TiO_2 NANOTUBE-BASED DYE SOLAR CELL RESEARCH IN SOUTH AFRICA

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CONTENT

- Background: South African Energy Statistics and PV Research Roadmap
- CSIR Solar Cell Research
- Some Results
- Ongoing Research
- Acknowledgements

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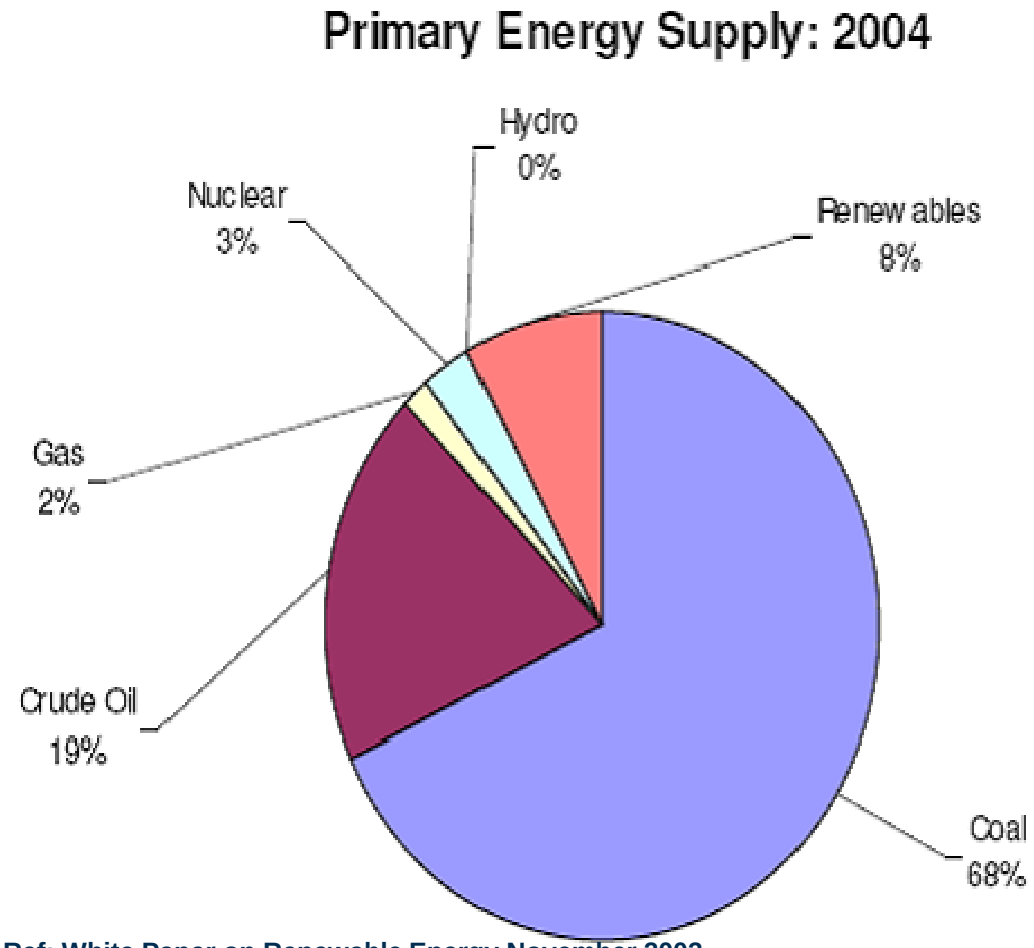
-----BACKGROUND----

South African Energy Statistics

- Energy supply dominated by coal
- Energy supplied from renewable sources are minimal
- Statistics sketch an impending energy crisis for RSA, for the coal resources are becoming increasingly limited
- Hydro and solar renewable energy sources have been earmarked by the government as future large-scale providers of power for rural areas, which household a great percentage of the South African population
- RSA has some of the best sunlight in the world: average daily solar radiation varies between 4.5 and 6.5 kWh/m^2, compared to about 3.6 kWh/m^2 for parts of the United States and about 2.5 kWh/m^2 for Europe and the United Kingdom ⟶
  Real need for solar research



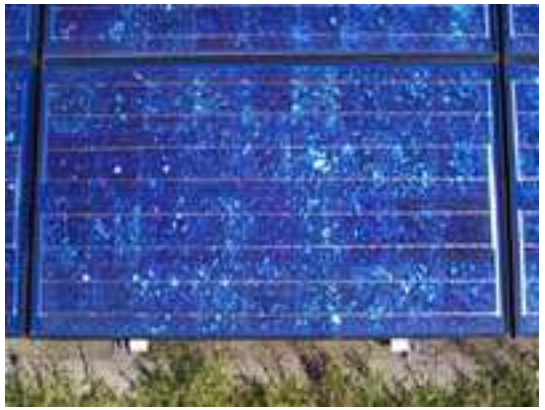
Ref: White Paper on Renewable Energy November 2003, Department of Minerals and Energy, Republic of South Africa, www.dme.gov.za/energy/renewable.stm [Accessed on 07 October 2008]

Introduction to Photovoltaics

DIFFERENT TYPES OF SOLAR CELLS:

