NANOTECHNOLOGY SAFETY EDUCATION

SRC ENGINEERING RESEARCH CENTER FOR ENVIRONMENTALLY BENIGN SEMICONDUCTOR MANUFACTURING (ERC) MONTHLY TELESEMINAR

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Walt Trybula, Ph.D. IEEE Fellow & SPIE Fellow

Co-Developers: Prof. Jitendra Tate, Prof. Craig Hanks, Prof Dominick Fazarro

ABSTRACT

This presentation will cover the steps that led to the development of and the details in two NSF sponsored nanotechnology safety education courses. The content of the courses is critical; however, traditional thinking would not fill the need for educating future nanotech workers. The concern for an impact on people and the environment is of primary safety concern. The two most significant challenges in nanotechnology safety development are that **a)** typical testing of toxicity can take seven or more years and **b)** there are over 10^{200} possible materials to be considered. It becomes almost impossible to understand the impact of novel materials prior to their development and testing. Added to these facts is that a typical start-up survives for 18 months or less. Starting with this understanding, the courses were developed to educate people on how to address situations with unknowns. From the beginning, it was recognized that both ethics and risk needed to be a significant component of the program. The courses have been thoroughly review and well received.

Content

- The background leading up to the first Nano-Safety courses.
- The development of the nano-safety courses.
  - The OSHA sponsored efforts.
  - The NSF sponsored development.
- The current development of the Nano-Safety certification program.

Key Course Developers

- Jitendra Tate, Ph.D., Ingram School of Engineering, Texas State University
- Craig Hanks, Ph.D., Philosophy Department, Texas State University
- Dominick Fazarro, Ph.D., Department of Human Resource Development and Technology, University of Texas at Tyler
- Walt Trybula, Ph.D., Ingram School of Engineering, Texas State University

See last four slides for individual contact information.

THE IDEA OF NANOTECHNOLOGY SAFETY

Development

- Texas State University formed the Nanomaterials Application Center (NAC) in 2003 to promote nanotechnology innovation.
- The Board of Directors consisted of personnel from Industry and Academia.
- In 2006, nanoTox, Inc., joined the NAC and promoted its analytical capabilities.
- After numerous meetings, events, and discussions, the idea occurred to me that more than toxicity analysis was critical.

Development

- The concern about safety in handling novel materials focuses on the unknown issues.
- Not knowing the impact on people or the environment can lead to unfounded concerns and reluctance to accept developments.
- This led to the 2007 Nano-Safety white paper
  - There are four key categories that define Nano-Safety and need to be addressed to approach the potential issues in a systematic manner.

NANO-SAFETY KEY CATEGORIES

1. Nanomaterial Properties
2. Impact on People and the Environment
   - i.e., Nano-Health, Nano-Toxicity
3. Safely Handling Nanomaterials
4. Business Focus
   - Safety
   - Risk Management

Nanomaterial Properties

- Theoretical and experimental results indicate surprising findings
  - 13 atoms of Ag has a magnetic moment [Theory]
  - 13 atoms of Pt have shown a magnetic moment [Experiment]
- Materials in nano realm are unique and different
  - Transition metal in five different states: as hydrated atom; metal complexed in a small protein; metal adsorbed to surface on 1nm mineral particle; metal adsorbed to surface of 20nm particle; the same except to a 200nm particle.[1]
- Crystal orientation preferences – size matters
  - CeO_2 < 10nm habit of truncated octahedron with {100} and {111} faces. CeO_2 > 10nm shifts toward {111} octahedron.[2]
- We really don't know all the possibilities

1 - Hochella, Michael F. Jr.. Nanogeoscience: From Origins to Cutting Edge Applications. December 2008 issue. Vol. 4, pp. 373-379.
2 - Waychunas, Glenn A., Hengzhong Zhang. Structure, Chemistry, and Properties of Mineral Nanoparticles. December 2008 issue. Elements. Vol. 4, pp381-387.

Nano-Health

- Toxicity investigations have been of significant interest [many call this Nano-Safety].
- Promising medical advances being developed employ nanomaterials.
- Impact of these materials on people and the environment needs a lot of evaluation.
- Beneficial materials, like Ag below 20nm aids in healing wounds by attacking bacteria, but the same Ag particles will also attack good bacteria if the material is not controlled.

Safely Handling Nanotechnology

- The handling of Nanomaterials is a challenge due to the unknowns involved.
- How do you protect people from materials with properties that are unknown?
- If there is a known impact, does it arise from only one part of the material distribution?
- Doing nothing is not acceptable.
- Education guidance and handling procedures must be developed.
- Key elements of this must be disseminated.

Business Management

- With Unknowns, we must be proactive.
- Not looking for ISSUES is asking for litigation.
- Developing future products must consider any potential impact on people and environment.
- Organizations must have plans in place to address contingencies.
- Safety efforts are required.
- Educational programs must be developed.

The Key Point

Education on NANO-SAFETY requires:

1. Communication of *Knowledge*
2. Which requires accurate *Information*
3. Which requires understanding of *Principles*
4. Which requires focused *Research*
5. Which requires . . . . . [the list continues]

The <u>POINT</u> is that we need to address the underlying knowledge acquisition in a systematic manner to understand nanotechnology implications!

What Must be Done

Education

- Provide sources of accurate information.
- Provide guidance for the public.
- Educate Businesses.
- Create Knowledge Based Workforce:
  - Scientist, Engineers, Technicians.
- Assess future liabilities.
- Much, much more.

Collaboration

- This issue is too large for one school, even one country to address by itself. Worldwide collaboration is an absolute necessity.

