The Abdus Salam
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Entrepreneurship for Physicists

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Relation between Scientific Research, Inventions and Products

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Scientific Research, Inventions and Products

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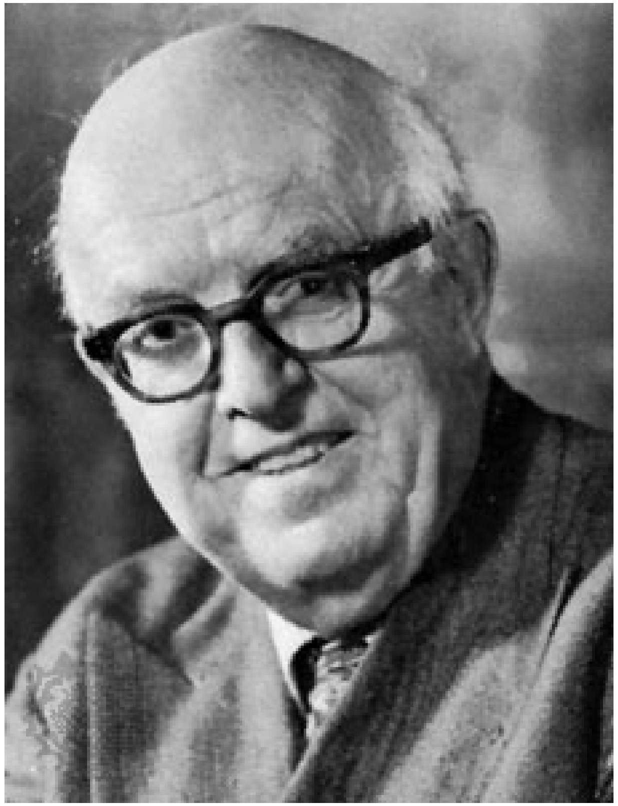
Trieste 17th March 2008

Outline

- Science and technology cultures
- Invention and Innovation
- Time gaps to commercial products
- Examples from Oxford
- Oxonica
- Oxford Biosensors
- Can we learn from this experience?

CP Snow recognised the science/technology gap in his 1959 “Two Cultures” Essay

- “I think it is fair to say that most pure scientists have themselves been devastatingly ignorant of productive industry…”
- “pure scientists and engineers often totally misunderstand each other”
- “pure scientists have by and large been dim-witted about engineers and applied science”
- “engineers have to live their lives in an organised community…..They are absorbed by making things….”



The New “Two Cultures”

- Basic Science Research
- Applied research – Technology

- “Basic research….build a bridge wherever it strikes the builder’s fancy. Applied research…..a bridge built where people want to get across the river” *Willis R Whitney, GE Labs, USA ~1920*

Scientific Research
the motivation

- Scientists view things on a short time scale! Their measure of success is simple: publications in top peer-reviewed journals
- Technologists have a longer, more tortuous time scale. Measure of success is to manufacture and sell into a market
- There is a culture gap
- There is also a time gap between invention and commercialization

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Invention: what is it?

- It is often confused with “discovery”, which is “making something known for the first time”.
- Invention can build on discovery
- Invention is the new, useful and non-obvious improvement to a process, object or product.

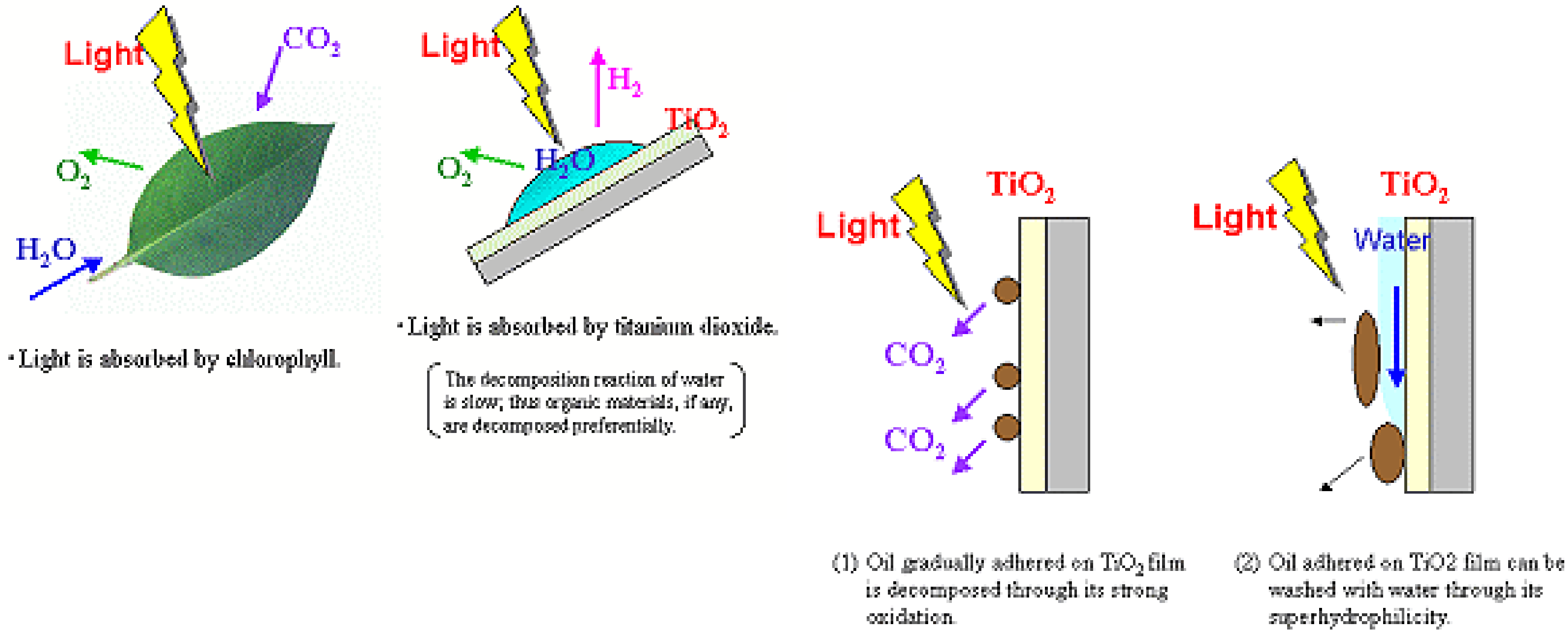
What is Innovation?

- Invention happens and IP is created, Patents filed etc…
- The IP has to be converted into a business or a product: this is the innovative step.
- Managing innovation is a new and poorly understood topic.
- In Oxford we introduced Enterprise Fellowships to do this