(1) Matured Photovoltaic Technologies

Single-crystalline Si Cell



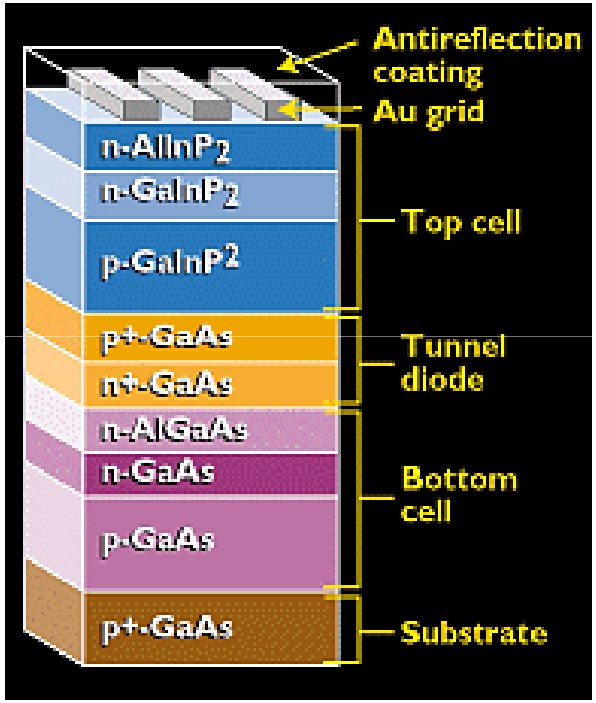
Poly-crystalline Si Cell

Amorphous Si Cell

Introduction to Photovoltaics

DIFFERENT TYPES OF SOLAR CELLS:

(2) High-efficiency Photovoltaic Technologies



Multi-junction (or Tandem) Solar cells

- Individual single-junction cells with different energy band gaps are stacked on top of one another
- Sunlight then falls first on the material with the largest bandgap, and the highest-energy photons are absorbed
- Photons not absorbed in the first cell continue on to the second cell which absorbs the higher-energy portion of the remaining solar radiation while remaining transparent to the lower energy photons.
- Energy efficiencies ~ 50% achieved

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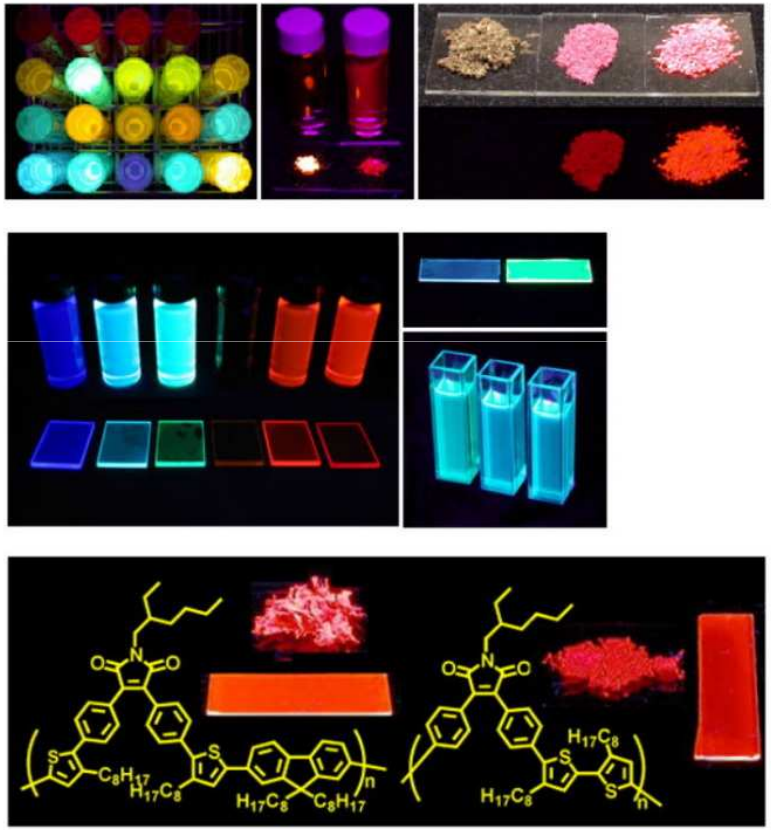
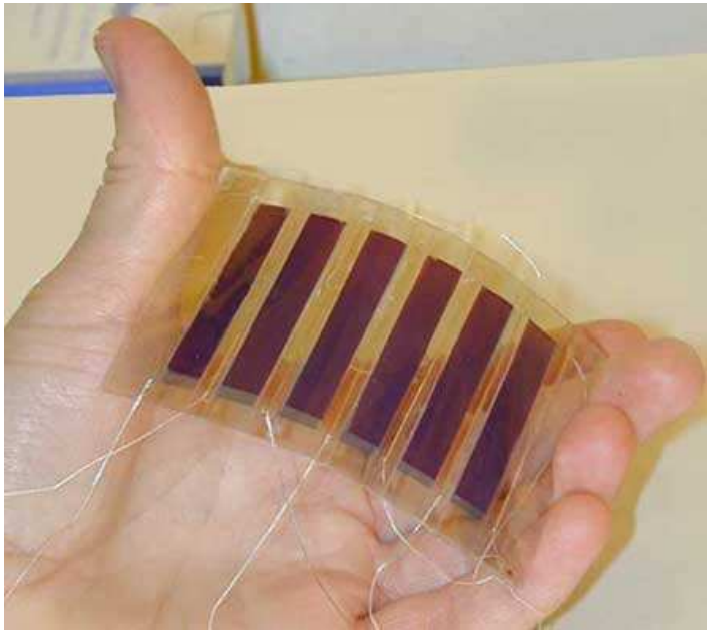
Introduction to Photovoltaics

DIFFERENT TYPES OF SOLAR CELLS:

