NANOSCIENCES & NANOTECHNOLOGIES FOR SDGs: SCIENCE BENEFITING SOCIETY

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United Nations Educational, Scientific and Cultural Organization

UNESCO-UNISA Africa Chair in Nanosciences/Nanotechnology (South Africa)

OUTLINE

1-Nanomaterials :Generalities,
2-Nanotechnologies for society addressing SDGs
-NanoPHYSICS for HEALTH,
-NanoPHYSICS for AGRI,
-NanoPHYSICS for WATER,
-NanoPHYSICS for ENERGY,

3-Physics Multi-disciplinarity & Way forward from the African perspective

4-Conclusion & Foresight

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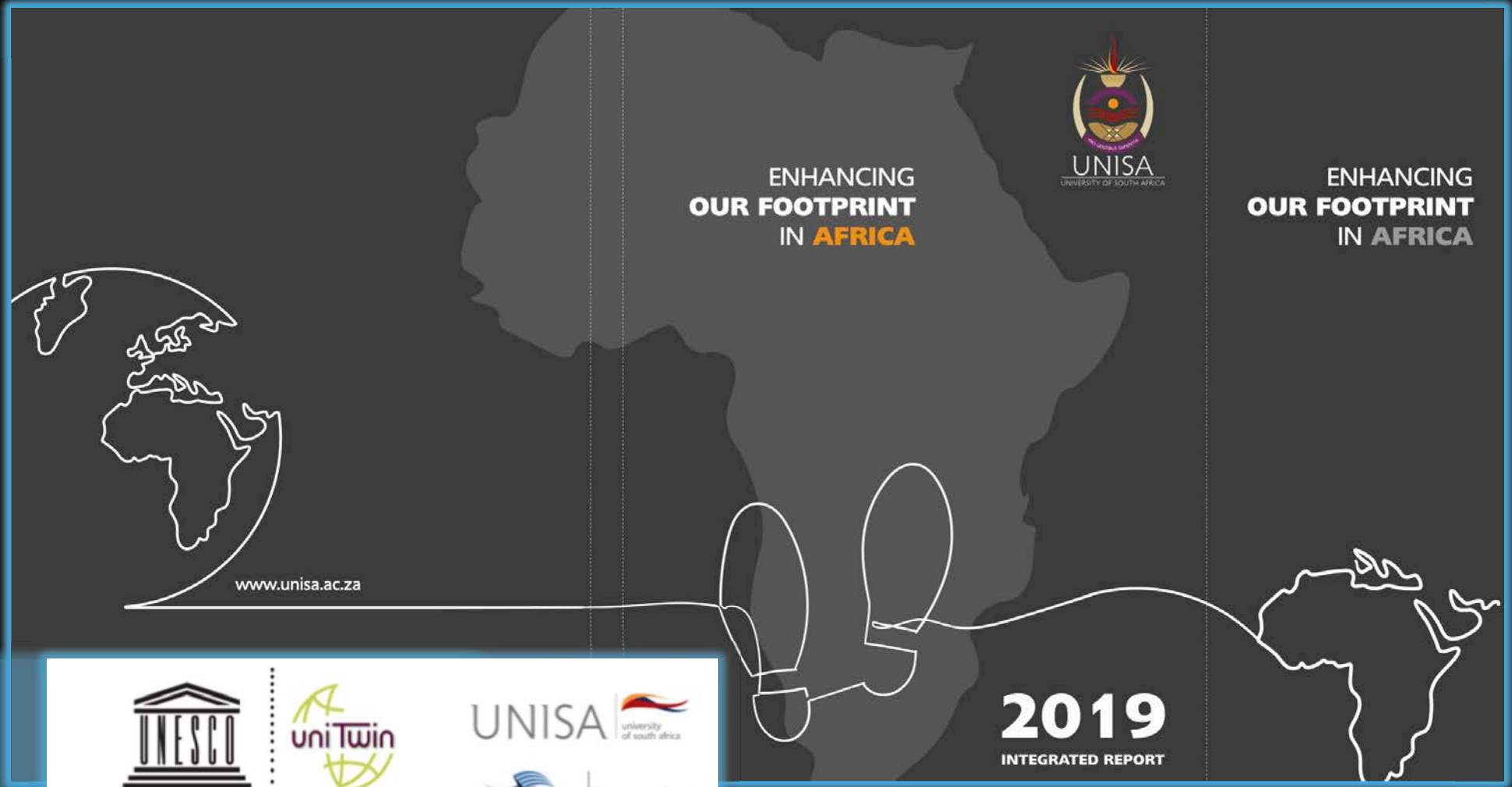
ENHANCING/CEMENTING THE NANO-FOOTPRINT IN AFRICA



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Since2013 NANO-AFRICA: MAJOR NODES

- MASCIR
"Morocco"
- CDTA
"Algeria"
- UMANAR
"Tunisia"

- NASENI , CERD, UNN
"Nigeria"

- BITRI
" Botswana"

- Mintek NiC,
- CSiR nano
"South Africa"

- Sheikh Zayed City
- Zewail City
- BUE
"Egypt"

- MAPRONANO
"Uganda"

- UNAIROBI
"Kenya"

- CREATES
"Tanzania"

- CBBR
"Mauritius"

- NANOAFNET, UNESCO Chair
"South Africa"

AFRICA-INTRA-SYNERGY:PREPARATION AFRICA TOMORROW WORKFORCE

65 MSCs, 70 PhDs Since 2005

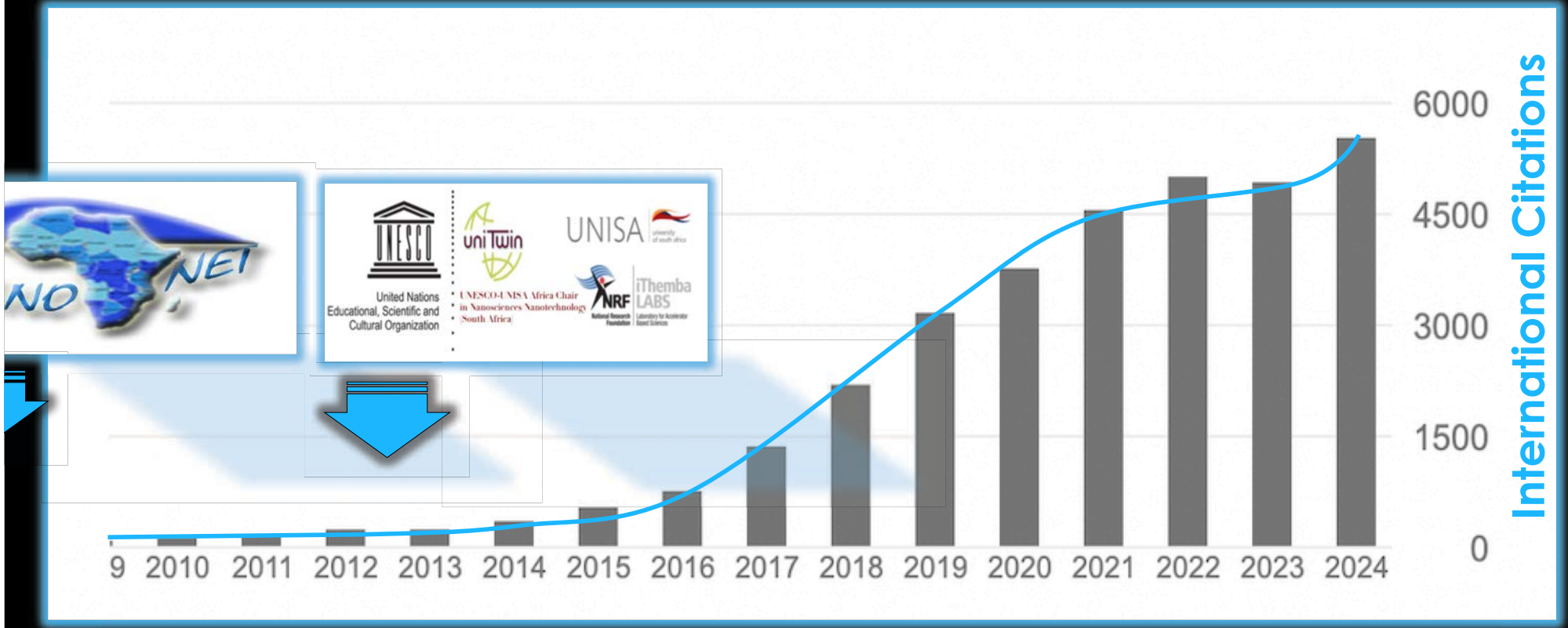
AFRICA-INTRA-SYNERGY:
HUMAN CAPITAL MOBILITY

194 MlidCar eer, 173 Senior Since 2005

AFRICA INTRA-SYNERGY:GENDER EQUITY

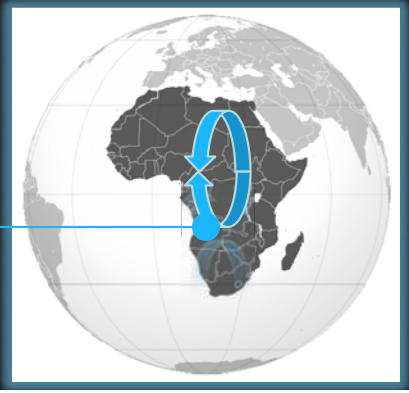
50% Female, 50% Male Since 2005

QUALITY ERESEARCH& QUALITY EDUCATIO
TOWARDS STI/STEM EXCELLENCE

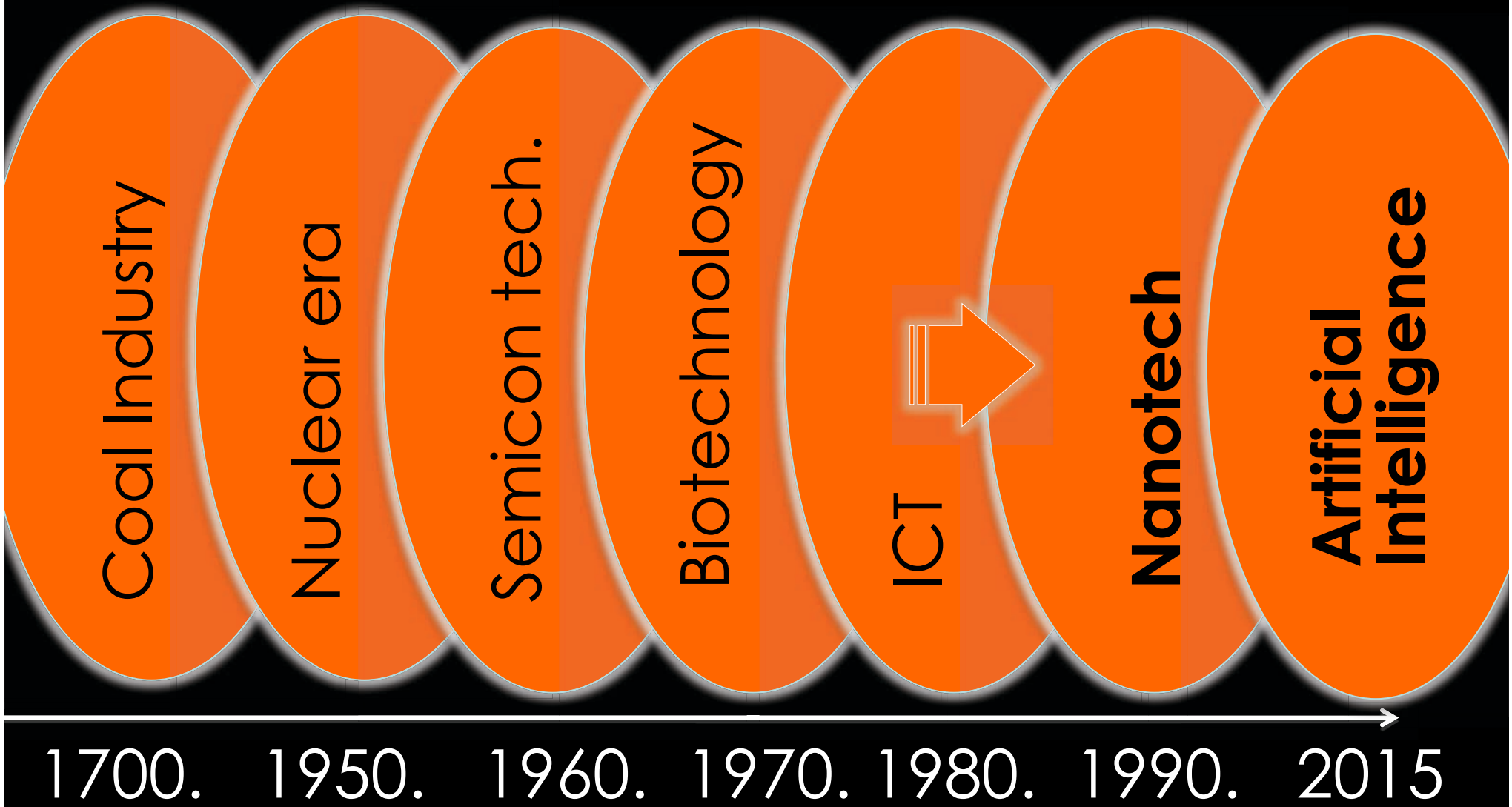


International Citations as a Metric compass:

- Contributions to body of knowledge
- Quality Education
- Continental synergy
- North-South 2 ways synergy



NANO: EVOLUTION not REVOLUTION



WHAT IS NANO?

<100 nm

IUPAP& IUPAC DEFINITION

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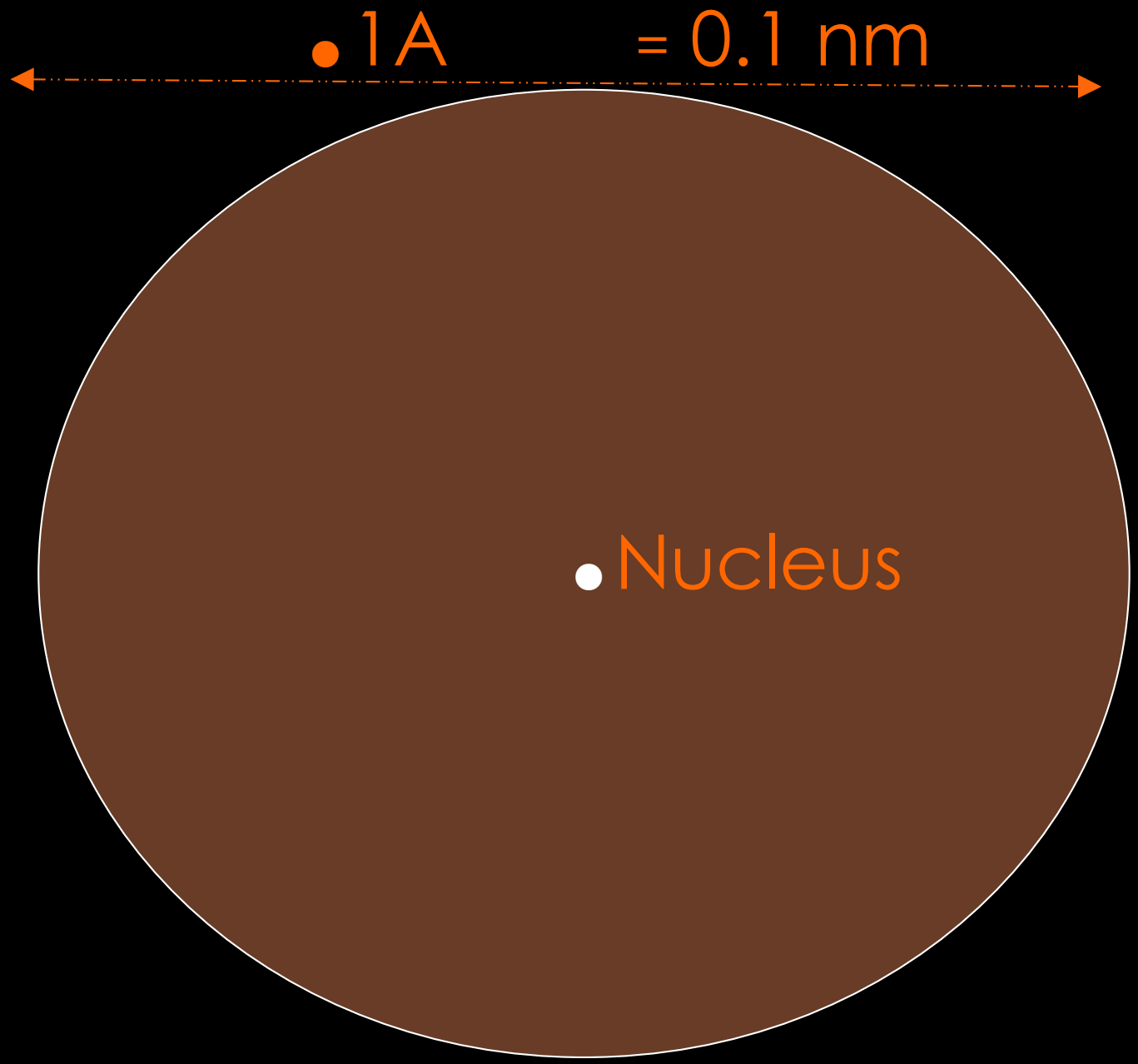
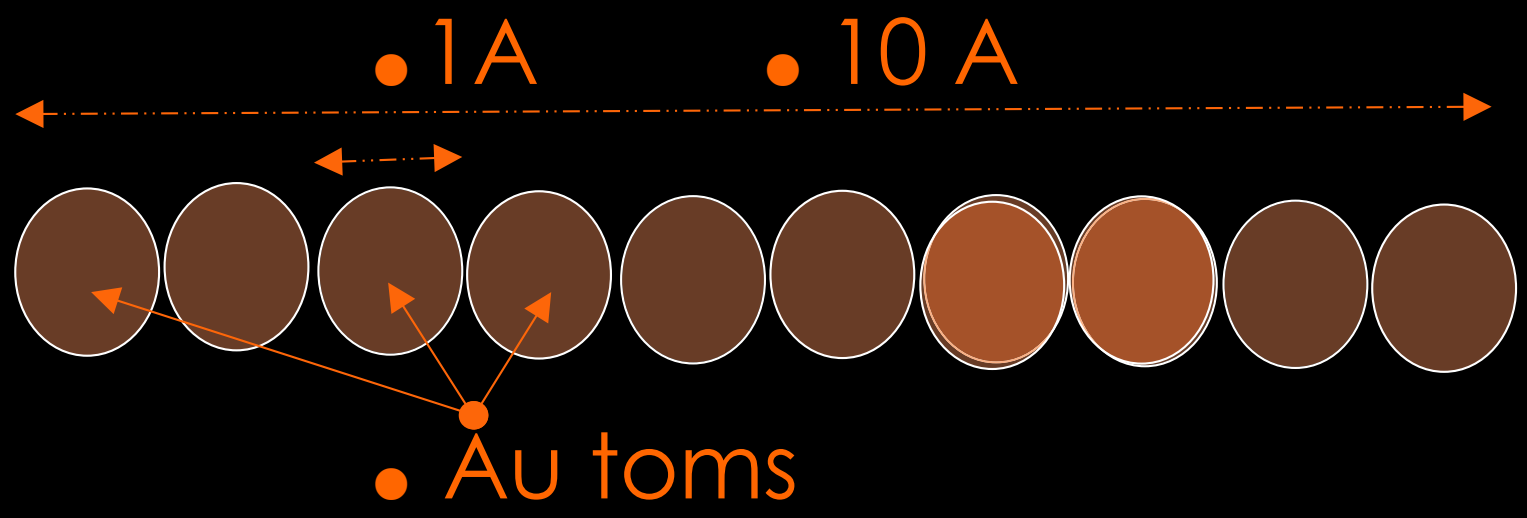
SIZE DOES MATTER: NANOMETER ???



SIZE DOES MATTER: NANOMETER ???



- 1 nm=10 A
- Neckless of 10 Au atoms
- 1m/1000=1mm
- 1mm/1000=1micrometer
- 1micrometer/1000= 1 nm

NANO: EVOLUTION not REVOLUTION

4 589 844 “IBM”= 1 “6M”

1Tb= ? IBM

Data Storage Capacity

1970 1995 2010

GENESIS

- Nano:Norio Taniguchi/Coined the term
- Nanotech:Proposed by Richard Feynman/
- 4th Century A.D.: Lycurgus Cup nanoAu
- Earlier: Magnetostatic bacteria

GENESIS

- Earlier: Magnetostatic bacteria

Nanoscaled FeS, Fe_2O_3 plots (25 nm)

WHAT PARAMETERS CONTROL NANO?

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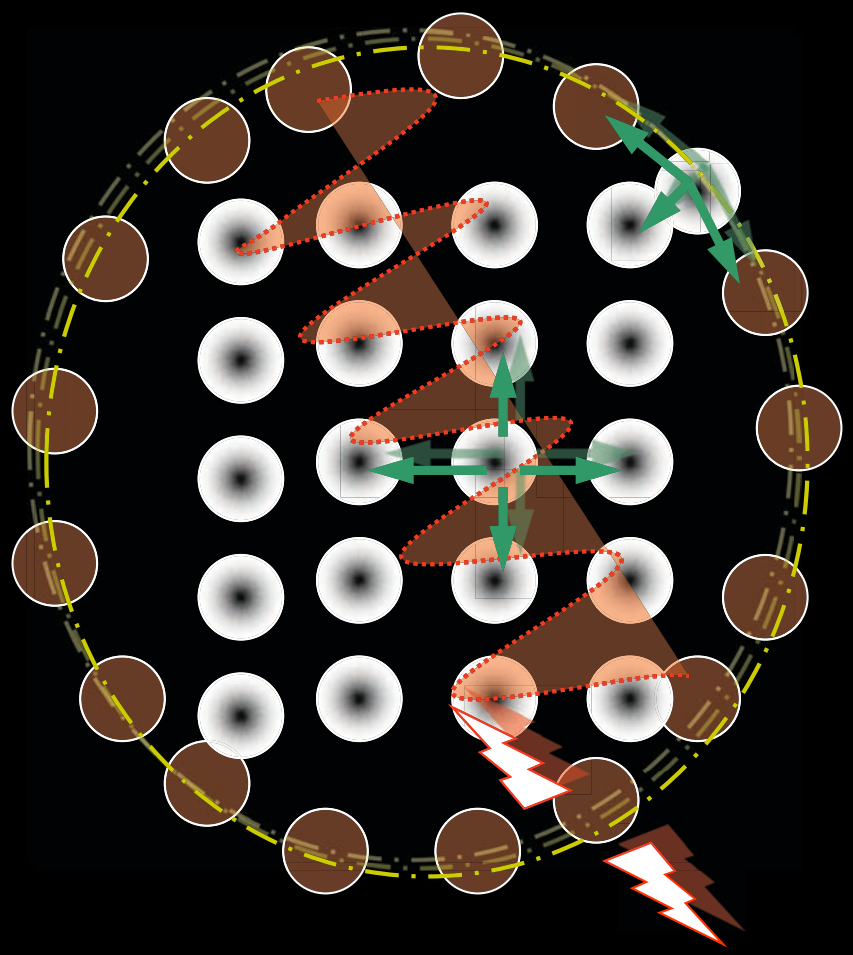
NRF National Research Foundation

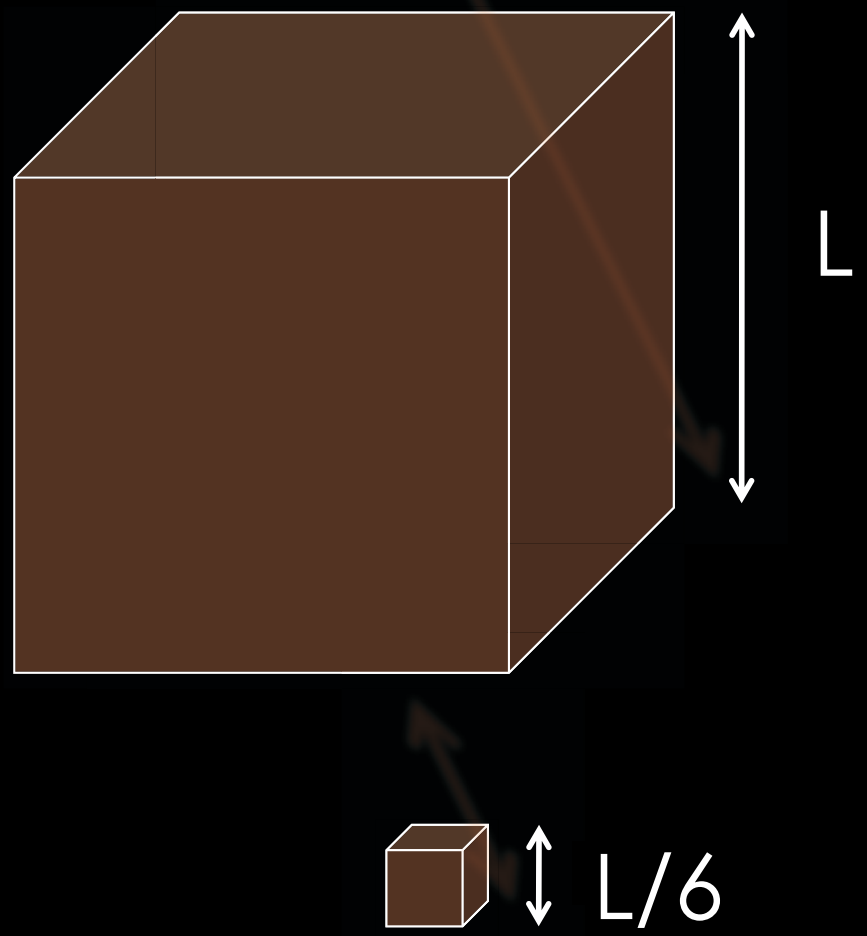
iThemba LABS Laboratory for Accelerator Based Sciences

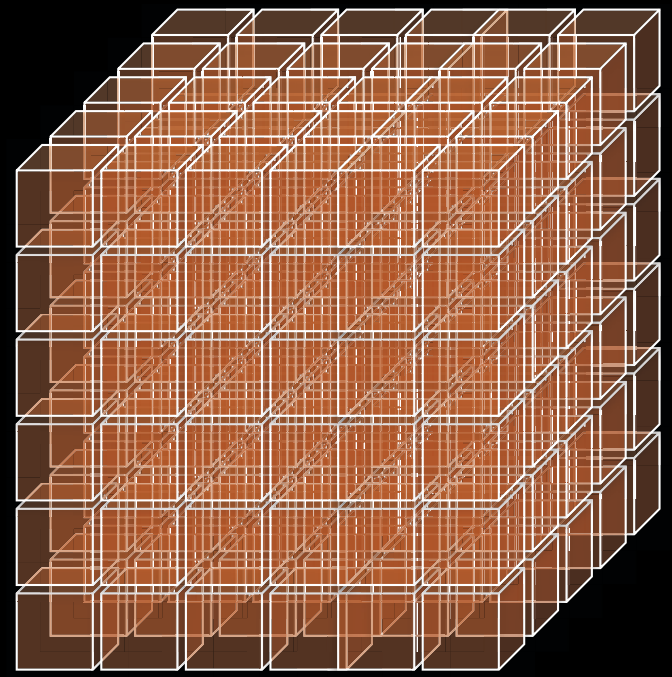
SIZE EFFECTS



- 3-D Symmetry Broken for Surface Atoms,
- Localized States: carriers/ phonons Confinement,
- High Surface/ Vol. > 50% “1/<ϕ>”

NANO-BACKGROUND: FUNDAMENTALS SURFACE/VOLUME

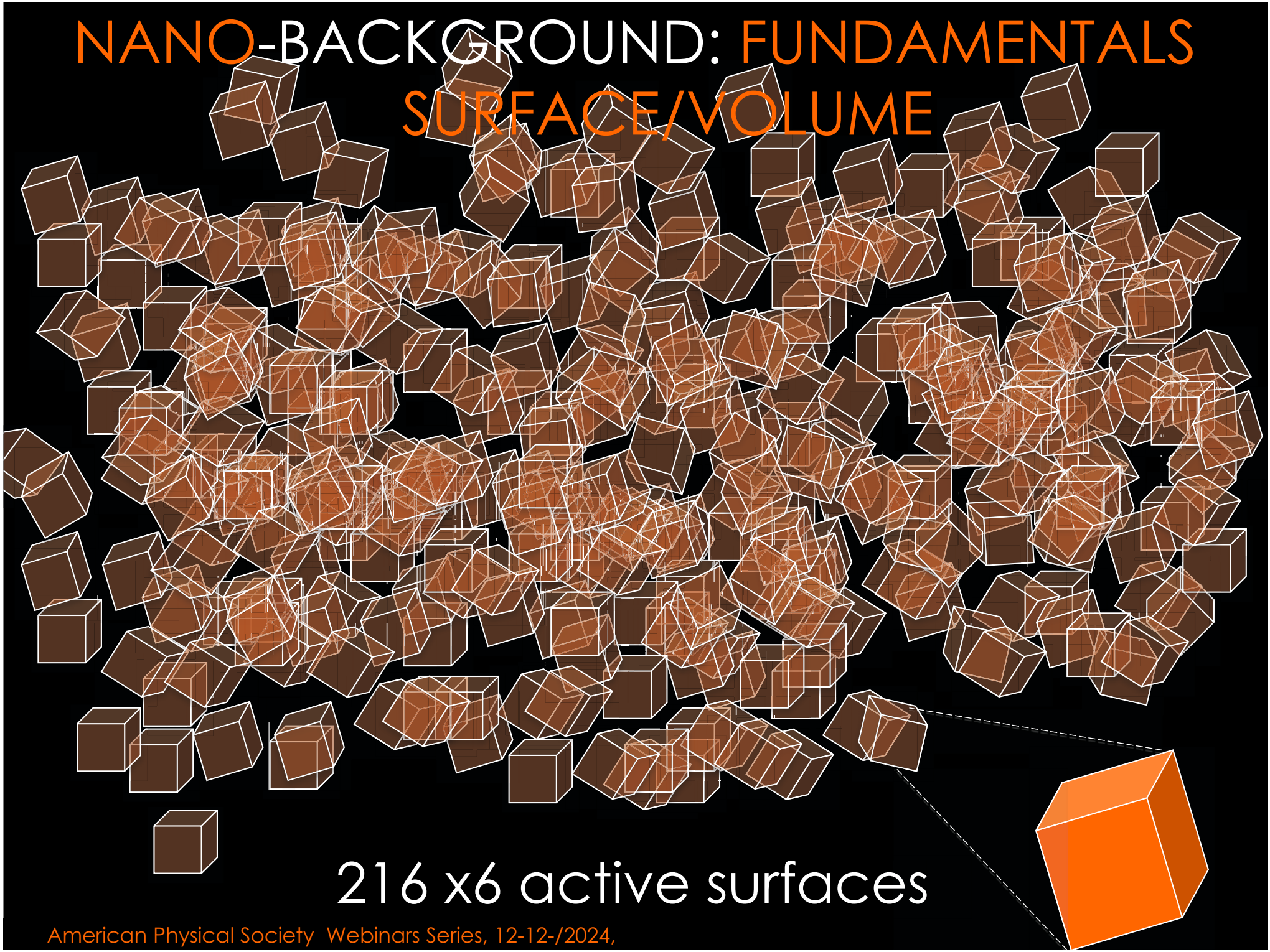




6x6x6= 216

- High Surface/ Vol. > 50% "1/<ϕ>

NANO-BACKGROUND: FUNDAMENTALS
SURFACE/VOLUME



NANO-BACKGROUND: FUNDAMENTALS SURFACE/VOLUME

- 1 kg of particles of 1 mm^3

has the same surface area as

- 1 mg of particles of 1 nm^3

HOW IT MANIFESTS ITSELF @NANO?