Examples of Discovery and Invention

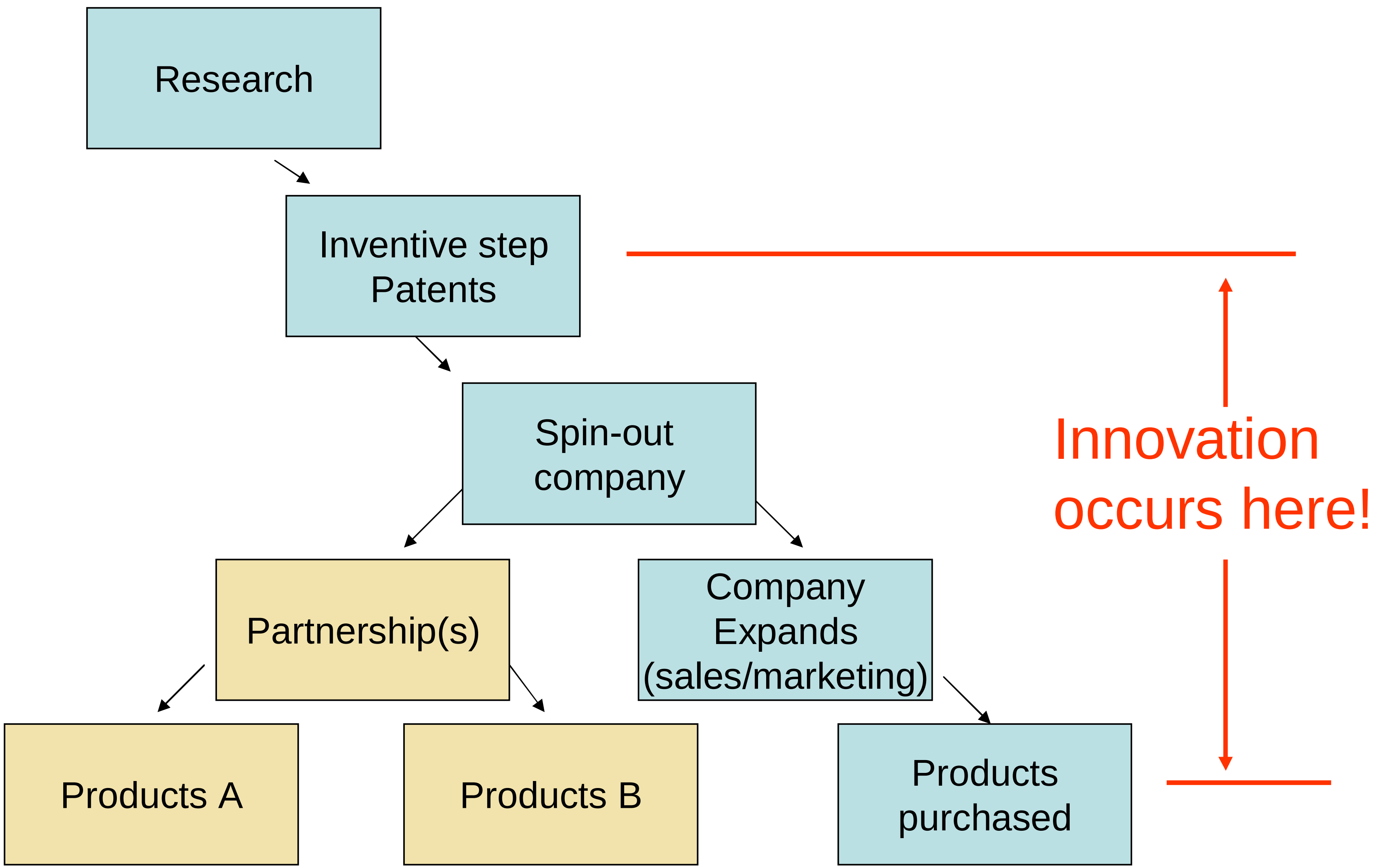
- Take the example of titania as a photocatalyst for self-cleaning surfaces
- Discovery was: Fujishima (Nature vol 238, 37, (1972) but had published in Japanese in 1969.
- Invention was filed in 1990's as PCT/JP96/003684 by Toto Ltd.

Titania (n-type) and light

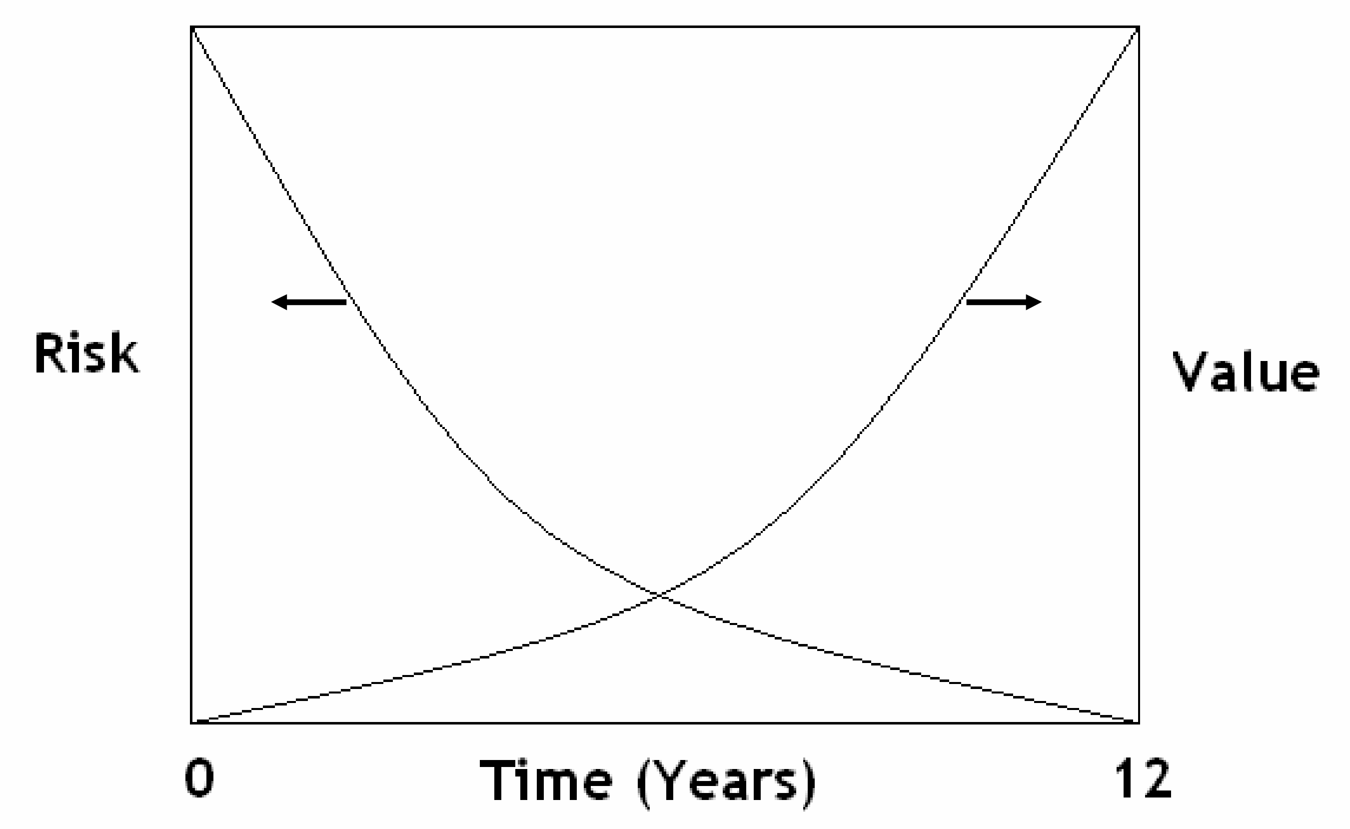


http://www.nanonet.go.jp/english/mailmag/2005/044a.html

The Innovation chain



Time Gap in the Innovation



Can we quantitatively predict these curves and determine investment profile?

Science and Technology
The time gap

There is a time lapse between first scientific publications and commercialisation

Transistors (10 years)
Liquid Crystal Displays (12+ years)
Tungsten filament light bulbs (10 years)
Semiconductor lasers (12+ years)
Enzyme-based glucose biosensor (10 years)

Why this time lapse? What goes on during this period?

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What goes on in the “Time Gap”

- Patents filed and substantiated
- Market assessment to establish a business case
- If a business case can be made: process and production issues addressed
- “scale up” may pose problems, and the real costs will emerge
- Market may change for better or worse! (Oxonica started to make phosphor nanoparticles for a display device that failed to capture market share)

The Time Gap

- Development takes longer than you think! It also costs around 10x research costs
- Is there a market/business to be had?

