Nanobioterials 1st Envisage What Should Be 2nd Envisage What Could Be William F. Buckley, Jr.

Arthur J. Ragauskas Institute of Paper Science and Technology Georgia Institute of Technology

### **Driving Forces of Change in Forest Products/Society**

The Technology Explosion

• About 90% of all scientific knowledge has been generated over just the last 30 years

• Greater than 80% of all the scientists and engineers who have ever lived are living and working now

- In 1960 < 5% of the general population in North America and Europe had completed 4 or more years of college
- In 1999 this increased to ~20%
- Demographic analysis indicates that this trend will continue
- Increased technological competence of society drives change

### **Basic Realities of New Millennium**

• Major forces of change will continually restructure all world economies

#### The Ruthless have the Edge

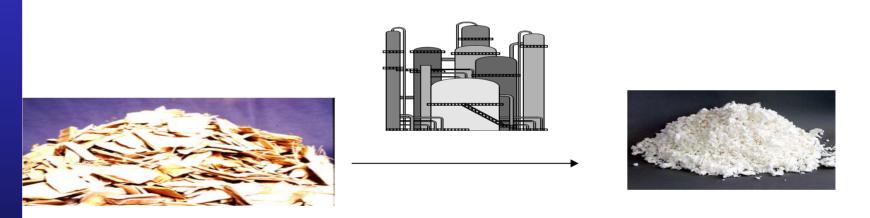
#### Morgan Witzel, Finanical Times (2004)

•"Eventually there comes a time when a company's core market can grow no further.....Share price begins to slip as investors seek better opportunities elsewhere

•Only three means of getting out of the saturation trap

- Aggressive method: Compete intensively with rivals, taking market share away from competitors
- Acquisition method: Buy or merge companies
- Innovative method: Discover a new way to break from the market and develop new markets"

### **Promising Research Patterns**



Process Research Publications:+140,000Product-Platform Research Publications:~9,000What's Next?

Look Back to Look Forward

## Overview of Material Science Development

Nanobioterials 2000 Nano Age 1990



Steel Age 1850

Subana III

Paper -100 AD

Concrete Age 200 BC

Iron Age 1200 BC

Bronze Age 3200 BC

Chalcothic Age 4500 BC



**Stone-Age** 

## What is Nano???

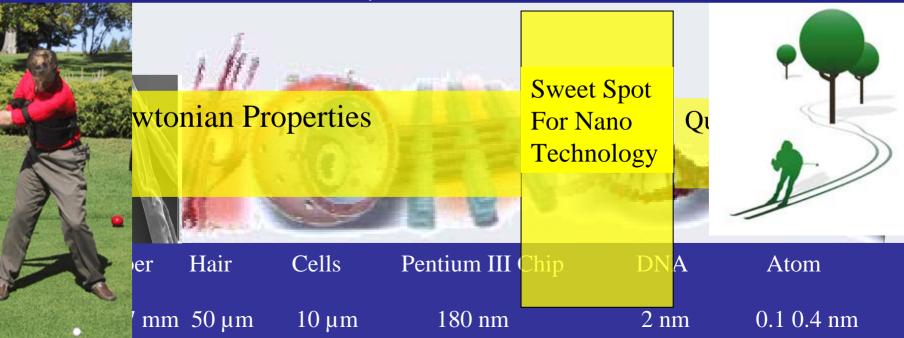
### What is Nano???

What is Nano???