(3) Low-cost Alternative Photovoltaic Technologies



Organic solar cells



Dye-sensitized solar cells

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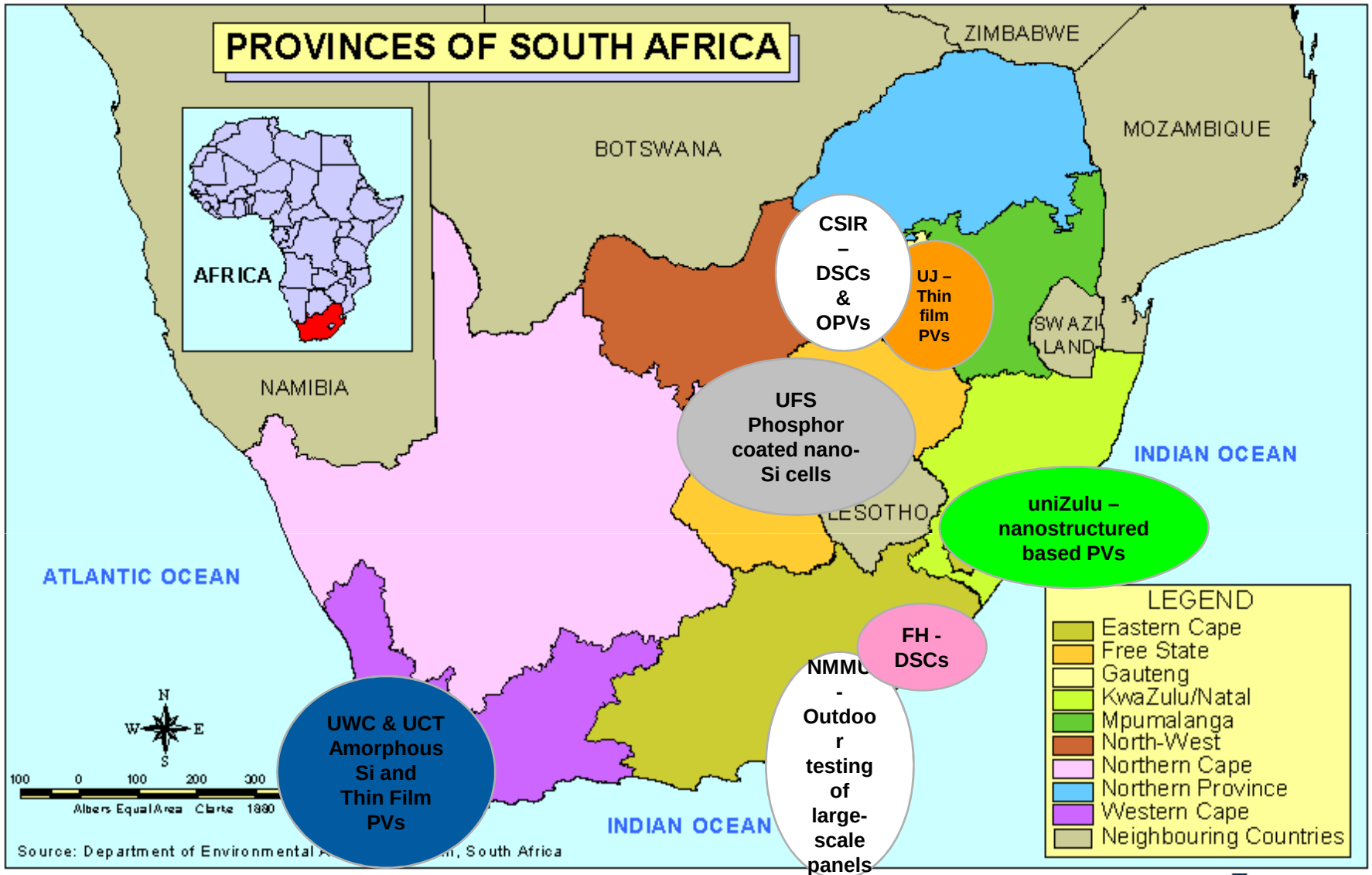

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----CSIR SOLAR CELL RESEARCH----