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UNISA university of south africa

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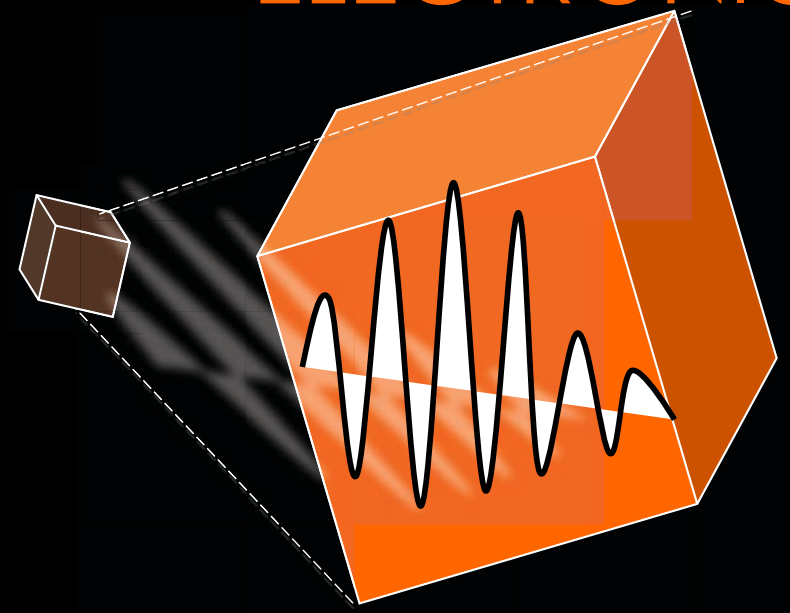
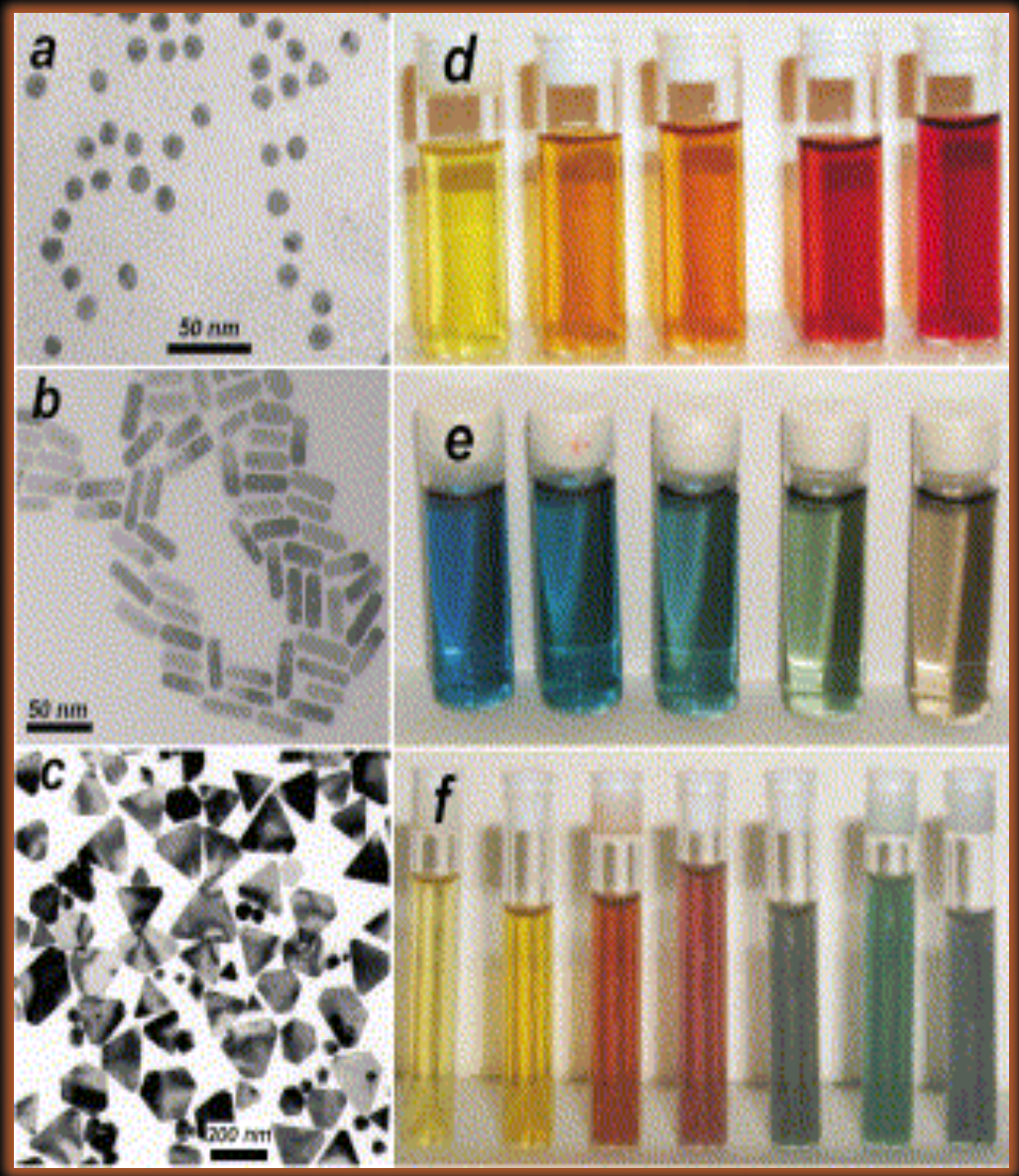
NANO-BACKGROUND: FUNDAMENTALS ELECTRONIC CONFINEMENT

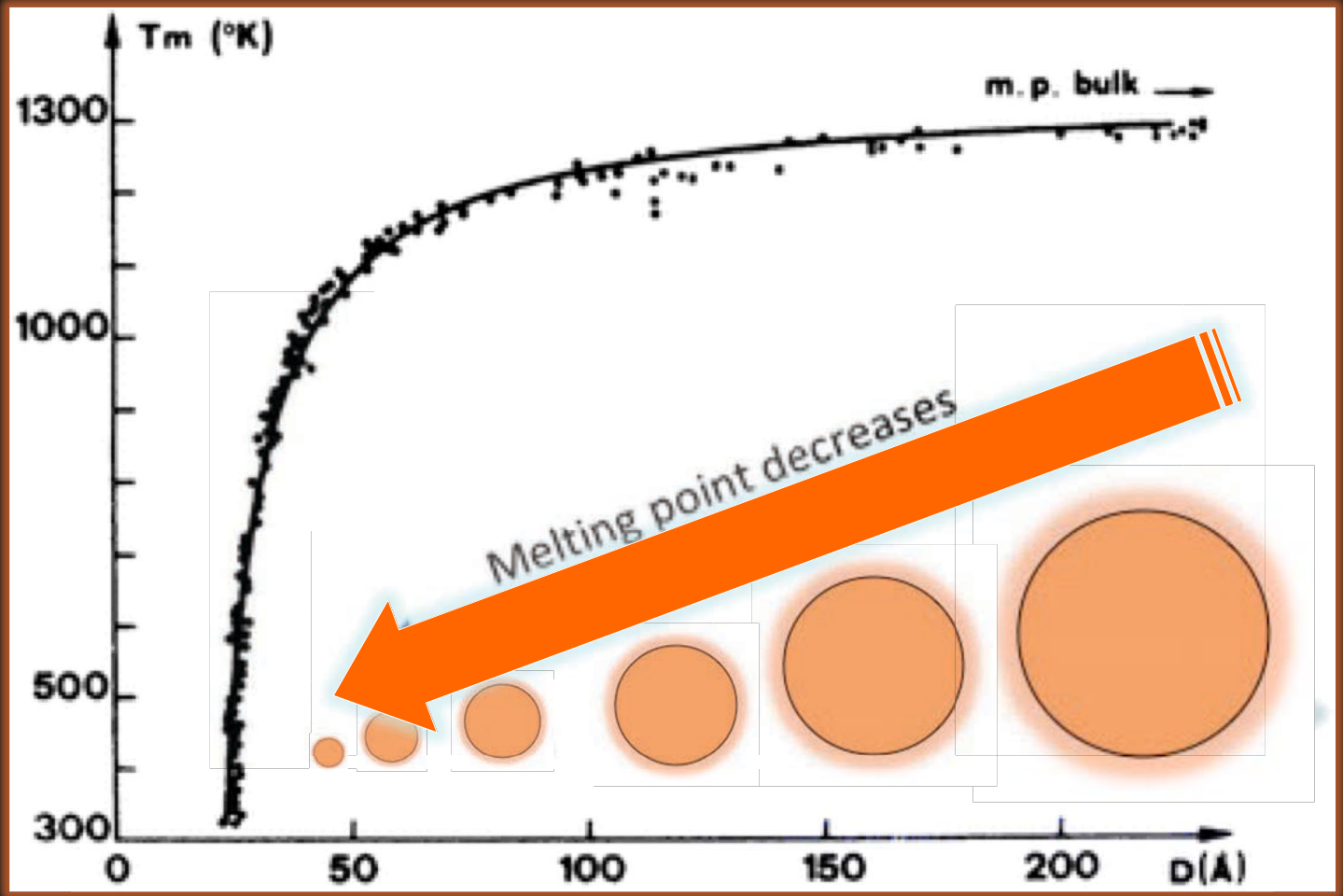


$$\Delta x \,.\, \Delta p \cong h/2\pi$$



Liz Marzin, Mater.Today.2004

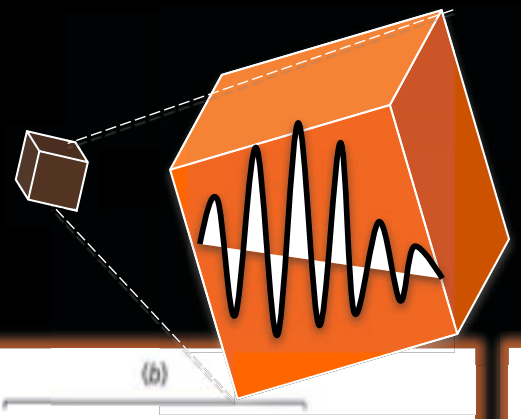
NANO-BACKGROUND: FUNDAMENTALS SURFACE COORDINATION



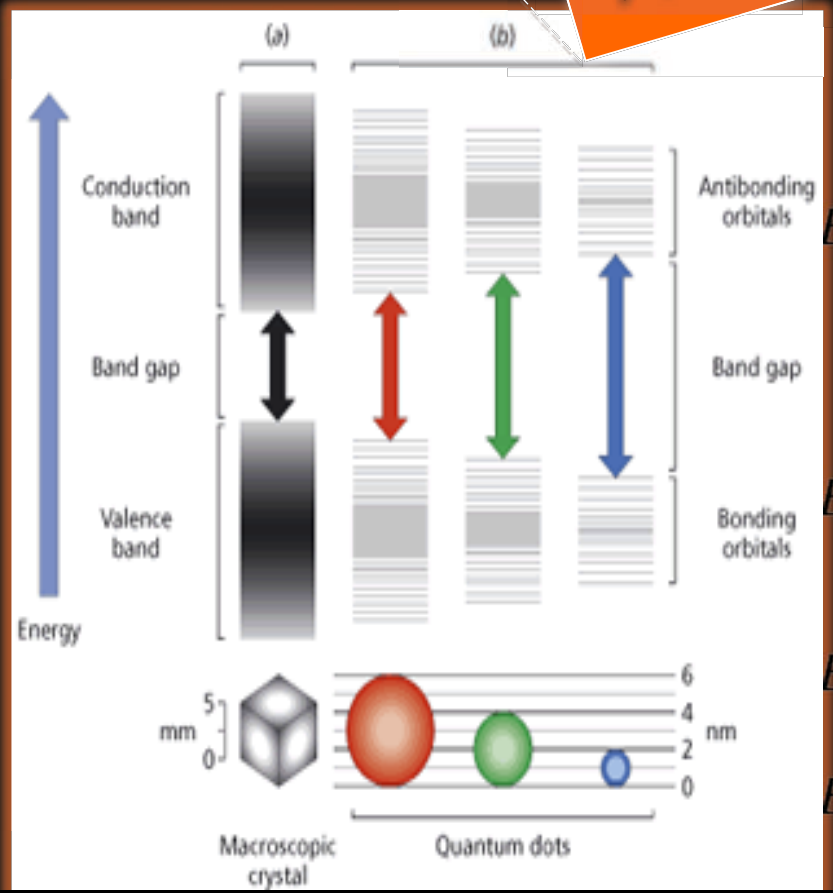
$$T_b/T_m = 1+(2/L\rho_s R)\ [\gamma_s-\gamma_l(\rho_s/\rho_l)^{2/3})]$$

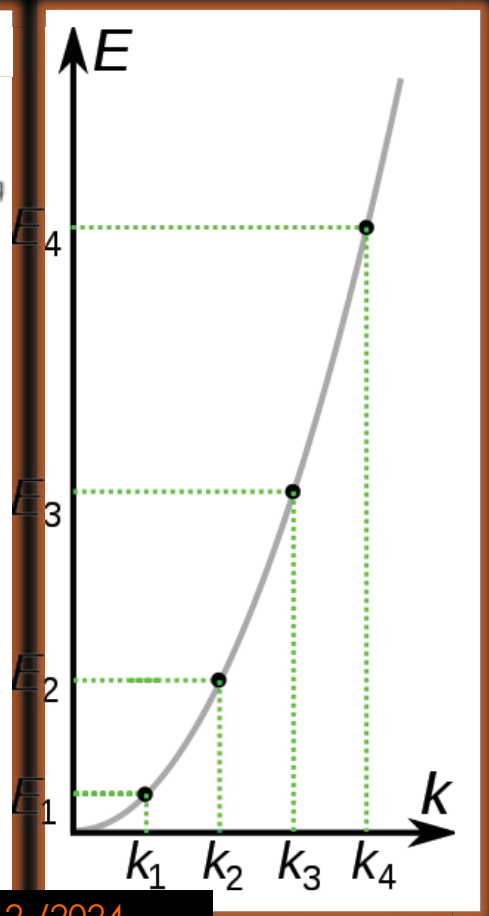
Buffat et al, Phys. Rev.A, 1976

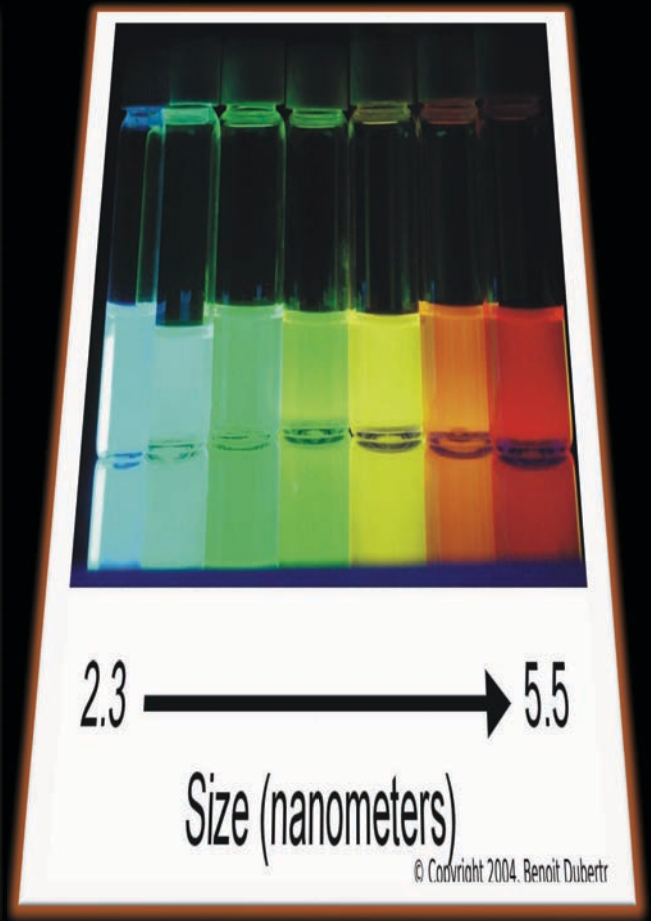
NANO-BACKGROUND: FUNDAMENTALS ELECTRONIC CONFINEMENT



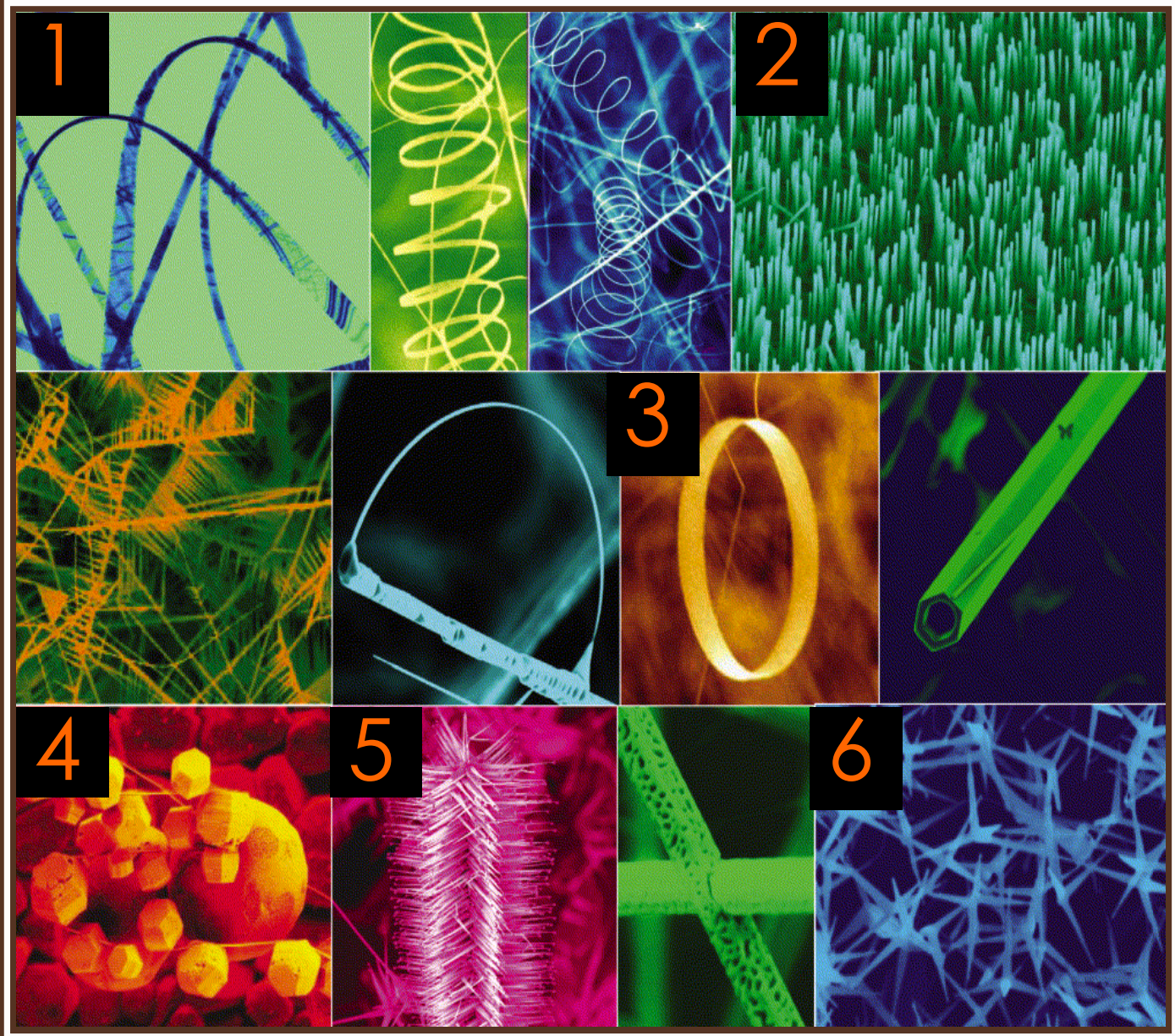
$$E = n^2k^2/8m\,L^2$$





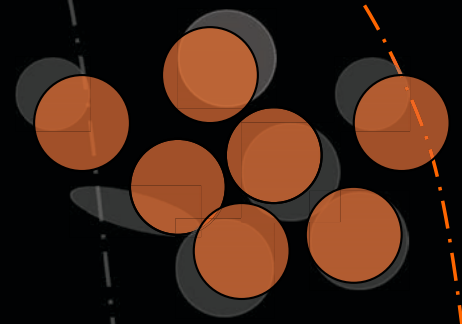


NANO-BACKGROUND: FUNDAMENTALS ELECTRONIC CONFINEMENT

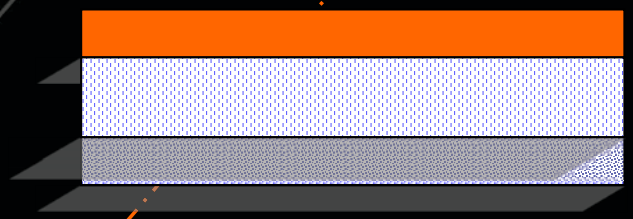


NANO-BACKGROUND: FUNDAMENTALS PROD.: BOTTOM-UP/ TOP- DOWN

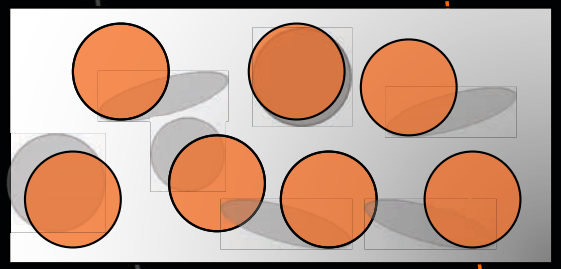
1-FREE NANOPARTICLES



4-NANO-SANDWICHS

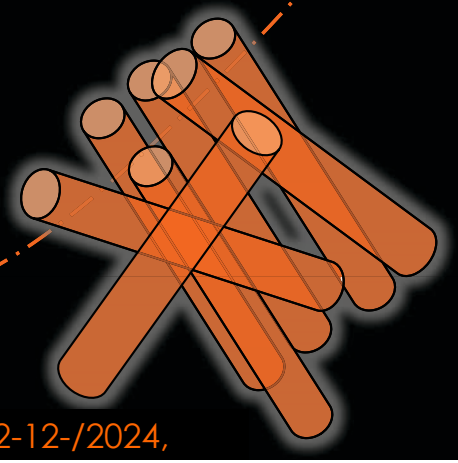


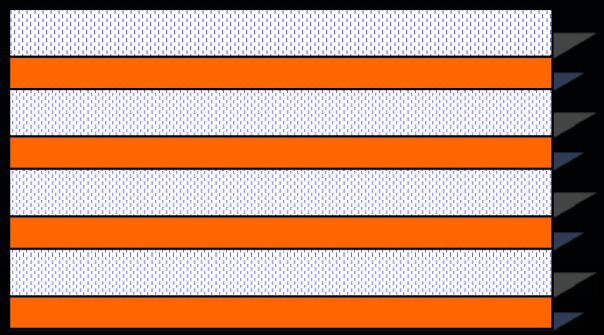
2-NANO-COMPOSITES



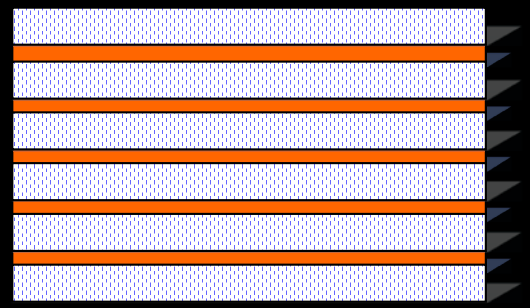
5-NANO-MULTILAYER

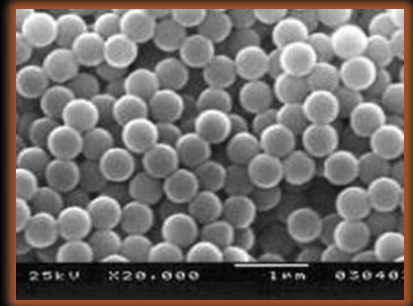
3-NANO-TUBULES

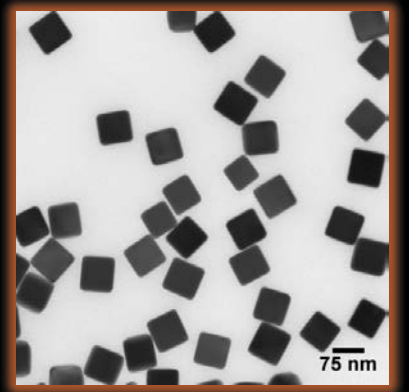


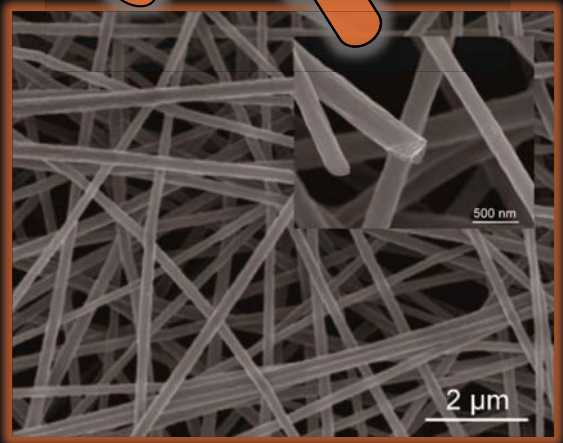


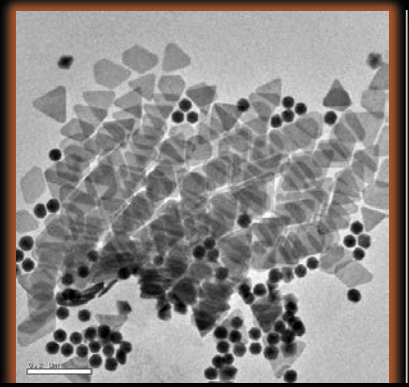
NANO-BACKGROUND: FUNDAMENTALS
PROD.: BOTTOM-UP/ TOP- DOWN

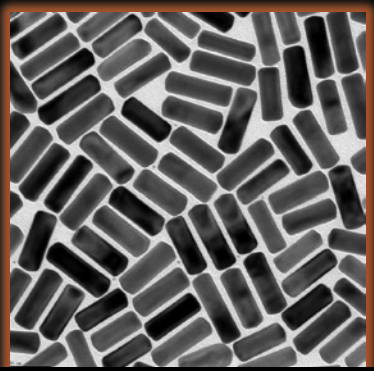


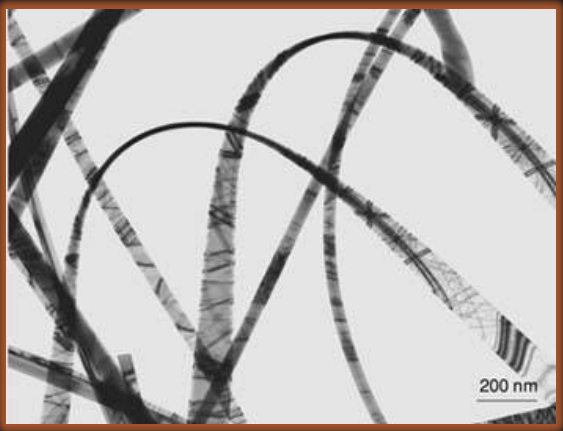












EFFECTIVE BRIDGE TO ADDRESS SDGs

HEALTH-WATER-ENERGY-FOOD NEXUS

OUTLINE

0- U2ACN2: Mission & vision,
1-Nanomaterials :Generalities,
2-Nanotechnologies for society addressing SDGs
-Nano-Physics for HEALTH,
-Nano-Physics for ENERGY,
-Nano-Physics for AGRI,
-Nano-Physics for WATER,

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Nano-HEALTH:Towards GR bio-engineering of nano-mats for Health.

