over 40 employees (Orlunet, Synanomet, Provectus, NNLabs, NanoMech, Nanoferr)*
- *State-of-the-art device fabrication facility,*
- *Authored some of the most compelling ideas in the field.*

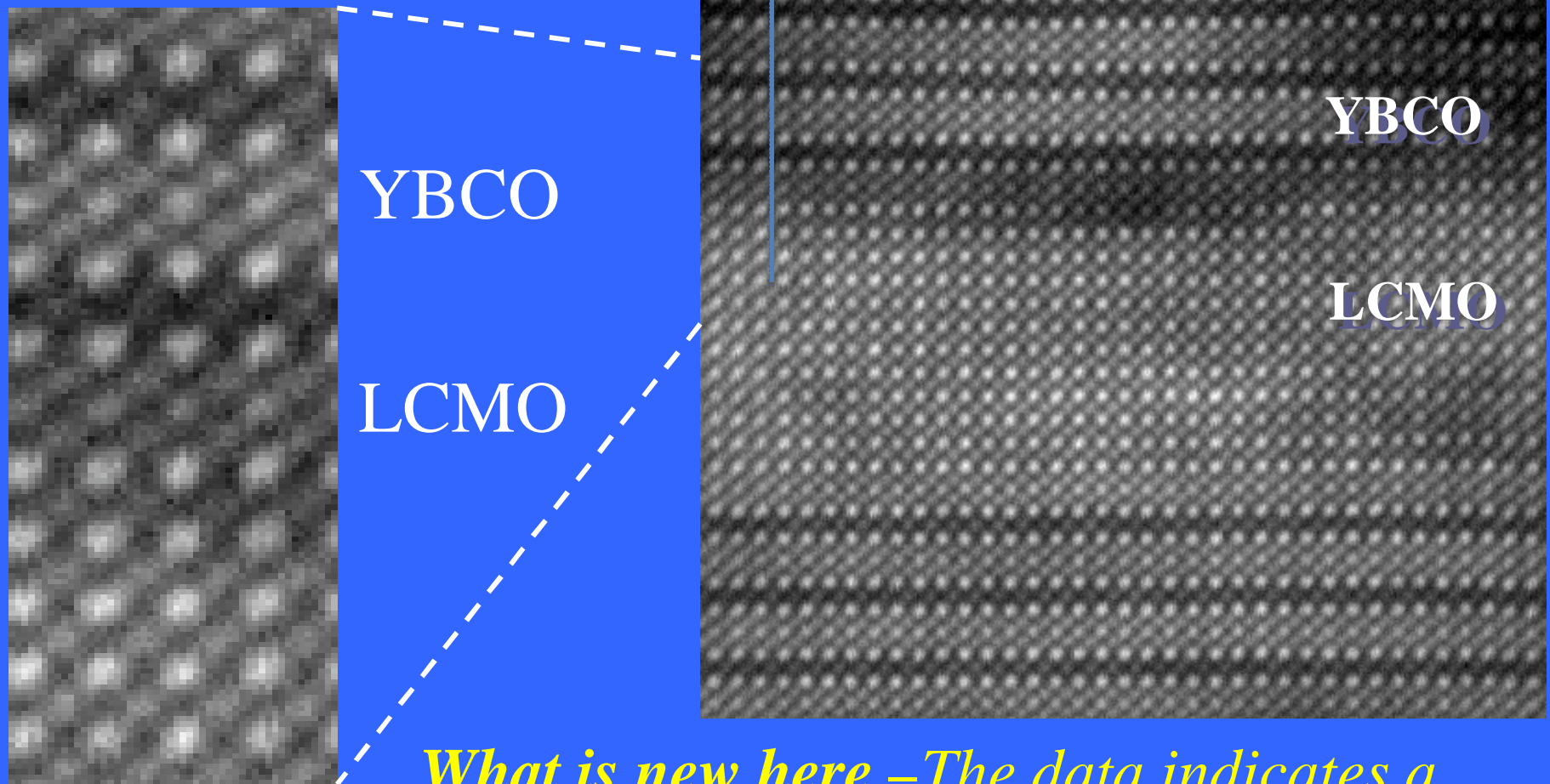
*2009 -About  
150  
Publications  
with over 3000  
Citations*