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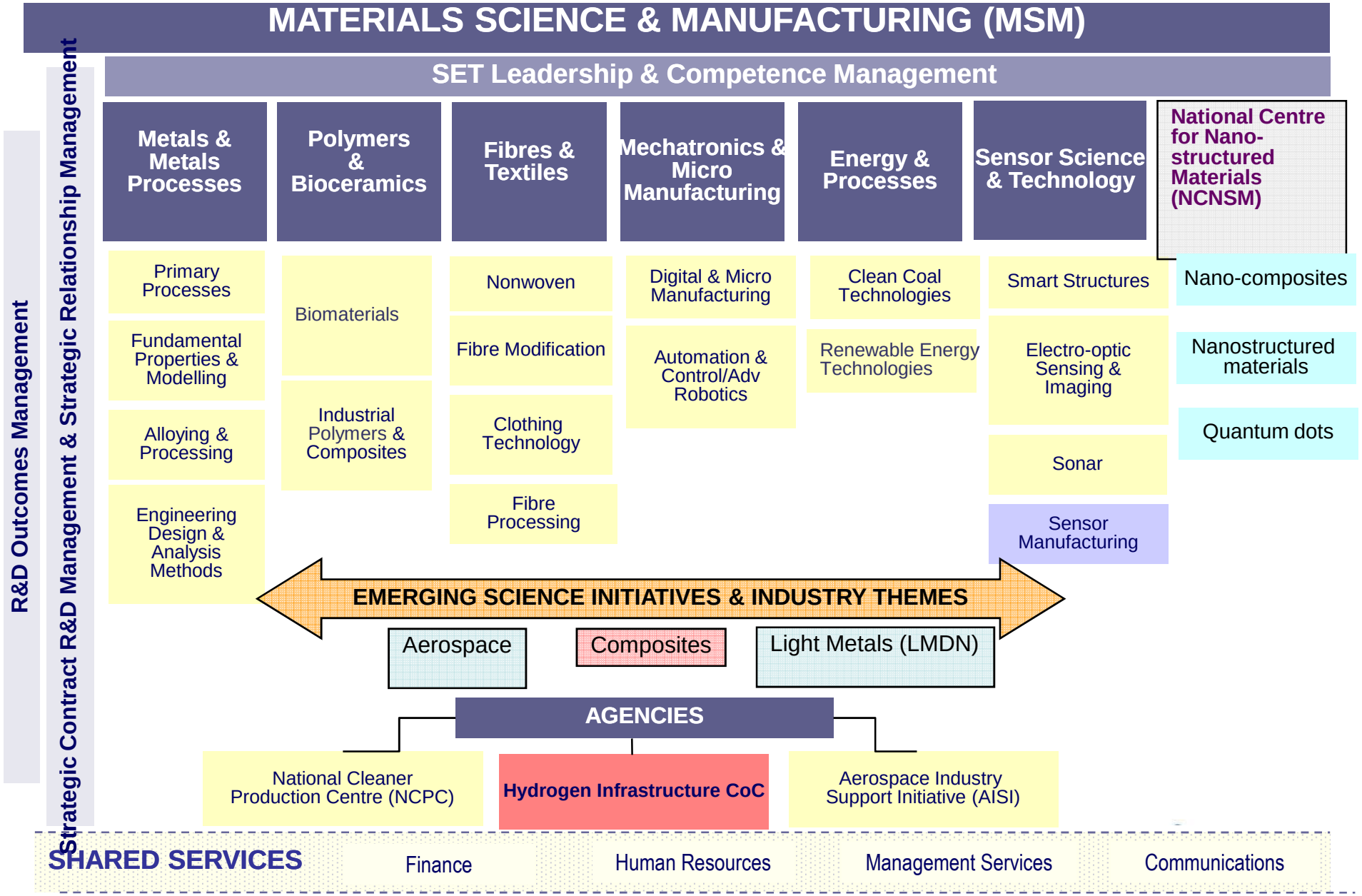
MATERIALS SCIENCE & MANUFACTURING (MSM)
SET Leadership & Competence Management
R&D Outcomes Management
Strategic Contract R&D Management & Strategic Relationship Management
Metals & Metals Processes
Polymers & Bioceramics
Fibres & Textiles
Mechatronics & Micro Manufacturing
Energy & Processes
Sensor Science & Technology
National Centre for Nano-structured Materials (NCNSM)
Primary Processes
Fundamental Properties & Modelling
Alloying & Processing
Engineering Design & Analysis Methods
Biomaterials
Industrial Polymers & Composites
Nonwoven
Fibre Modification
Clothing Technology
Fibre Processing
Digital & Micro Manufacturing
Automation & Control/Adv Robotics
Clean Coal Technologies
Renewable Energy Technologies
Smart Structures
Electro-optic Sensing & Imaging
Sonar
Sensor Manufacturing
Nano-composites
Nanostructured materials
Quantum dots
EMERGING SCIENCE INITIATIVES & INDUSTRY THEMES
Aerospace
Composites
Light Metals (LMDN)
AGENCIES
National Cleaner Production Centre (NCPC)
Hydrogen Infrastructure CoC
Aerospace Industry Support Initiative (AISI)
SHARED SERVICES
Finance
Human Resources
Management Services
Communications

CSIR Photovoltaic Research and Development

- Two PV research projects:
  - Dye-sensitized solar cells (DSCs)
  - Organic solar cells/photovoltaics (OPVs)

- Primary Objectives:
  - Low cost manufacturing of moderate efficient devices
  - Synthesis of nanomaterials with novel opto-electronic properties for implementation within the above cells
  - Manufacturing on flexible substrates for miniature device application

