COMMERCIAL PROSPECTS FOR VIRGINIA TECH NANOTECHNOLOGY

Cutting Edge Research Investment in Emerging Technologies

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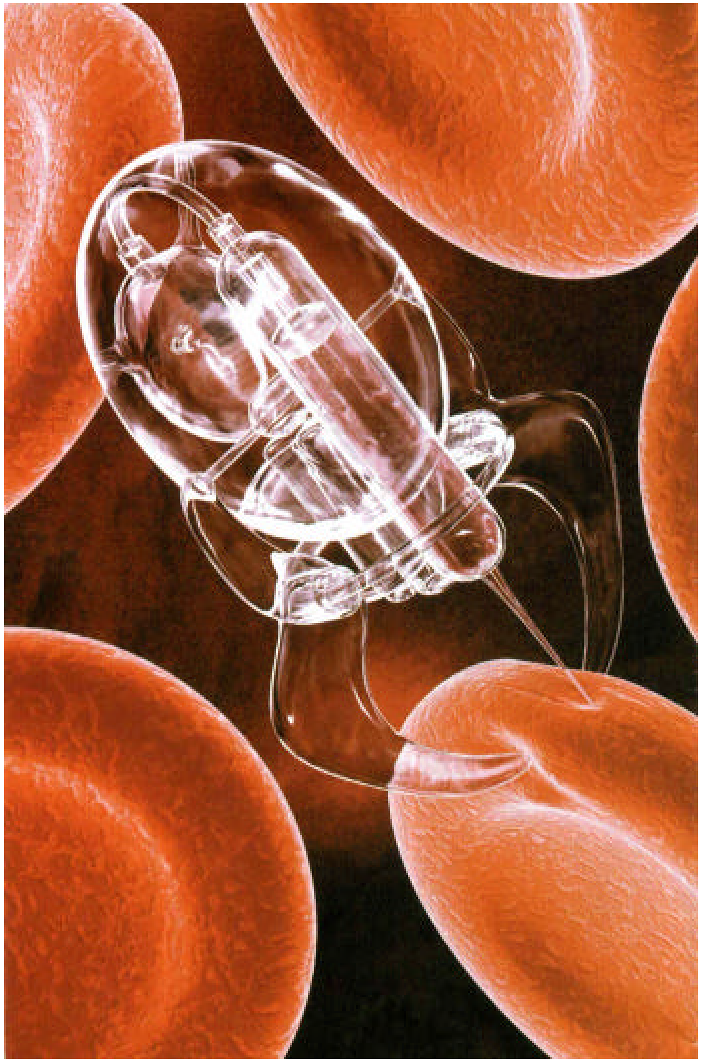
August 3, 2004

THE POPULAR CONCEPTION OF NANOTECHNOLOGY IS NOT THE REALITY



WHAT IS NANOTECHNOLOGY AND WHY IS IT IMPORTANT?

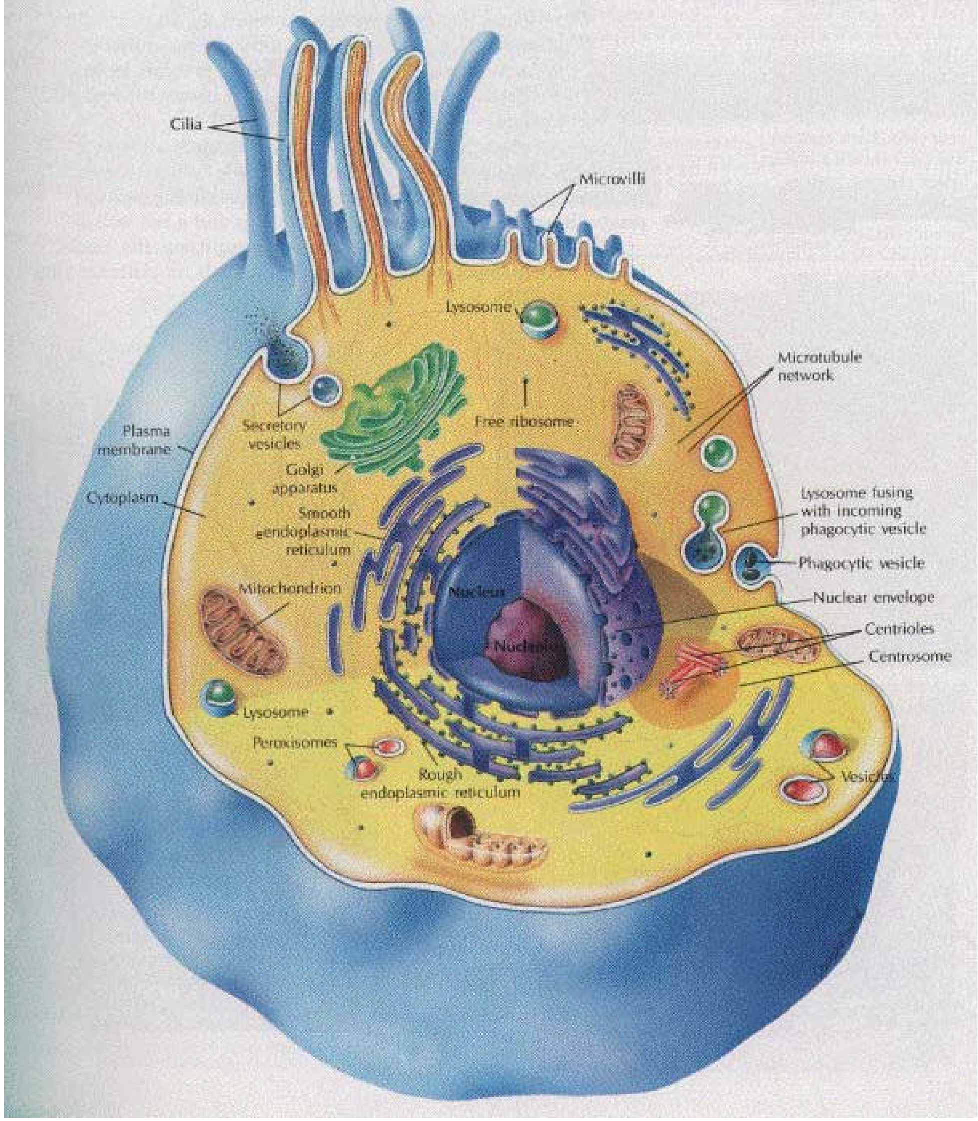
- Nanotechnology is based on the controlled manipulation of very large molecules for specific purposes
- Much of the inspiration for nanotechnology and its applications comes from life itself
- Aspects of nanotechnology include