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Nano-HEALTH: IKS based novel Anti-skin Cancer (Khoissan Com.)

- Ms. Ntombi Ditlopo (PhD Fellow-South Africa)
- Dr. Nandipha Botha (Postdoc Fellow-South Africa)
- Dr. Hamza Mohamed (Postdoc Fellow-Egypt)
- Dr. Razie Morad (Postdoc Fellow-Iran)
- Dr. Ali Talha Khalil(Associate Fellow-Pakistan)
- Prof. A. Krief (Senior Associate Fellow-Belgium)
- Prof. E. Gnanasekaran(Senior Associate Fellow-india)

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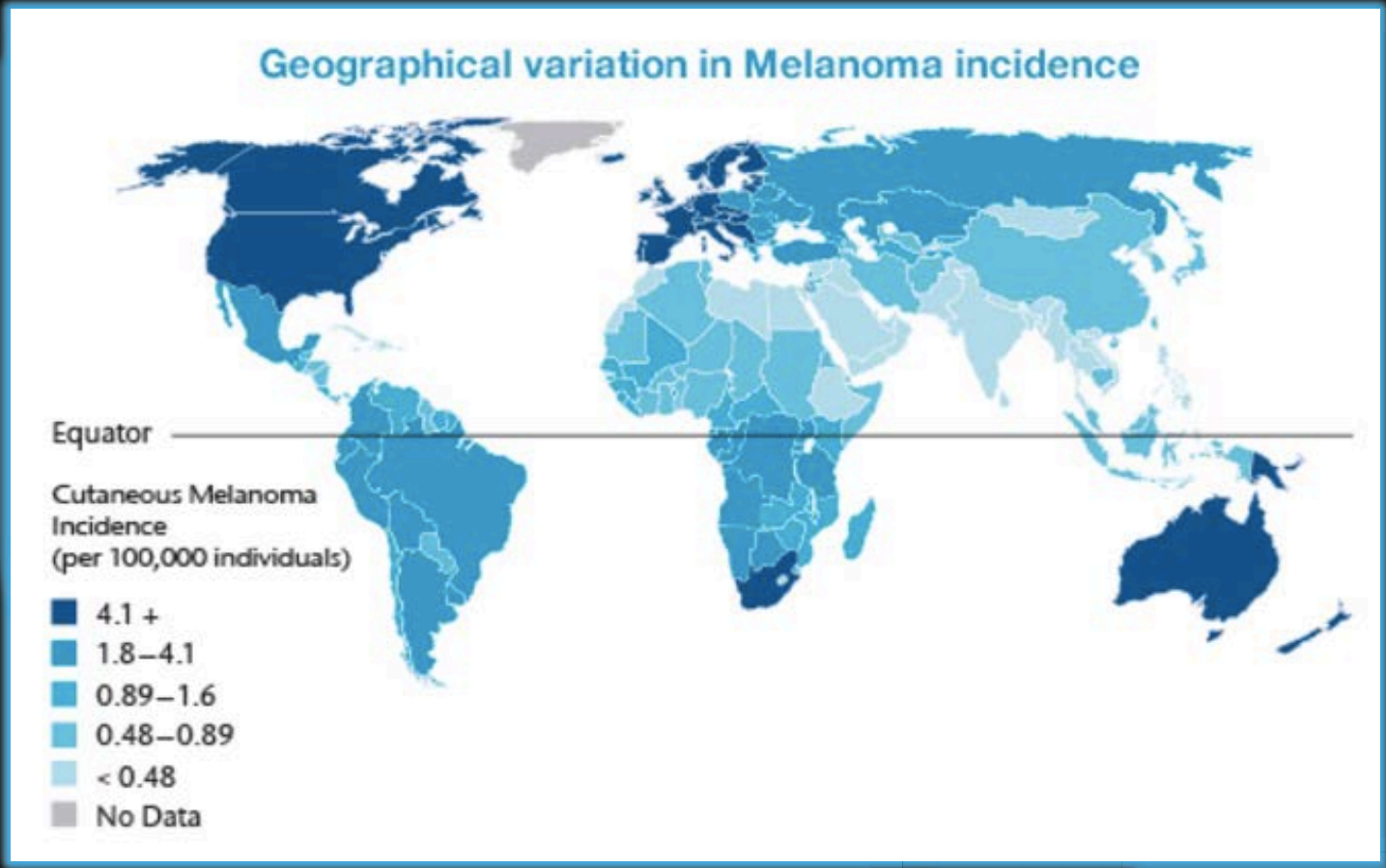
U2ACN2:Towards GR bio-engineering of nano-mats for Health applications.



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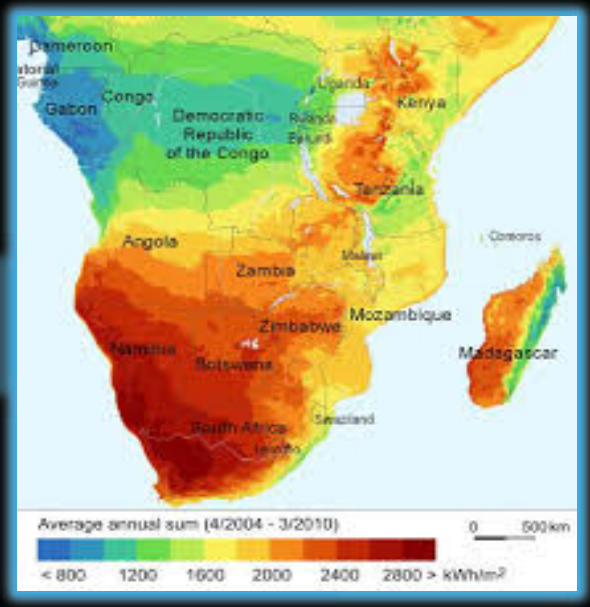
Nano-HEALTH: IKS based novel Anti-skin Cancer (Khoissan Com.)



- Within the Southern Africa Landscape:
- Elevated Direct Normal Irradiance DNI: 220 W/m^2 >>> Average
- keratinocyte skin cancer, melanoma skin cancer, • 132 000 malignant melanomas occur globally every year.
- South Africa has the second highest incidence of skin cancer in the world after Australia.
- More than 90% skin cancers are caused by sun exposure

Nano-HEALTH: IKS based novel Anti-skin Cancer (Khoissan Com.)

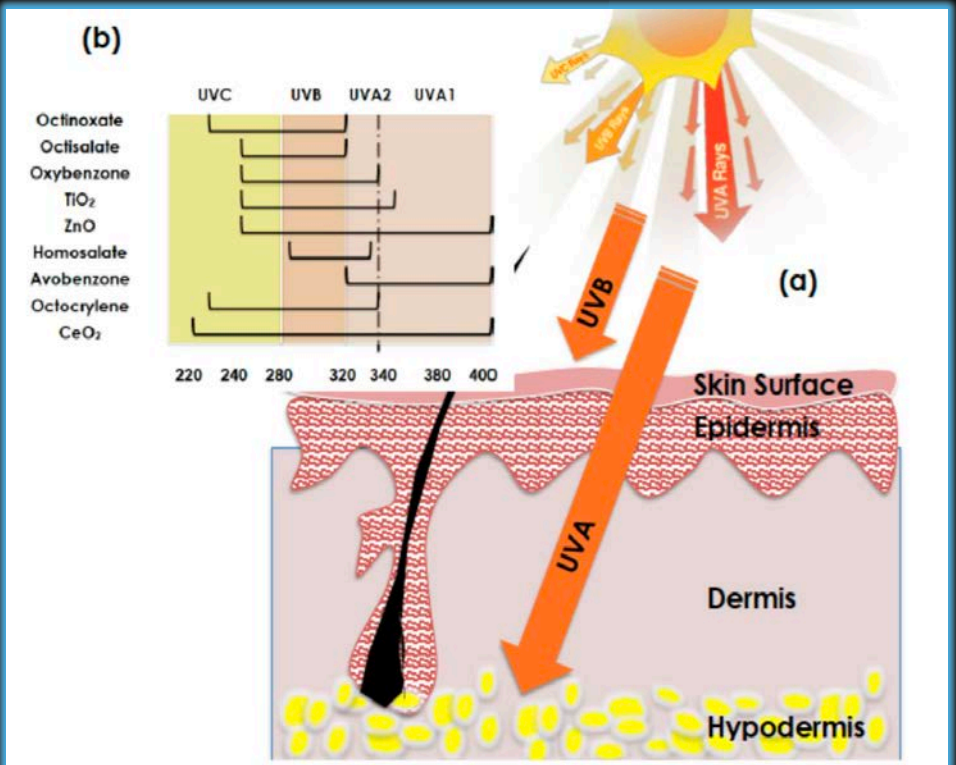


Figure 2. (**a**) Depth penetration of the various UV solar radiations within a human skin, (**b**) UV protection window of the current biosynthesized CeO_2 compared to those standard compounds (organics) and traditional nanoscaled oxides ZnO and TiO_2.

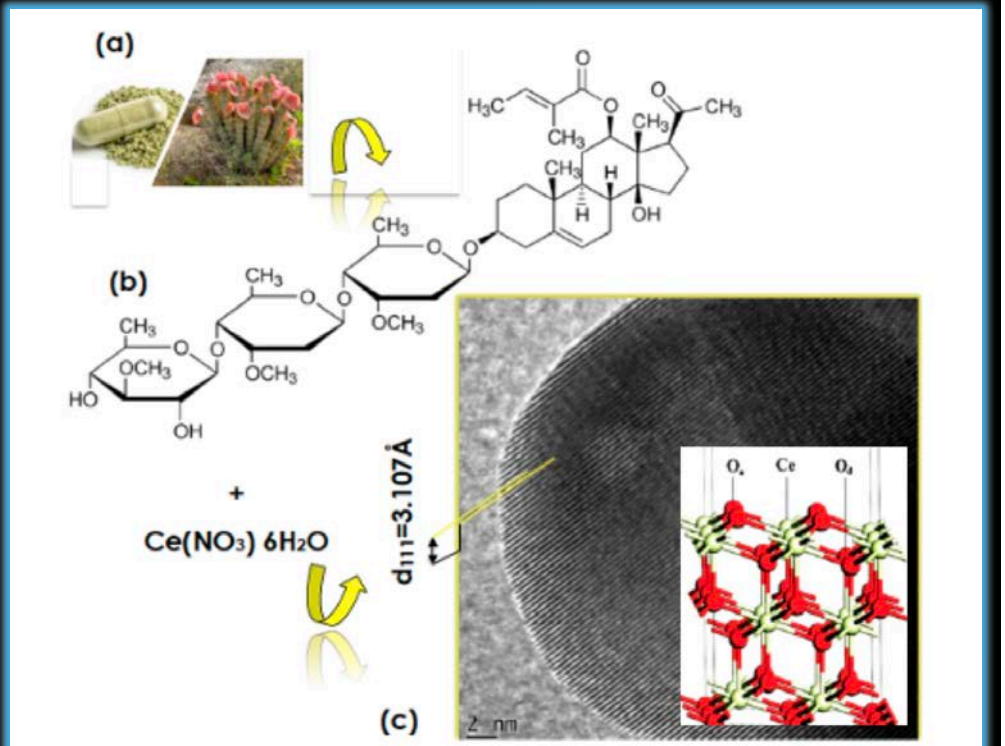


Figure 1. (**a**) Hoodia *gordonii* plant and in a powdered form, (**b**) chemical structure of the most active biocompound known as P57 (12-O-Trigloyl-3β,12β,14β-pregn-5-en-20-one3-O-β-D-thevetopyranosyl-(1→4)-β-D-cymaropyranosyl-(1→4)-β-D-cymaro-pyranoside), (**c**) typical HRTEM scan of a biosynthesized CeO_2 nanocrystal.

- Ditlopo, Maaza et al.," From Khoi-San indigenous knowledge to bioengineered CeO2 nanocrystals to exceptional UV-blocking green nanocosmetics". Nature Scientific Reports 12, 3468 (2022). https://doi.org/10.1038/s41598-022-06828-x.

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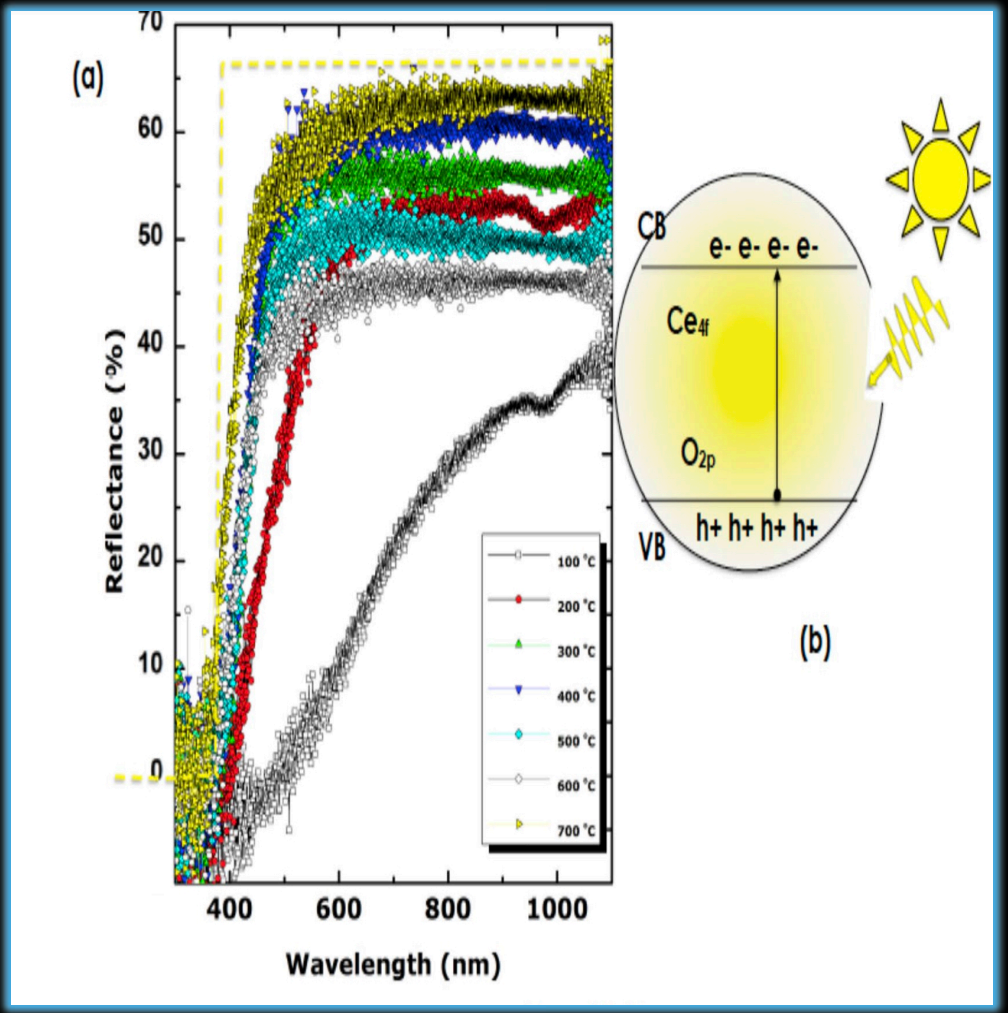
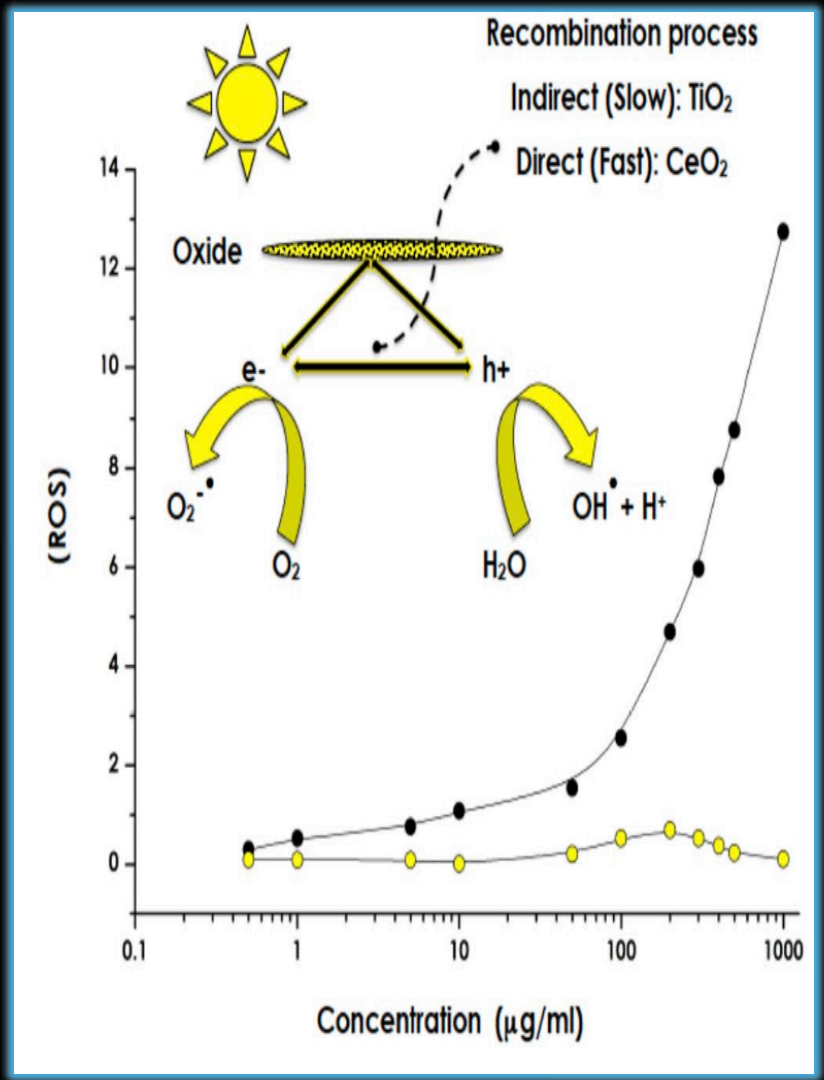
Nano-HEALTH:Towards GR bio-engineering of nano-mats for Health : ANTI-CANCER: Khoisan Trad.Know.





Nano-HEALTH: IKS based novel Antibacterials (Himba Com.)

- Dr. Nandipha Botha (Postdoc Fellow, South Africa)
- Dr. Nagla Numan (Postdoc Fellow, Sudan)
- Ms. Boitumelo Machabakacha (PhD Fellow, Botswana)
- Dr. Razie Morad (Postdoc Fellow, Iran)
- Dr. Mahmood Akbari (Postdoc Fellow, Iran)

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Towards GR bio-engineering of nano-mats for Health applications:

ANTI-BACTERIAL: Himba Trad.Know.

Himba
Red Ocre

Nano-HEALTH: IKS based novel Antibacterials (Himba Com.)

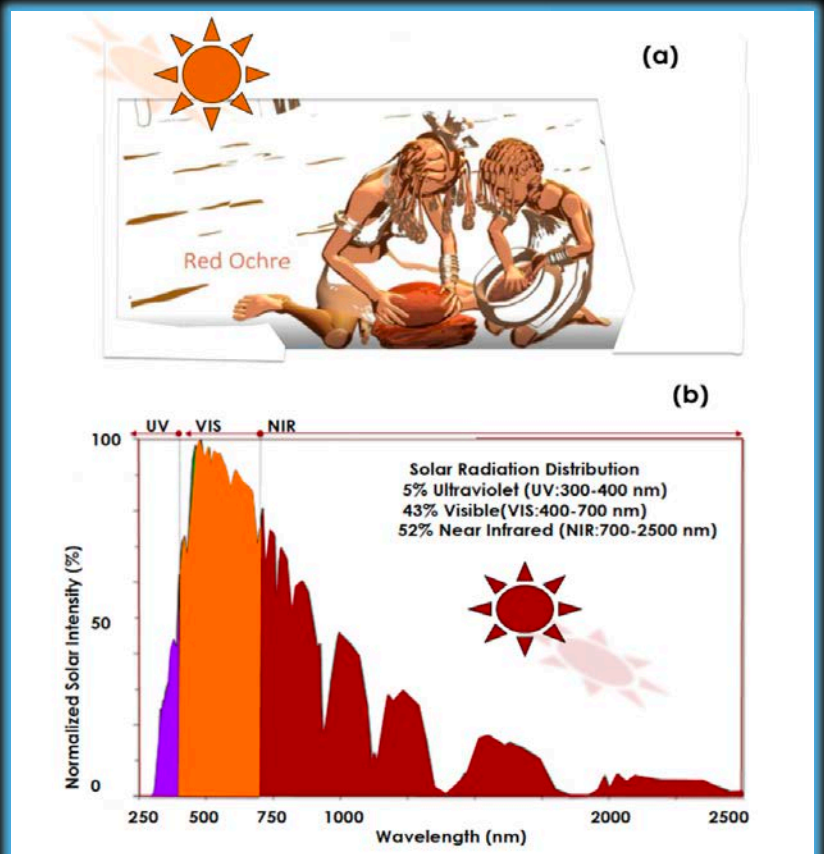
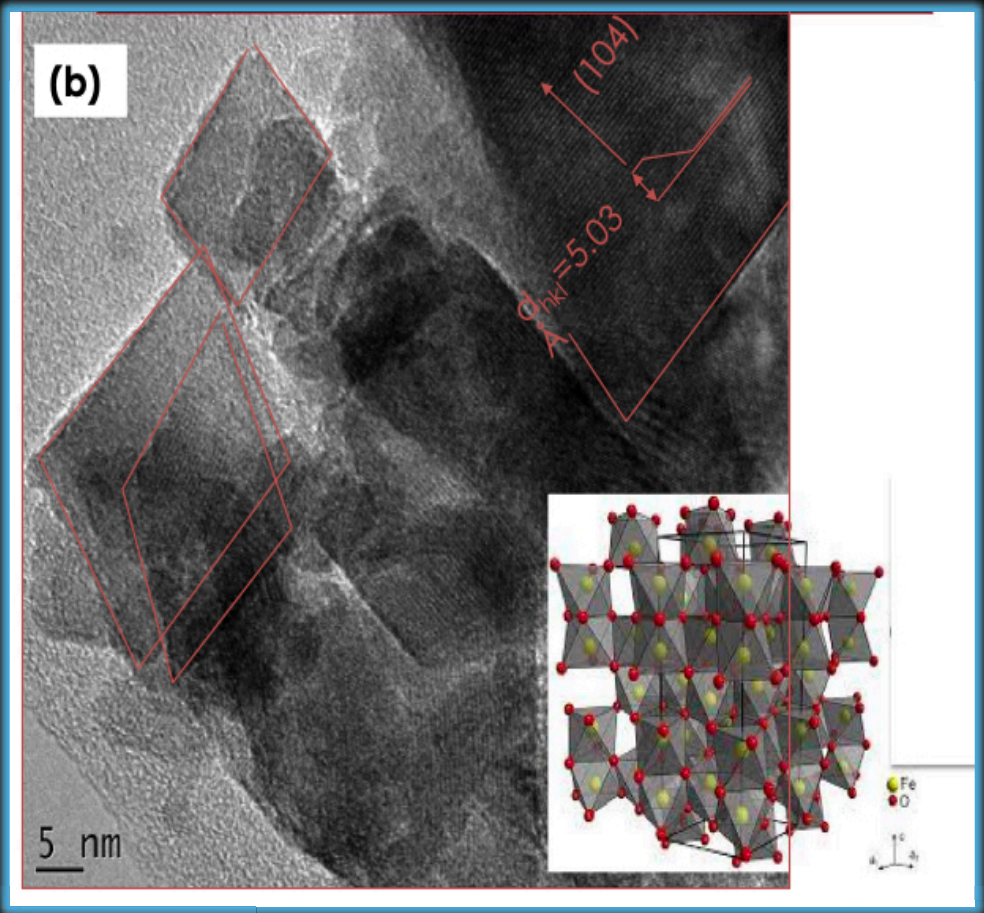


Figure 1. (a) Traditional preparation of the Red Ochre pigment by the Himba community, (b) Solar spectral distribution in the north of Namibia to which the Himba group community is exposed.



- Havenga, Maaza et al. "From Himba indigenous knowledge to enginee
Fe2O3 UV-blocking green nanocosmetics". Nature Scientific Repor
12, 2259 (2022). https://doi.org/10.1038/s41598-021-04663-0

Nano-HEALTH: IKS based novel Antibacterials (Himba Com.)

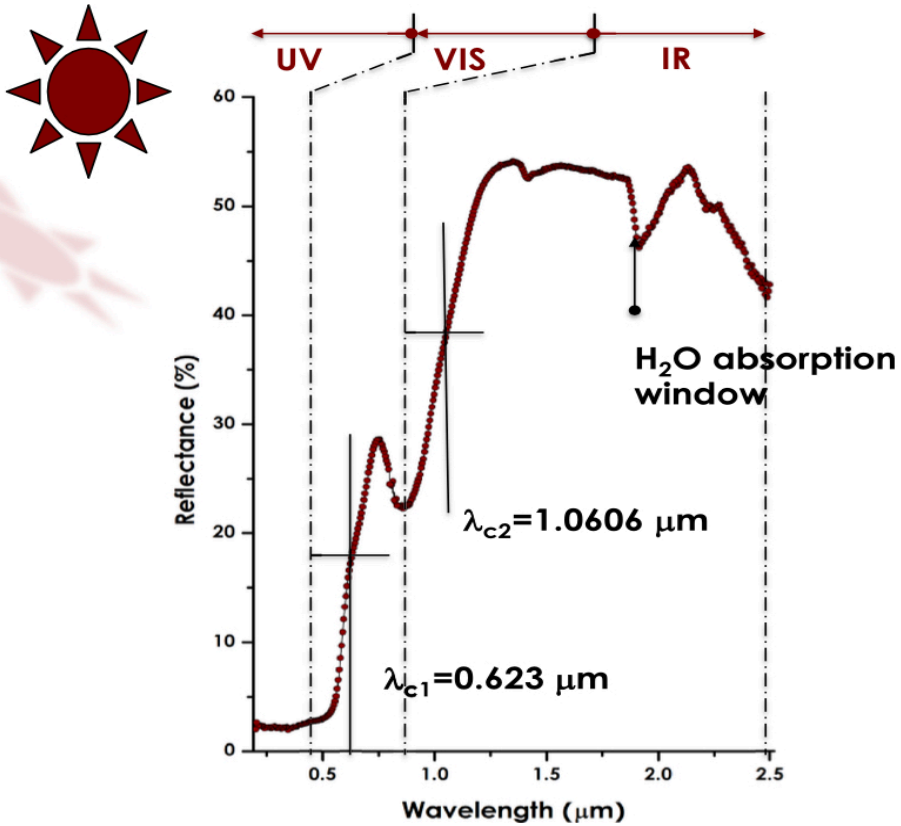


Figure 4. (**a**) ATR-FTIR vibrational modes of the Red Ochre pigment, (**b**) its Photoluminescence emission spectrum under an excitation wavelength λ_{exc} = 270 nm, and (**c**) its UV–VIS-NIR reflectance in the spectral range of 190–2500 nm.