*32 Applied Physics Letters (APL)  
12 Physical Review Letters (PRL)  
2 Nature Materials  
5 Nano Letters (NL)  
6 Journal American Chemical Society (JACS)  
5 Optics Letters (OL)*

# What's Next?



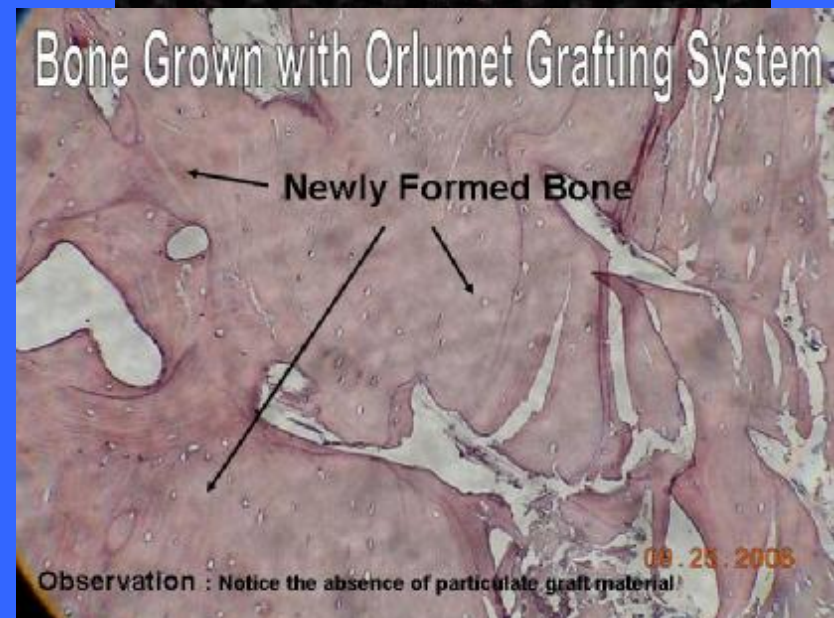
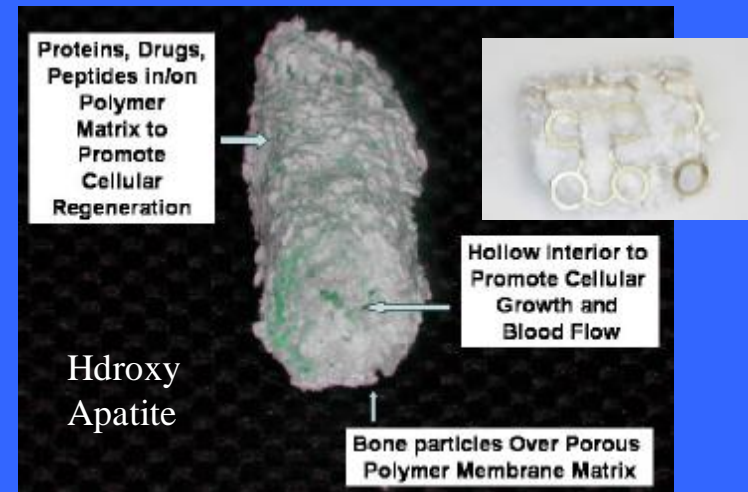
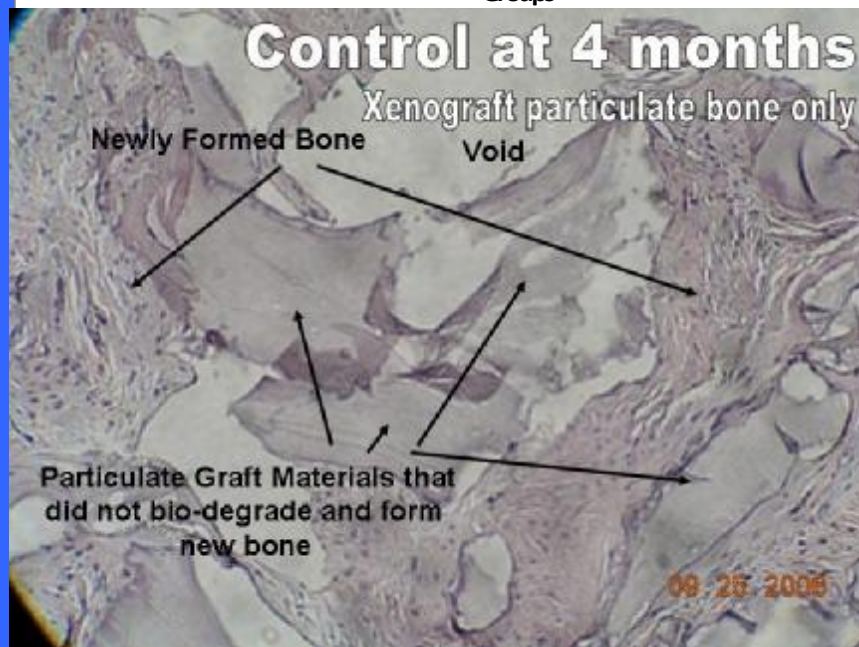
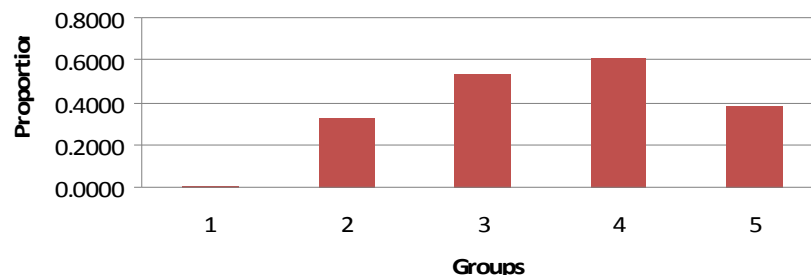
# One Layer of Atoms at a Time Creates a New Material Never seen Before