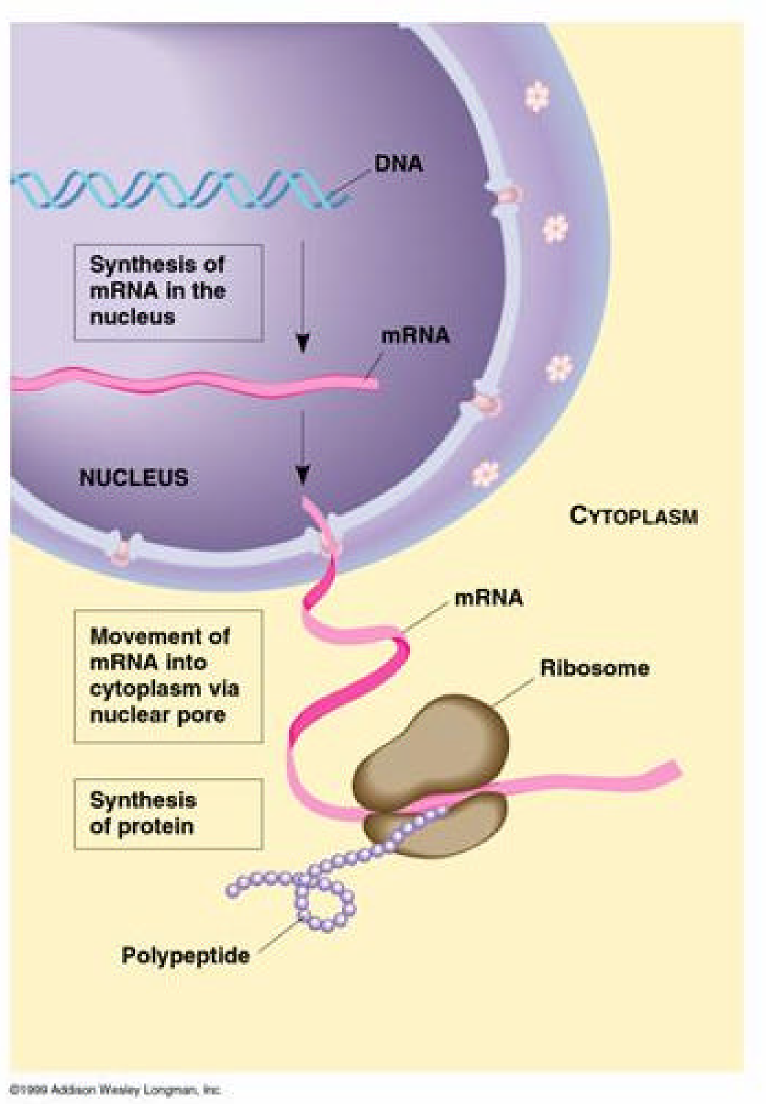
    molecular self-assembly

    molecular machines

    molecular sensing and actuation
- Many significant potential applications of nanotechnology are biomedical
- Nanotechnology has the potential to revolutionize manufacturing, lowering costs and improving quality, while at the same time creating new capabilities that would not be possible without its use

THE POTENTIAL OF NANOTECHNOLOGY CAN BE SEEN IN NATURE





REAL APPLICATIONS OF NANOTECHNOLOGY ARE IN THEIR INFANCY

Nanotech Is Wall Street's Latest Love

By THE ASSOCIATED PRESS

Published: July 13, 2004

Filed at 4:50 p.m. ET

NEW YORK (AP) -- The chief executive of Nano-Tex LLC warned about the mounting hype around his company and other nanotechnology startups at a recent investor conference. But the first question from the audience showed how his message had been digested.

``When is your IPO?''

Nanotechnology, or science at the atomic level, has become the latest fad on Wall Street as the stock market shakes off its dot-com funk. Bankers and venture capitalists are pushing for initial public offerings of nanotech startups. Everyone, from day traders to fund managers, seems eager to get in early on what they hope will be the next big thing.

THIS PRESENTATION WILL BE A TALE OF TWO CENTERS

- The *Fiber&Electro-Optics Research Center* (FEORC) in the College of Engineering has a long and distinguished record of extraordinary achievement in research and commercial development

- The new *Virginia Tech Applied Biosciences Center* (VTabc), a University Center, shares facilities and personnel with FEORC and collaborates closely with it on nanotechnology research and commercialization

THE COLLEGE OF ENGINEERING IS THE FOCUS FOR INTERDISCIPLINARY NANOTECHNOLOGY RESEARCH AT VIRGINIA TECH

- FEORC is one of <u>many, many</u> success stories within the College of Engineering at Virginia Tech, past and present

- FEORC is perhaps best an example of how an investment of state funds and university support can lead to contributions to each of Virginia Tech’s multiple land grant university missions – scholarship, research and service

- The College of Engineering’s expertise in interdisciplinary nanotechnology research provides an extremely significant contribution to the future success of “the larger university”

FEORC BACKGROUND

- Created: 1985, as first Virginia “CIT” center
- Mission: advanced materials and electronics; emphasis in optics/sensors
    - recent co-location with Advanced Biosciences Center
- Discriminator: Industry/government, classified/unclassified research mix
    - e.g. $9.6M classified NRL contract – “Optical Sciences Research”
- Activity: > 500 separate research programs; > $35 million
- Production: > 1000 journal/conference papers; > 100 issued patents
- Impact: > 80% of IP licensed by industry
- Impact: > 20 spin-off companies, most in Virginia

FEORC RESEARCH AREAS

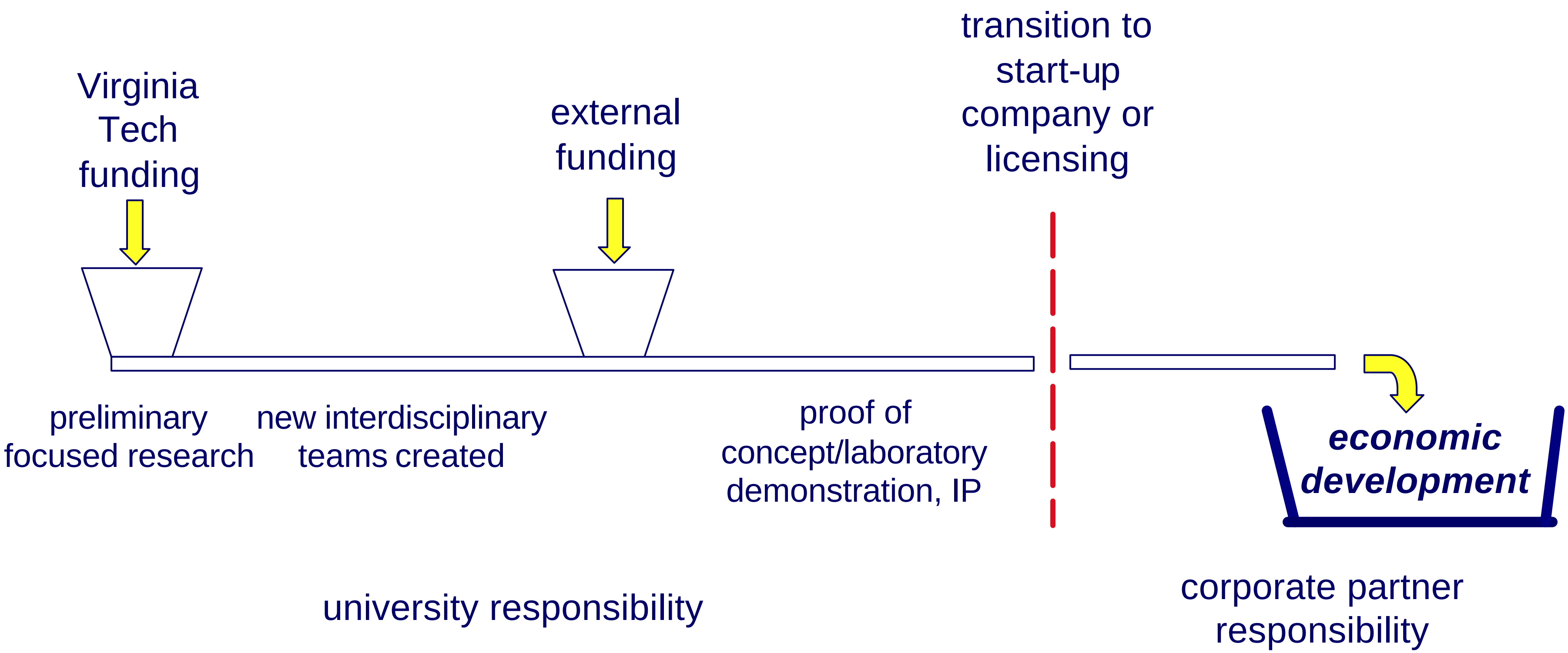
- Materials – optical fibers, specialized coatings,
- Advanced nanocomposites, biomaterials
- Devices – active and passive optical devices, actuator materials
- Sensors – optical fiber sensors, LIDAR, nanosensors, biosensors
- Communication – optical fiber local area and long distance networks

THE VIRGINIA TECH APPLIED BIOSCIENCES CENTER WAS CREATED IN 200

The Virginia Tech Applied Biosciences Center (VTabc) conducts *focused* research and engineering activities involving optics and other disciplines to create knowledge and technology to benefit the medical, biomedical and veterinary fields, while supporting the practical goals of improving services and reducing the costs of health care.