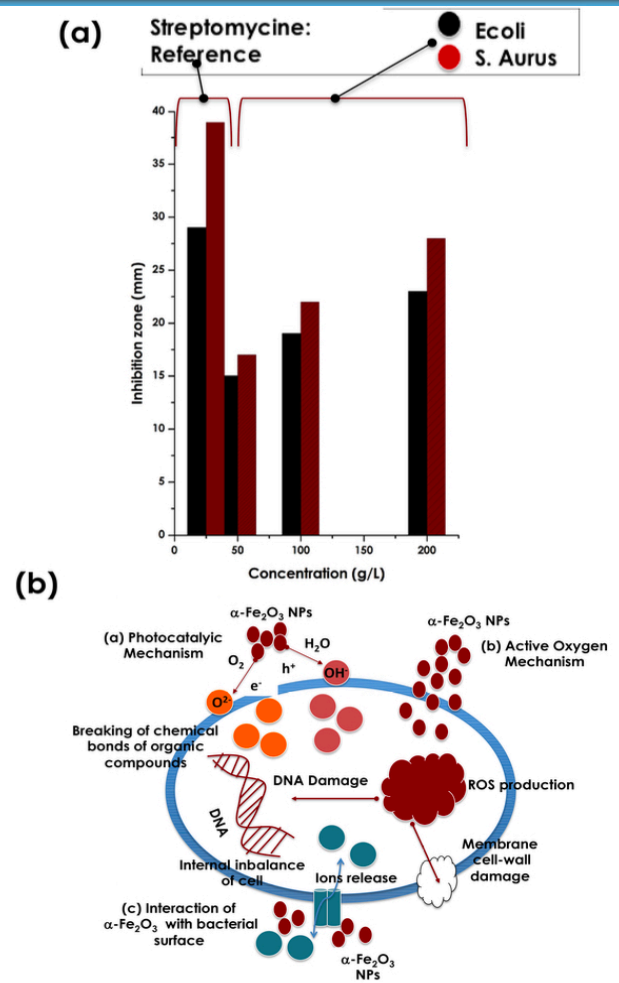


Figure 5. (**a**) Antibacterial response of the Red Ochre pigment against the E-coli & S-Aurus compared to standard reference Streptomycine (**b**), Schematic representation of the 3 potential mechanisms inducing the antibacterial activity of the Ochre.

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-Nano-Physics for WATER,

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UNESCO-UNISA Africa Chair in Nanosciences/Nanotechnology (South Africa)

Nano-AGRI:Towards Nanofertilizers for Sustainable Farming

United Nations Educational, Scientific and Cultural Organization

UNESCO-UNISA Africa Chair in Nanosciences Nanotechnology (South Africa)

UNISA

Nano-AGRI:Towards Nanofertilizers for Sustainable Farming

SA fertilizers import
US$823.41 M (2023)

- Dr. Nandipha Botha (Postdoc Fellow-South Africa)
- Dr.Karen Cloete (Emerging young scientist-South Africa)
- Dr. Hamza Mohamed (Postdoc Fellow-Egypt)
- Ms. Thobo Mothlamme(PhD Fellow-Botswana)
- Mr.G. Kanningini (PhD Fellow-DRCongo)

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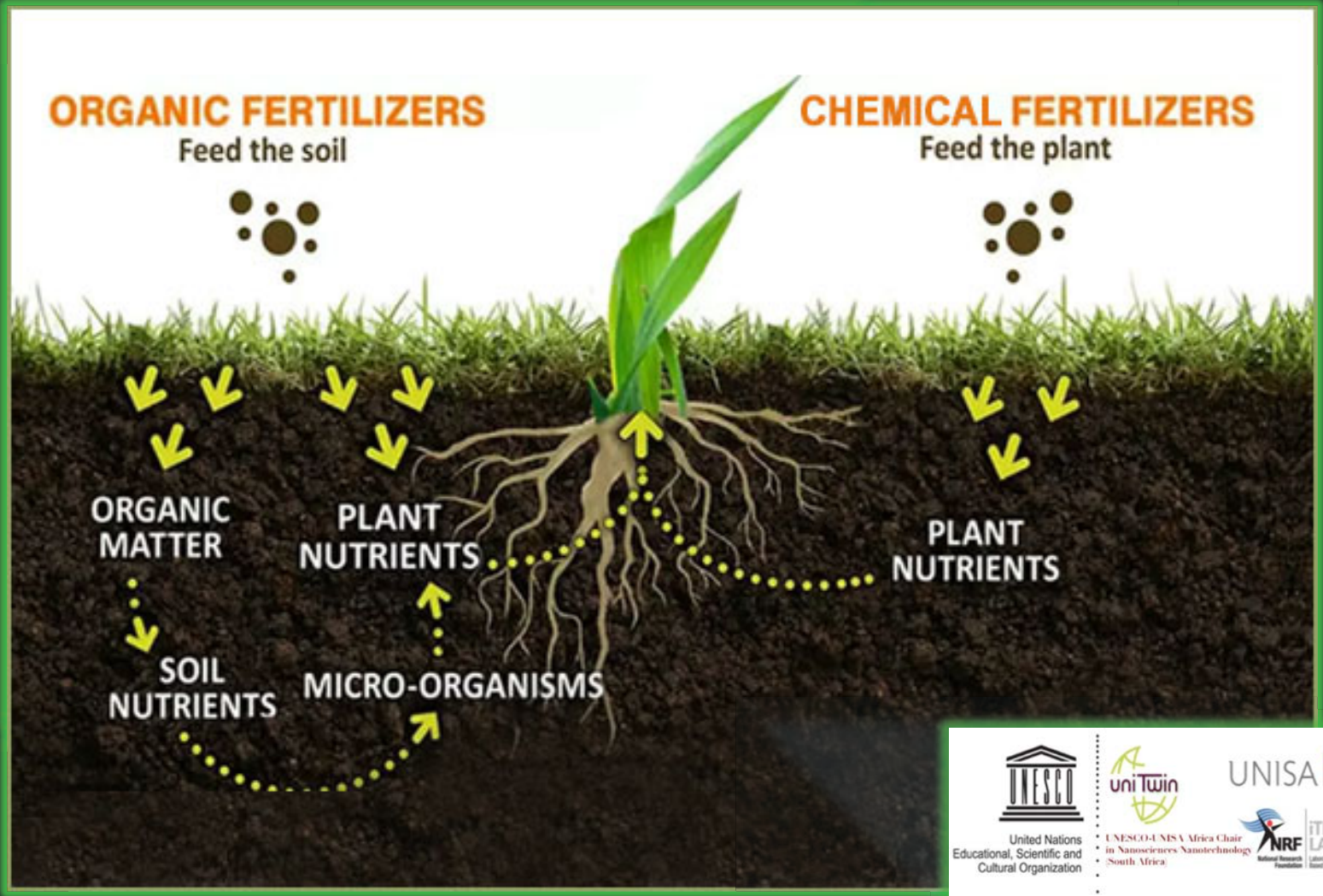
UNISA
NRF
iThemba LABS

American Physical Society Webinars Series, 12-12-/2024,

Nano-AGRI:Towards Nanofertilizers for Sustainable Farming



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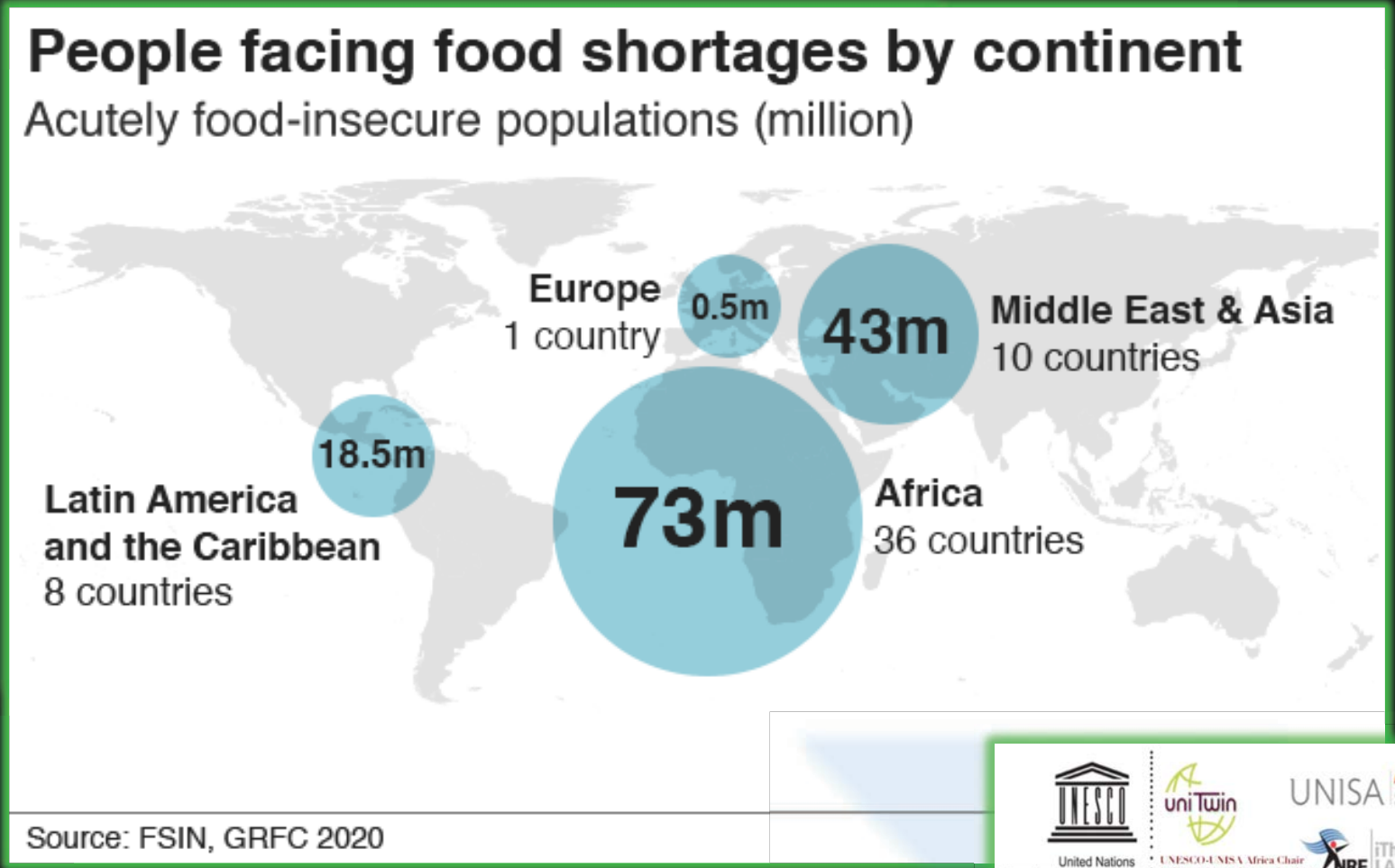

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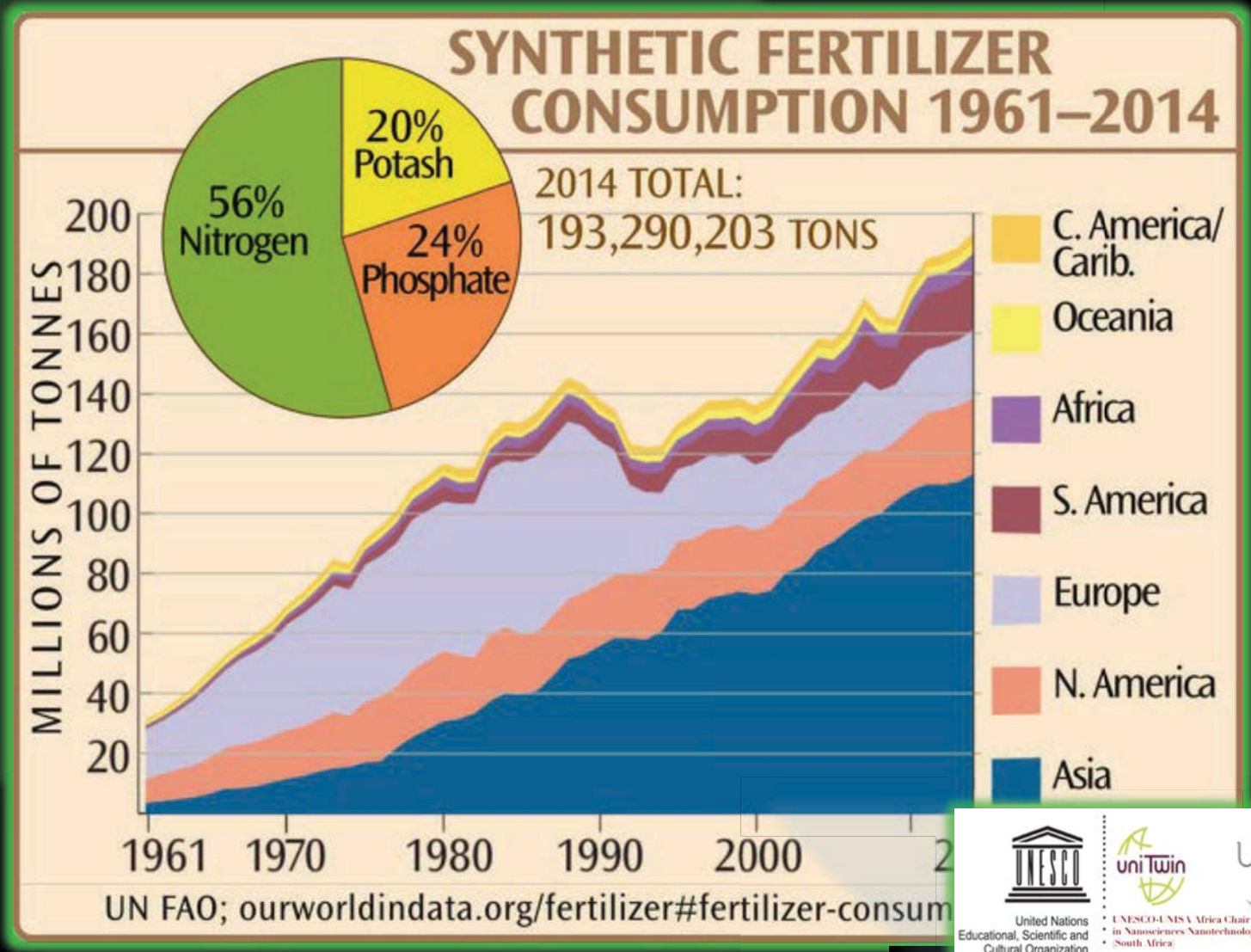
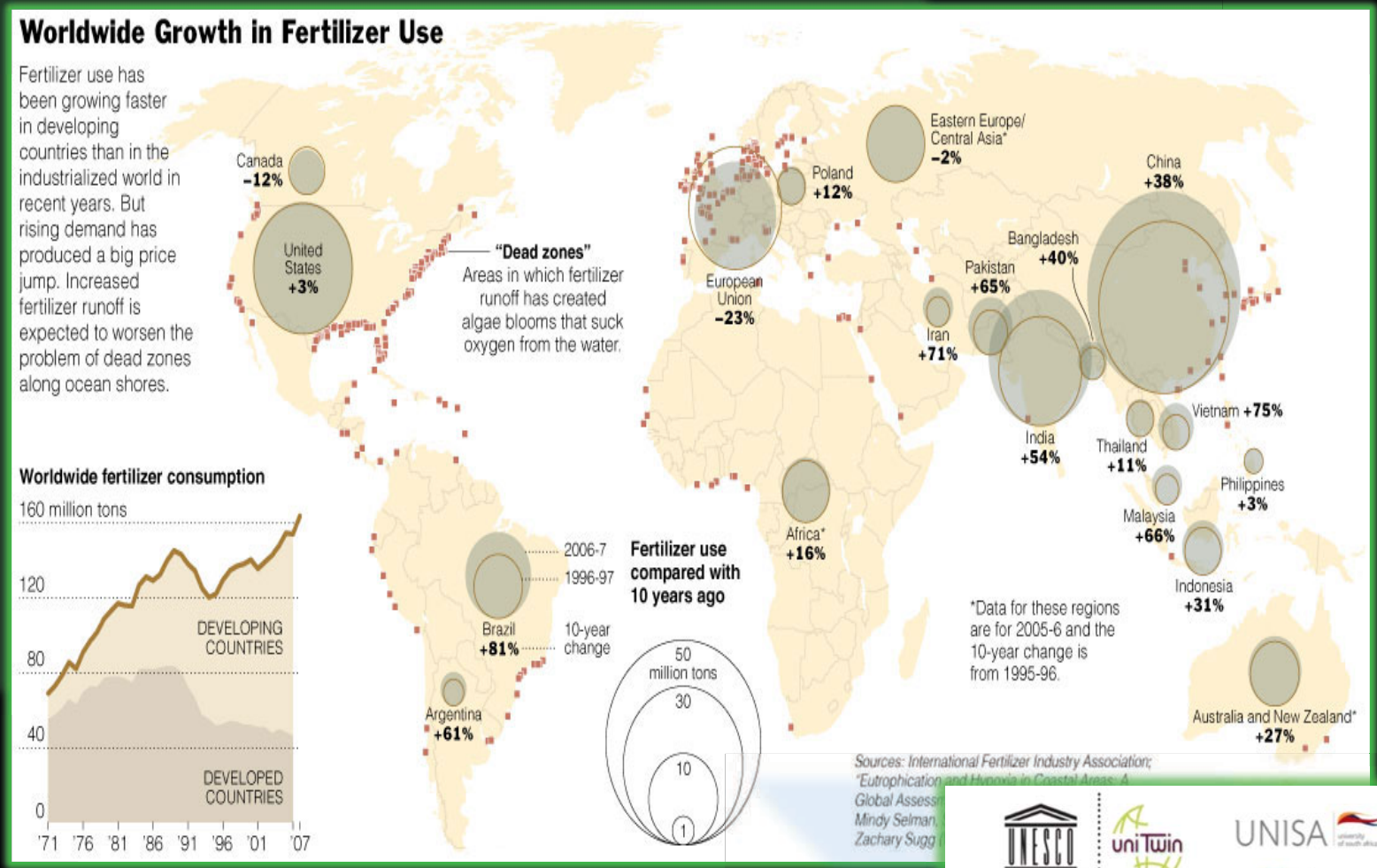


Nano-AGRI:Towards Nanofertilizers for Sustainable Farming



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Nano-AGRI: Towards Nanofertilizers for Sustainable Farming: $_{Nano}CaCO_3$

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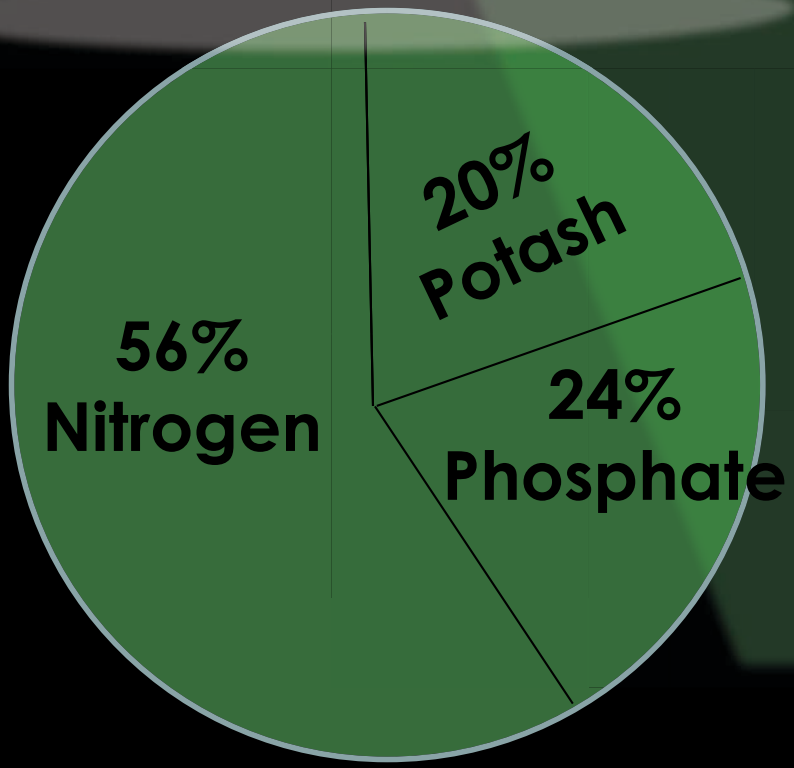
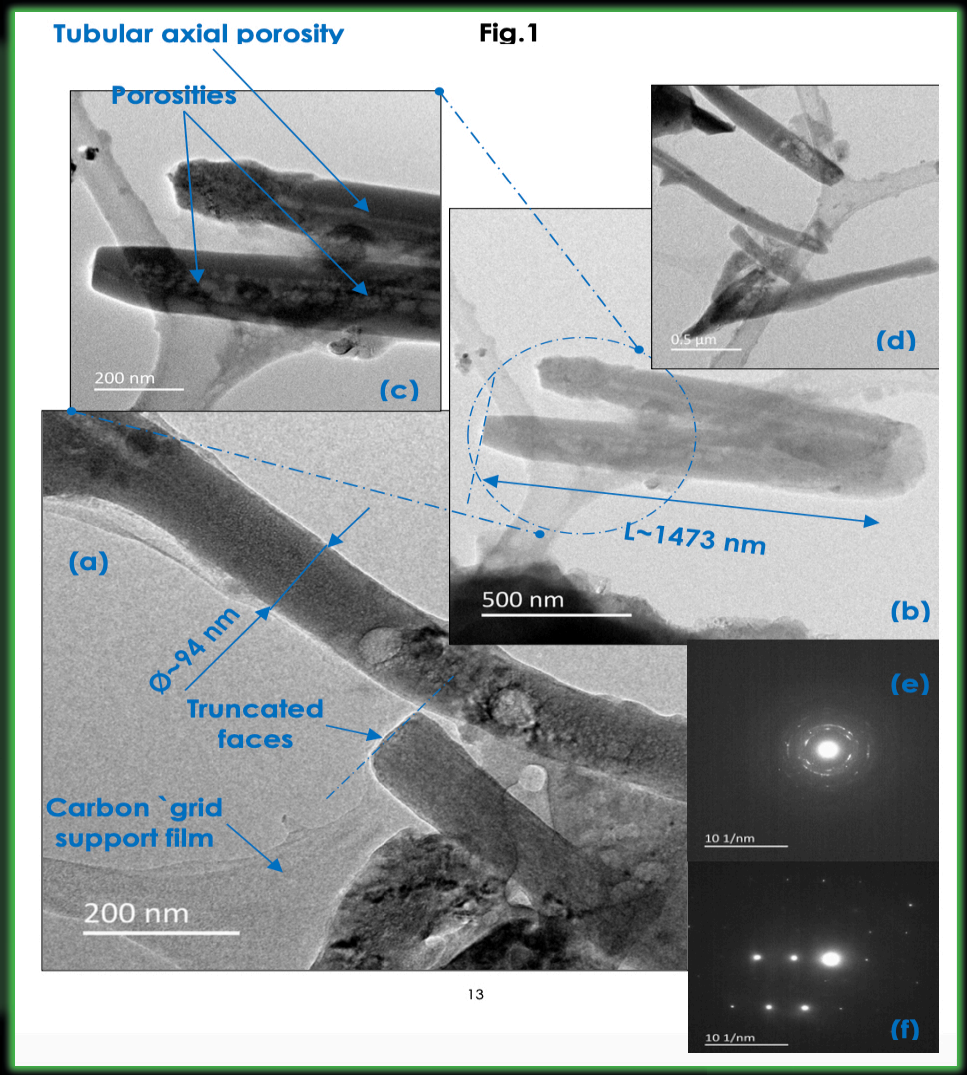
US$823.41 M (2023)





Nano-AGRI:Towards Nanofertilizers for Sustainable Farming

- Mohamed, H, Maaza et al. Room Temperature Bio-Engineered Multifunctional 1-D Nanoscaled Carbonates for CO2 Sequestration &Valorization. Nature Scientific Reports 11, 2131 (2021). https://doi.org/10.1038/s41598-021-81617-6

Nano-AGRI:Towards Nanofertilizers for Sustainable Farming

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Nano-WATER:Towards Defective active photocatalyst for removal of peticides in water

United Nations Educational, Scientific and Cultural Organization

UNESCO-UNISA Africa Chair in Nanosciences/Nanotechnology (South Africa)

Nano-WATER:Towards Defective active photocatalyst for removal of peticides in water

- Mr. Adama Fall (PhD Fellow-Senegal)
- Dr. Nandipha Botha (Postdoc Fellow-South Africa)
- Dr. Nagla Numan (Postdoc Fellow-Sudan)
- Dr. Hamza Mohamed (Postdoc Fellow-Egypt)
- Dr. Razie Morad (Postdoc Fellow-Iran)
- Dr. Mahmood Akbari (Postdoc Fellow-Iran)
- Dr.Shohreh Azizi (Postdoc Fellow-Iran)

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NRF National Research Foundation

iThemba LABS Laboratory for Accelerator Based Sciences

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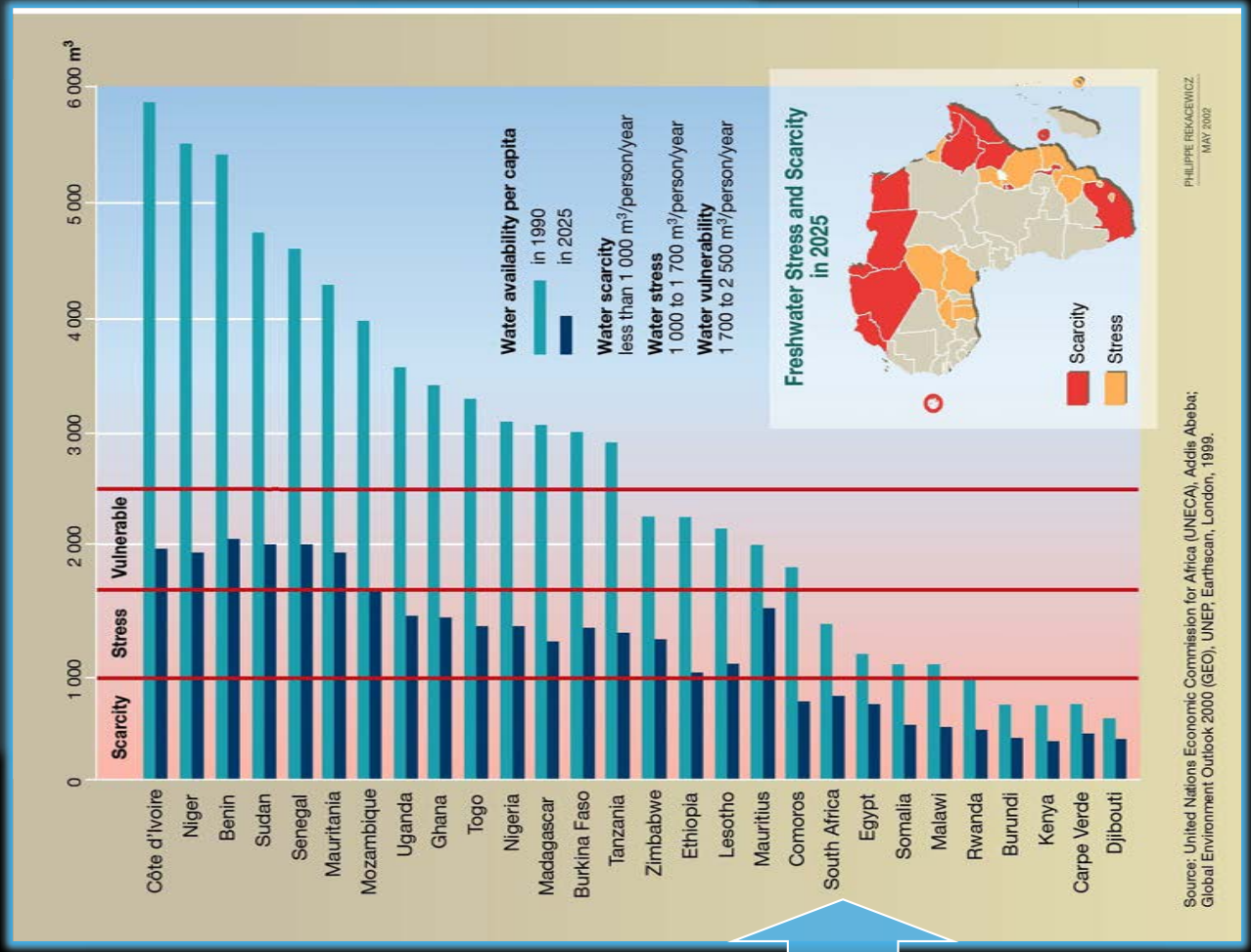
Nano-WATER:Towards Defective active photocatalyst for removal of peticides in water