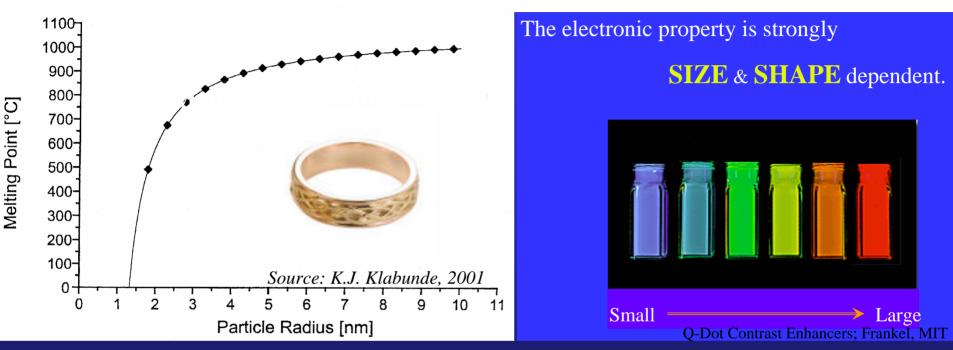
What is Nano??? What is Nano??

Nanotechnologies are characterized by structural elements in the  $\sim 1 - 100$  nanometer range

 $1 \text{ m} = 1000 \text{ mm} = 1,000,000 \mu \text{m} = 1,000,000,000 \text{ nm}$ 



### **Behavior of Materials at the Nanoscale is OFTEN DISTINCT FROM LARGE SCALE**



Nanoparticles can adsorb UV light and make different colors

### Behavior of Materials at the Nanoscale is

### **NOTHING Like That at the Large Scale** Going to Extremes

PROPERTY

SINGLE-WALLED BY COMPARISON NANOTUBES

can Scientist

50 nm MoGe superconduct ing wire

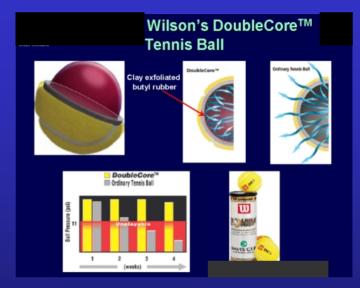
opyright: 2001 by N

### Common Day Nano - Applications Nano-Barriers

### **BC-** Applications



Lycurgus Cup Mesopotamia 4,500 BC





ZnO Transparent at ~25 nm





NANO-CARE® fabric protection imparts superior wrinkle/stain resistant fabric that minimizes stains

## Nanotechnology in Forest Products Where are We - Where are We Going?

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### **Current Nanotechnologies in Modern Pulp Mill**





Printing speeds continue to increase Consumer demands more/sharper colors

• Silica nanoparticles for highperformance retention/drainage providing better formation

-Silica sol 1<sup>st</sup> generation 1980s

-350 paper machines/25 countries

• Silica nanoparticles yielding a favorable open sheet structure for select bag applications

#### **Current Generation of Nanotechnologies in Modern Pulp Mill**

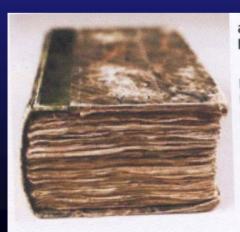


New nano-sizing technologies to improve surface sizing

Nanoparticles – Improved coating hold out – Improved print quality

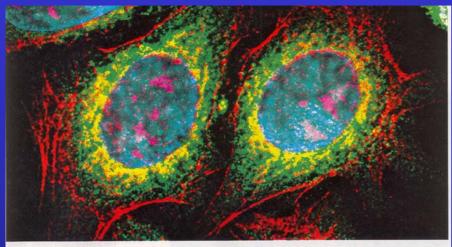


**EKA Chemicals Inc** 



Nano lime particles to stabilize post 19<sup>th</sup> century books

### **Current Generation of Nanotechnologies in Forest Products**



RAINBOW EFFECT Quantum dots allow simultaneous five-color imaging in fixed human epithelial cells for the first time. The colors allow localization of cellular proteins and substructures: The nuclei are stained cyan, Ki-67 cell proliferation proteins are magenta, mitochondria are orange, microtubules are green, and actin filaments are red.