VTABC HAS A SPECIAL GOAL TO FOSTER COMMERCIALIZATION

VTabc is Focused on Improving Public Health by Making Advances in the Biosciences Commercially Available



IN ITS FIRST 5 YEARS, VTABC HAS PRODUCED SIGNIFICANT RESULTS

Virginia Tech Support ($M)	5
Proposals($M)	56
Awards($M)	15
Disclosures(#)	42
Prov. Patents(#)	25
Utility Patent Applications(#)	11
Utility Patents(#)	2
Licenses(#)	8
Companies Created(#)	1

Projects(#)	93
Faculty(#)	101
Postdoc's(#)	16
Grad Students(#)	99
Undergrads(#)	56
Papers(#)	47
Presentations(#)	87

commercialization measures ~ 5X better than the US university average per $1M invested

[2002 Annual Survey, Association of University Technical Managers, www.autumn.net]

FEORC/VTABC RESEARCH INCLUDED NANOTECHNOLOGY PROJECTS

During 2003-2004 a variety of research projects were carried out involving:

- Biomedical image analysis
- Spectroscopic cancer screening
- Comparative cancer genomics and genetics
- Validation of animal modeling systems for cancer
- Computational approaches to cancer modeling
- → **Photodynamic therapy**
- → **DNA analysis in a test tube using quantum dots**
- → **Biocompatible coatings for medical implants**
- Non-intrusive patient monitoring for eldercare
- → **Magnetic nanoparticle-based systems for targeted drug delivery**
- → **DNA analysis chip**

FEORC/VTabc carried out a significant portion of this research program jointly with the *Center for Comparative Oncology* at the Virginia Maryland Regional College of Veterinary Medicine

COMMERCIAL PARTNERSHIPS

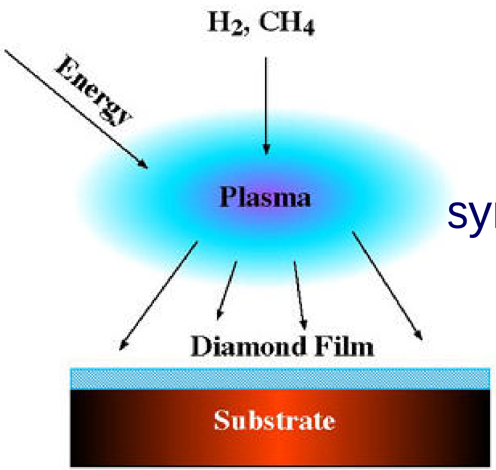
- FEORC/VTabc actively seek collaboration and sponsorship from the commercial sector

- The focus is on practical applications

- Researchers have had extensive experience in the commercial sector and understand its requirements

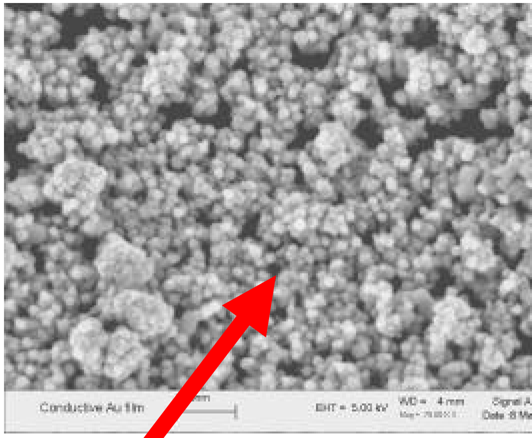
- A close relationship exists with the *Virginia Tech Intellectual Properties Corporation* (VTIP), ensuring that the transition of scientific research into intellectual property is facilitated

MATERIALS EXAMPLE – NANO SELF-ASSEMBLY

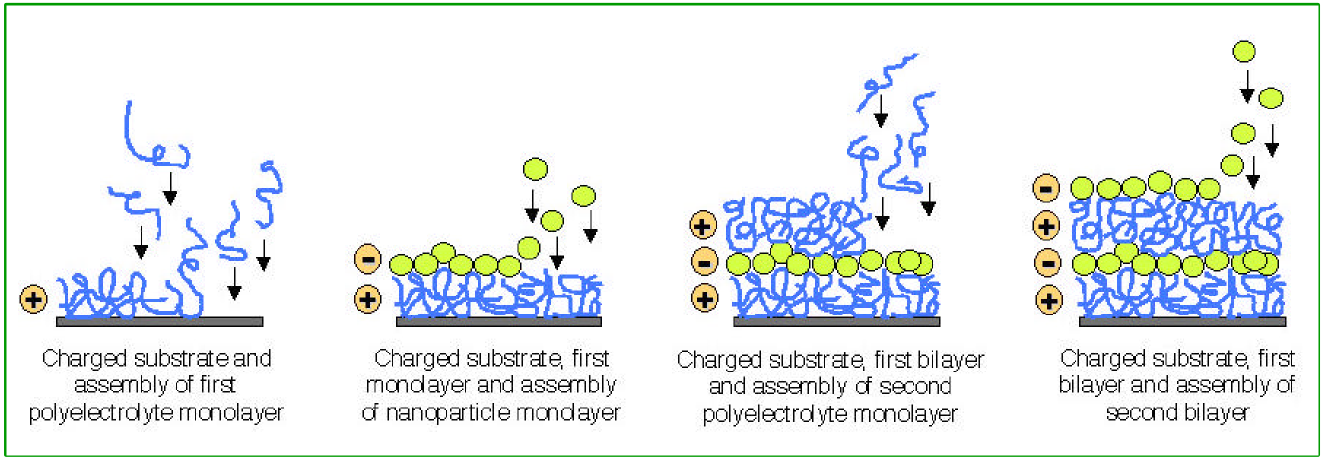


Conventional route to synthesize advanced thin films

e.g. low-cost artificial diamond



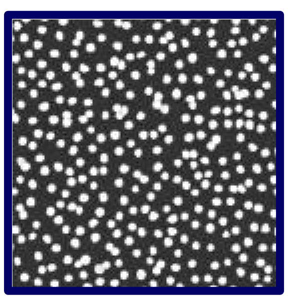
Modified self-assembly Processing (IP)



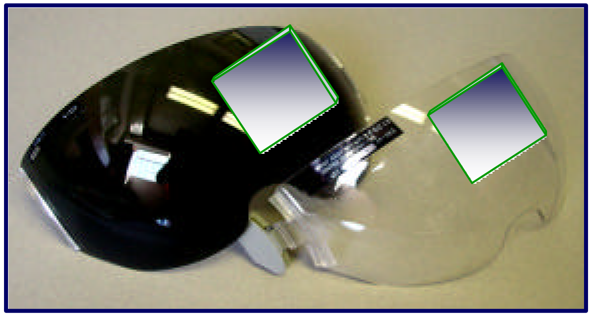
Nanomolecular modeling

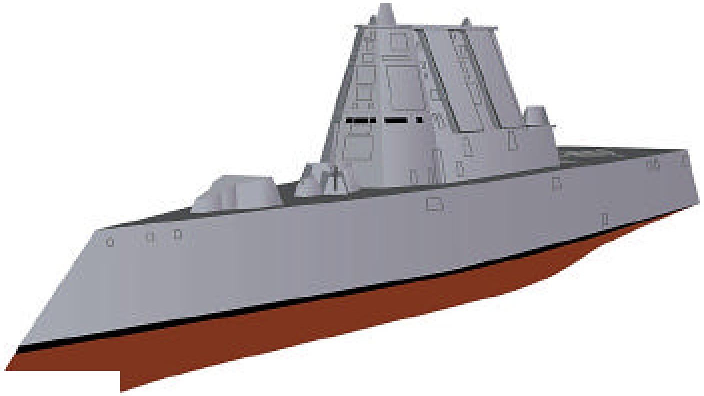
MATERIALS EXAMPLE – "NANO-TO-MACRO"