  Too many scientists ignore this
- Manufacture is capital intensive and it takes time.

  The skills are completely different from scientific research
- Manufacture costs can cost 10x development!

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The Time Gap
Can it be shortened?

- Money needs to be available for the risky development stage.

  This must come initially from Govt.

- The risks and market dynamics need to be understood (and controlled).

  A role for Business Schools (and Banks?)

- A new "culture" of entrepreneurism and acceptance of this needs to be instilled.

  Education at all levels

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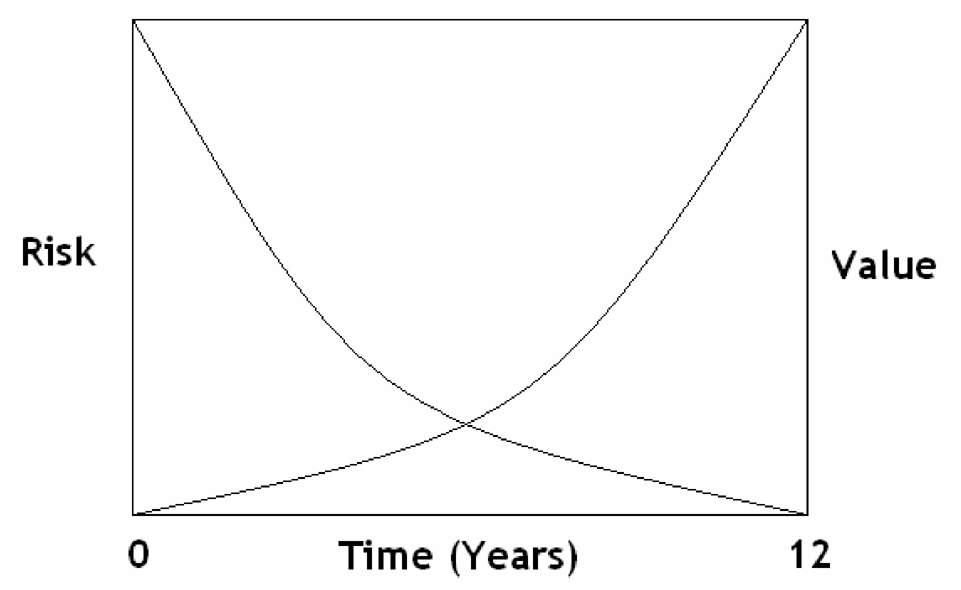
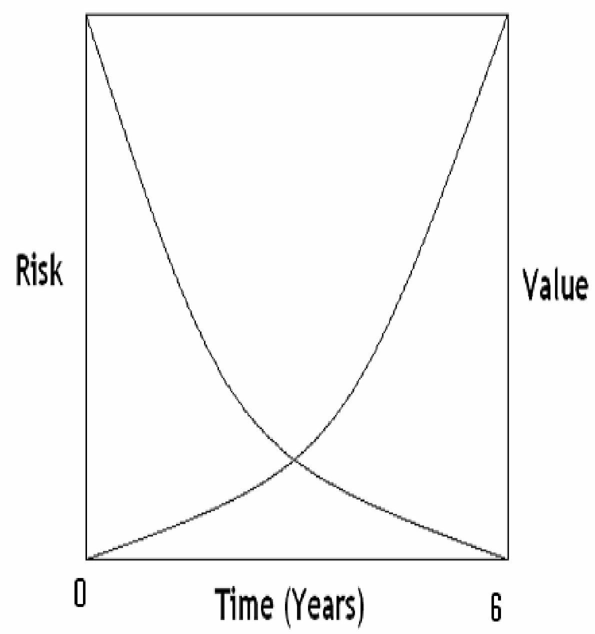
Can we shrink the timescale?



Form partnerships with other companies

Use toll manufacturing

Use other sales/marketing



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How should we try to commercialize anything?

- We could take a “technology push” point of view, eg: nanotechnology has the key to everything.
- We could look at the market and understand what customers want and why they want things.
- This market driven view leads to a “solution driven” approach and then draws upon the appropriate technologies.

Two distinct approaches
Technology push vs Market Pull

- Take a particular technology
- Find new things that the technology enables
- Try to sell these

This is high risk and could be "disruptive".

- Identify a market need
- Provide a solution to satisfy the need.

  This might use several technologies
- Sell

This approach is lower risk

Examples of Oxford spin-outs at Begbroke

•Oxonica: formed in 1999, from Engineering Science. Invented nano-phosphors, sunscreens, diesel fuel additives and biotags. Floated on AIM July 2005. cap. £60m

•Oxford Gene Technology: formed in 1995 from Biochemistry, came to site in 2000: gene array technology.

•Oxford Biosensors: formed in 2000 from Engineering Science and Chemistry, makes point of care sensors based on enzyme electrochemistry and microelectrodes. Moved to Yarnton in 2004 to manufacture.

•Hardide: formed in 2000 from Russia, making hard coatings, moved to Bicester

How Oxonica started: the original vision

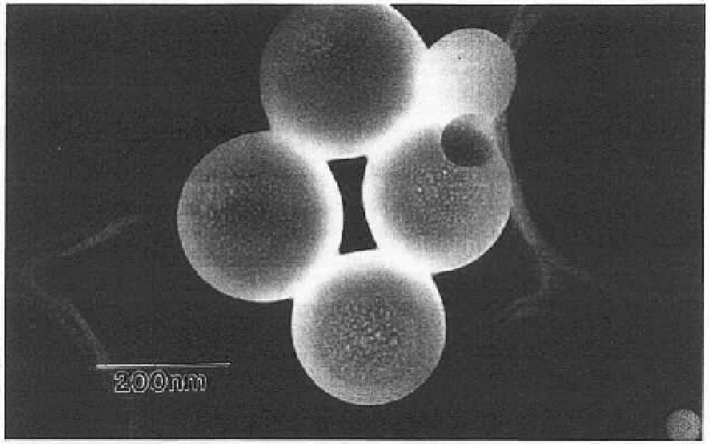
- Research on manufacture of luminescent nanoparticles in the late 1990s led to belief that we could offer low voltage nanoparticle phosphor materials to the field emission display industry.
- This idea was flawed, because industry wanted a complete solution and not a small part of the solution.

  Note a field emission display needs electron emitters, the phosphors, a screen, fully integrated into a product.
- Attention was then given to nanoparticle sunscreens and diesel fuel catalyst additives. The former had strong internal University IP, the latter did not.

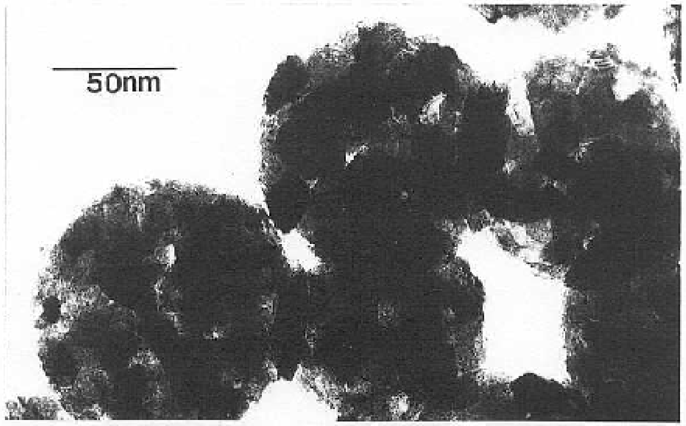
Oxonica plc

- University of Oxford spin-out formed 1999 after 7 years background research
- Focus on Energy, Environment and Healthcare
- “Solution Provider” ethos
- £2.3M from Angels and DTI awards
- £8.2M from Institutional Funding
- Revenue generating from 2002
- Tailoring nanoparticles for customer applications, building revenues based on IP generation
- Floated on AIM 20-7-05, market cap. £35M
- Took over Nanoplex (US) 20-12-05
- Deal with a Turkish oil company broke down in 2007, reduced valuation.
- ~40 Employees, strong commercial and industrial experience.
- Current shares trade at ~25p