*What is new here –The data indicates a strong chemical bond between Cu and Mn and a new superconductor*

# Bone Regeneration (Biris & Jensen)

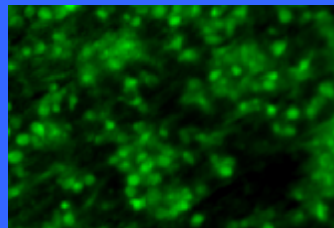
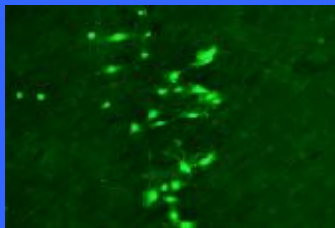
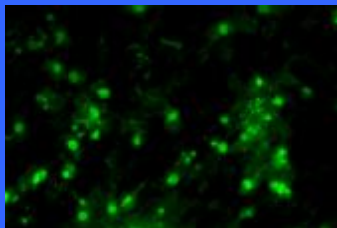
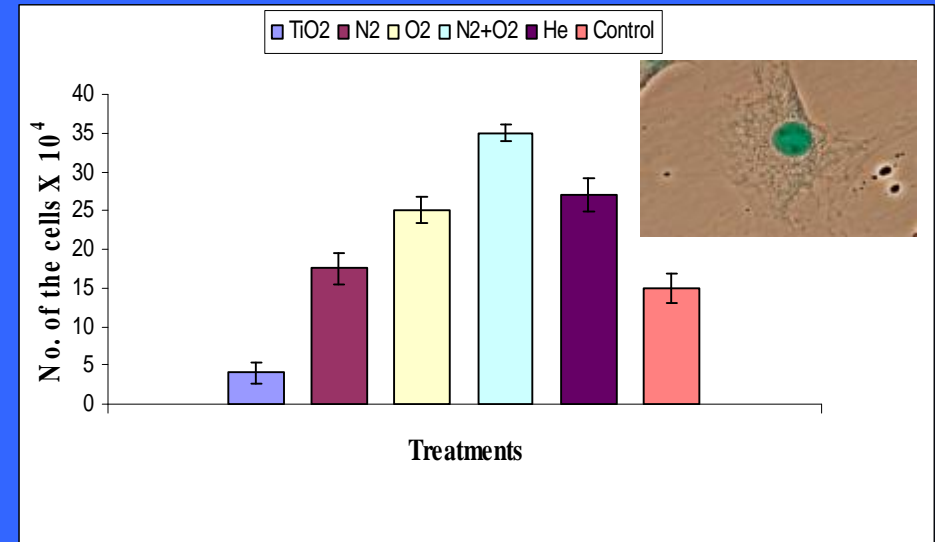
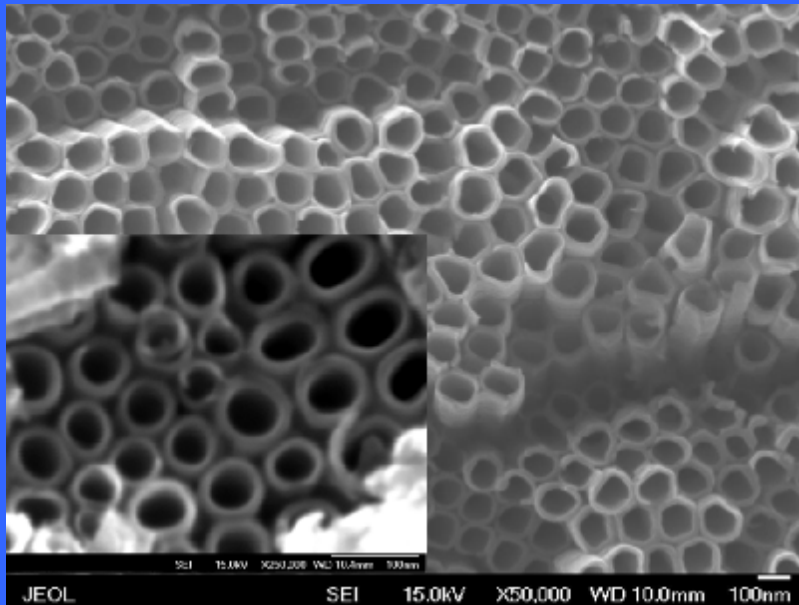
**Proportion of Medullary Canal filled  
by Endosteal New Bone**