Material Properties	Precursors	Measured Properties	Comments
Electrical conductivity	Noble metal nanoclusters (Ag, Cu, Au, Pt)	0.1 – 1.0 W /? 10^{-4} W • cm	Mechanically flexible, optically transparent
Refractive Index	Polymers and polymer / nanocluster combinations	n = 1.2 to 1.8	Tailored transparent stacks
Thermal conductivity	Polymers and nanoclusters	2 W/mK	20 W/mK feasible based on current work
Mechanical Robustness	Oxide nanoclusters (ZrO_2, Al_2O_3, SiO_2)	Good Taber abrasion and haze results	Nanohardness 1 GPa




"NANO-TO-MACRO" MATERIAL APPLICATIONS



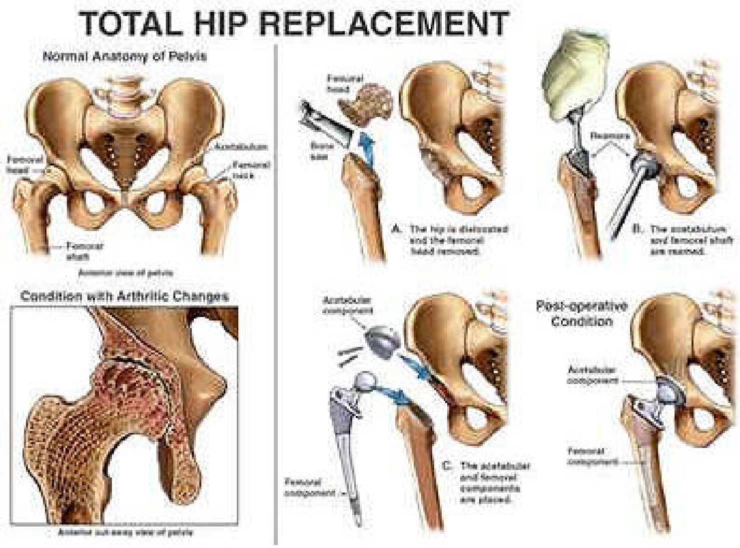


Northrop Grumman, Lockheed Martin, Boeing, Raytheon, MITRE, others

DARPA, NASA, AF, Navy, Army, MDA, SOCOM

EXAMPLE#1: NANOFABRICATED BIOCOMPATIBLE COATINGS

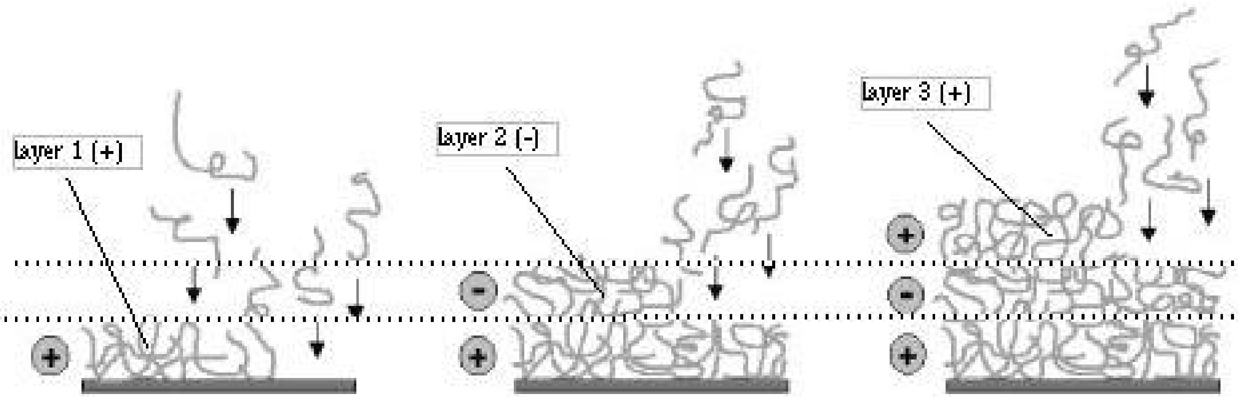
Problem: the design of biomedical implants is always a compromise between optimum mechanical characteristics and biocompatibility

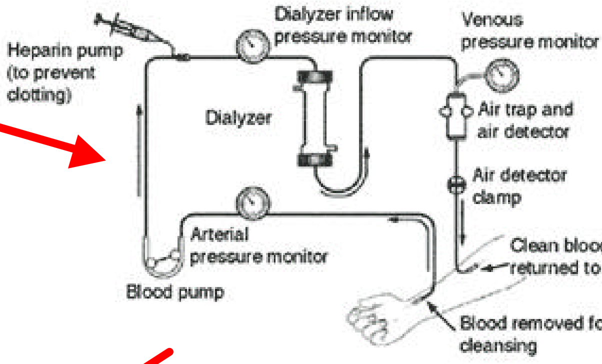


Solution: mechanically optimum implant structures with nanofabricated biocompatible coatings

STENTS

ONE OF THE FIRST APPLICATIONS FOR THIS TECHNOLOGY IS BIOCOMPATIBLE COATINGS FOR HEMODIALYSIS TUBING





BIOCOMPATIBLE COATINGS HAVE STRONG COMMERCIAL POTENTIAL

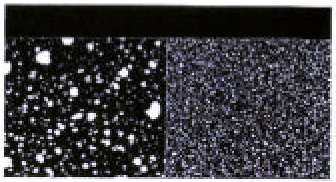
SELF-ASSEMBLED THIN FILM COATING TO ENHANCE THE BIOCOMPATIBILITY OF MATERIALS

Patent number: CA2405242
Publication date: 2001-10-25
Inventor: SPILLMAN WILLIAM B JR (US); CLAUS RICHARD O (US); WANG YOU-XIONG (US)
Applicant: VIRGINIA TECH INTELL PROP (US)
Classification:
- international: C08L39/06; B32B33/00; C09D139/06; B32B27/42
- european:
Application number: CA20012405242 20010413
Priority number(s): US20000197776P 20000414; WO2001US12042 20010413

Also published as:
WO0178906 (A1)
WO0178906 (A1)