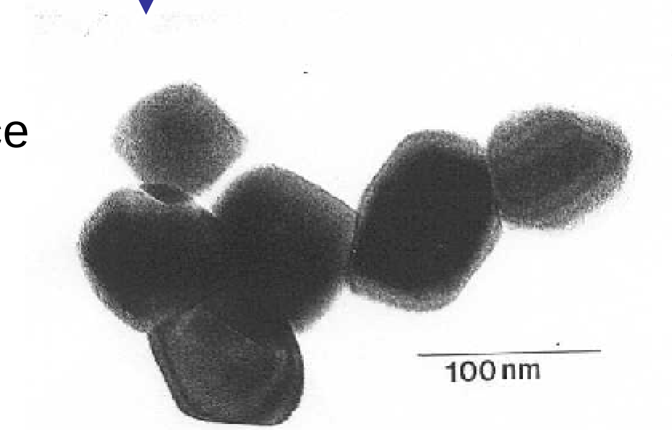
Nanophosphor particles Y_2O_3:Eu (an early product)



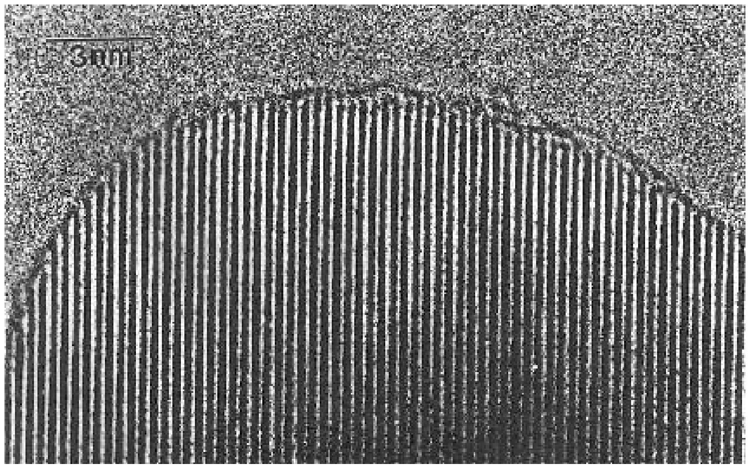
Mild anneal



High temperature heating



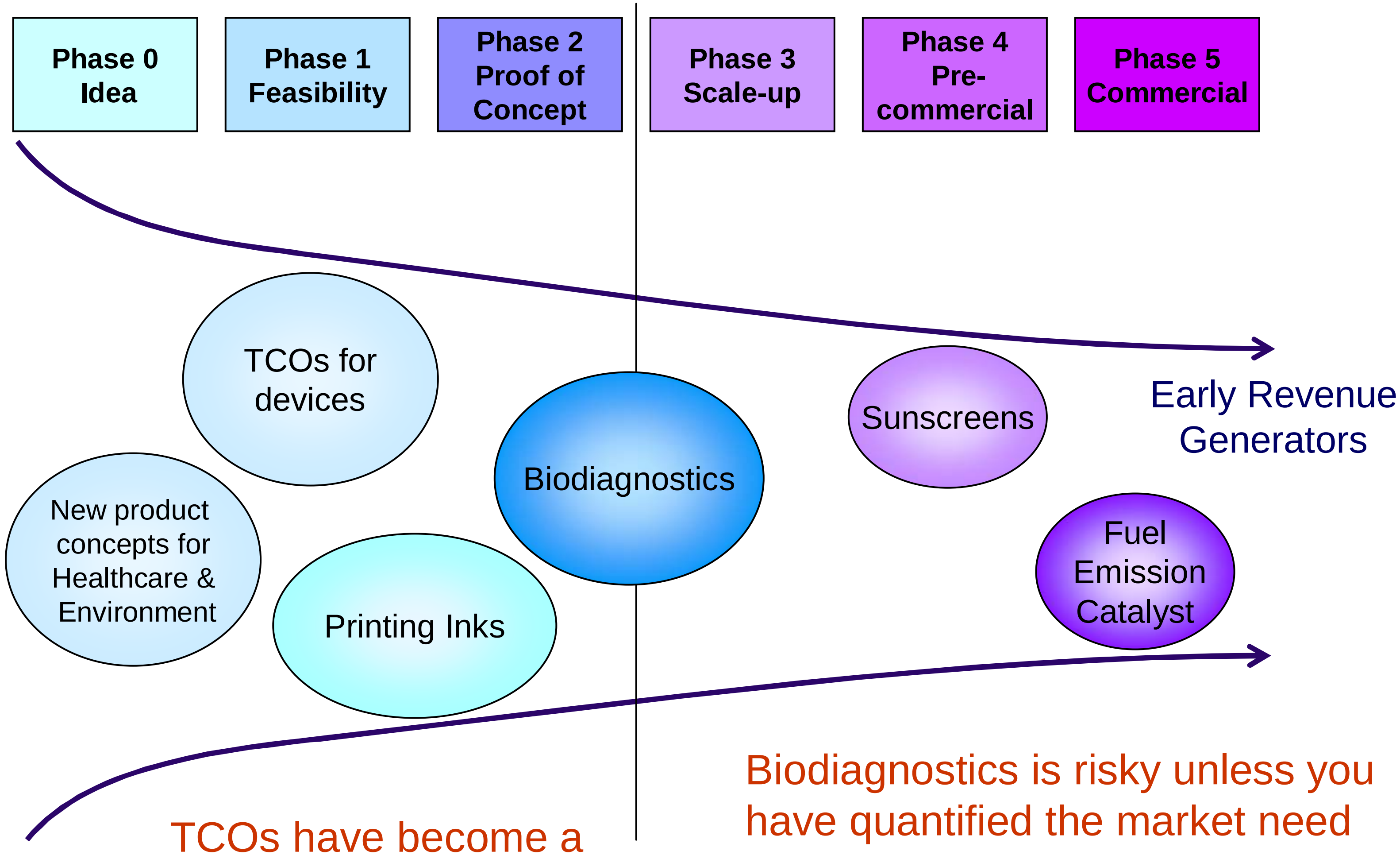
Detail of surface



The early lessons

- Discard the idea of pushing clever nanotechnology
- Try to provide a complete solution to a market need
- Quantum dots were “fashionable” but where is the market? (this is true today!)