# **NANOTECH IP**

As nanometer-scale materials start making money, intellectual property issues are heating up

SUSAN J. AINSWORTH, CONTRIBUTING EDITOR

And although nanotechnology has already



ANOTECHNOLOGY-THE STUDY OF THE UNIQUE properties of structures on the nanometer scaleis living up to its reputation as "the next big thing" in the scientific realm. Institutions and companies, around the world are pumping billions of dollars into nanotech research, and investment continues to escalate.

Still a nascent field, nanotechnology promises to revolutionize manufacturing processes and products in almost any industry, including medicine, plastics, energy, electronics, and aerospace. Pulp and Paper/Forest Products is notably absent but this provides a business opportunity as technology is in early stages of "S" curve

Investment

R.N. Foster

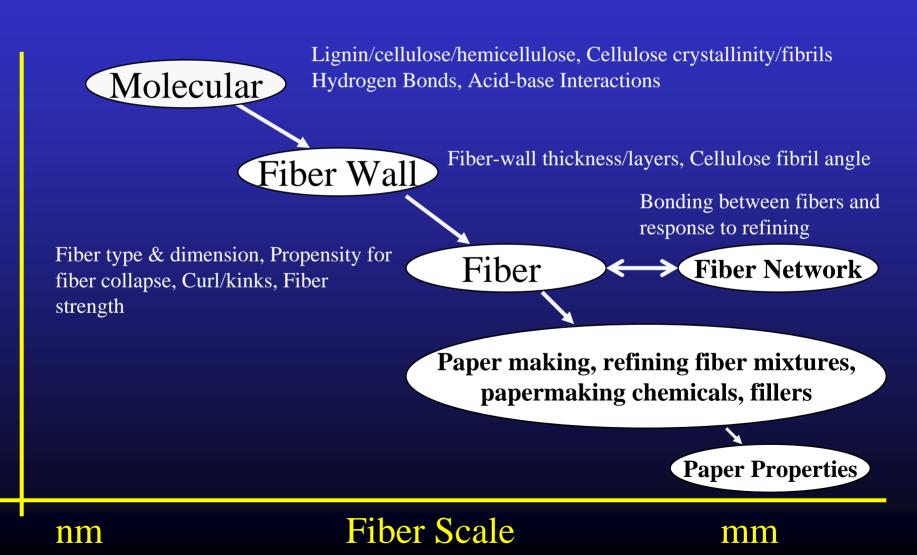
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nanotecnnology consulting mm. but nanotechnology is expected to have a tremendous impact on the global economy. Eager to get in on the ground floor,

# **Hierarchical Structure of Paper**



## Nanotechnology Comprises Many Very Different Issues and Research Areas that Will Impact Forest Products

Nanocoatings/Barriers: Secure Environment Packaging

- Food/Pharmaceutical
- Electronics
- Defense

#### Homeland Security

- Tamper proof
- Counterfeit resistance
- Security Paper/Branding

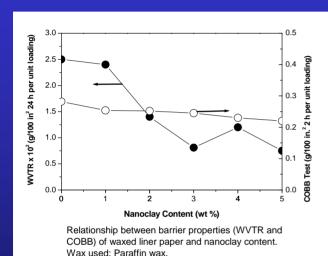
Provide controllable inner environment for packages: - CO<sub>2</sub>, O<sub>2</sub>, H<sub>2</sub>O, N<sub>2</sub>

Defense systems for bacterial/fungus growth - Passive - Active

- Spoilage/Flavor Control
- Long Term Storage
- Spoilage Indicators
- New biocomposite packaging materials

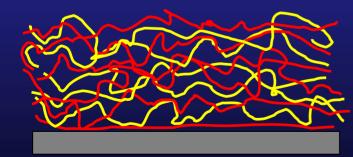
# **Polymer-Nanoclay Composites**

### Drs. Y. Deng, A.J. Ragauskas, Z.L. Wang/GA Tech



• 3% nanoclay in wax can increase water-barrier by 50%, and gas barrier by 100%, target for wax-coated paper container