Abstract of **CA2405242**

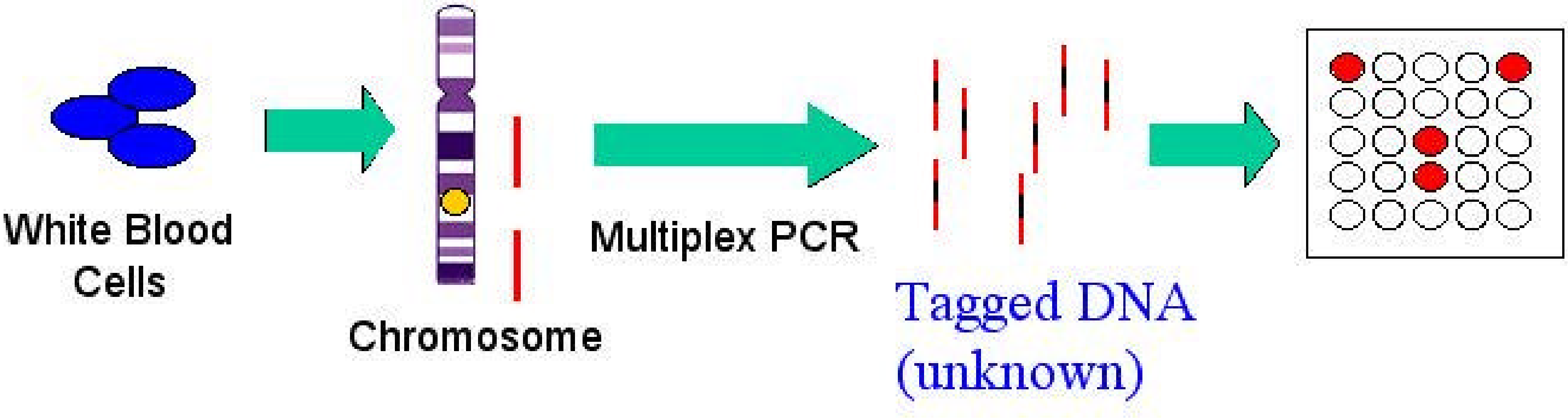
We make a subtrate biocompatible by contacting it with a starting material a nd initiating alternating charge layer electrostatic self-assembly to form a th in film. Starting materials may be poly(vinylpyrrolidone), poly[bis-(carboxylatophenoxy)phosphazene], poly(methacrylic acid), poly(l-lysine, poly(ethylene glycol), poly(D-glucosamine), poly(l-glutamic acid), poly(diallyldimethylamine), poly(ethylenimine), hydroxy fullerene, long-sidechain fullerene, or other polymers that participate in electrostatic sel f- assembly. The thin film fabrication advantageously may be at room temperatur e. A biocompatible thin film that is uniform and homogeneous can be provided. Optionally, ZrO2, Al2O3 or TiO2 nanoclusters also may be used in the film assembly. The film may be used in a drug delivery device or a medical device. The film may be used for tissue engineering. We also provide a biocompatible composition in which are present a plurality of layers electrostatically sel f- assembled from at least a polymer or fullerene asmentioned. The substrate is not particulary limited, and may be quartz, glass, plastic, metal or ceramic , a material for a bone implant, bioactive glass, polyester or other polymers, plastic or rubber tubing, bandaging material, composite material, insulator material, semi-conductor material, an artificial hip, a pacemaker, a cathete r, a stent or other substrates.



Data supplied from the ***esp@cenet*** database - Worldwide

- A patent has been filed through VTIP and a license negotiated
- Potential market is large (multi-$B)
- Partnerships have been established with a local company, *Valley Nephrology Associates of Roanoke*, a company that produces dialysis tubing, *Fresenius USA*, and the *Department of Nephrology at Wake Forest University*
- Discussions have been held through the auspices of VTIP with the *Roanoke-New River Valley Investment Fund* (established by the Carilion Health System, the Virginia Tech Foundation and Third Securities LLC) to consider the formation of a company based on this technology

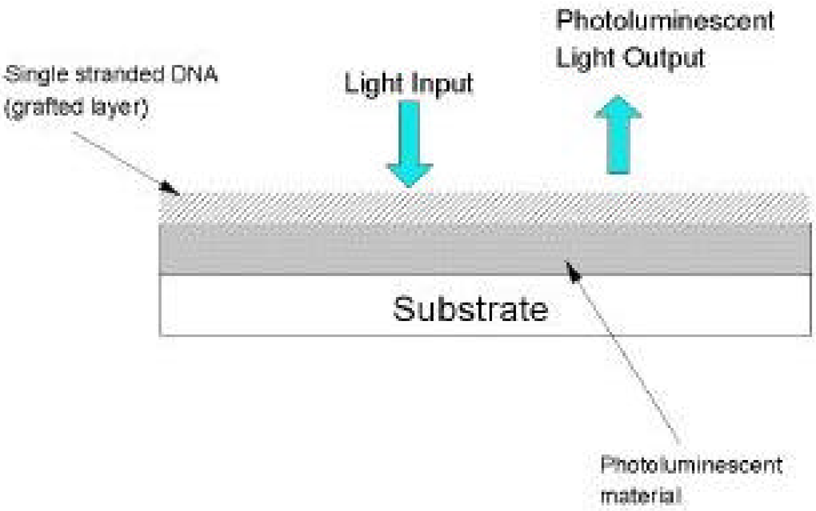
EXAMPLE#2: NEXT GENERATION DNA ANALYSIS CHIP

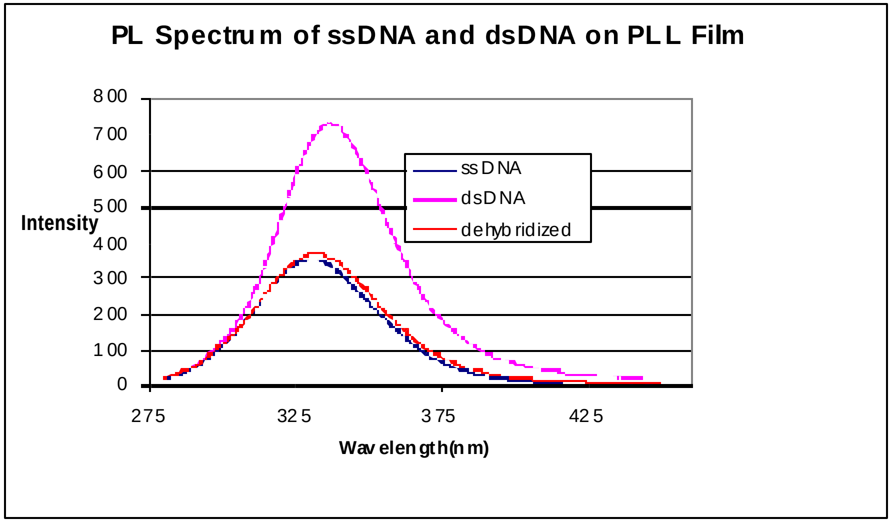


Problem: current DNA analysis requires costly PCR (a patented process), utilizes complex statistical analysis and is slow/inefficient

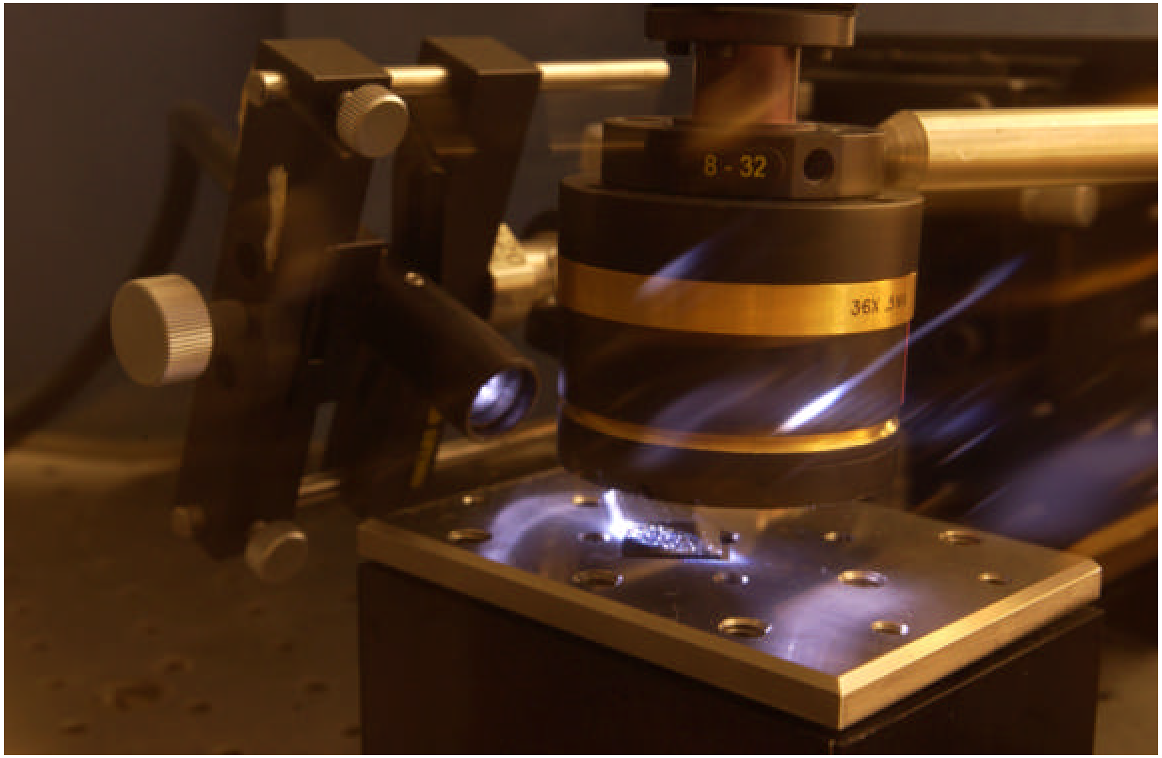
Solution: optical DNA analysis chip having a nanofabricated photoluminescent substrate and exploiting the UV absorption difference between single stranded and double stranded DNA