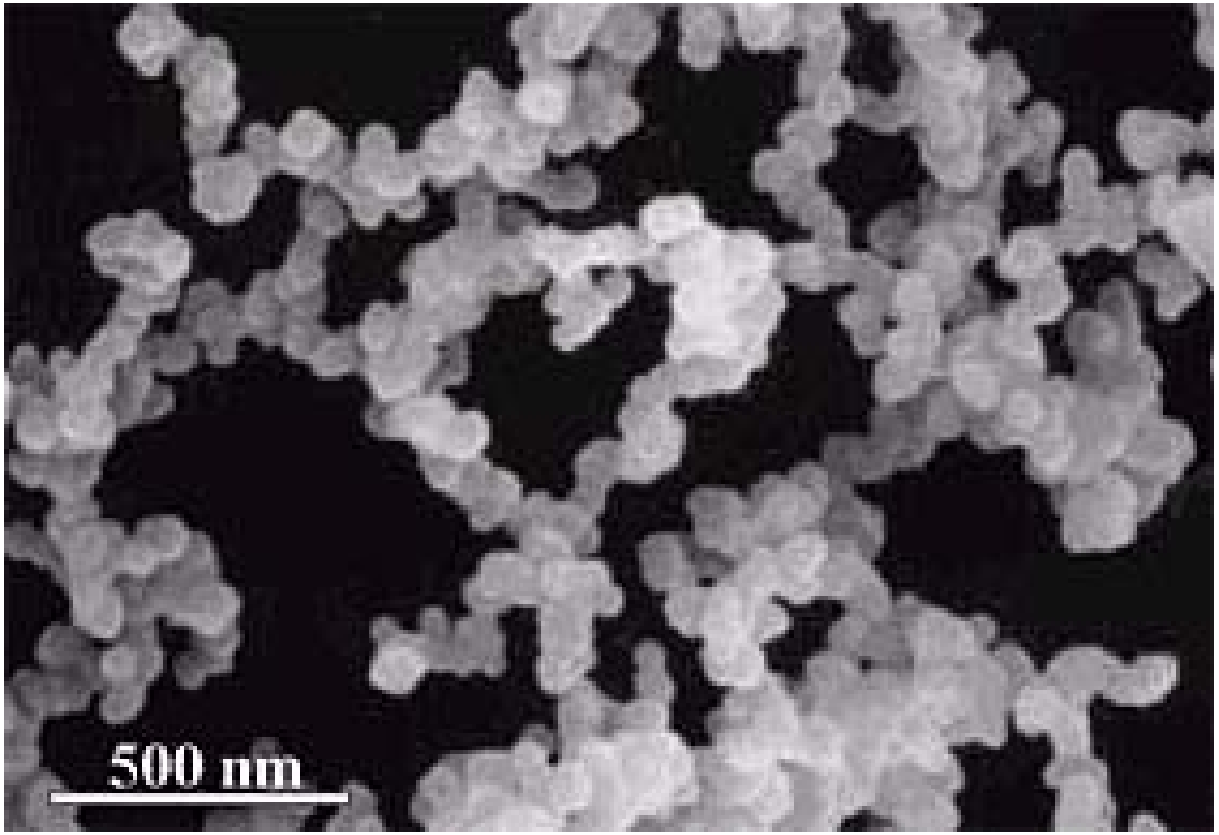
Oxonica product pipeline



TCOs have become a very important market need

Biodiagnostics is risky unless you have quantified the market need and supply chain

Cleaning up diesel exhaust



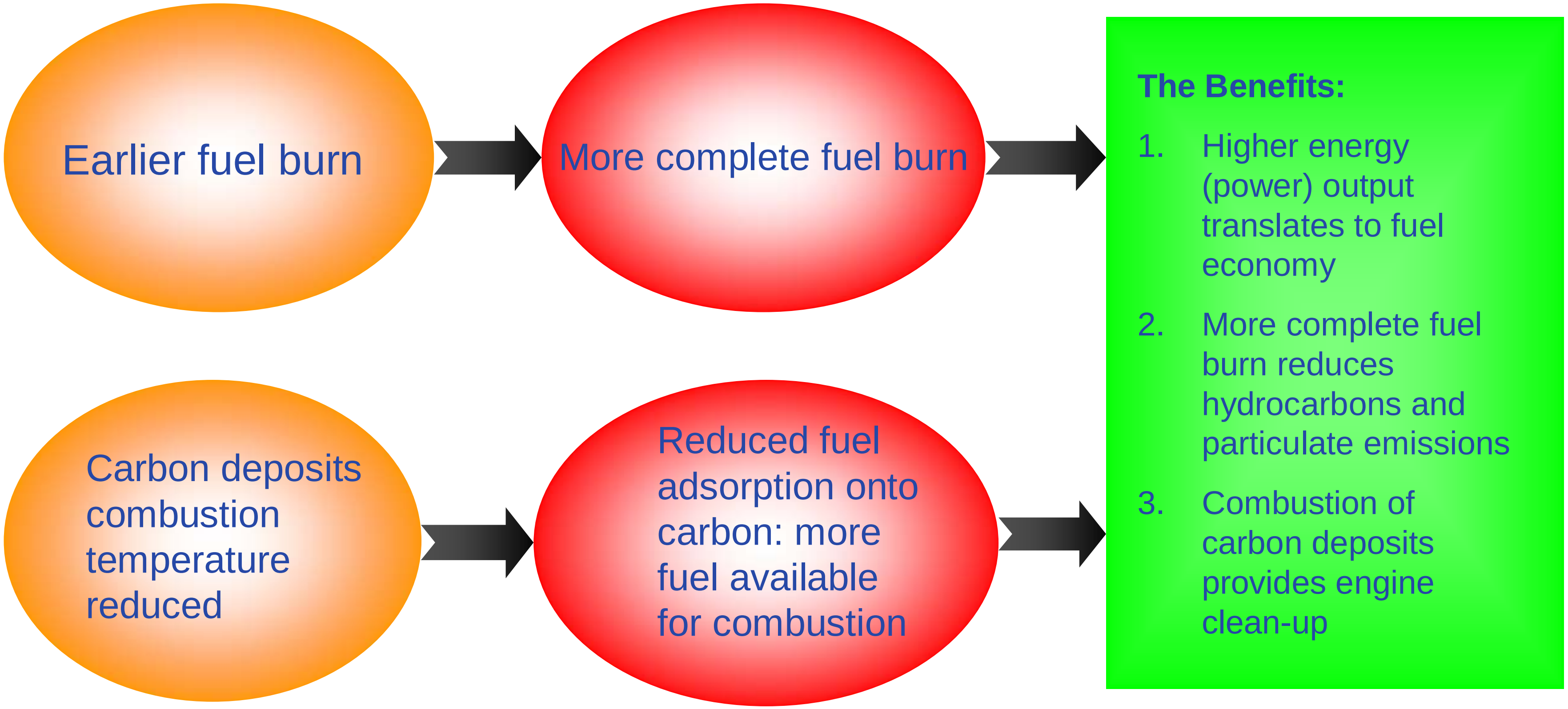
Examples of diesel exhaust particles

Envirox Technology reduces diesel particulates

- **Based on a Cerium Oxide dispersed in hydrocarbon solvent**
  - Fuel-borne additive
- **Nanoscale particle size**
  - Extremely high catalyst surface area
- **Direct addition to diesel fuel:**
  - Fuel-borne catalysis
- **Approx. 5ppm Cerium Oxide**
  - Low application rate – only 1 litre of Envirox to 4000 litres of fuel
  - No engine modifications required