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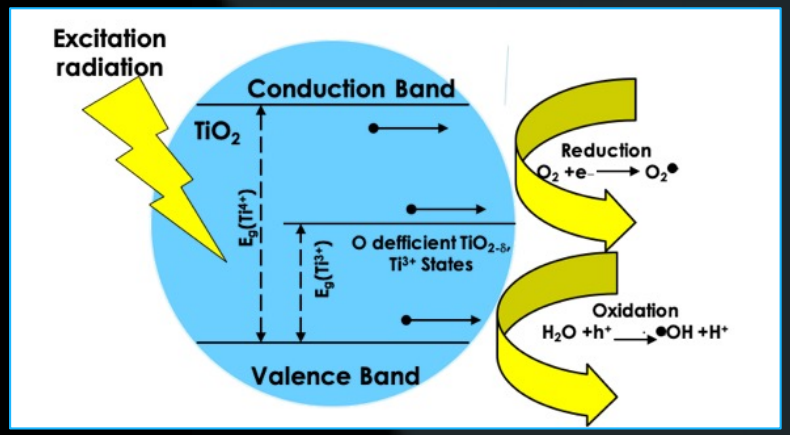
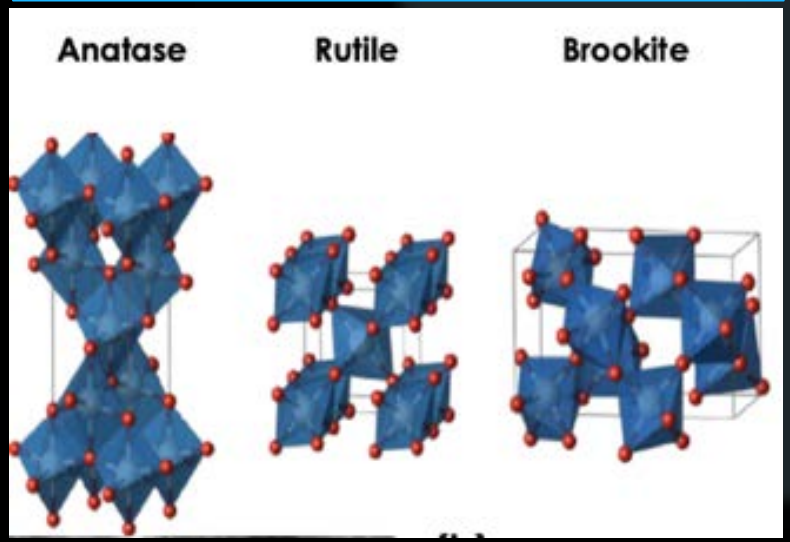
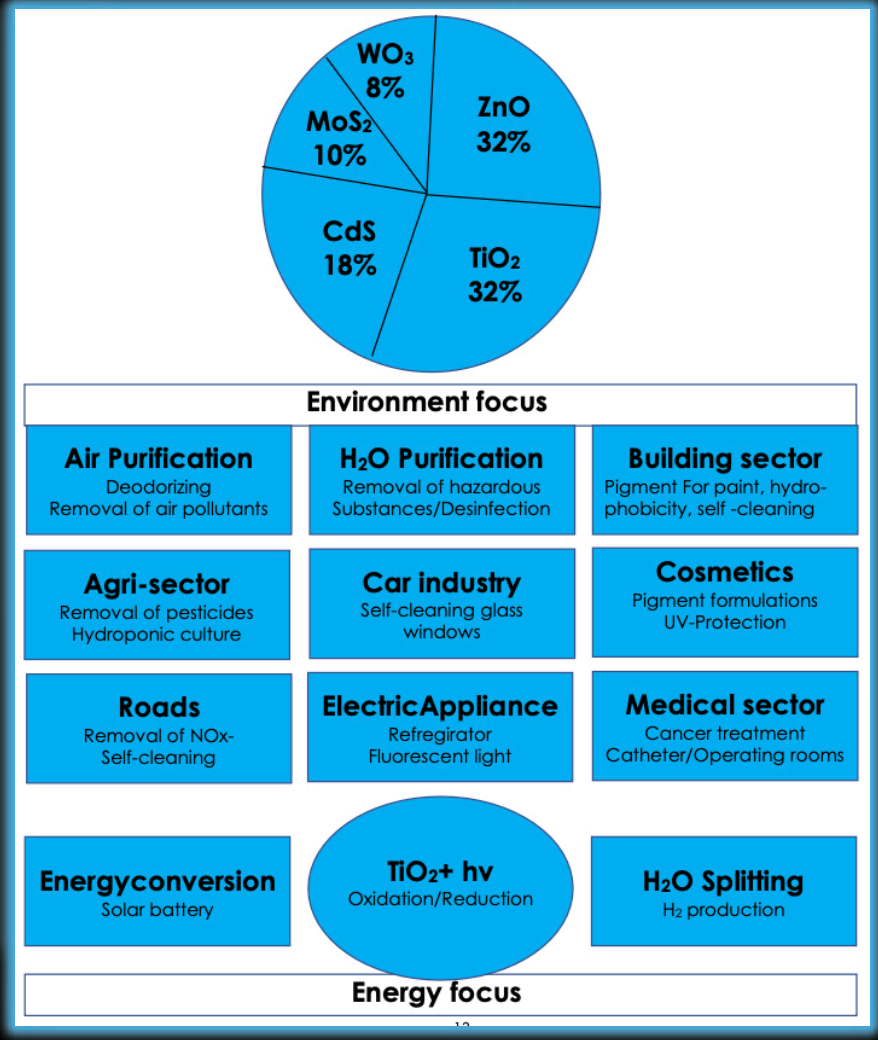
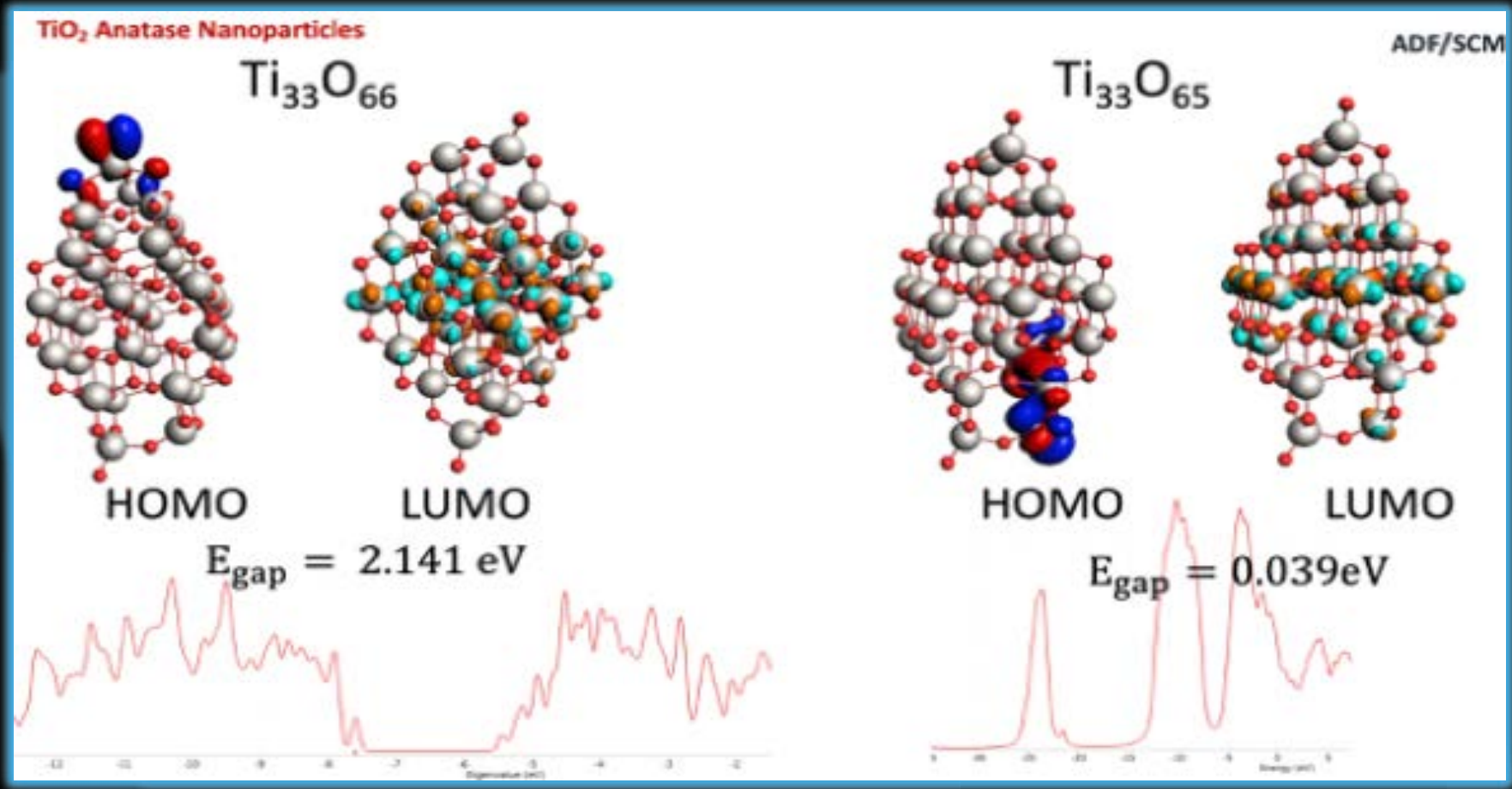






Nano-WATER:Towards Defective active photocatalyst for removal of pesticides in water



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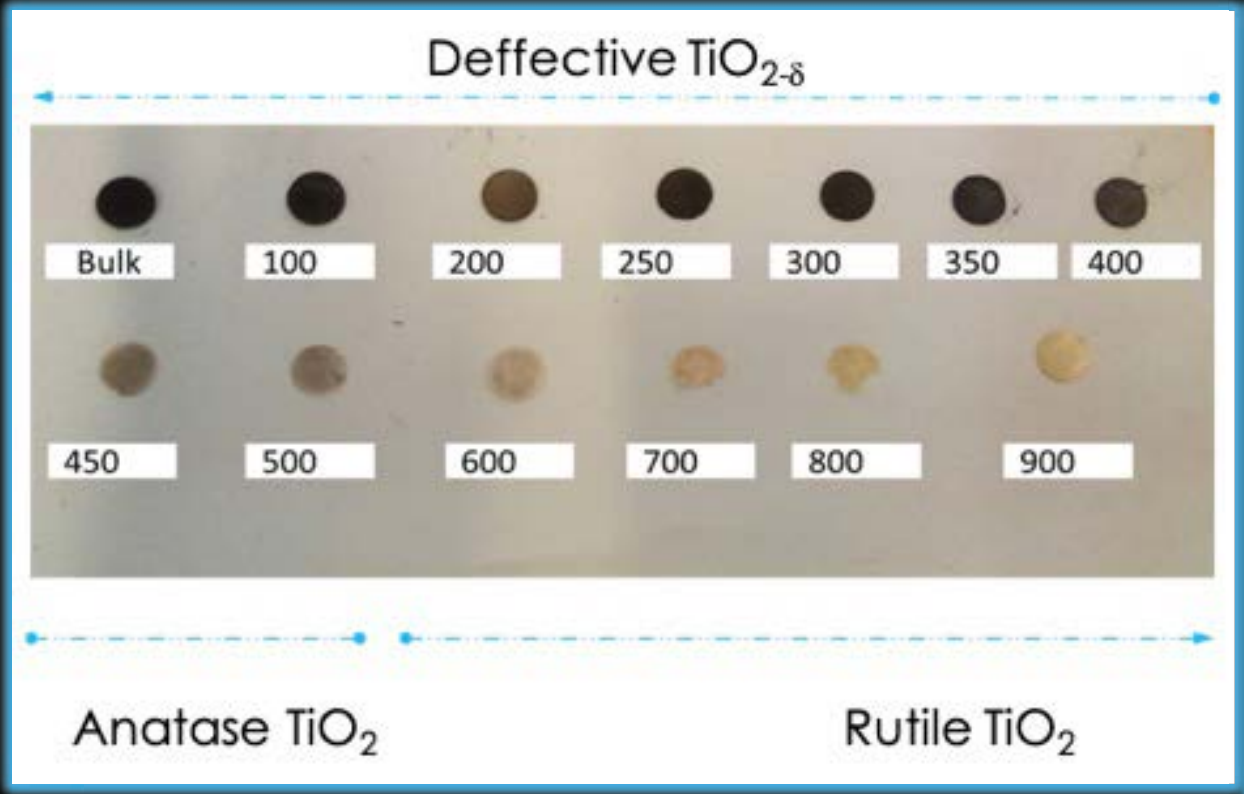

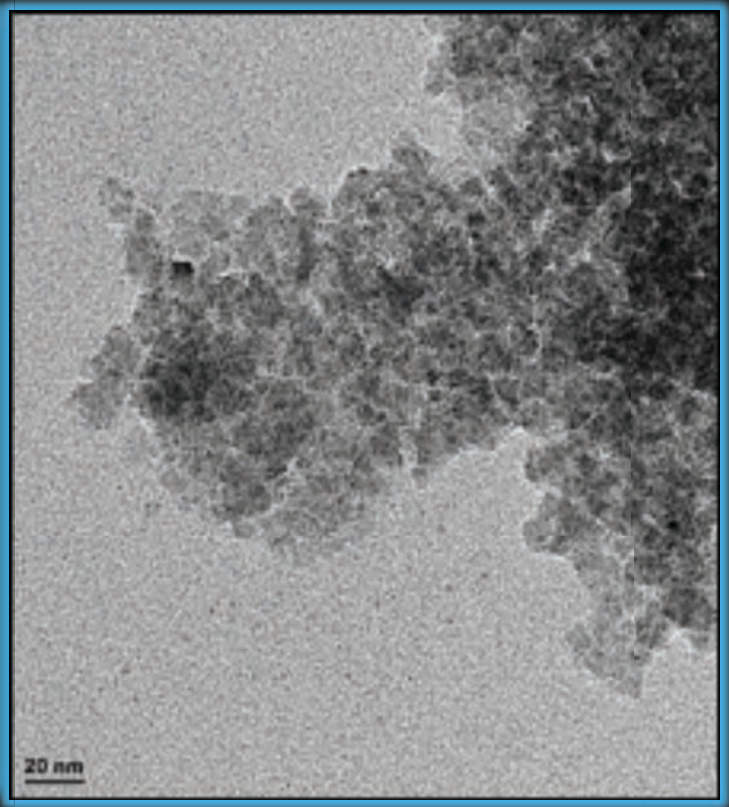

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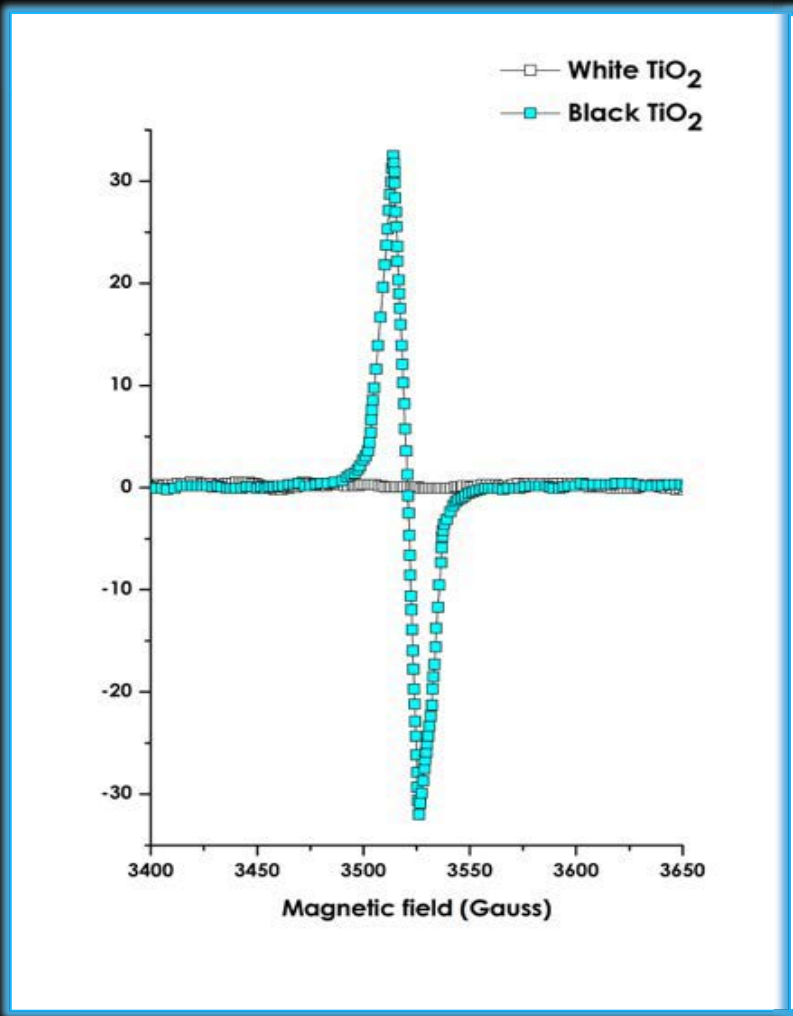

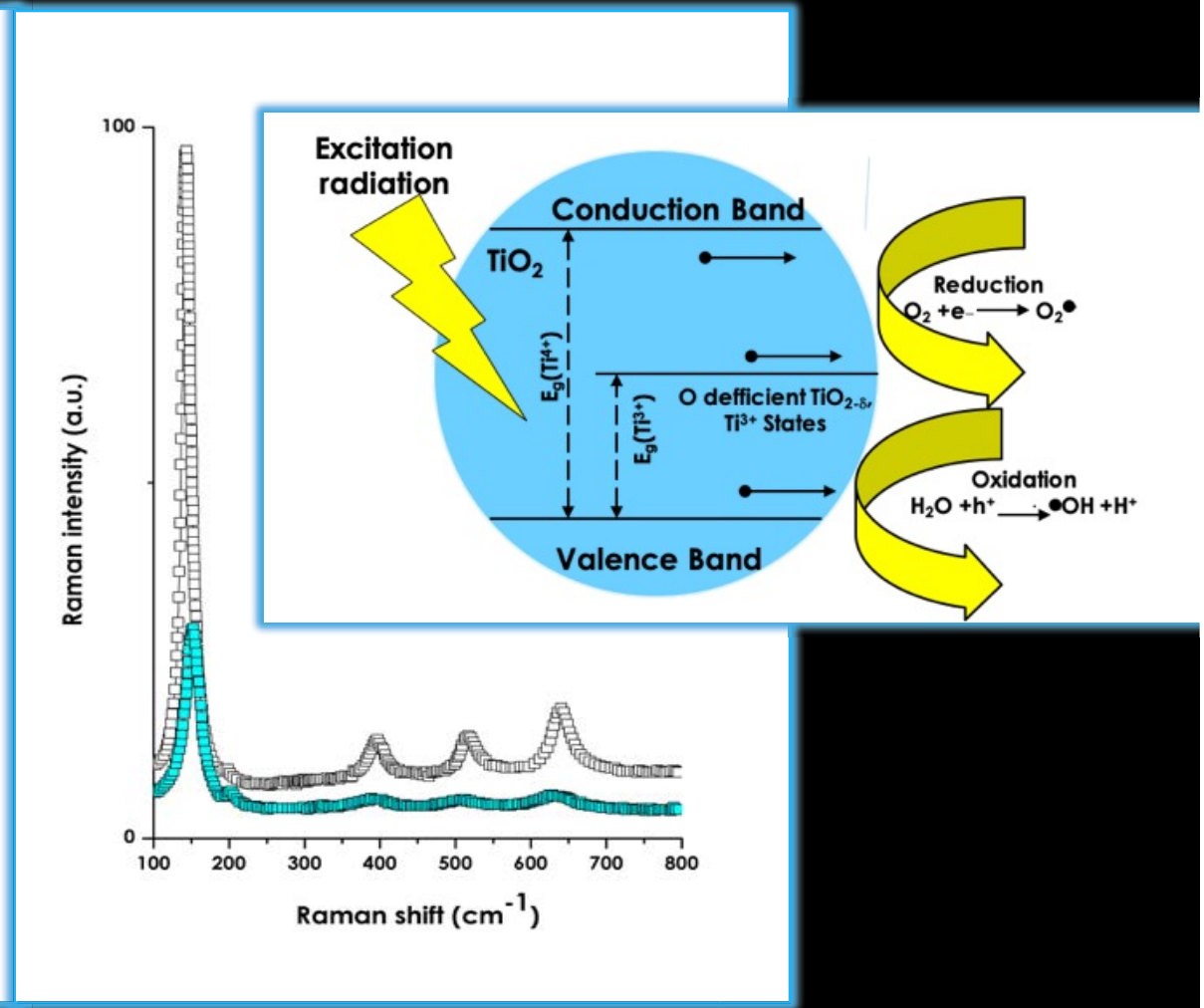

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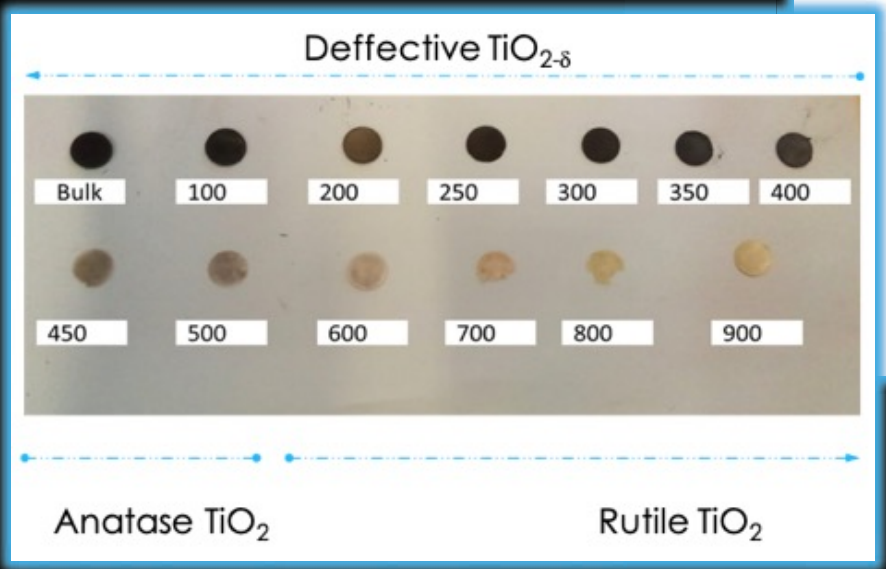

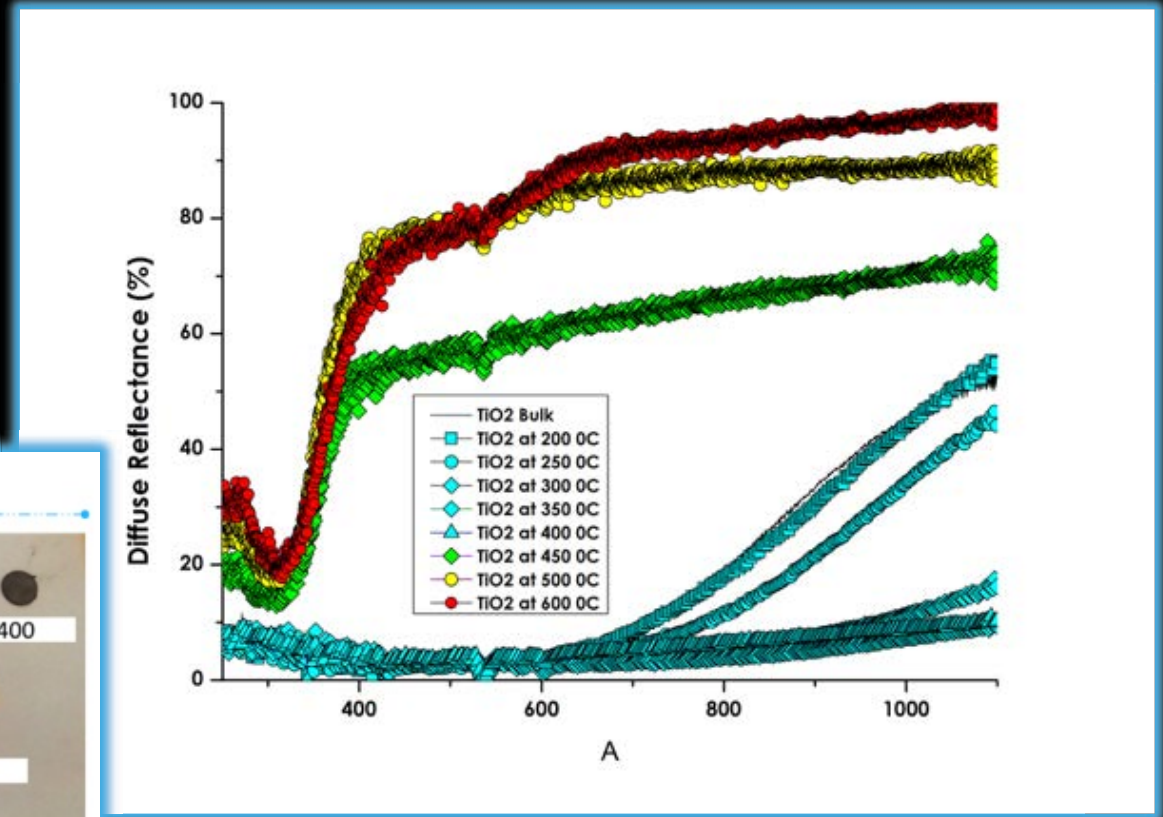

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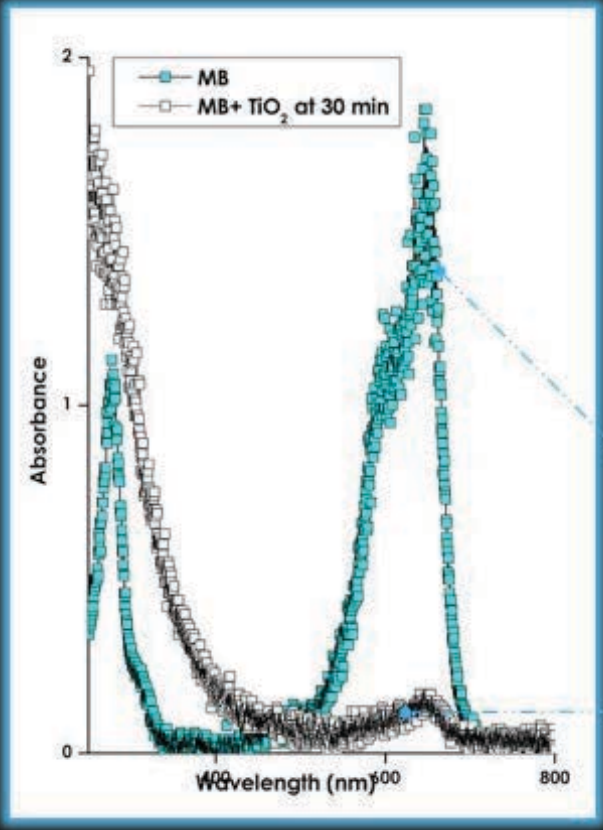