THE TECHNIQUE CLEARLY IDENTIFIES UNKNOWN DNA SEQUENCES



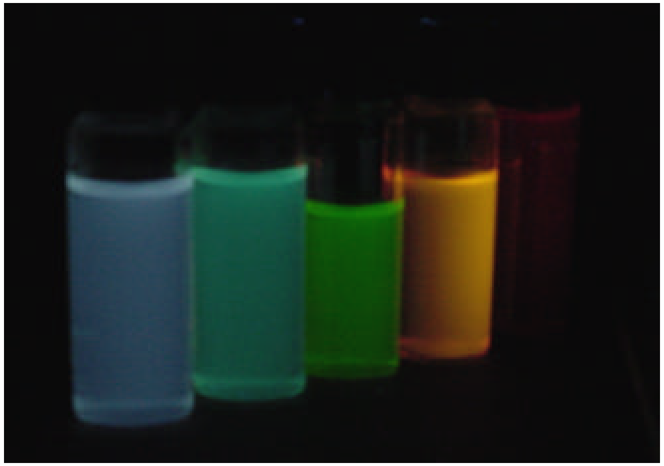


HIS BIOCHIP COULD REPRESENT THE NEXT GENERATION OF DNA ANALYS



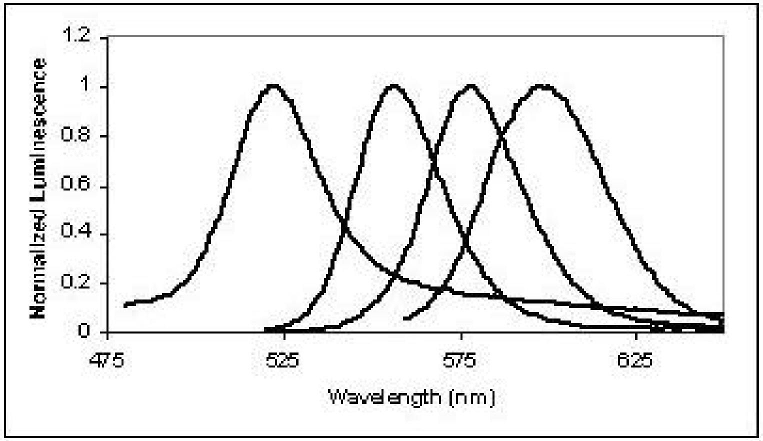
- The technology eliminates both costly PCR and fluorescent tagging
- Patents have been filed on the technology
- The technology has been licensed from VTIP
- A company has been formed based on the IP developed

EXAMPLE#3: DNA ANALYSIS IN A TEST TUBE



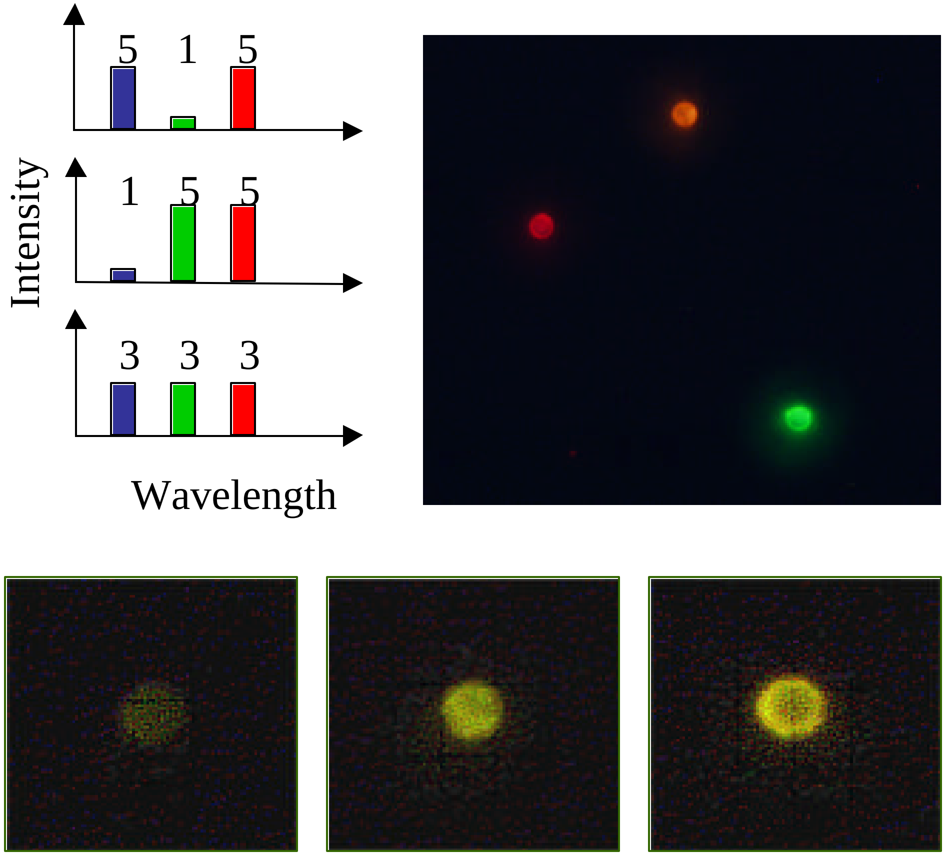
Problem: current DNA chips are low volume, difficult to use and inefficient

Solution: DNA analysis in a test tube using quantum dot "bar coded" microsphere probes