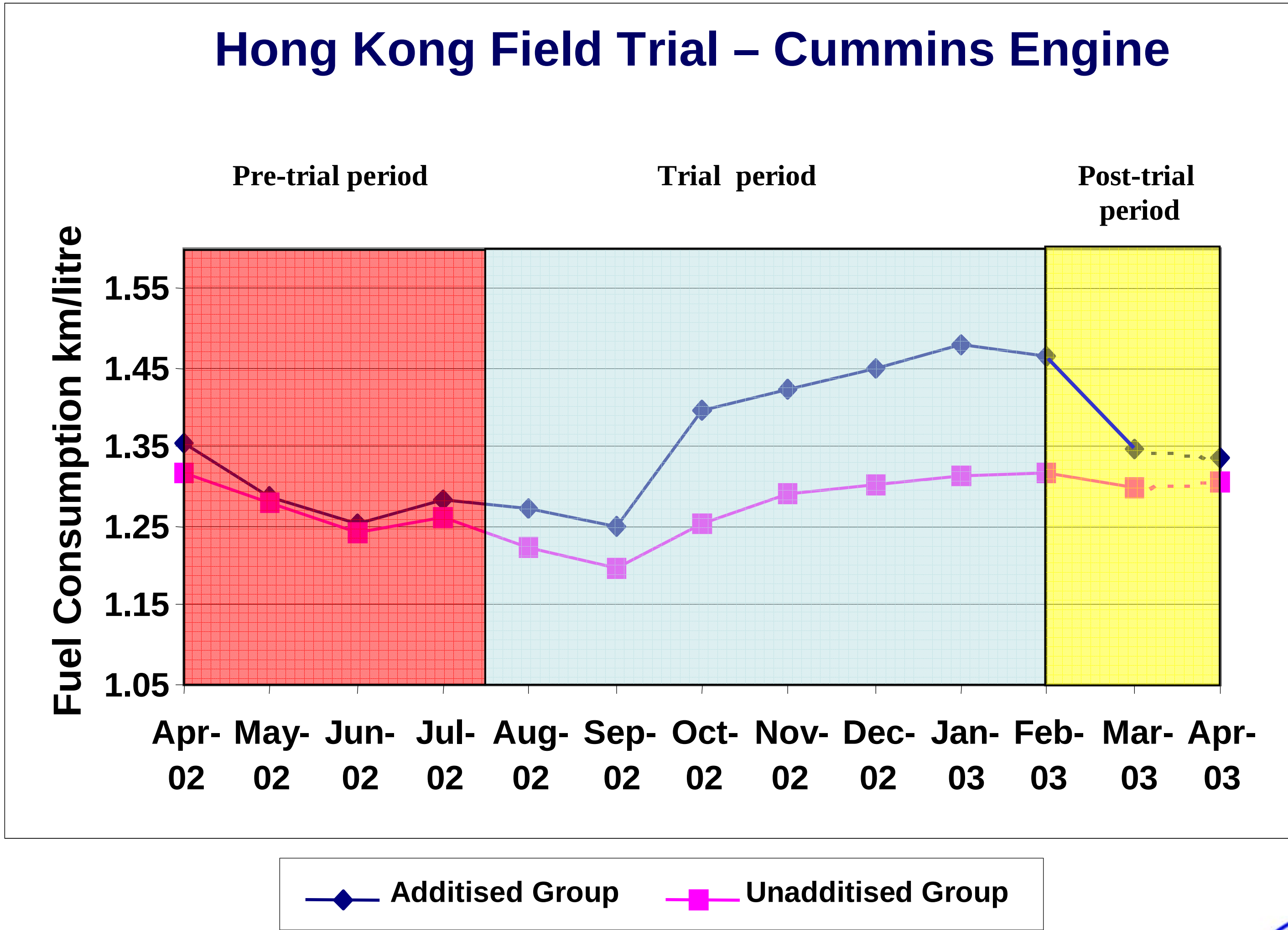
OXONICA

Envirox™: The Process



OXONICA

Envirox™ : Fuel Economy Performance



OXONICA

Has Envirox worked?

- Yes, it has proved its value in conventional diesel engines and turbodiesels.
- But, it is not effective in high sulfur content fuels
- It may yet find other applications as an “in situ” combustion catalyst

Envirox Future

- Need to expand into biodiesel and other heavy oils for transport
- Possible uses in oil-fired heating and coal-fired applications?
- Can cerium oxide be enhanced?
- Can it be adapted to cope with high sulfur content fuels?

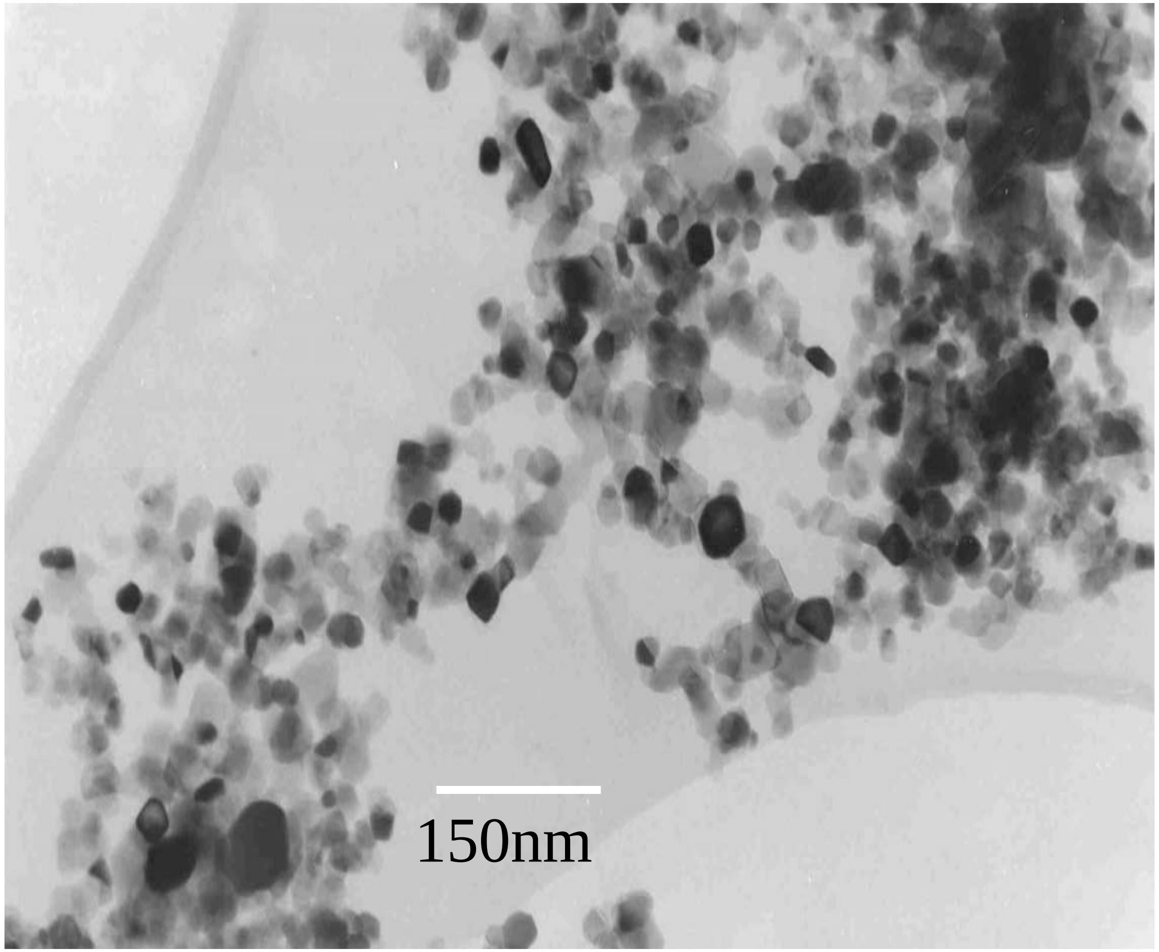
Optisol TM®

- The “driver” for this product was the evidence that most “transparent” sunscreens in the 1990s posed a health hazard.
- Nanoparticles of titania are used so that they appear transparent to visible light on the skin, but block UV
- The titania is doped in a special way so that it does not behave as a photocatalyst (that would cause skin damage)
- The new titania particles prevent the formation of “free radicals” and hence the formulation lasts much longer in sunlight and protects the skin.