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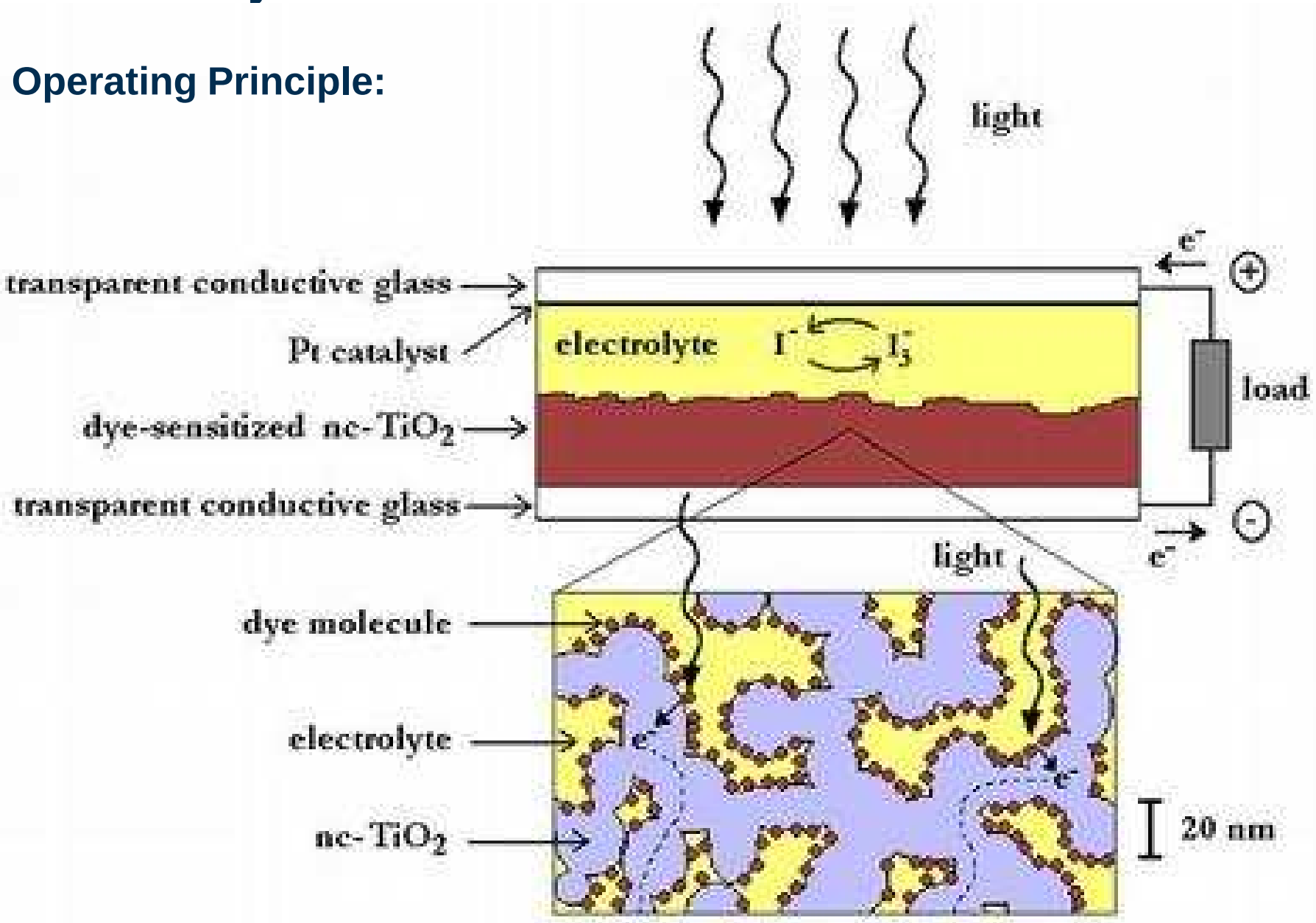
Dye-sensitized Solar Cell R&D

Operating Principle:



Dye-sensitized Solar Cell R&D

Major Research Areas:

Improvement in DSC Efficiency

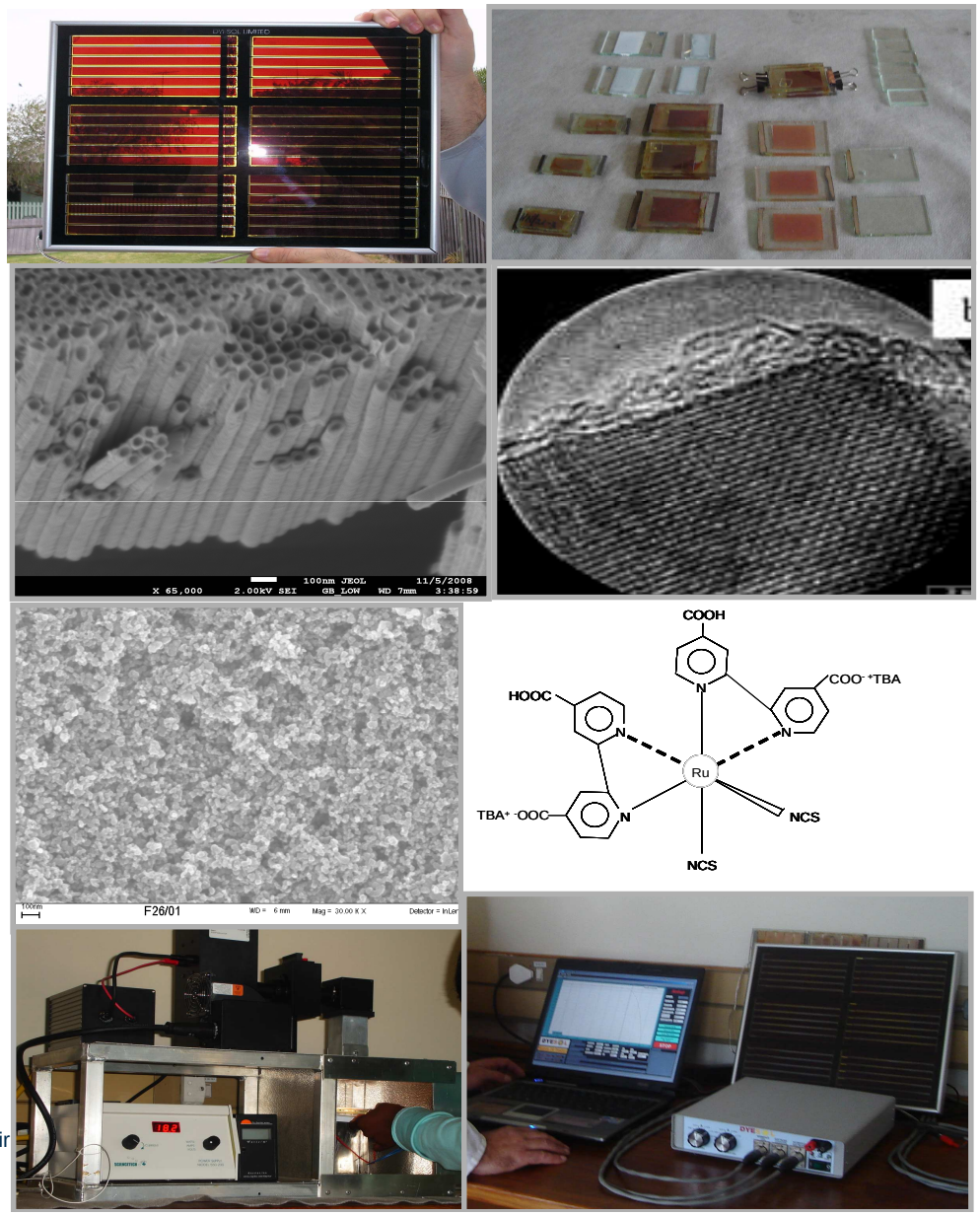
- Application of TiO_2 nanotubes in DSCs for improvement in the charge transport
- Al_2O_3/TiO_2 core-shell nanoparticle synthesis and application for minimizing interfacial recombination
- Development of phthalocyanine dye complexes for increased light harvesting