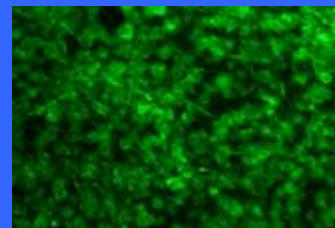
**What is new here – 43 human pre-clinical cases and 36 goat models**



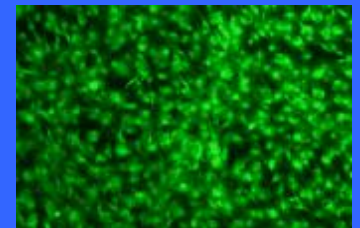
# Nanostructural $\text{TiO}_2$ Nanotubes For Implant Coatings (Biris)



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**What is new here –  $\text{TiO}_2$  enhances tissue regeneration**

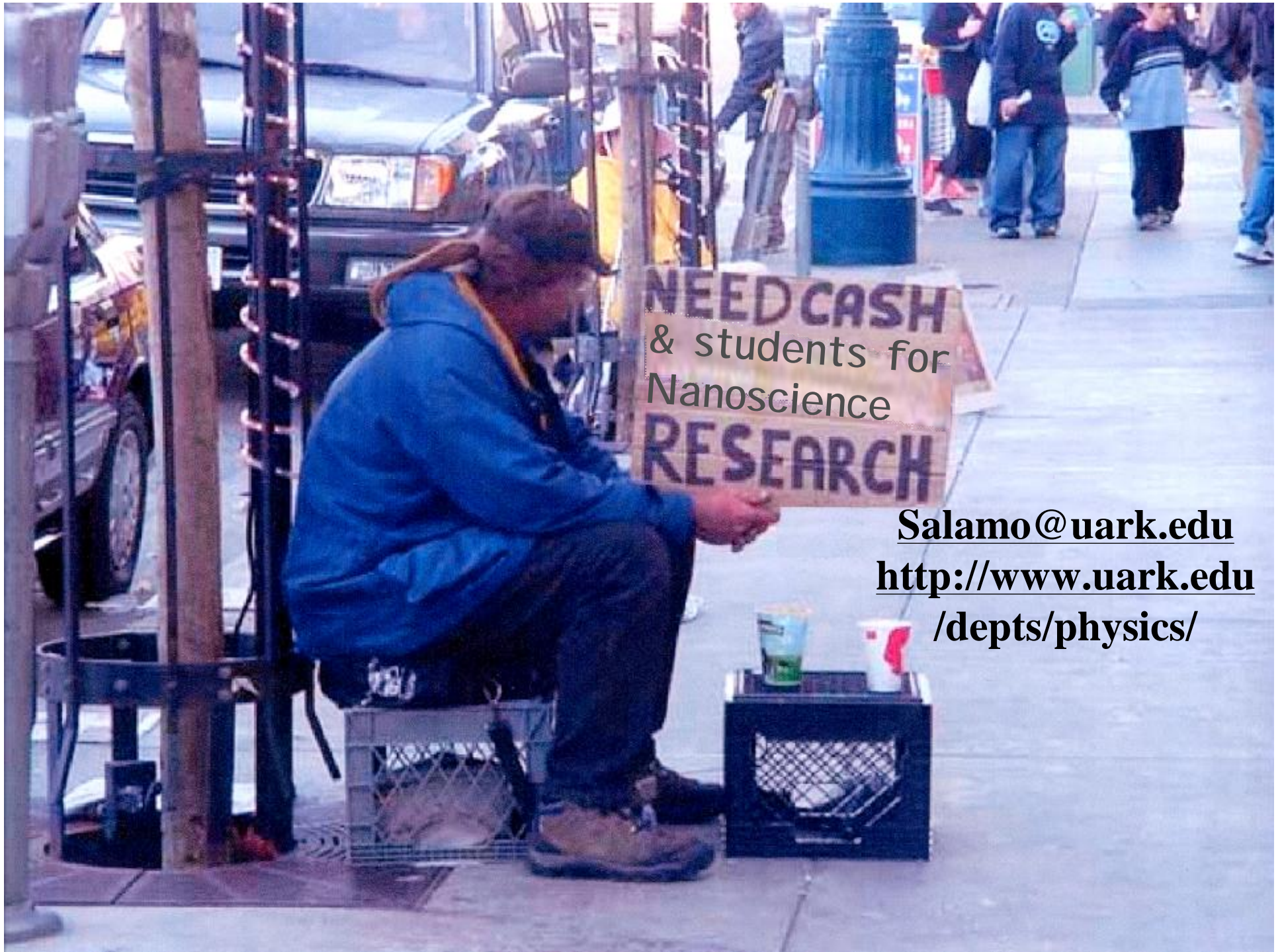
# We Supplying Nanoscale Structures to many Research Organizations