Other thoughts to improve sunscreens (1999-2000)

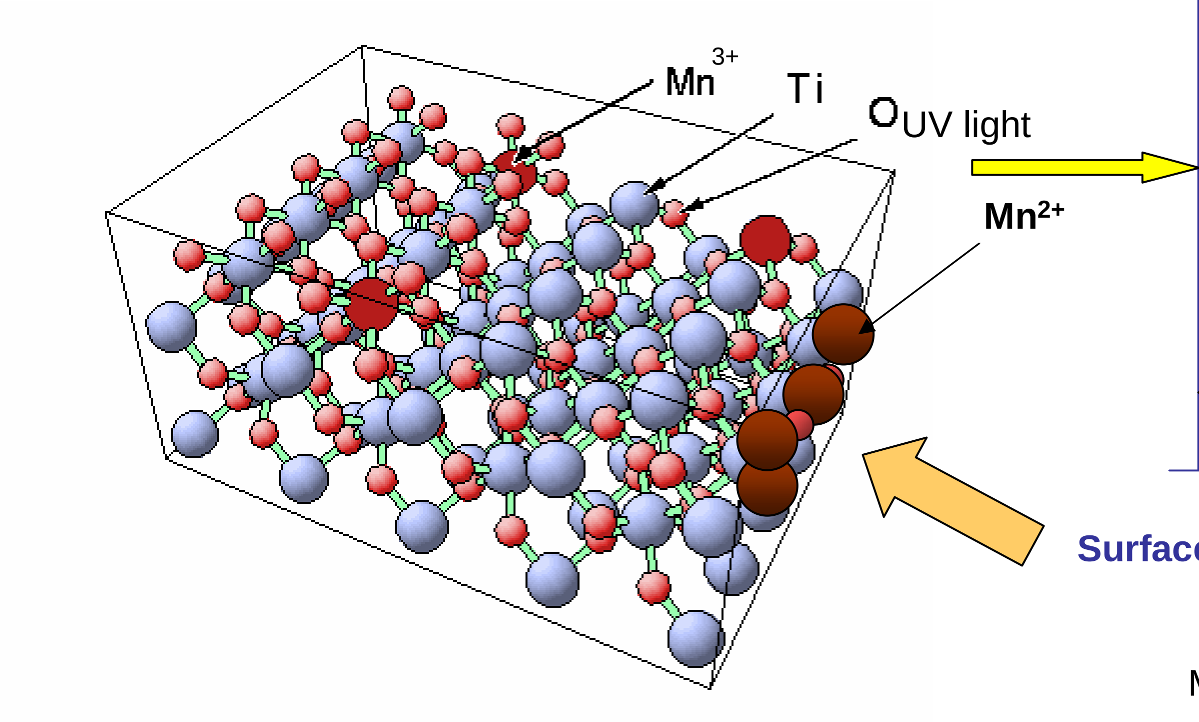
- Could we convert uv light to visible? ZnO could be used as a "convertor"
- Was the idea of using TiO_2 doped to make it p-type a general solution?
- Could this be used to make other uv protective layers in the paint and plastics industries?

Titania sunscreen nanoparticles



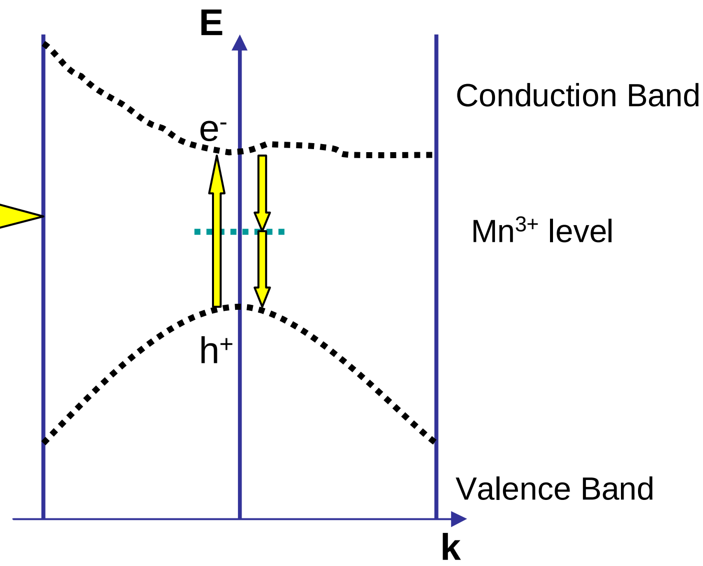
These are Mn-doped rutile particles, small enough not to scatter light, but still absorb the harmful UV rays.

OPTISOL: Mode of action



Rutile $P4_2/mnm$ Titanium Oxide lattice

Schematic band structure



Surface Mn^{2+} free radical scavenging

$Mn^{2+} \Leftrightarrow Mn^{3+} + e^-$

$Mn^{2+} + OH^\bullet \Rightarrow Mn^{3+} + OH^-$

$Mn^{3+} + {}^\bullet O_2 \Rightarrow Mn^{2+} + O_2$

Optisol TM based on nanoparticles of titania

Photostable UV absorption with enhanced UVA protection for skincare & materials applications

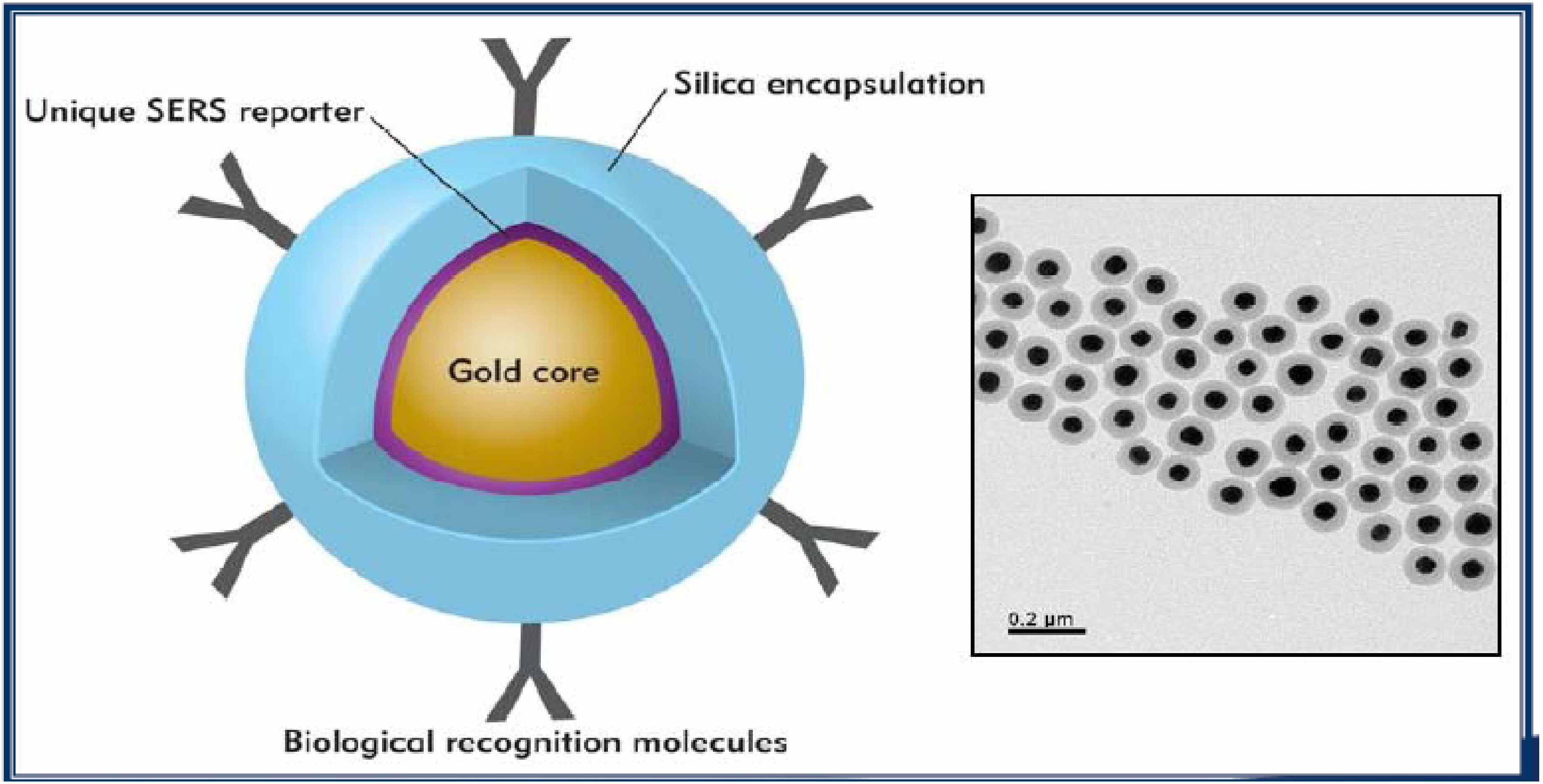
- Safer sunscreens and cosmetics
- Anti-ageing properties
- Skin-lightening applications
- Formulation enhancement
- Extended in-use product lifetime