Improvement in Long-Term Stability of DSCs

- Studying the effect of reverse biased potentials on the stability of the cell
- Outdoor testing: DSC performance vs. a-Si and c-Si cells over extended periods

Cell Cost Reduction

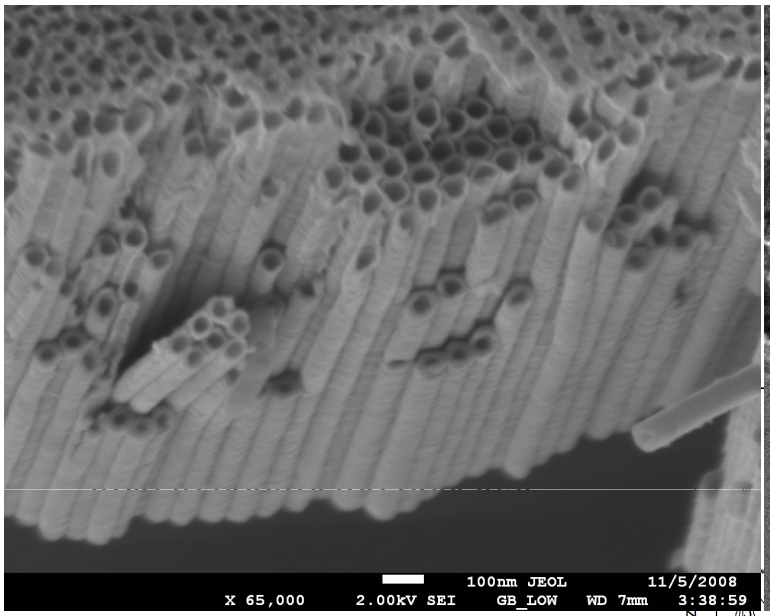
- Novel dye synthesis from CSIR collected Ru waste products