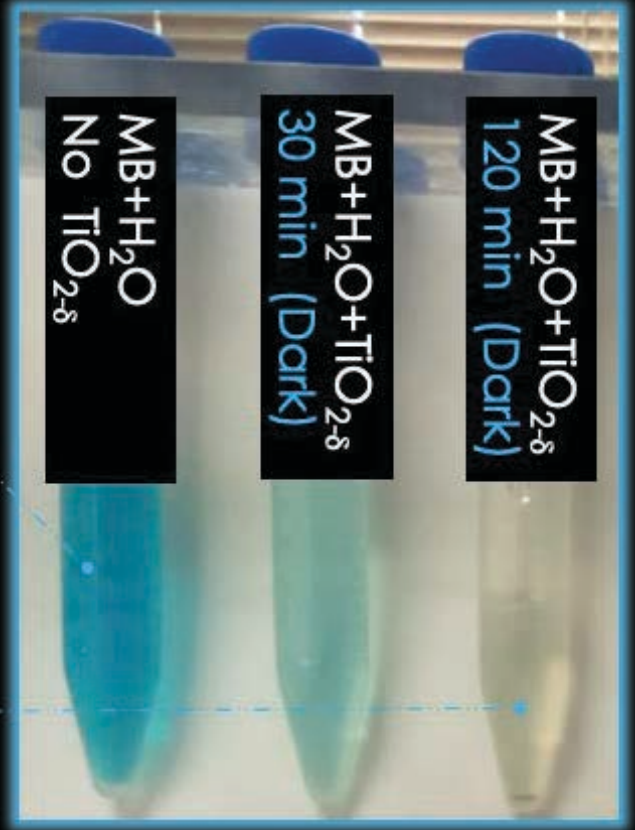

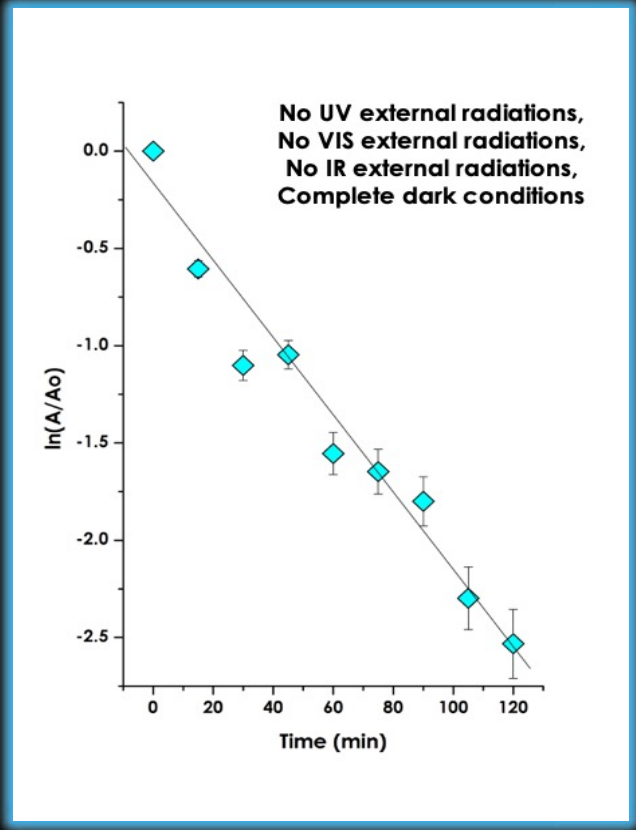

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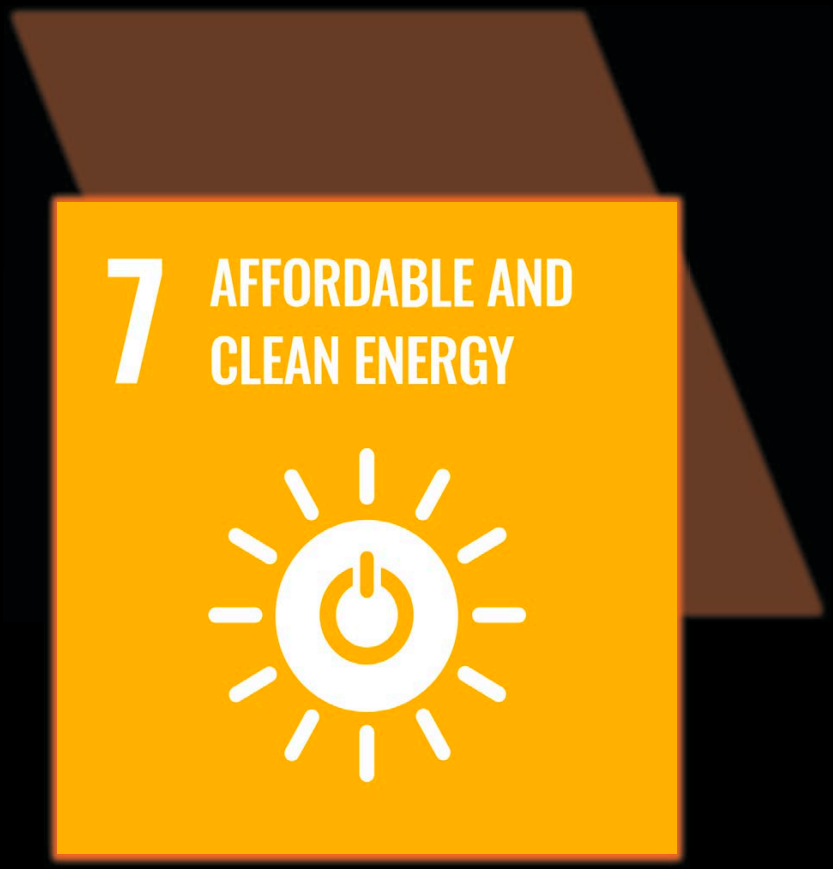
Phase Transition:Towards green air-con via smart windows & .



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Phase Transition:Towards green air-con via smart windows & .

- Today, 55% of the world's population lives in urban areas,
- to 2.5 billion by 2050, with 90% of this increase in Asia & Africa.

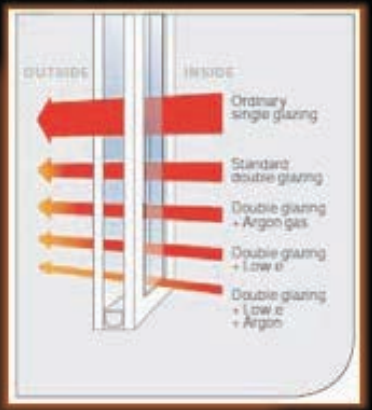
- With such an upsurge of urban population air conditioning demand in urban areas would sky-rocket. • Global energydemand from AC:iexpected to triple by 2050, requiring significant electricity capacity, equivalent to the combined electricity capacity of the USA, EU & Japan today.

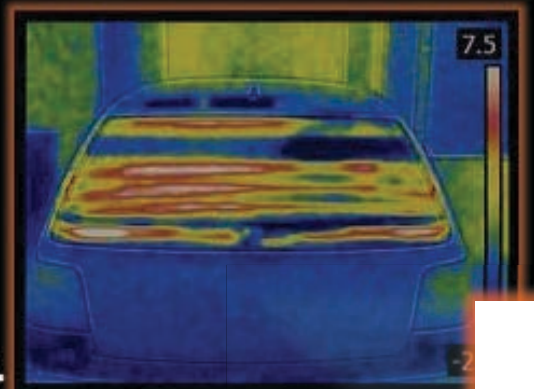
- The global stock of air conditioners in buildings & automotives is expected to grow to 5.6 billion by 2050 from 1.6 billion today.

Phase Transition:Towards green air-con via smart windows & .

Typical Heat loss/gain in a residential housing unit

- Roof: ~Var
- Walls: ~Var
- Windows: ~25-30 %
- Draughts: ~10-20 %





In a standard automotive

- 15-27 % of fuel consumption eq.

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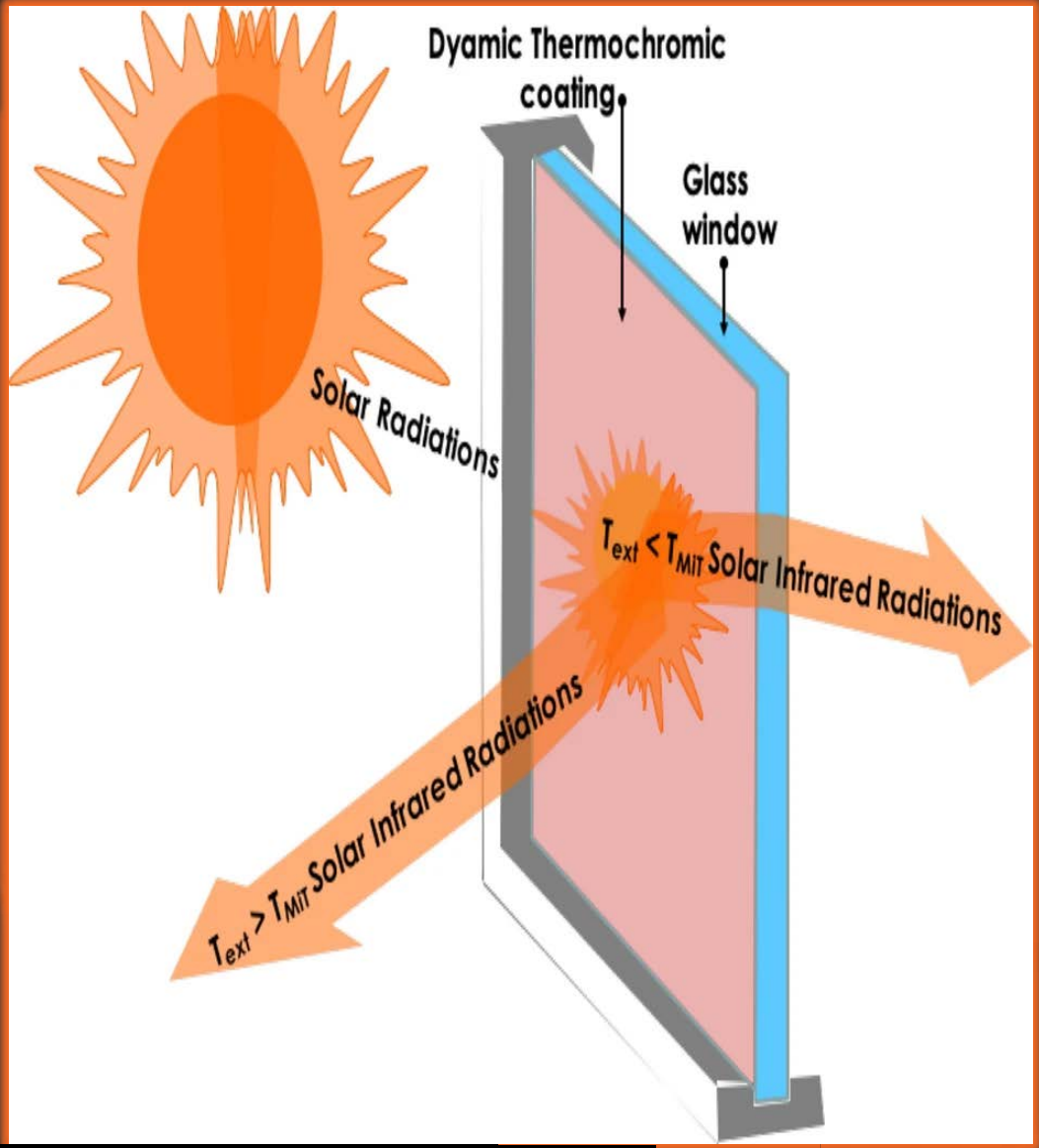

Phase Transition:Towards green air-con via smart windows & .

- Ms. Boitumelo Machabakacha (PhD Fellow, Botswana)
- Dr. Nagla Numan (Postdoc Fellow, Sudan)
- Dr. Aline Simo (Alumni Fellow, Cameroon)
- Dr. Itani Madiba (Emerging Scientist , South Africa)
- Dr. Sfundo Khanyile (U2ACN2 Associate , South Africa)

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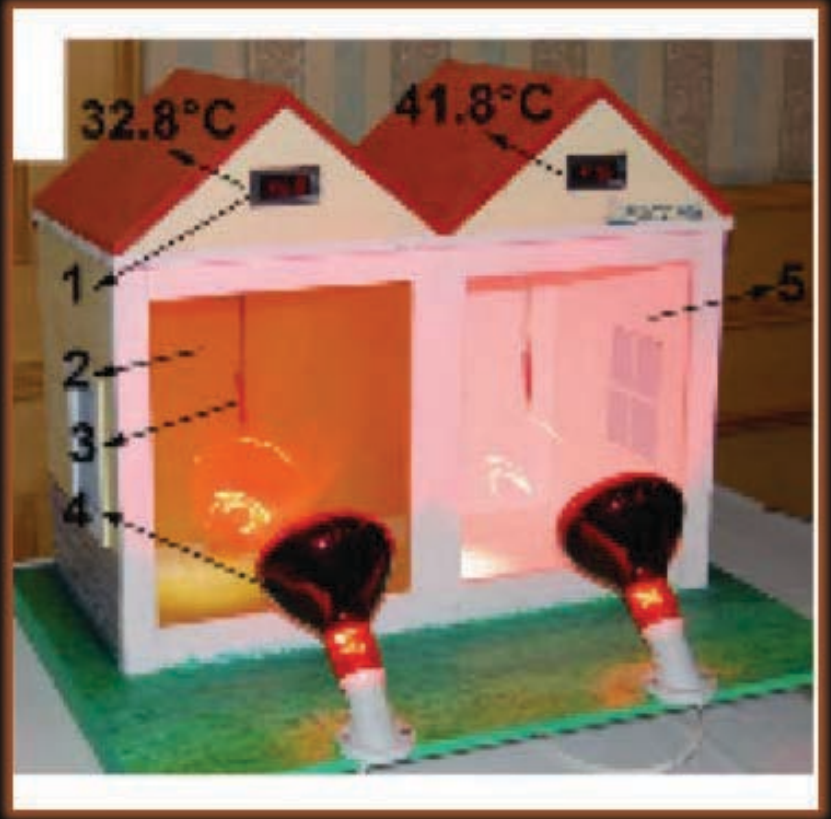

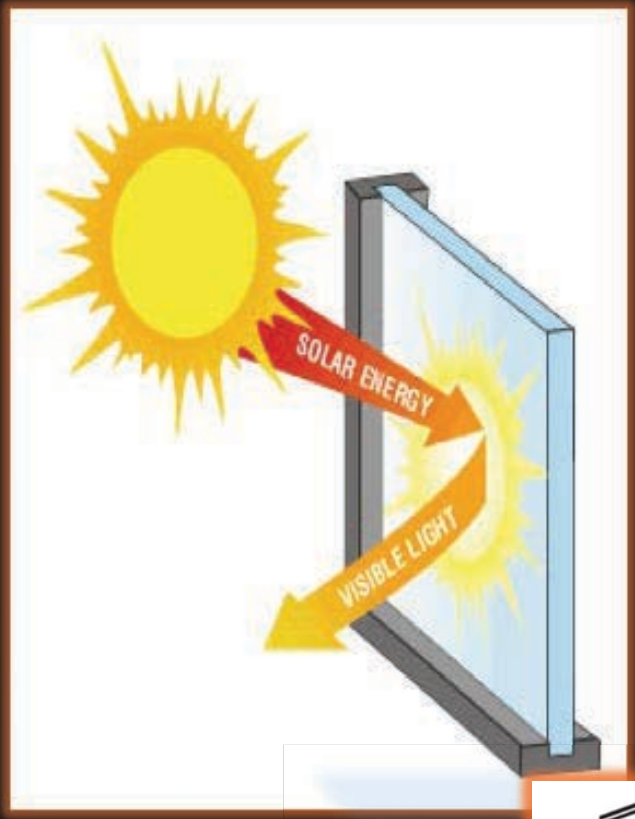

- Tuning down the Transition Temperaure: W/Mo dopi
- Good T_{VIS} but not satisfactory ΔT_{IR}

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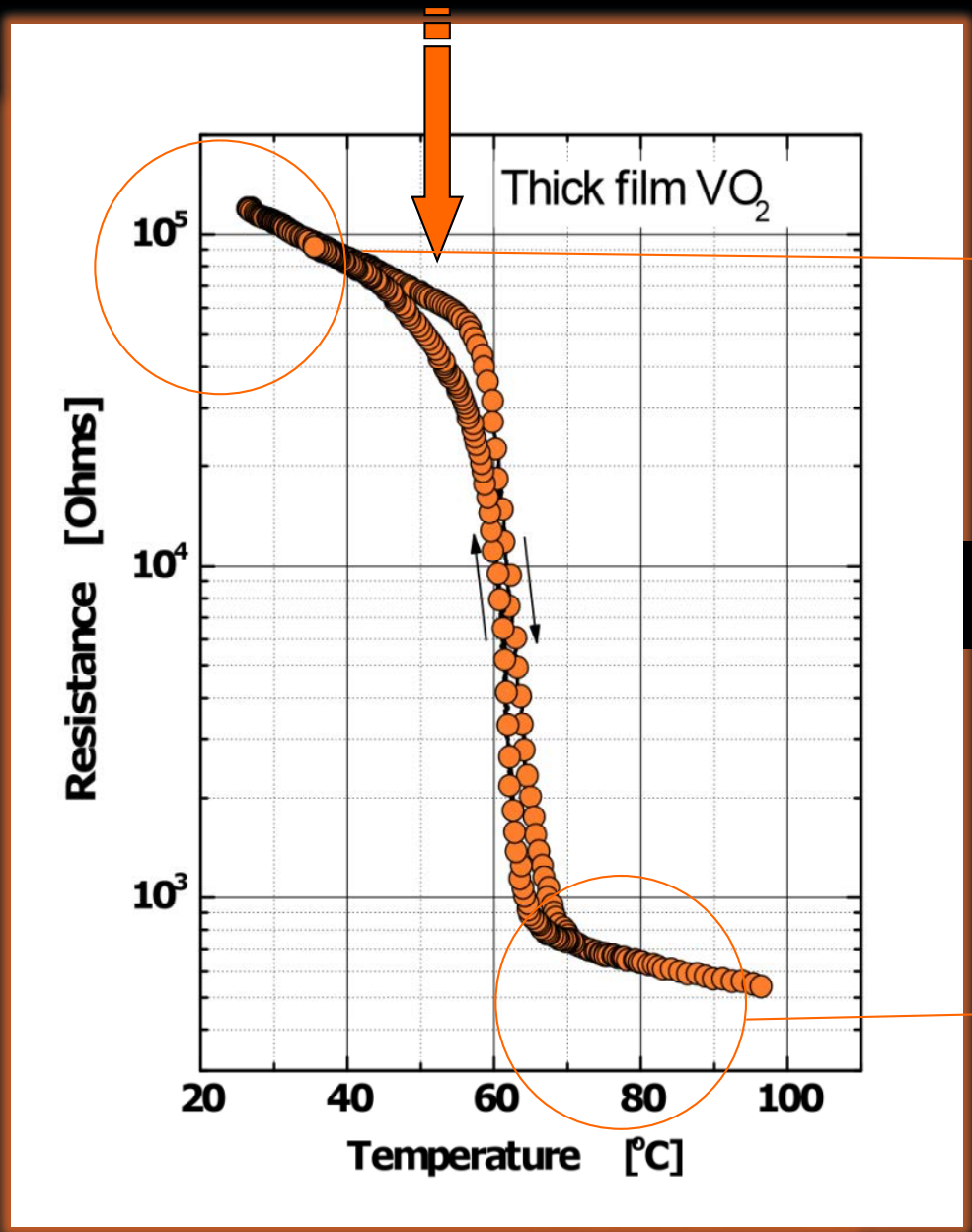
VO_2:SOLAR HEAT REGULATION

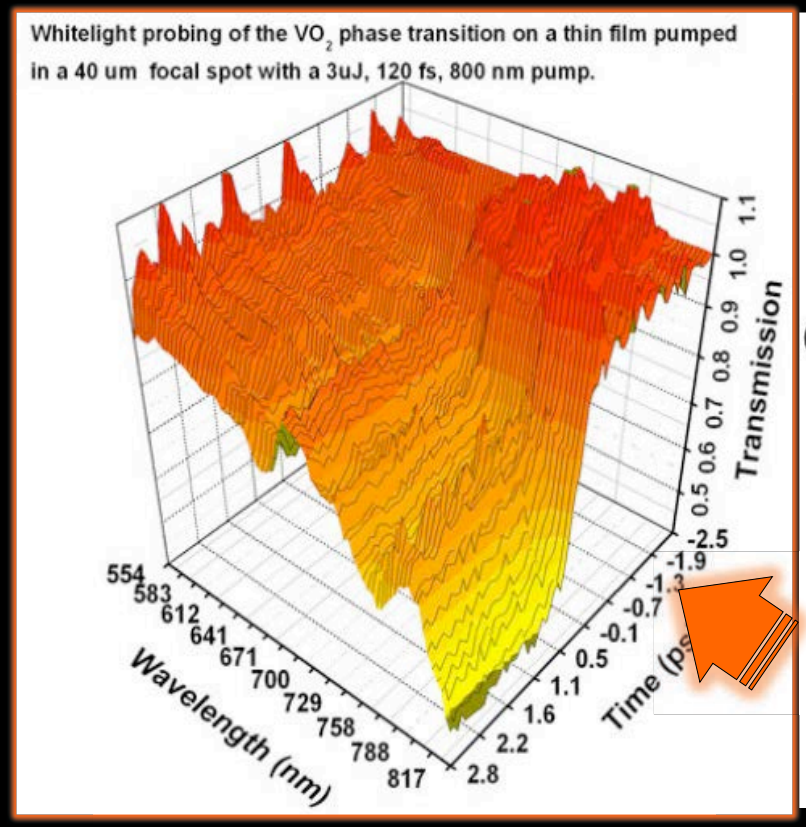


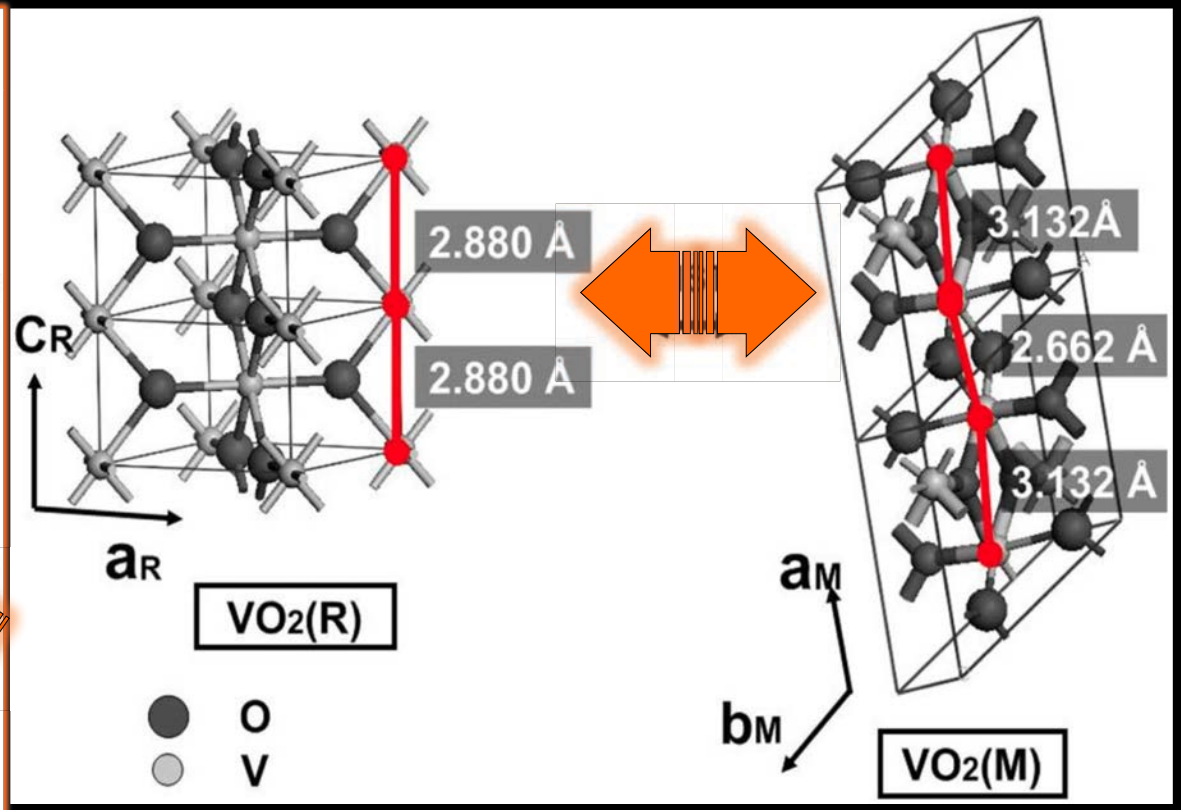
$T < T_c$ Bulk
Semiconductor

$T_c = 68°C$

$T > T_c$ Bulk
Metallic

Phase Transition:Towards green air-con via smart windows & .

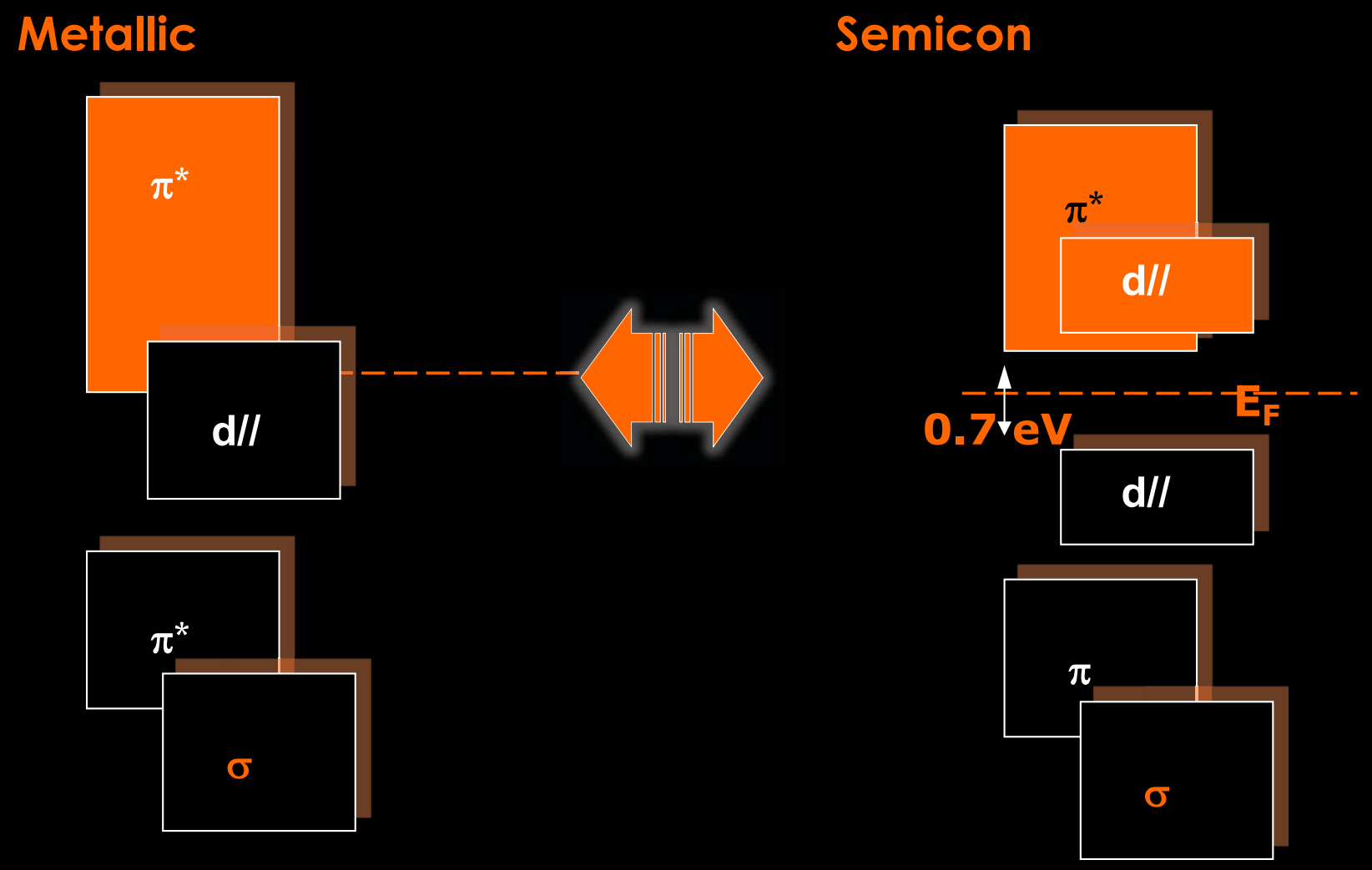




VO_2:Utrafast Reversible MIT transition τ_{VO2}=180 fs

Cavalleri et al, PRL 2004

Phase Transition:Towards green air-con via smart windows & .