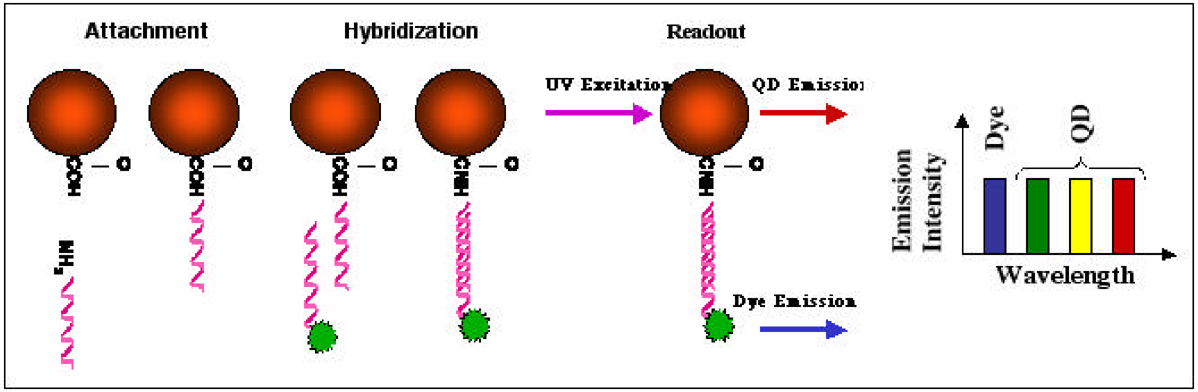


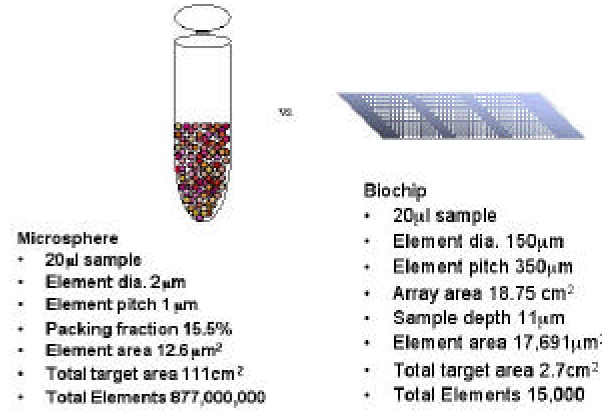
BOTH THE INTENSITY AND THE COLOR OF THE QUANTUM DOTS CAN BE CONTROLLED

Multiple intensity levels



HIS TECHNOLOGY HAS THE POTENTIAL TO REVOLUTIONIZE DNA ANALYS





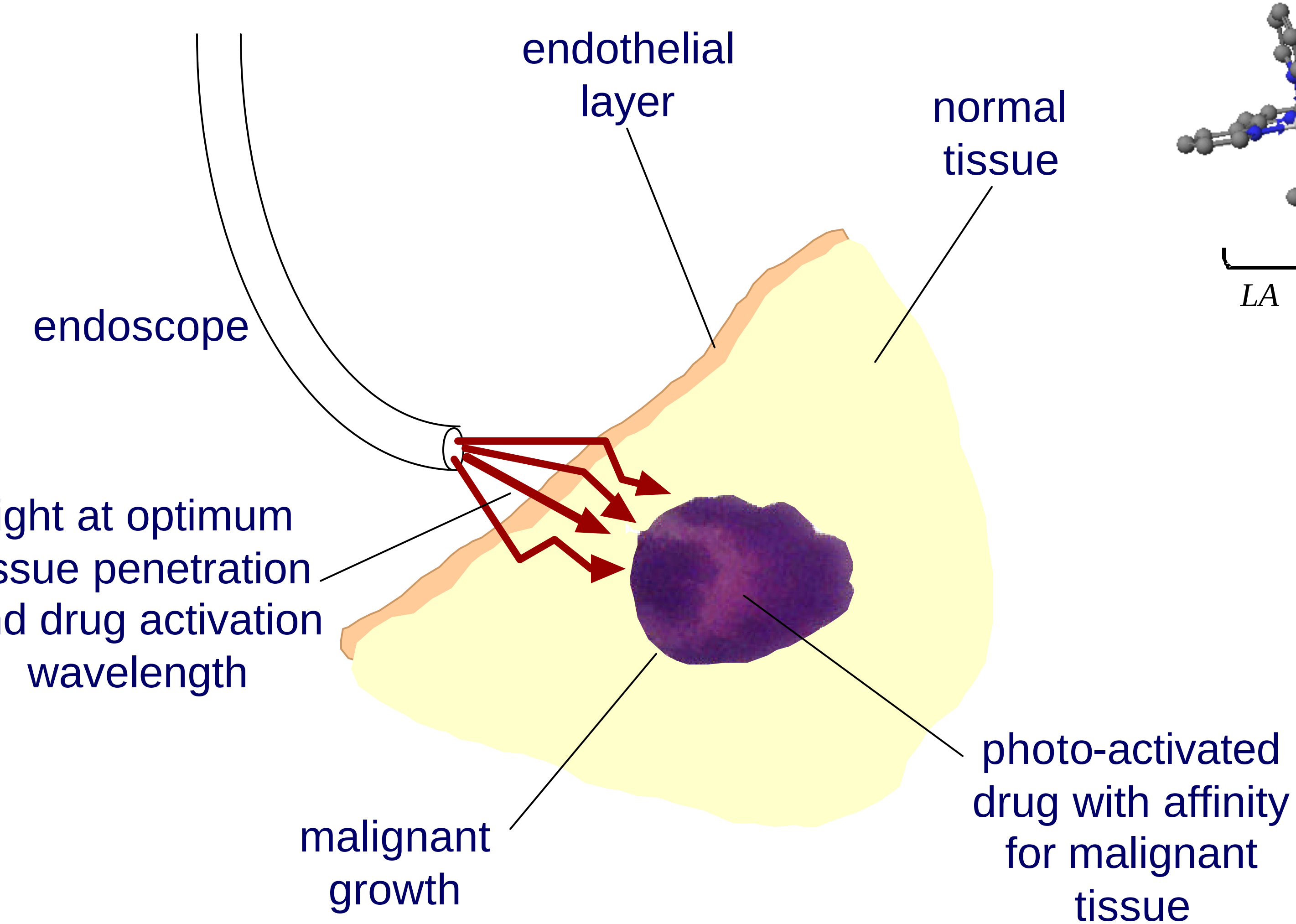
- The technology was developed jointly by *FEORC, VTabc and VBI* scientists and engineers
- Has potential as a biohazard sensor for *Homeland Security Applications*
- A patent has been filed on the technology
- Based on his work on this technology, a student, *Eric Herz*, was awarded a *prestigious Fulbright Scholarship*
- Undergraduate students have contributed significantly to the development of this technology

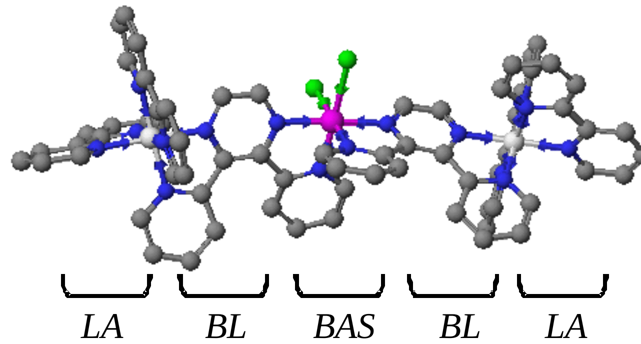
EXAMPLE#4: PHOTODYNAMIC THERAPY

Problem: the chemotherapy used to treat cancer indiscriminately attacks the immune system of the whole body and is extremely dangerous

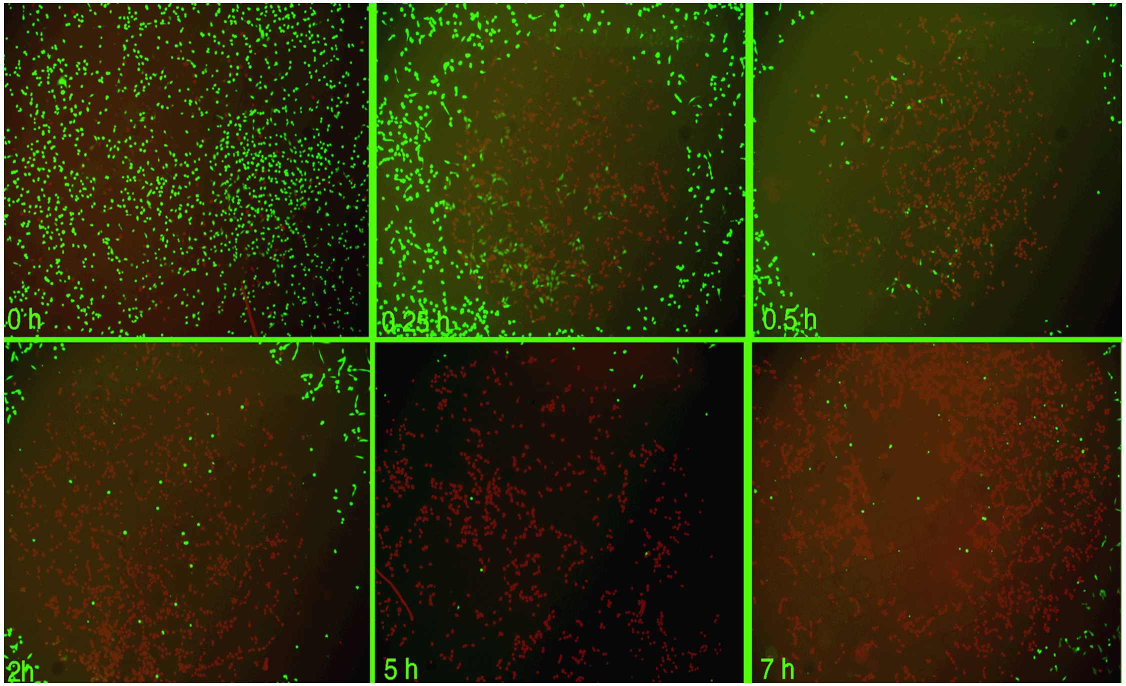
Solution: targeted cell killing using photodynamic therapy