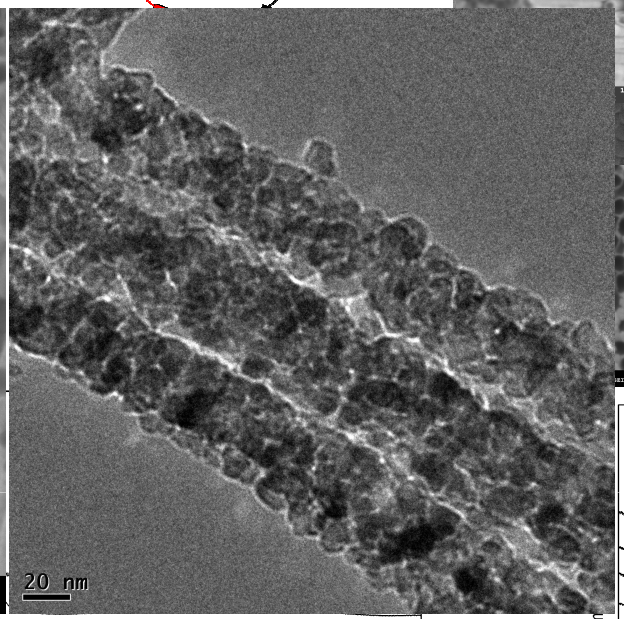


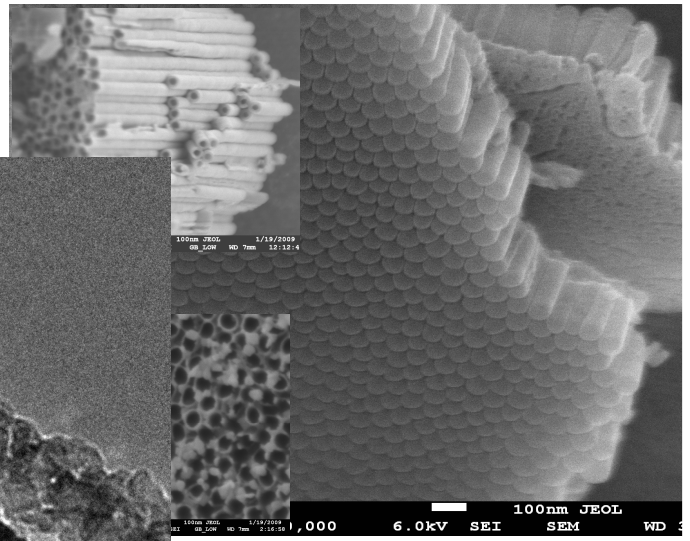
-----SOME RESULTS-----

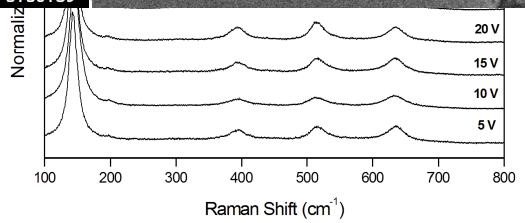
Some Results

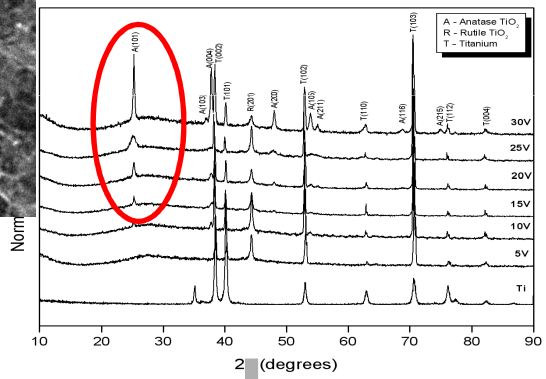
TiO_2 Nanotubes



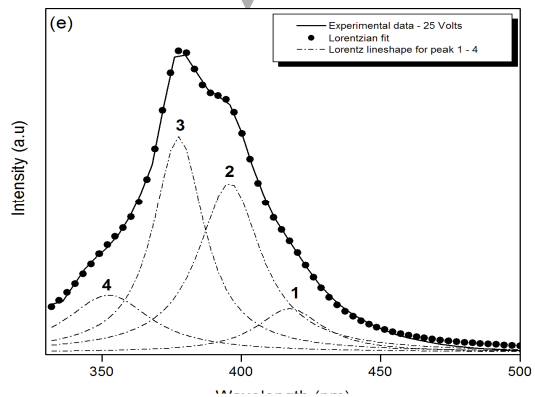








- Nanotube structure influences crystallinity
- Alters optical properties; subsequently able to control optical properties (e.g. band gap) of tubes
- Lead to transparent DSCs, novel applications, e.g. office window panes

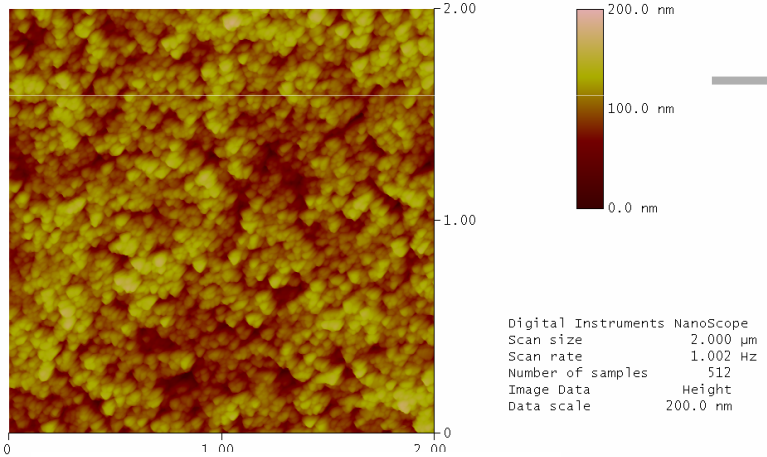


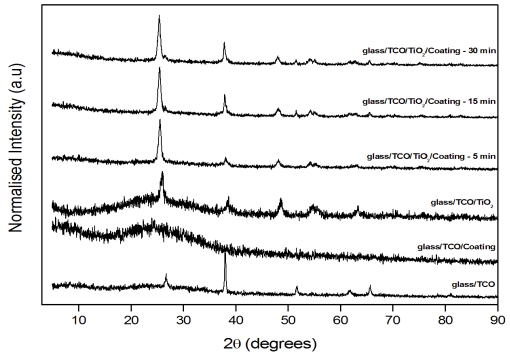
Some Results

TiO_2/Al_2O_3 Coreshell Nanostructures

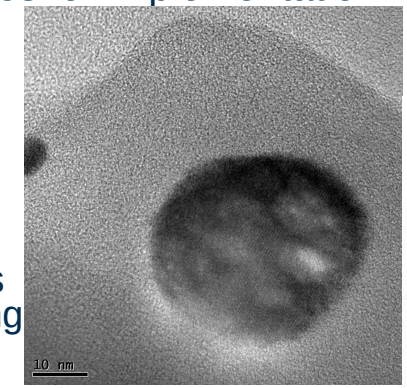
Aim: Implementation of Al_2O_3 coated TiO_2 nanoparticles for implementation in DSCs to reduce interfacial recombination