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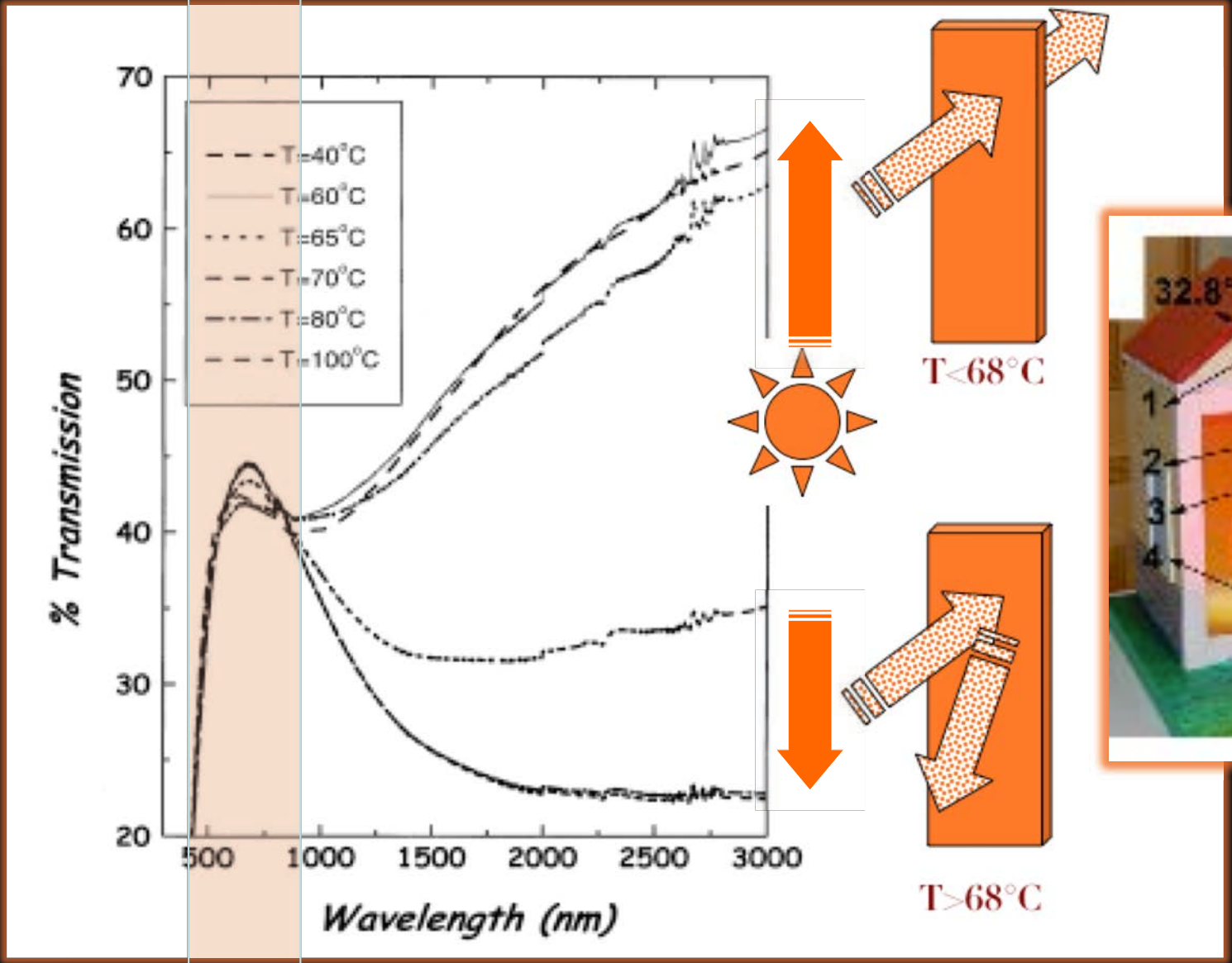
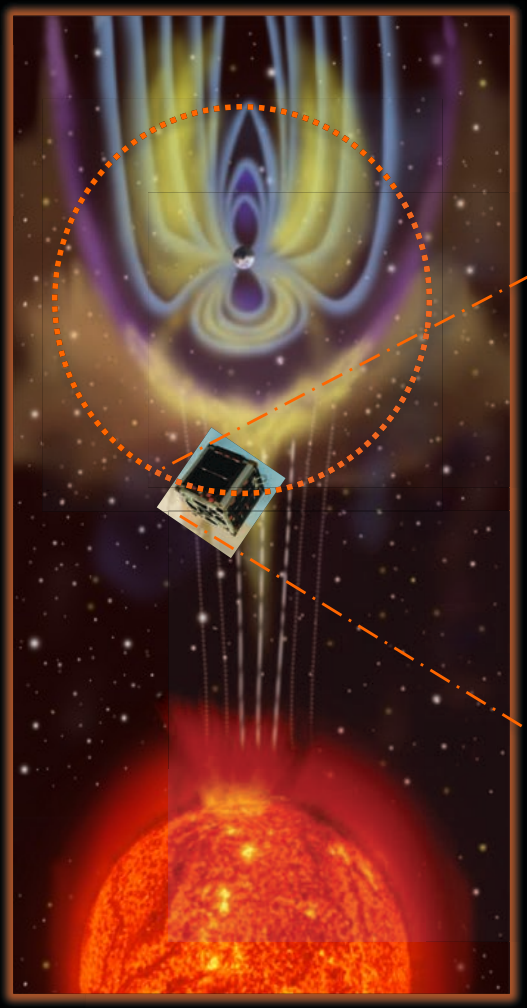
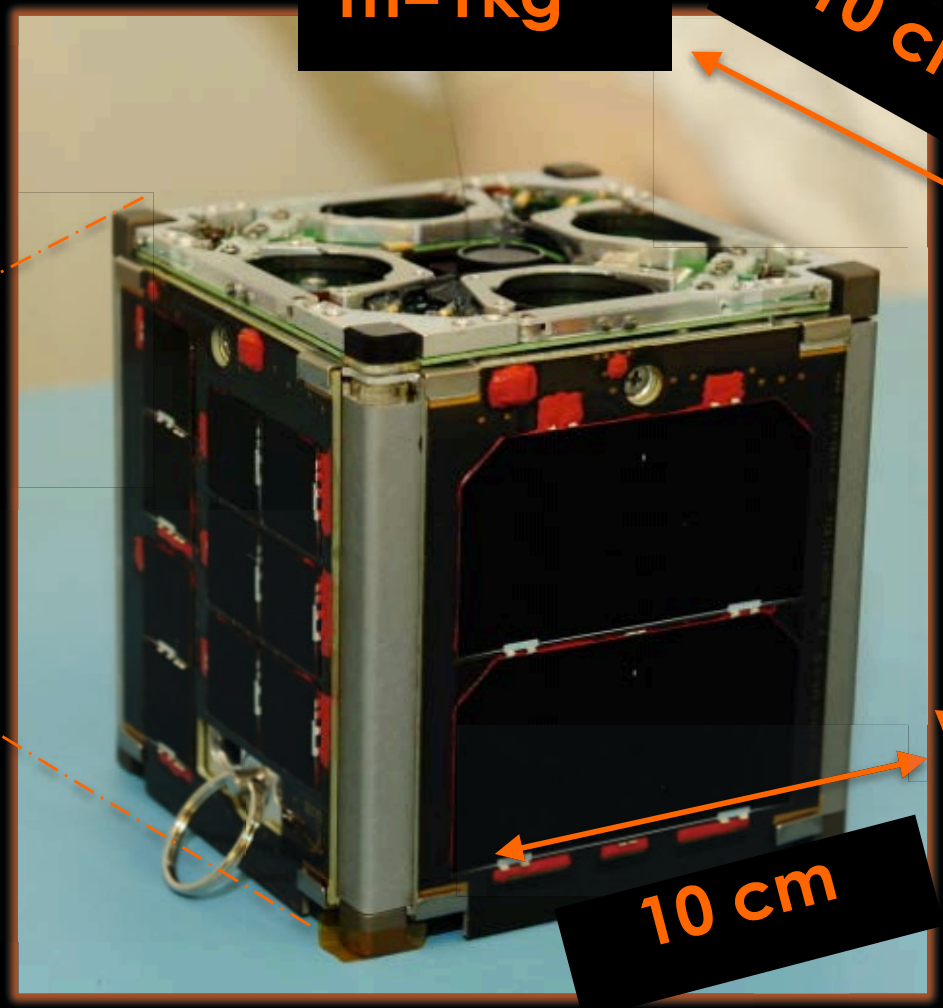


VO_2:SOLAR HEAT REGULATION





– Multi-functionality: Heat control in small satelittes
- JAXA, ESA, Canadian Space Agency,
- SANSA: Sumbandilla: ≈ 81 kg/ZACube ≈ 1.175 kg

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-Nano-Physics for AGRI,
-Nano-Physics for WATER,

3-Way forward from the African perspective

4-Conclusion & Foresight

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UNESCO-UNISA Africa Chair in Nanosciences/Nanotechnology (South Africa)

Thermal Physics:Towards New Coolants,Heat management: Nanofluids

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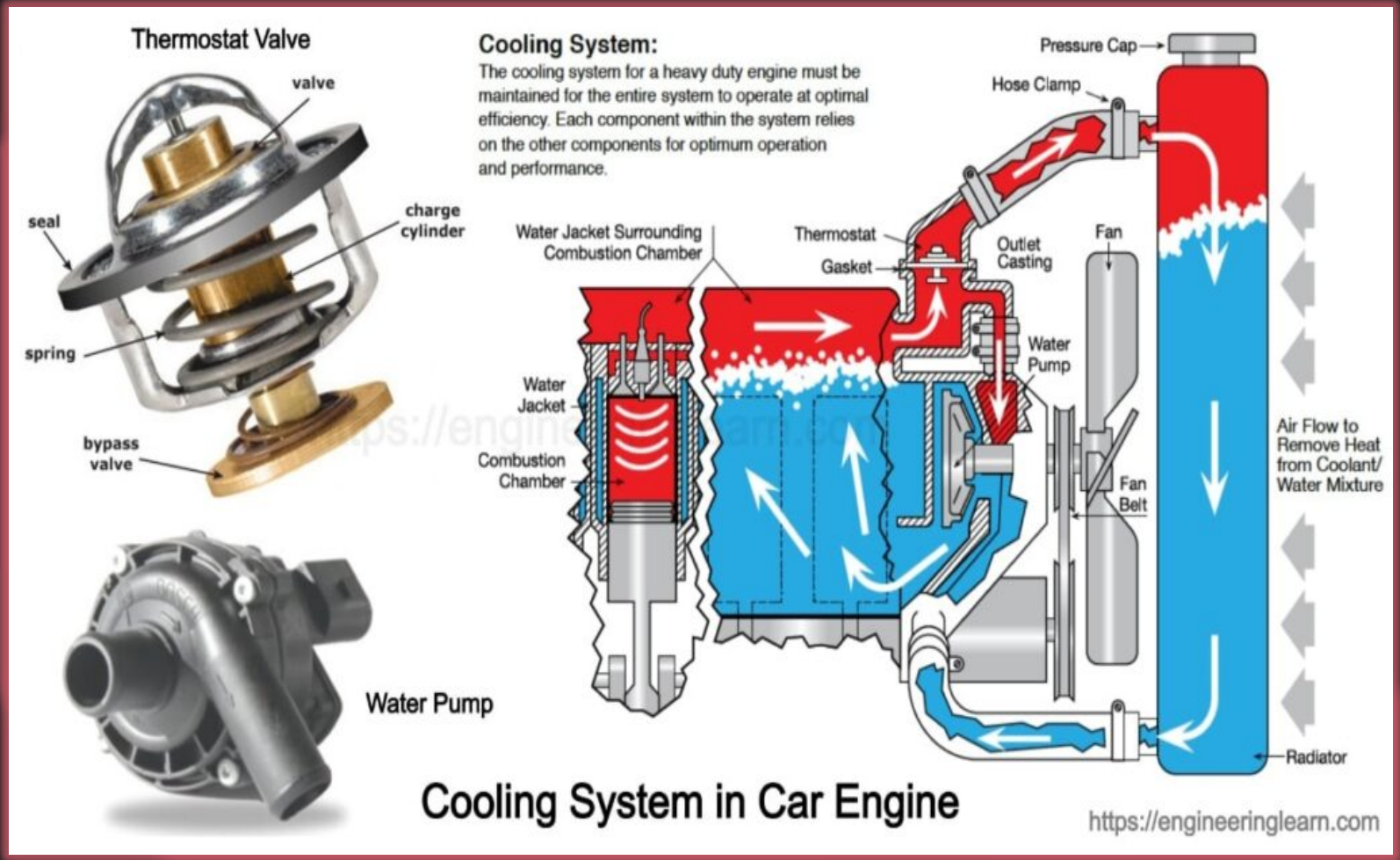
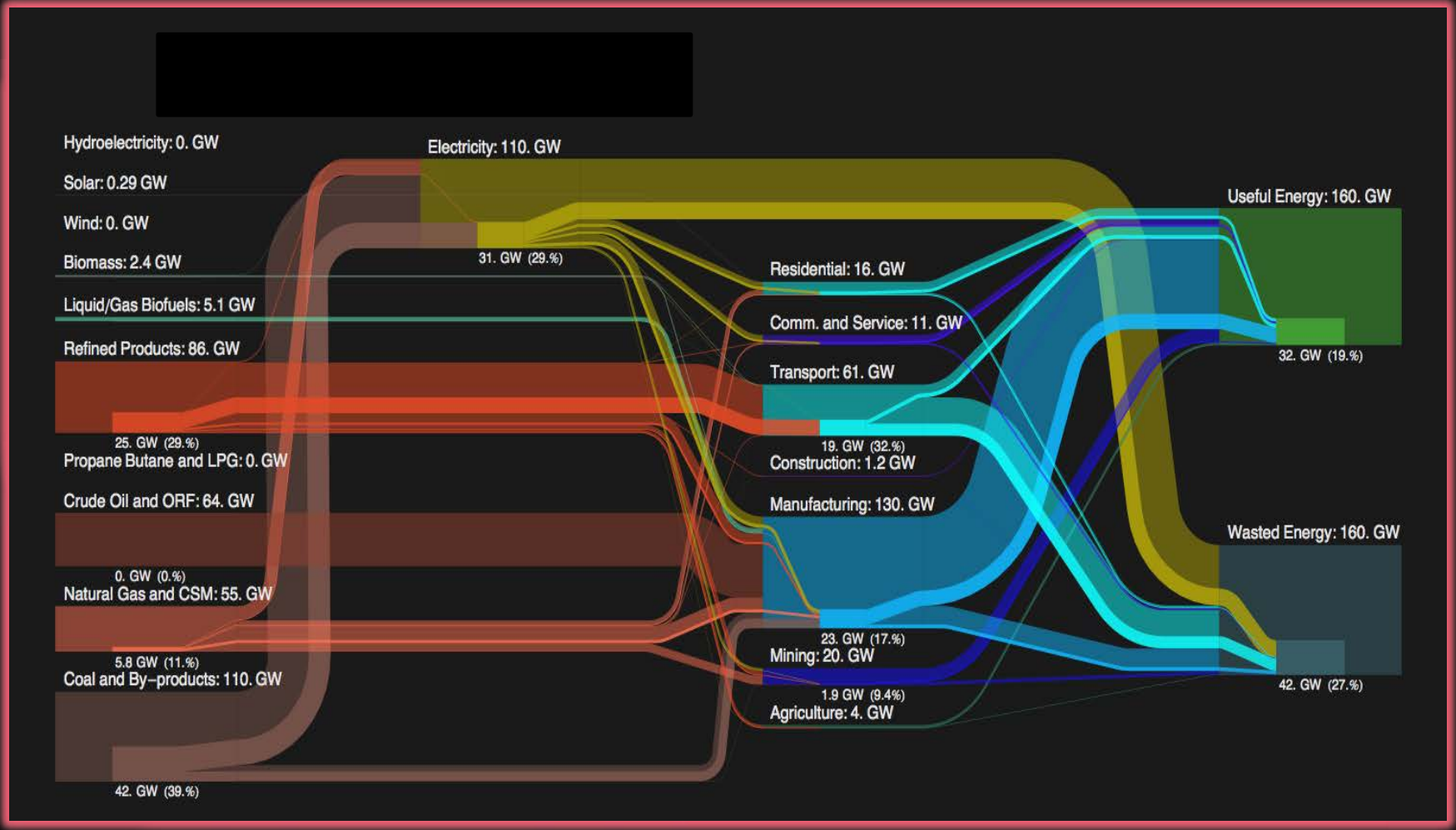
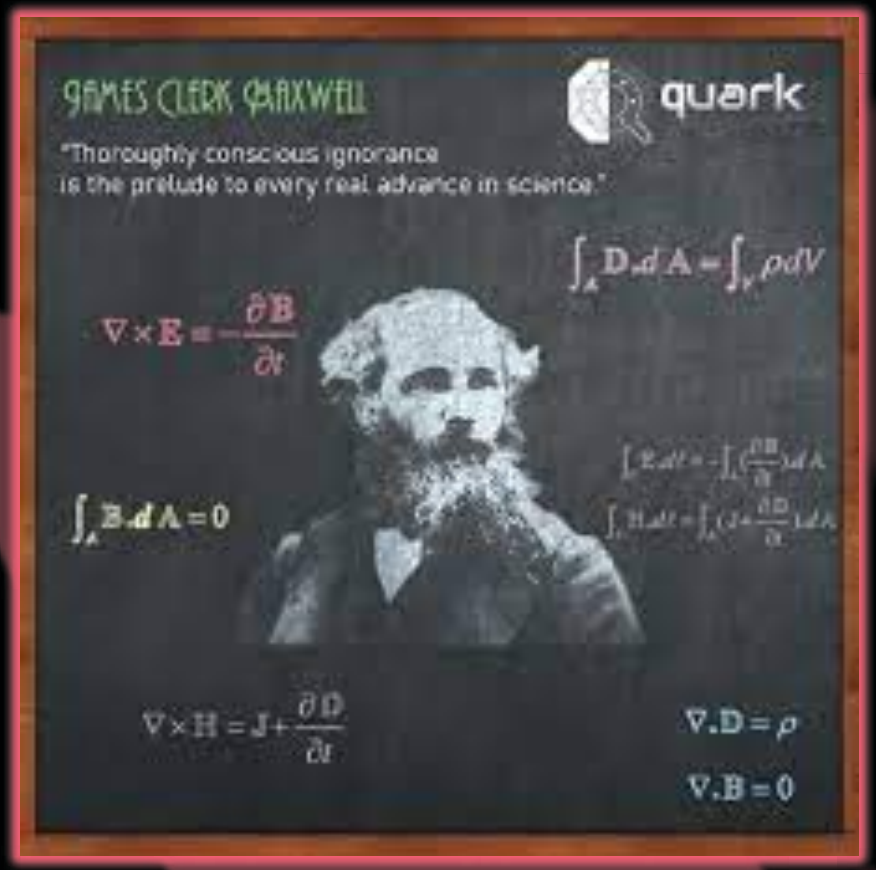
FUEL EFFICIENCY:
ENHANCED THERMAL CONDUCTIVITY



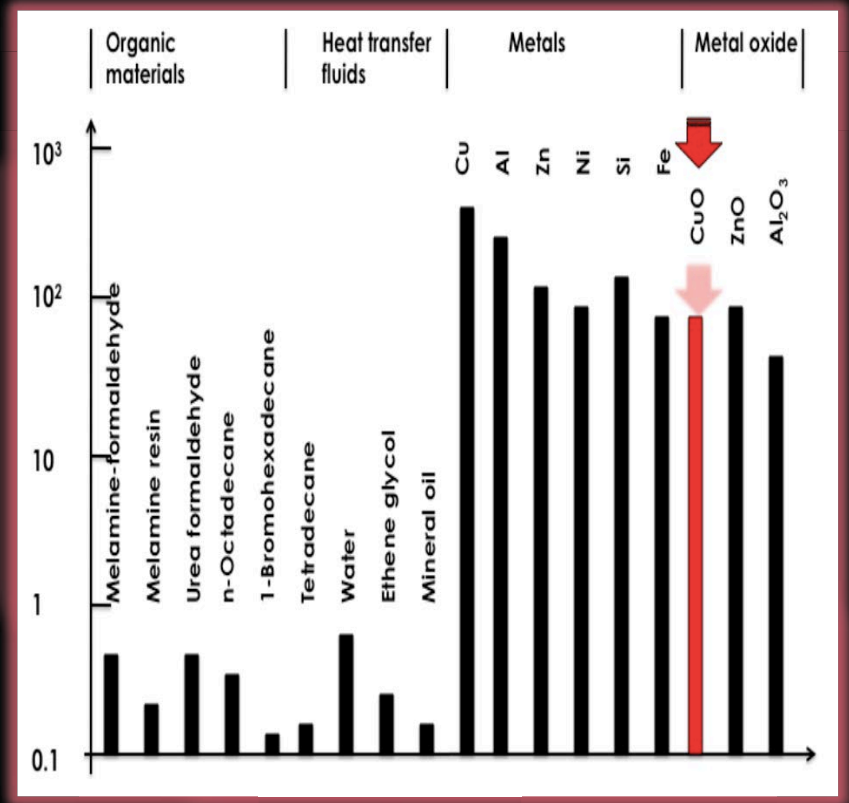
Waste Heat recovery:Towards New Coolants,Heat manag.: Nanofluids

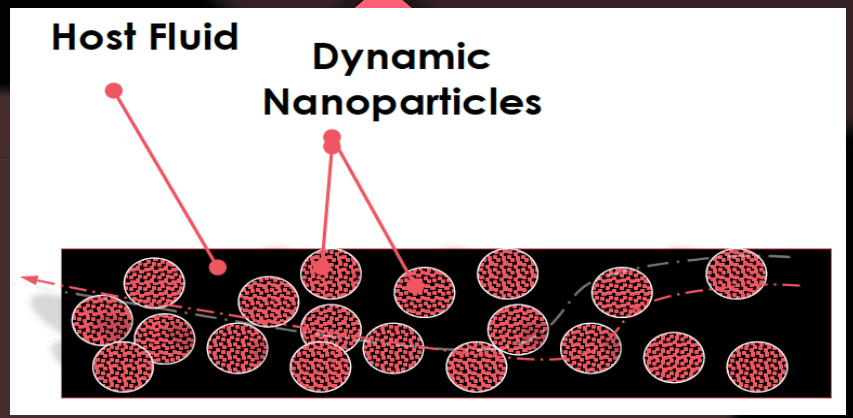


FROM MAXWELL'S CONCEPT TO NANOFLUIDS



James Clerc Maxwell, 1867



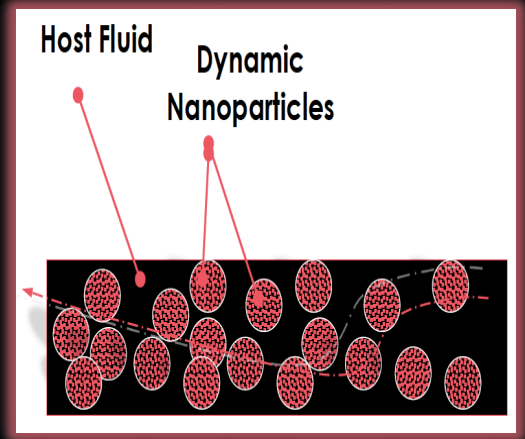


THERMAL CONDUCTIVITY: DERIVATION

James Clerc Maxwell, 1867

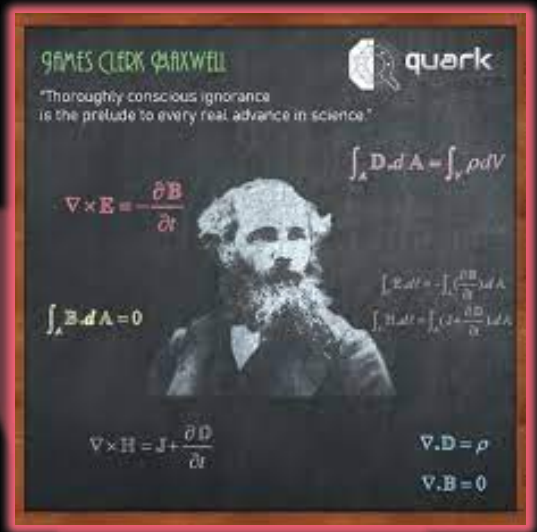
$$k_{\text{eff}} = k_{\text{static}} + k_{\text{Brownian}}, \qquad (1)$$

$$\frac{k_{\text{static}}}{k_c} = 1 + \frac{3\left(\frac{k_d}{k_c} - 1\right)\alpha_d}{\left(\frac{k_d}{k_c} + 2\right) - \left(\frac{k_d}{k_c} - 1\right)\alpha_d}, \qquad (2)$$



James Clerc Maxwell, 1867

where α_d is the particle volume fraction, k_c, the thermal conductivity of the carrier fluid and k_d is that of the particles. Since the speed of thermal wave propagation is much faster than the particle Brownian motion, the static part cannot be neglected.