• Directed, hierarchical self-assembling fillers



- Nano Cellulose:Plastic Composites
- Nano Cellulose:Clay Composites

• Novel water repellency properties for OSB, MDF

Nanotechnology Comprises Many Very Different Issues and Research Areas that Will Impact Pulp and Paper



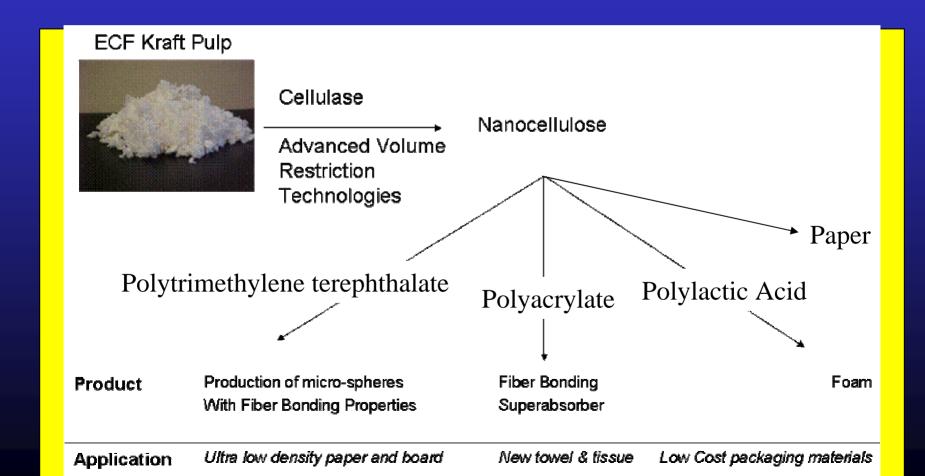
- Directed <u>self assembling</u> nanocoatings
  - -Improved gloss/printing-Reduced capital cost-New products including:



- R<sub>f</sub> version of thermal paper
  Integration of advanced digital electronics into paper
- New felts with nano-dewatering and sheet formation capabilitiesElimination of hornification

## NanoCellulose/Plastic – New Materials

• Synthesis of Innovative Nanocellulose Composites



## **Biofunctional Fibers**

Bacteriophage Structure

Bacteriophage are virus and the legs are used to bind to assorted hosts – 10<sup>9</sup> different binding codes... could provide genetic code to provide Innovative Wet/Dry Strength Aids Functional Tissue/Towel

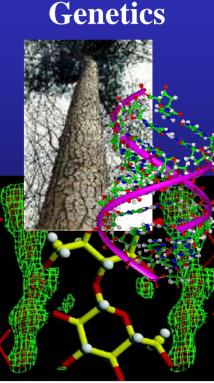


Enzyme grafted paper/fibers - Improved food packaging

- storage
- odor control
- flavor control

- Biosensors

- Integrated hygiene applications



# **Road to Future**

### Nano Forest Products Future

The bridge to the future needs a consortium of sponsors including TAPPI, pulp manufactures, suppliers, universities, and government

You are invited to participate in the

#### Nanotechnology Workshop

for the Forest Products Industry

#### October 17-19, 2004

The National Conference Center 18980 Upper Belmont Place Lansdowne, VA 20176

Participants will work together to develop a roadmap for federal agencies in support of nanotechnology research.

This workshop aims to:

- · Develop a vision for nanotechnology in the Forest Products Industry
- Develop a roadmap for nanotechnology in the Forest Products Industry (identify potential applications and uses, identify knowledge gaps and the research needed)
- Interest federal funding entities in nanotechnology for the Forest Products Industry
- Foster cooperation and collaboration among industry, academia, and government to fill knowledge gaps





Contribute to the development of new markets, new high-value renewable forest products, utilizing the intrinsic US manufacturing knowledge of the industry and lead in nanotechnology



arthur.ragauskas@gatech.ipst.edu ragauskas@hotmail.com "Destiny is not a matter of chance, it is a matter of choice, it is not a thing to be waited for, it is a thing to be achieved" W.J. Bryan