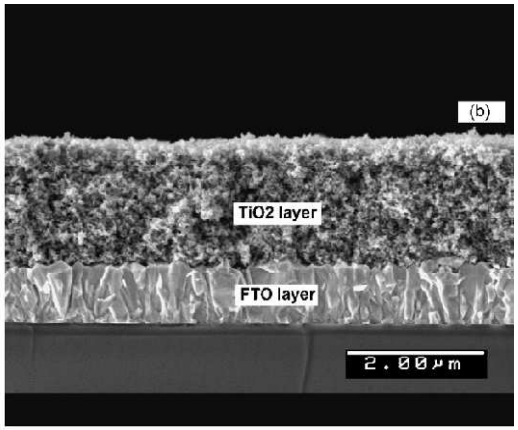
Synthesis of TiO_2 nanoparticle films via wet-chemical methods

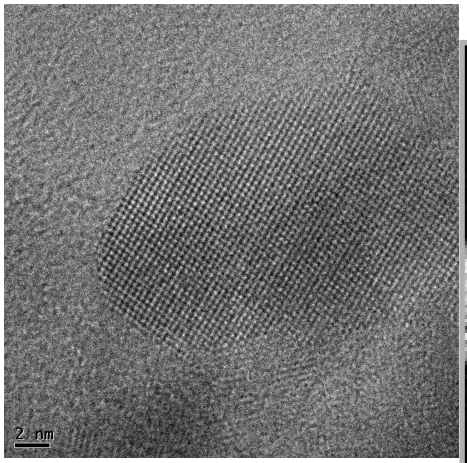


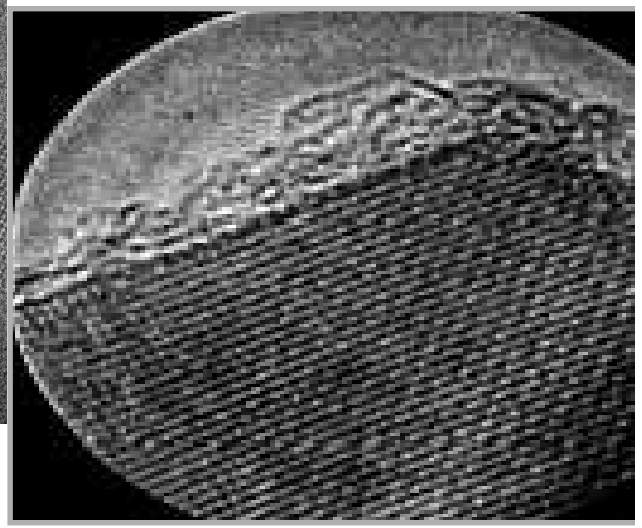


Coating of Al_2O_3 thin layers onto TiO_2 nanoparticles via dip-coating technique



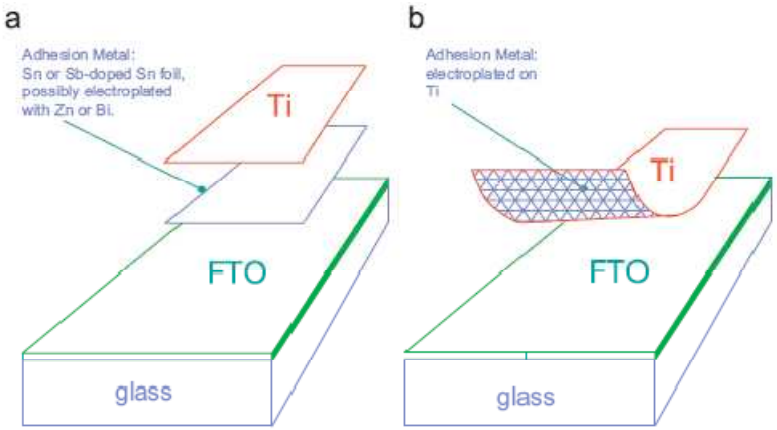






-----ONGOING/FUTURE RESEARCH-----

Ongoing/Future Research



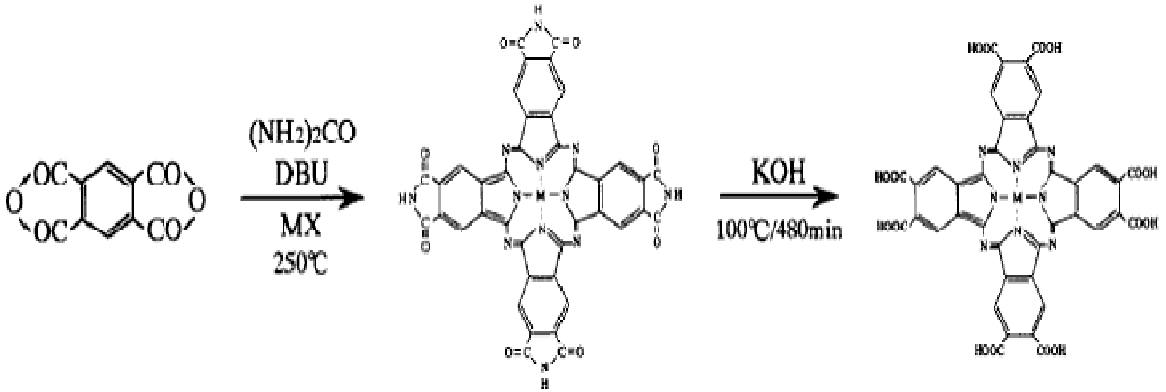
Low-cost bonding of Ti thin films onto conductive glass substrates and synthesis of TiO_2 nanotubes

Implementation of cost-effective Al_2O_3-modified TiO_2 NTs in DSCs

Further optimization of coreshell Al_2O_3-TiO_2 nanoparticle materials for DSC application

Synthesis of phthalocyanine based dyes and their testing in the DSC

Modelling of opto-electronic materials used in DSCs



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- Supervisors

Thank You