COMMERICAL PROSPECTS FOR VIRGINIA TECH NANOTECHNOLOGY

Cutting Edge Research Investment in Emerging Technologies

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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
Nanotech Is Wall Street's Latest Love

By THE ASSOCIATED PRESS
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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.
THE 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.
• FEORC is one of many, many 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 (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.

Virginia Tech funding leads to preliminary focused research. New interdisciplinary teams are created, and external funding is obtained. This leads to proof of concept/laboratory demonstration, IP, and transition to start-up company or licensing. Economic development is the ultimate goal under corporate partner responsibility.
IN ITS FIRST 5 YEARS, VTABC HAS PRODUCED SIGNIFICANT RESULTS

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

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

Modified self-assembly Processing (IP)

Nanomolecular modeling

e.g. low-cost artificial diamond
# MATERIALS EXAMPLE – “NANO-TO-MACRO”

<table>
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<th>Material Properties</th>
<th>Precursors</th>
<th>Measured Properties</th>
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<td>Electrical conductivity</td>
<td>Noble metal nanoclusters (Ag, Cu, Au, Pt)</td>
<td>0.1 - 1.0 $\Omega /?$ (10^4) $\Omega \cdot \text{cm}$</td>
<td>Mechanically flexible, optically transparent</td>
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<tr>
<td>Refractive Index</td>
<td>Polymers and polymer / nanocluster combinations</td>
<td>$n = 1.2$ to $1.8$</td>
<td>Tailored transparent stacks</td>
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<tr>
<td>Thermal conductivity</td>
<td>Polymers and nanoclusters</td>
<td>2 W/mK</td>
<td>20 W/mK feasible based on current work</td>
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<td>Mechanical Robustness</td>
<td>Oxide nanoclusters (ZrO(_2), Al(_2)O(_3), SiO(_2))</td>
<td>Good Taber abrasion and haze results</td>
<td>Nanohardness 1 GPa</td>
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Precursors:
- Noble metal nanoclusters (Ag, Cu, Au, Pt)
- Polymers and polymer / nanocluster combinations
- Polymers and nanoclusters
- Oxide nanoclusters (ZrO\(_2\), Al\(_2\)O\(_3\), SiO\(_2\))

Comments:
- Mechanically flexible, optically transparent
- Tailored transparent stacks
- 20 W/mK feasible based on current work
- 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
ONE OF THE FIRST APPLICATIONS FOR THIS TECHNOLOGY IS BIOCOMPATIBLE COATINGS FOR HEMODIALYSIS TUBING
BIOCOMPATIBLE COATINGS HAVE STRONG COMMERCIAL POTENTIAL

- 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
**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
This biochip could represent the next generation of DNA analysis.

- 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

Intensity

5  1  5
1  5  5
3  3  3

Wavelength
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

- Endoscope
- Endothelial layer
- Normal tissue
- Malignant growth
- Light at optimum tissue penetration and drug activation wavelength
- Photo-activated drug with affinity for malignant tissue
- DNA Photocleavage
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

Nature's way of plating

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

Take a piece of metal and two buckets of flour, each containing a solution of charged particles. Wash the metal in pure water, which gives it a negative charge. Then place the metal in one of the buckets, allowing positively charged ions to deposit on it. Repeat again and again, until the metal builds up a coating of thin, unreacted layers of film.

This recipe for making thin-film was first described in the late 1960s by Ralph K. and his team at the Virginia Polytechnic Institute in Blacksburg. nalyzed commercial uses for the process. Many years later, the team is still working on the idea's potential for practical applications. One of the first things that Dr. Claus and his coworkers have developed is thin films of metal deposited by electrochemical self-assembly processes at the same degree of electrical conductivity as bulk metals. This is important because thin films coated by other methods do not. Dr. Claus believes that this is probably because films produced by other methods are more prone to surface contamination and diffusion, which leads to lower electrical conductivity.

Other methods of depositing thin layers of material on objects may be more familiar, but must have limits in their usefulness. For instance, electroplating can be used to coat a thin layer of gold on a cheap piece of material. But only small numbers of microelectronic devices can be coated this way.

Alternatively, various materials can be coated on objects using " vapour deposition": placing the target object in a shielded vacuum chamber along with a small batch of the material to be deposited. When heated to a high temperature, the material gives off a stream of atoms that fall out on the surface of the object. This method works for deposition onto metal objects, but only a few kinds of metal objects can be coated with a thin phosphorous or silver layer.

Electrostatic self-assembly, however, can coat 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 aluminum, but also on silicon, polycrystalline, ceramics, proteins and even "molecular balls" (amorphous forms of carbon). Any substance that takes on a charge when put in a solution can be deposited, says Dr. Claus. Even human bone can be coated with calcium in this way. After all, nature uses a similar process to make bone on the body. The Virginia Tech group is now a variety of applications for electrostatic self-assembly. Magnetic materials used in mobile phones and other devices could be made much more reliably at lower temperatures, thus improving performance. Spectacular could be coated more effectively with microelectronic chips, simply by dipping them in the appropriate solution. Plastic tiling used in medical equipment could be coated with thin layers of bio-friendly proteins. Certain materials that can be used to make these materials in regular paper could be used to make the reflective properties of road signs at a night.

Under a defense contract, Dr. Claus's laboratory is testing a photovoltaic cell constructed from films of polymer and silicon which works so well that it is used to replicate the roads on a night.

Companies to Watch

Nanosonics

Chief Executive: Richard Claus

What does: Produces coatings and thin film materials.

Why: Nanosonics is located in the Virginia Beach area. The company has been in business for many years and produces a variety of thin-film materials that are used in a variety of industries, including the automotive, aerospace, and electronics industries. The company's thin-film materials are used in a variety of applications, including solar cells, electronic devices, and medical implants. The company is also involved in the development of new materials for use in the electronics industry. Nanosonics is recognized as a leader in the thin-film materials industry, and the company is committed to providing high-quality products and services to its customers. The company's success is attributed to its dedication to innovation and its commitment to customer satisfaction. Nanosonics is a proud member of the Virginia Beach Chamber of Commerce and the Virginia Beach Economic Development Authority, and the company is committed to being a good corporate citizen in the community.
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