OXONICA

New doped titania products

- Enhanced performance for many other cosmetic foundation formulations
- Possible use as a uv protective agent in coatings and polymers: “Solacor”®

Oxonica's new biotag technology



Oxonica, new lessons!

- Make use of core technology to provide solutions
- Provide solutions where there is a market need
- Early revenue generation is essential
- Balance the team, remember sales/marketing, but keep a strong technical base
- Collaborate with many universities
- Form strategic alliances to speed time-to-market and reduce costs

Oxford Biosensors

- Based on electrochemical sensing using enzymes coupled to microelectrodes
- Enzymes provide for high selectivity of important biomolecules
- Microelectrodes give a fast response time and simplified interpretation
- Proof-of-concept done with silicon-based structures
- Current technology is based on printed ink-on-plastic
- Target is 3%CV with 4 analytes for cardiac risk

Oxford Biosensor's Multi-Analyte Platform

PROFESSIONAL (POINT OF CARE) DIAGNOSTIC SYSTEM - CLIA waived:

- Hospital
- Doctor's Office
- Clinics (diabetes, renal etc)
- ER

FUTURE MARKETS:

Consumer - 'Empowering the patient'

e.g. Management of Cardiac Risk

"More than 200 million people worldwide meet the criteria for treatment, but fewer than 25 million take statins." Dr.Eric J. Topol, "Intensive Statin Therapy -- A Sea Change in Cardiovascular Prevention", New England Journal of Medicine, April 8, 2004.

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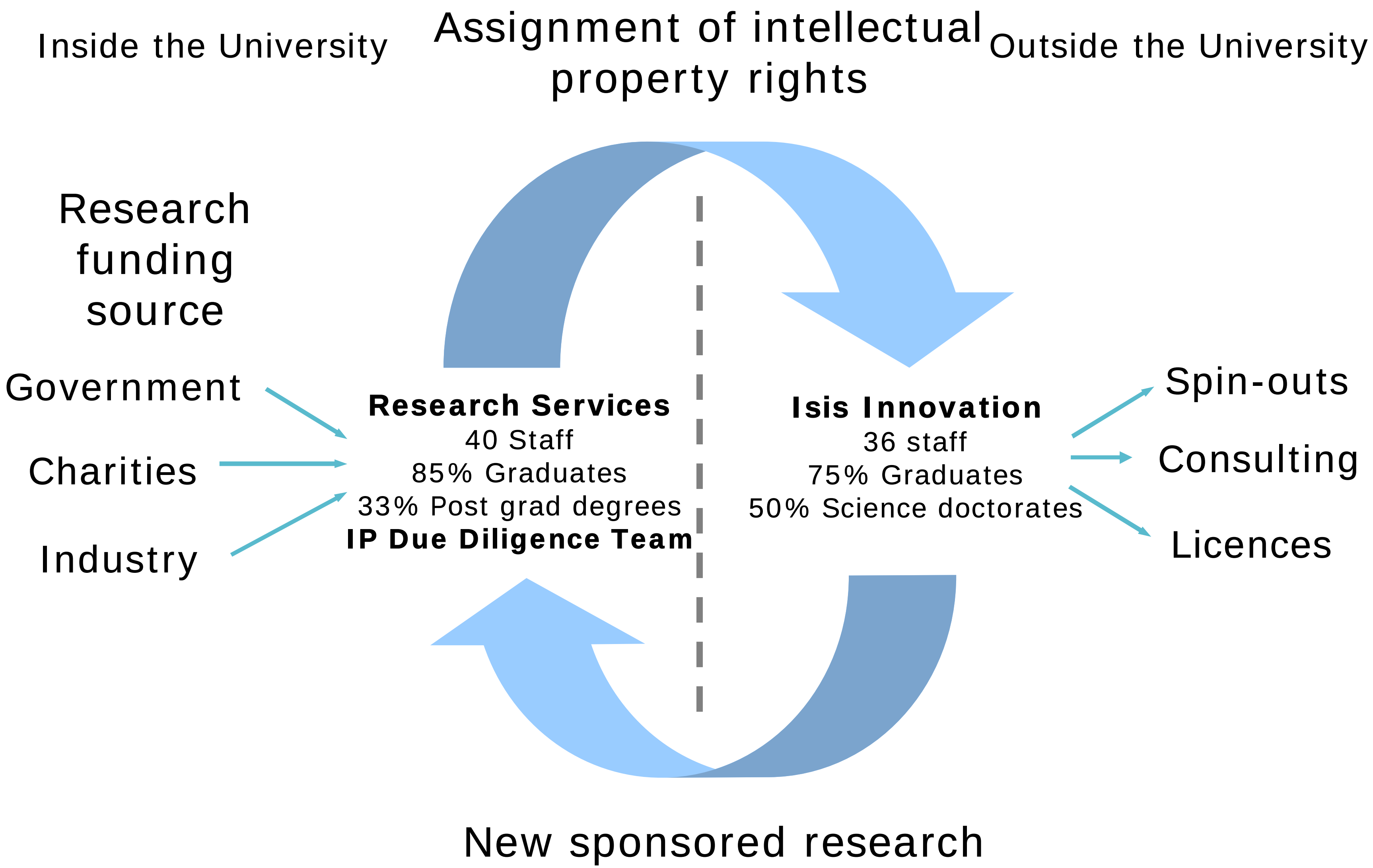
Oxford Biosensor lessons

- The technology was too “disruptive” for any license deal
- The time to market is long because of FDA approval issues
- The complexity increased as the improvements to performance to achieve a 3% CV were made
- Many questions of basic science and technology have been identified, eg: polymer cutting, machining, bonding, surface wetting, drying, printing…

Overall Conclusions
How can we speed up Innovation?

- Never "push technology" but look for market-led solution provision
- Develop a balanced team, especially help with sales/marketing, but do not neglect the technical team
- Try to shorten the time from invention to revenue generation by partnerships
- Treat investors' money as your own and respect their risk and confidence

Transfer of Intellectual Property in Oxford University



Can the "Oxford experience" be applied elsewhere?

- A large University with diverse skills is not essential (but helpful!)- it can provide a good environment to make things happen
- Need to establish at the outset, the way IP is managed
- Remember that the innovation stage is crucial (and we don't have the optimal solution yet!)
- Sales and marketing are as important as the technology
- Scale-up of manufacturing/partnership important
- Sources of investment are essential
- Government fiscal policy is important

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