# The Future of Nanotechnology In Arkansas



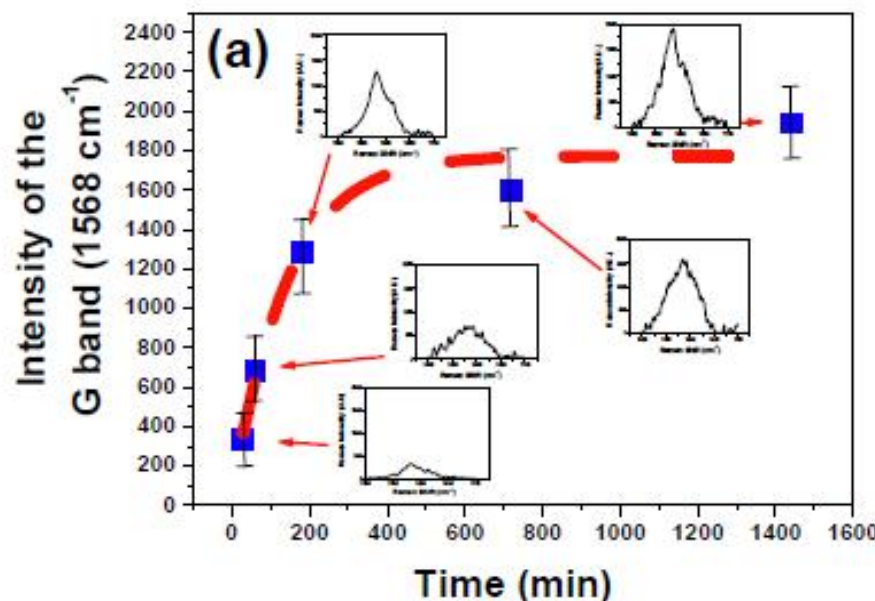
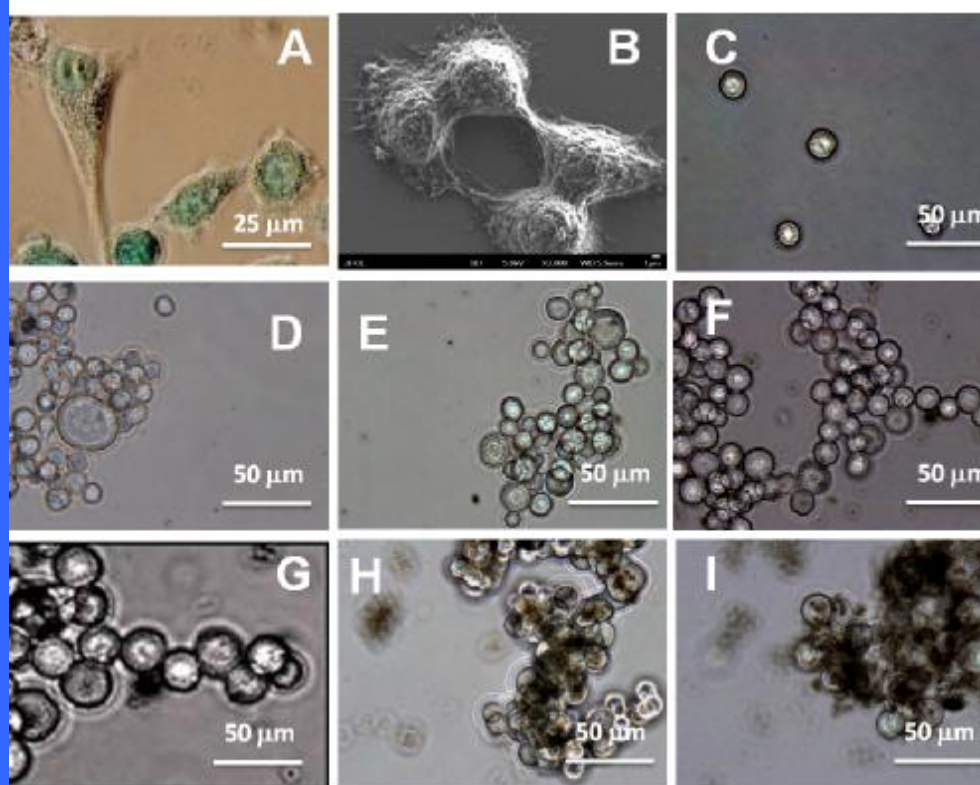