Thermal Physics:Towards New Coolants,Heat management: Nanofluids

- Mr. Sanelise Nongauza(PhD Fellow, South Africa)
- Dr. Mbambo Makhangela(Postdoc Fellow, South Africa)
- Dr. Karen Cloete (Postdoc Fellow, South Africa)
- Dr. Touria Khamliche(PhD Fellow, Morocco)
- Dr. Salah Khamlich(Associate Fellow, Morocco)
- Mr. Snenkosi Dlamini(MSC Fellow, South Africa)
- Dr. Mahmood Akbari (Postdoc Fellow, Iran)

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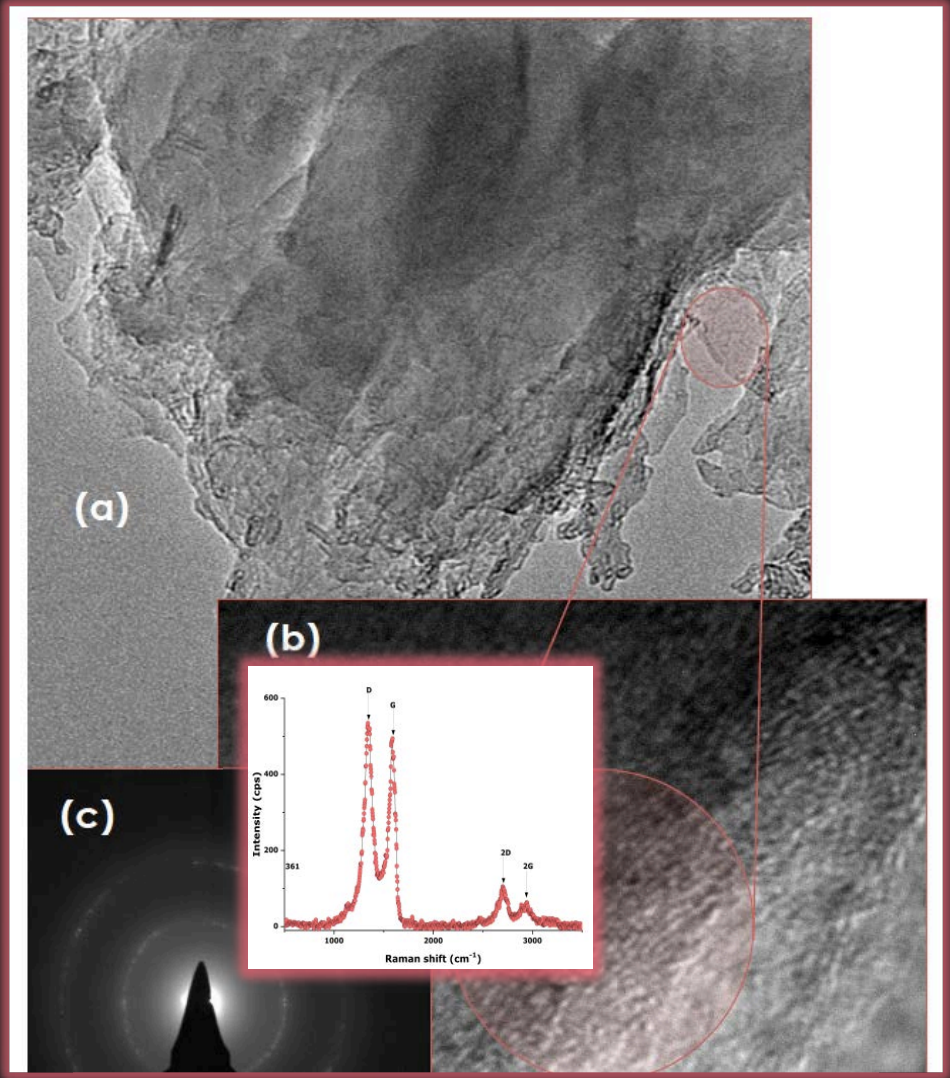
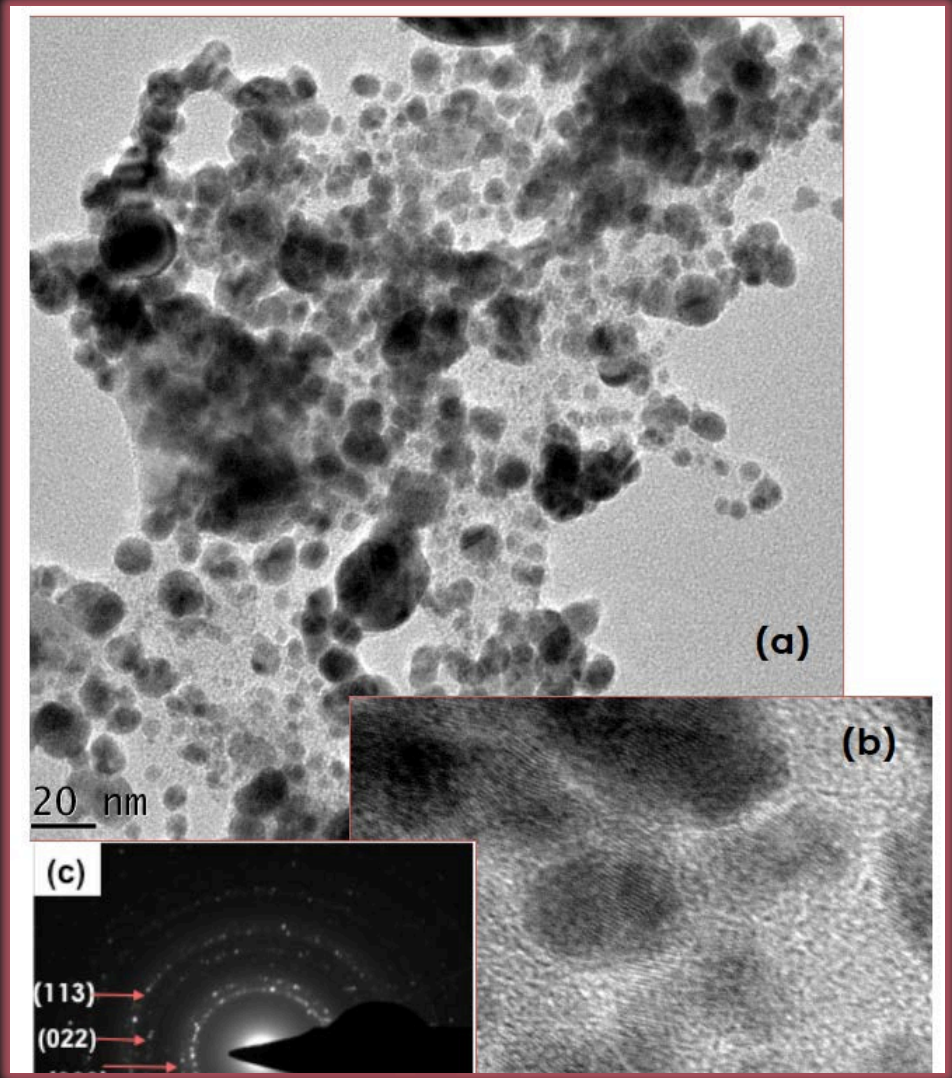
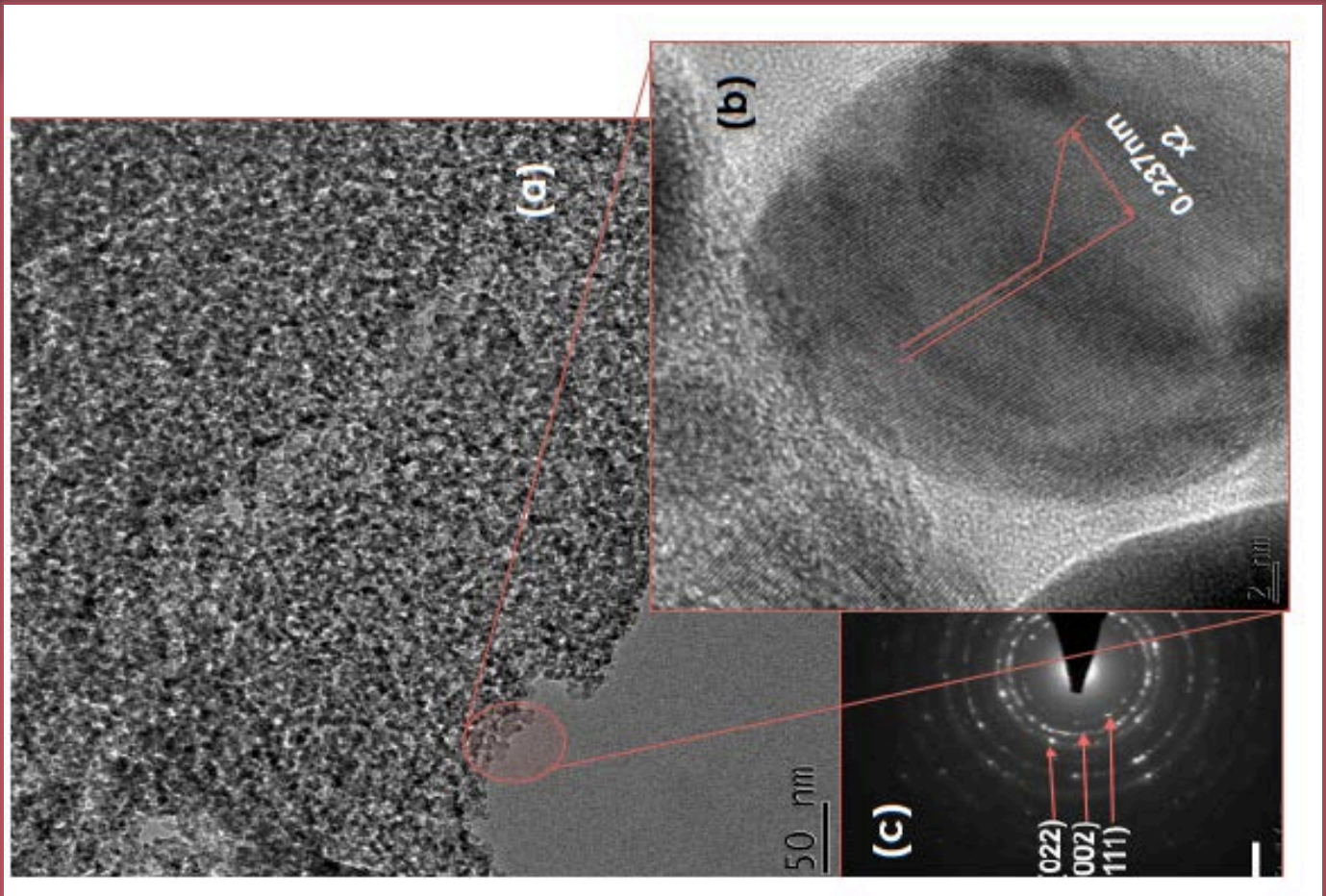
NANOFLUIDS:FUEL EFFICIENCY





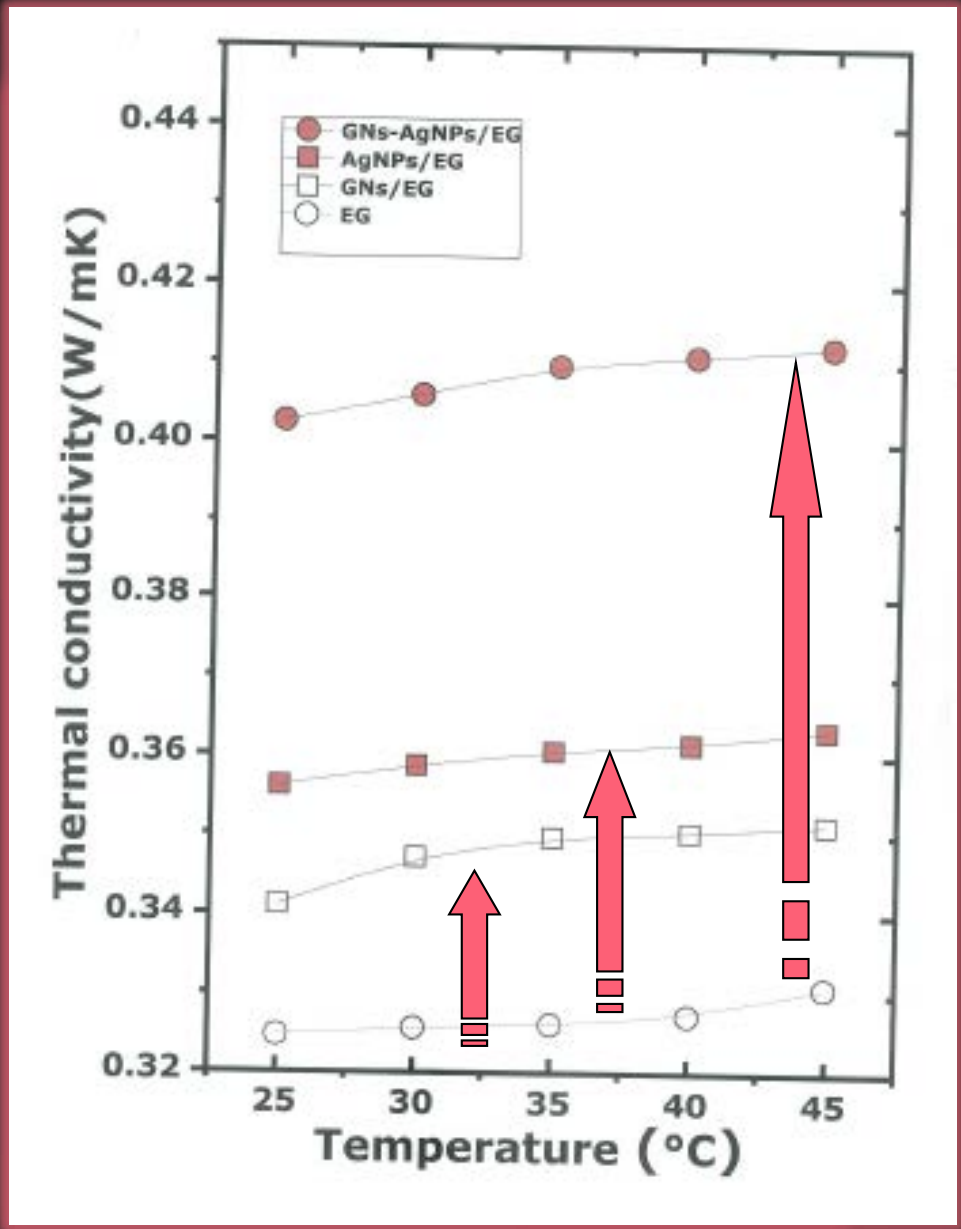
NANOFLUIDS:FUEL EFFICIENCY

Significant Ag NPs anchorage onto GNs



- $D_{Ag} = k_B T / 6p\eta\langle Ø/2\rangle$ at room temperature is about: 16.7 10^{-16}m (η_{EG}=14 (mPa.s)).
- Wook Kang et al (2008), • Vi & Lue (2017) & • Zhang (2012)

NANOFLUIDS:FUEL EFFICIENCY



- $\sigma_{thermal}$EG: ~0.327 W/mK
- GNs-EG: ~6.25%
- AgNPs-GNs: ~12.5%.

- AgNPs-GNs-EG:33%

NANOFLUIDS: APPLICATIONS

- 1- Minimizing Heat stress in engines
- . At high speeds, approximately 65% of the total energy output from a truck is expended in overcoming the aerodynamic drag.This fact is partly due to the large radiator in front of the engine positioned to maximize the cooling effect of oncoming air. Argonneresearchers, Singh et al. , have determined that the use of high-thermal conductive nanofluids in radiators can lead to a reductionin the frontal area of the radiator by up to 10%. This reduction in aerodynamic drag can lead to a fuel savings of up to 5%.

- 2- Industrial cooling applications
- .Using nanofluids in closed-loop cooling cycles could save about 10-30 trillion Btu per year.The associated emissions reductions would be approximately 5.6 million metric tons of carbon dioxide, 8,600 metric tons of nitrogenoxides and 21,000 metric tons of sulfur dioxide. In rubber and tire plants industry, nanofluids are a potential object to cooling therubber efficiently during the processing time (Michelin North America) [J. Routbort et al., Argonne National Lab, Michellin North America, St. Gobain Corp.http://www1.eere.energy-.gov/industry/nanomanufacturing/pdfs/nanofluidsindusttrialcooling.pdf, 2009.]

- 3-Solar energy cooling (Both CSP & PVs),
- The efficiencyimprovement was up to 5% in solar thermal collectors by utilizing nanofluids as the absorption means. Under the similar operatingconditions, the efficiency of an absorption solar collector using nanofluid as the working fluid was found to be up to 10% higher than that of a flat plate collector.

- 4-Nuclear reactors' cooling as a potential of increasing critical heat flux (CHF).

desirable to retain the molten fuel within the vessel by removing the decay heat through the vessel wall, if there are such accidents.This process is limited by the occurrence of CHF on the vessel outer surface, but investigation indicates that the use of nanofluid can increase the inner vessel retention capabilities of nuclear reactors by as much as 40%. Many water-cooled nuclear power systems areCHF-limited, but the application of nanofluid can greatly improve the CHF of the coolant so that there is a bottom-line economicbenefit while also raising the safety standard of the power plant system. [Buongiorno et al. A Nuclear Eng.Design. 239(5), 941-948, 2009]

- 5-Geothermal

- 6-Nanoelectronics
- It is expected that the next generation of computer chips will produce localized heat flux more than 10 MW/m^2, with the total power exceeding 300 W.

- 7-Data centres cooling,

- 8-Biological & Biomedical /Antibacterial agents

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uniTwin

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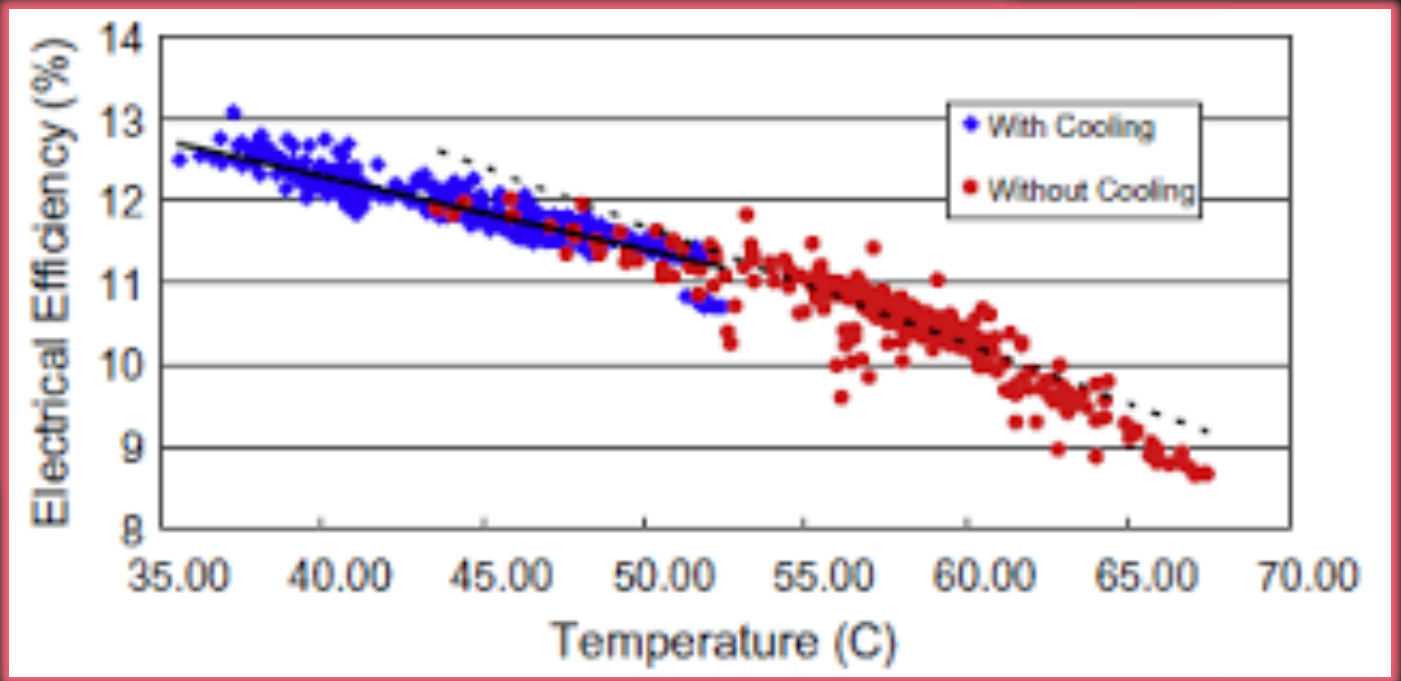
Thembalabs

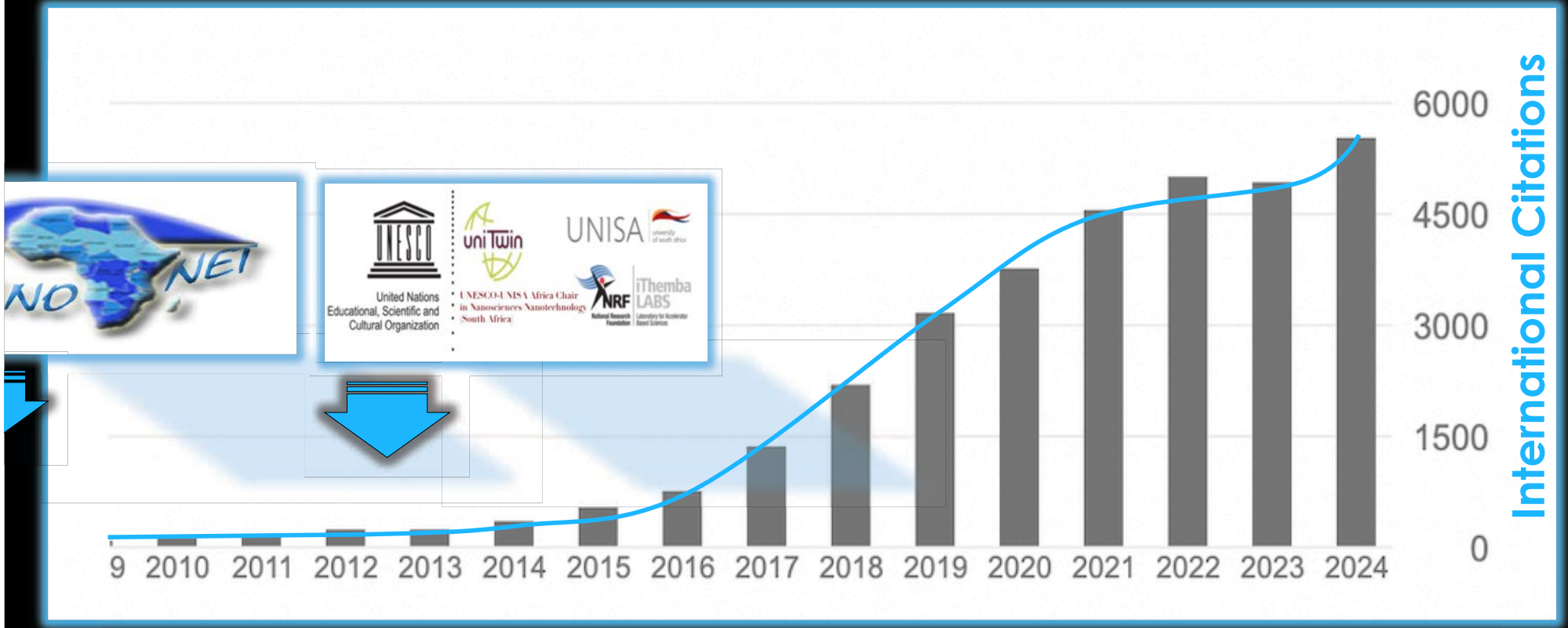
NANOFLUIDS: NEW COOLANTS GEN.



NANOFLUIDS: WASTE HEAT RECOVERY.

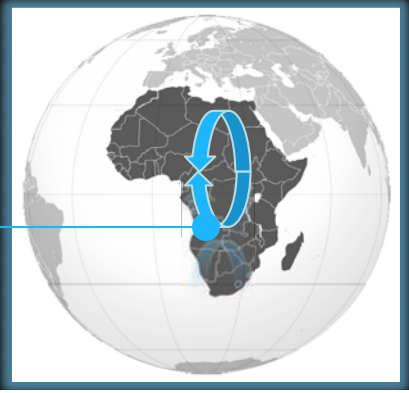
HOW ARE WE DOING FROM AFRICA ANGL

TOWARDS STI/STEM EXCELLENCE



International Citations as a Metric compass:

- Contributions to body of knowledge
- Quality Education
- Continental synergy
- North-South 2 ways synergy



OUR GRATITUDE TO TRIESTE SYSTEM & THOSE TO WHOM WE ARE INDEBTED FOREVER

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Organization of Women in Science for the Developing World

ICTP
The Abdus Salam
International Centre
for Theoretical Physics

twas

Organization for Women in Science for the Developing World

ICTP

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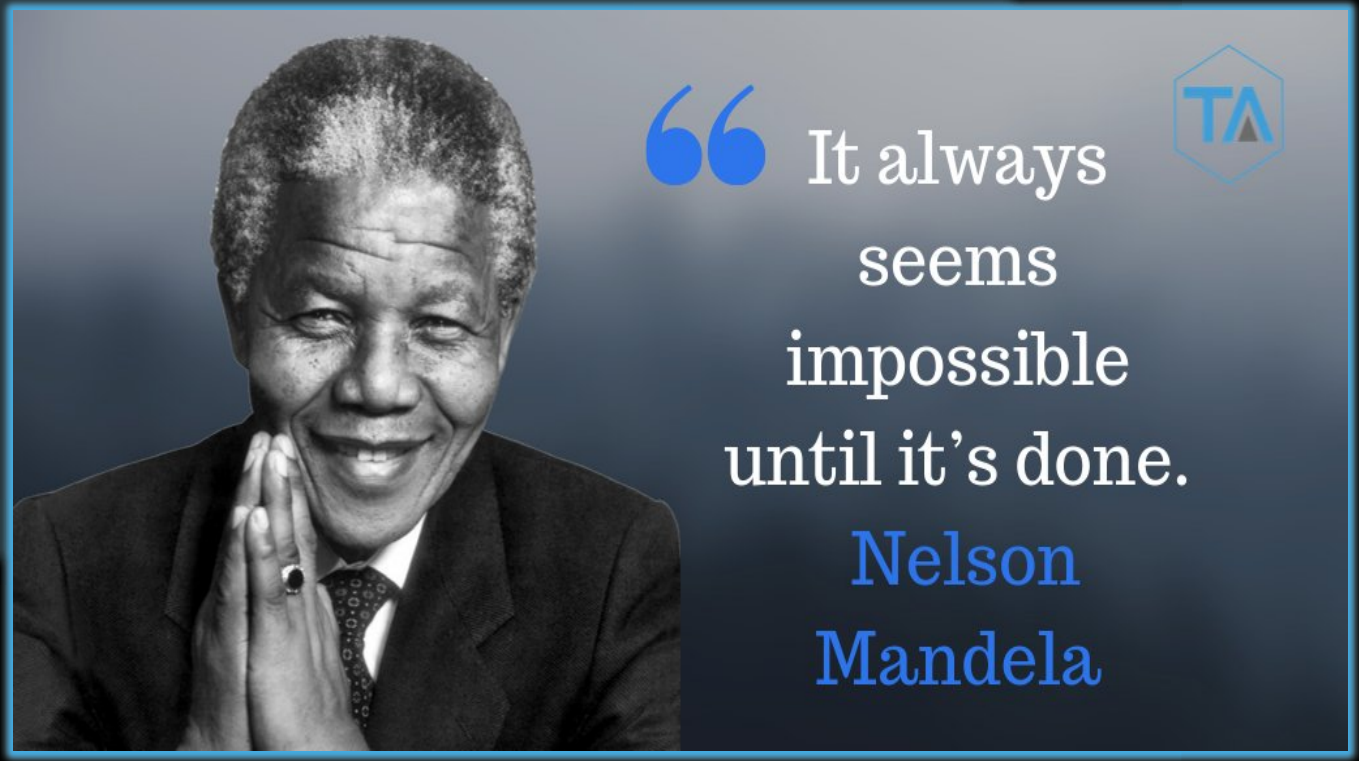
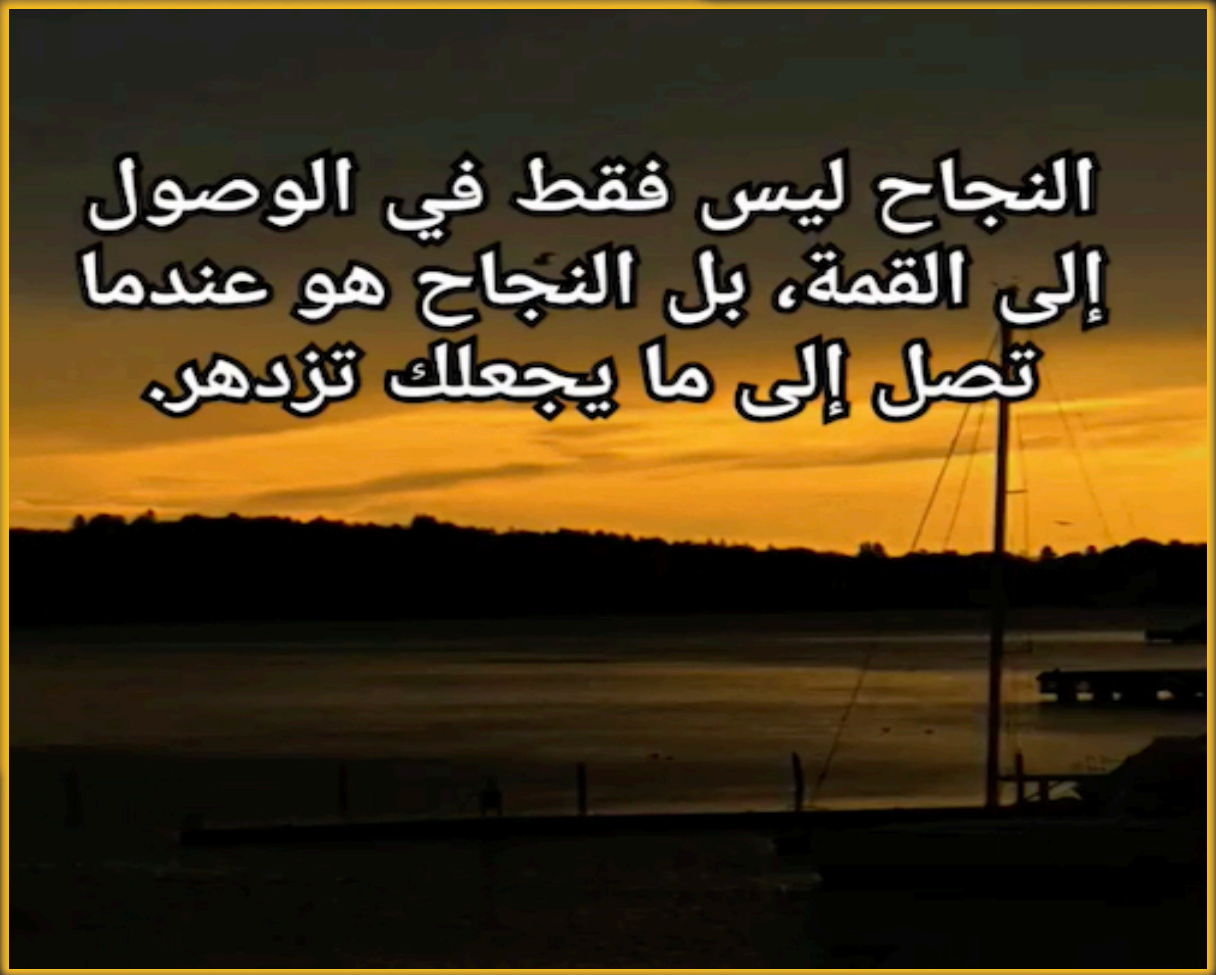
CENTRE OF EXCELLENCE
China-Pakistan Economic Corridor

NGIYABONGA, ENKOSI, MERCI, DANKIE, KE A LEBOGA, CHUKRAN ASANTE SANA,THANK YOU



CHUKRAN,NGIYABONGA, ENKOSI, MERCI, DANKIE, KE A LEBOGA, ASANTE SANA,THANK YOU