CELL KILLING NANOMOLECULES ARE TUNED TO WAVELENGTH OF BEST TISSUE PENETRATION





THIS TECHNOLOGY OFFERS THE POTENTIAL OF MORE EFFECTIVE CANCER THERAPY WITH FEWER SIDE EFFECTS



- Patents have been filed on the technology through VTIP
- The technology has been licensed through VTIP by *Theralase Inc.*

RECENT BUSINESS PUBLICITY

The Economist

JUNE 22ND–28TH 2002

The Economist Technology Quarterly June 22nd 2002

Nature's way of plating

Some obscure thin-film chemistry from the 1960s is making a comeback as a way of putting pure coats of practically anything on to anything

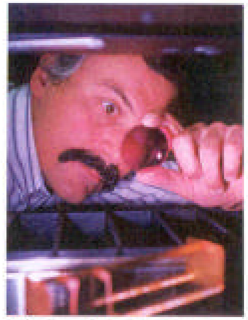
TAKE a piece of metal and two buckets of liquid, each containing a solution of charged particles. Wash the metal in purified water, which gives its surface a negative charge. Then dunk the metal in one of the buckets, allowing positively charged ions in the solution to adhere to the metal in a thin layer. Wash the metal a second time to remove any impurities and then plunge it into the second bucket. This time, the negative ions in the second bucket's solution stick to the first bucket's layer of positive ions. Repeat again and again, until the metal builds up a coating of thin, sandwiched layers of film.

This recipe for making thin films was first described in the late 1960s by Ralph Iler of DuPont. Unfortunately, after publishing his paper on the topic, Dr Iler died, and the procedure fell into obscurity. In the 1990s, the idea—by then known as colloidal (or electrostatic) self-assembly—was investigated by chemists in Germany, America and Japan. But each group focused on the idea's theory rather than its practice. Only in the past few years have Rick Claus and his team at the Virginia Polytechnic Institute in Blacksburg studied commercial uses for the process. What they have found holds a number of intriguing possibilities.

One of the first things that Dr Claus and his team have established is that thin films of metal deposited by electrostatic self-assembly possess the same degree of electrical conductivity as bulk metals. That is important because thin films created by other methods do not. Dr Claus believes that this is probably because thin metal films produced by other methods are more likely to harbour impurities. Such impurities find it impossible to gain a foothold within the Velcro-like lattices typical of electrostatic self-assembly.

Other methods of depositing thin layers of material on objects may be more familiar, but most have limits to their usefulness. For instance, electroplating can be used to coat a thin layer of gold on to a cheap piece of material. But only metals—not polymers, ceramics or proteins—can be coated in this way.

Alternatively, various materials can be coated on objects using "vapour deposition": placing the target object in a sealed vacuum chamber along with a small bath of the material to be deposited. When heated to a high temperature, the bath gives off a mist of atoms that fall on to the surface of the object. The problem with vacuum deposition is that only the tops of objects get coated, not their bottoms. It is particularly hard to coat spheres or objects covered with textured surfaces this way.



Laying it on—electrostatically

Electrostatic self-assembly, however, coats every exposed surface of an object, and does it at room temperature. Moreover, it can be used not only on metals such as gold, silver, copper and aluminium, but also on oxides, polymers, ceramics, proteins and even "buckyballs" (an exotic form of carbon). Any substance that takes on a charge when put into a solution is fair game, says Dr Claus. Even human bone can be coated with calcium in this way. After all, nature uses a similar process to make bones in the body.

The Virginia Tech group envisages a variety of applications for electrostatic self-assembly. Magnetic materials used in mobile phones and other devices could be manufactured with fewer imperfections, thus improving performance. Spectacles could be coated more effectively with scratch-resistant chemicals, simply by dunking them in the appropriate solution. Plastic tubing used in medical equipment could be coated with thin layers of bio-friendly proteins. Certain materials that can be made to adhere to surfaces in regular lattices could be used to maximise the reflective properties of road signs at night.

Under a defence contract, Dr Claus's laboratory is testing a photovoltaic cell constructed from films of polymer and ceramic which feels as flexible and hardy as cloth. The idea is to attach a patch of the stuff to tents, so soldiers in the field have a built-in power source. ■

Forbes / Wolfe

NANOTECH REPORT

Companies to Watch

Nanosonic

[Private]

www.nanosonic.com (540) 953-1785

Blacksburg, Virginia

Chief Executive: Richard Claus

What it does: Produces coatings and thin film materials.

There must be something in the water at Virginia Tech. How e
explain the hotbed of nanotech entrepreneurship that has risen
southwestern Virginia? Blacksburg-based Luna Innovations (see "
panies to Watch," May 2002) used nanotechnology research deve
at the university to spin off five companies. Now, Nanosonic is fo
ing Luna's lead, creating precisely controlled thin film material
coatings through its proprietary self-assembly process.
It was spun off in 1998 from the research of Nanosonic pre
Richard Claus (a Luna co-founder) and Virginia Tech graduate st
Yanjing Liu. Nanosonic currently has nine patents licensed from
ginia Tech and nine wholly owned provisional patent application
Nanosonic's patented ESA (electrostatic self-assembly) man
turing process creates custom designed thin films. These films e
enhanced optical, electronic, magnetic, thermal and mechanical
erties not available in bulk materials. The company believes its
film materials will ultimately be used in commercial products
verse as window coatings, fuel cells, space structures, biomedica
electronic devices, and optical networking equipment. "We are lo
into corrosion-resistant coatings for the aircraft and automoti
dustries for 2004-2007," according to Nanosonic's Dr. Marten de
Nanosonic currently has two undisclosed customers in the d
industry. It is also in advanced talks with a large multi-national
rials company for a thin film polymer product for a consumer ap
tion, likely 3M [MMM], BASF [BF] or DuPont [DD].
The ESA process Nanosonic utilizes has many advantages ove
ventional fabrication processes. It can be done at room tempe
and dramatically cuts costs because it requires little special equip
And unlike other deposition techniques, ESA's uniform molecula
ers (1-20nm thick) can coat complex shapes or ones filled with ca
This is very valuable for products like microwave filters for wi
handsets where the filter's surface has many tiny holes.
Here's how it works. First, a material is treated to retain a sp
charge. Then Nanosonic uses its own dipping machine to repe
submerge the material into baths with ions of alternating positiv
negative charges. The oppositely charged particles attract and st
one another and build nanometer layers of film. This is repeated
a multi-layered molecular coating with the desired thickness for
Competitors in molecular self-assembly include Molecular
tronics and Microcoating Technologies, although neither targ
same broad industries as Nanosonic. The company is looking to l
its process and manufacturing technology instead of trying to be
yet another large scale materials manufacturer.
Most of Nanosonic's revenues are currently from govern
grants: it has garnered seven Phase 1 SBIR and two Phase 2 SBIR
since its inception. The company has not raised nor is it seeking
ture financing right now. But Nanosonic says it is looking to rep
Luna Innovations' model of spinning out different companies to
on individual market opportunities. ◻

SUMMARY

- The College of Engineering is the focus of nanotechnology research and development at Virginia Tech
- The College has pro-actively reached out to other parts of the university to form the interdisciplinary teams required for successful research on nanotechnology
- Partnerships, essential for successful commercialization and transfer of the benefits of the research from the laboratory to the private sector, have been actively pursued outside the university
- The FEORC/VTabc collaboration clearly demonstrates the success of the College of Engineering’s focus on nanotechnology