**[Salamo@uark.edu](mailto:Salamo@uark.edu)**  
**<http://www.uark.edu/depts/physics/>**

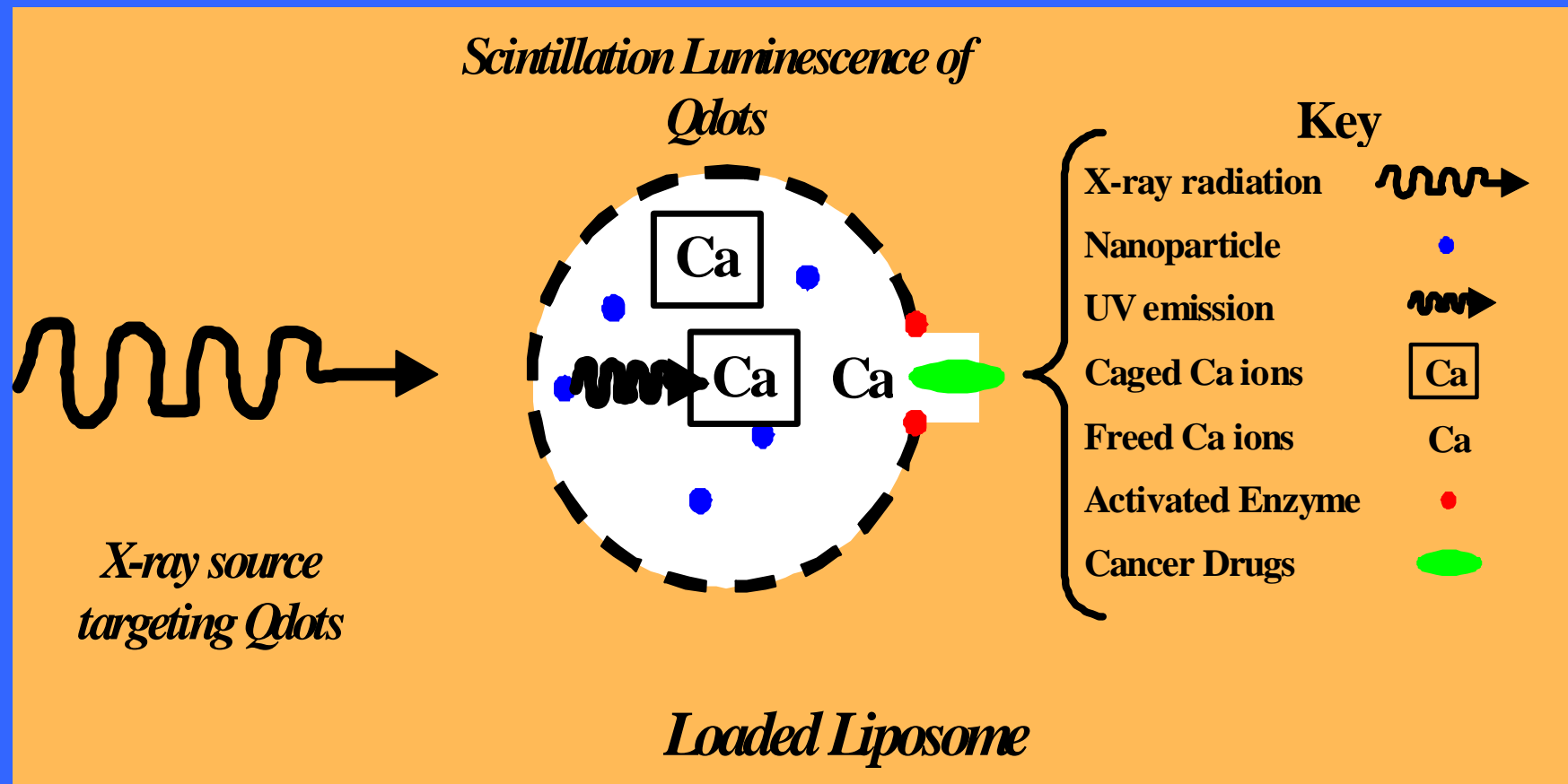


# Specific Delivery of CNTs Time Dependence (Biris)



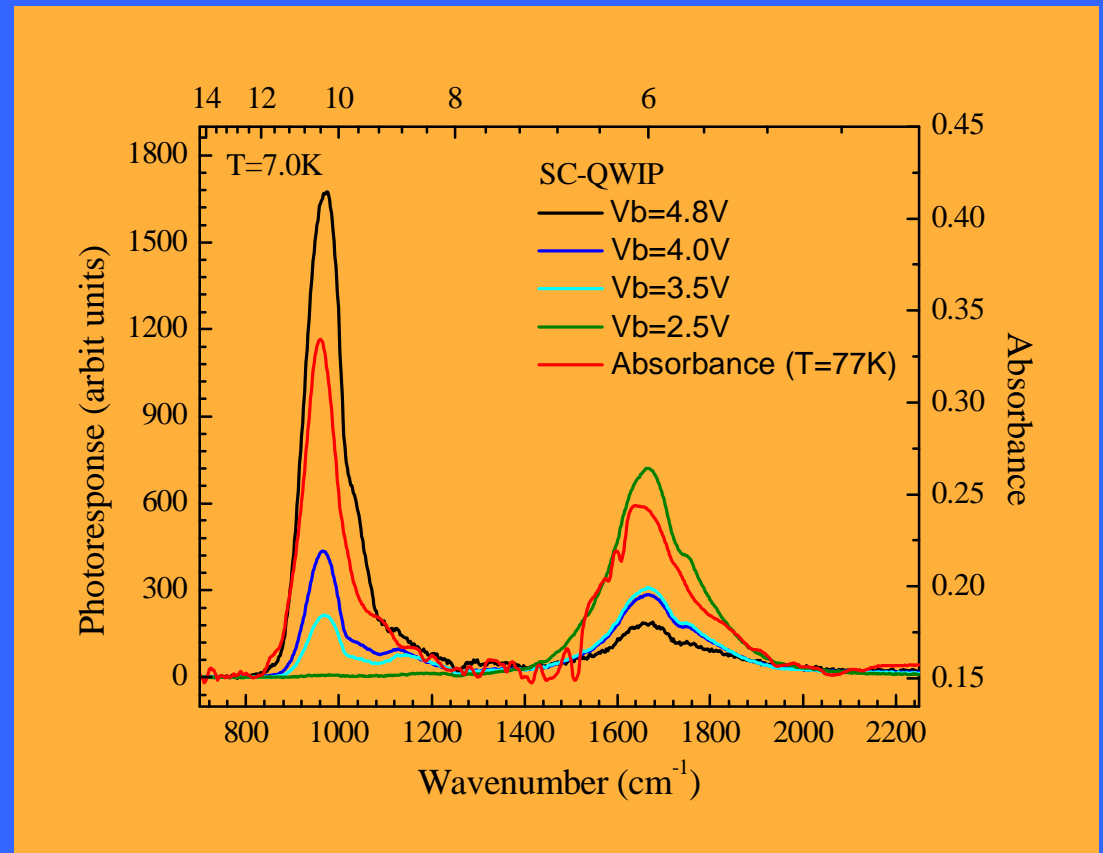
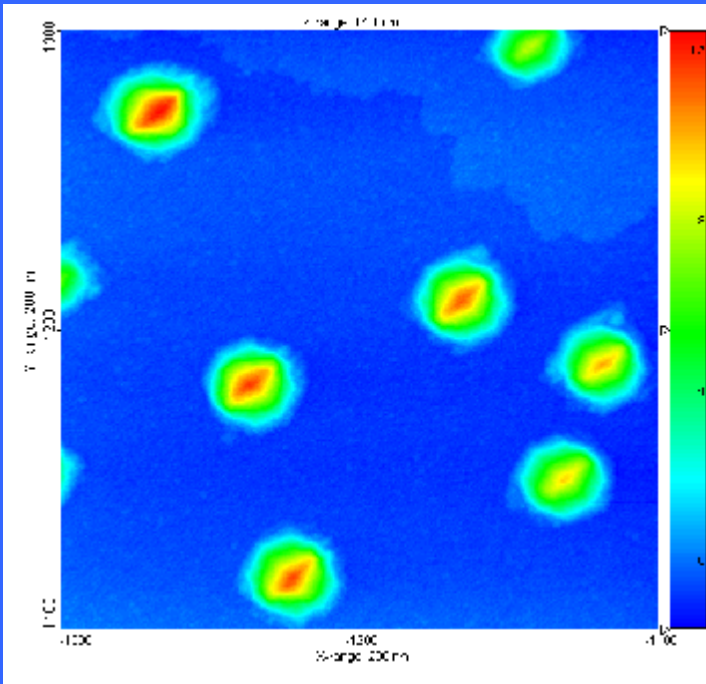
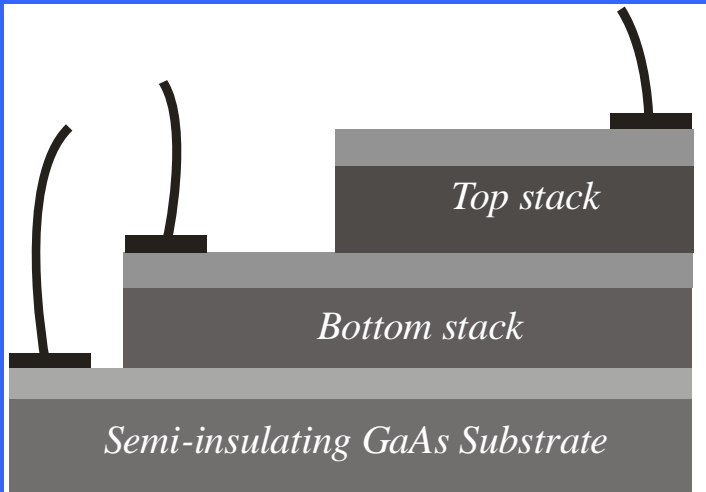
**What is new here – Demonstrated CNT delivery to a Cancer Cell**

# Drug Delivery (Fologea & Borrelli)



*What is new here: Utilize X-ray absorbing Q - dots that emit UV light to release, caged  $\text{Ca}^{2+}$  ions, which activates an enzyme to open the liposome and release the drug.*

# Tunable Infrared Photodetector (Manasreh)



*What is new here – voltage tunable  
color selection*

# Arkansas Nano Net