Regulation?

- How do you regulate what you don't know?
- In December 2006, the City of Berkeley, California passed a regulations that required all nanomaterials being brought into the city for research must have an MSDS.
- How did researchers bring carbon nanotubes (CNTs) into the city?
- They used MSDS for similar materials. CNT is carbon and so is graphite, which has an MSDS.

Nanomaterials' Reality

Nanomaterials are broadly regulated as materials 100nm or smaller.

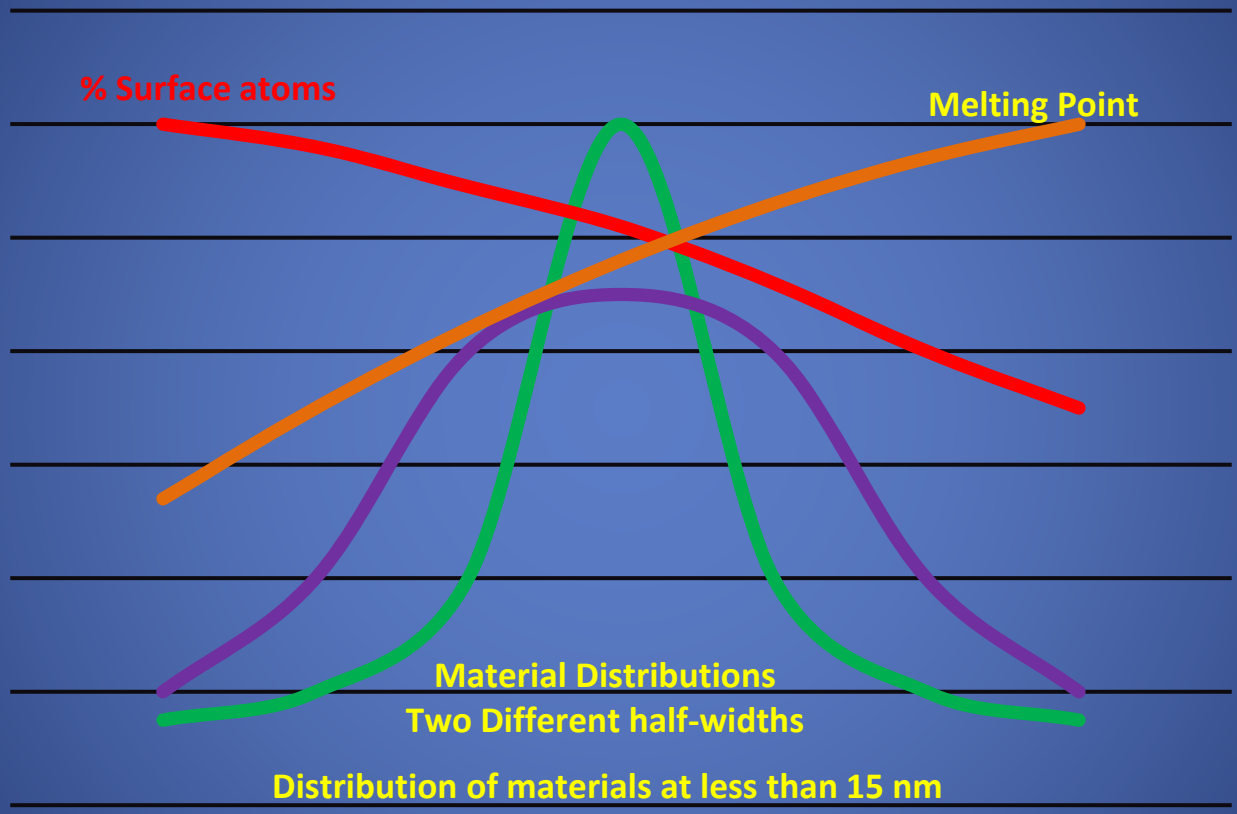
- Aluminum nanoparticles are a very good example of the issues with general classifications. 80nm aluminum is a dust that can cause inhalation issues. 30nm aluminum is highly explosive when exposed to air.

According to current regulations, the two sizes are treated identically.

- Gold nanoparticles exhibit different colors depending on the size of the particle and approaching 1nm in size gold is a semiconductor.

There is no difference recognized in the general classification of the nanogold .

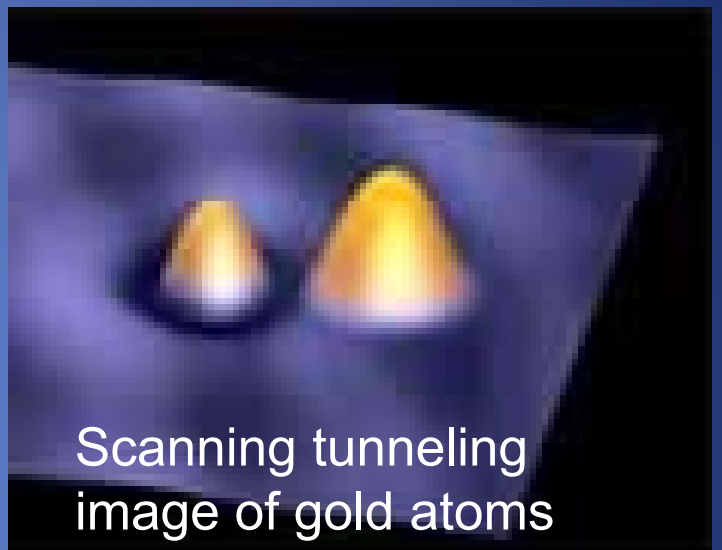
NANOMATERIALS' REALITY



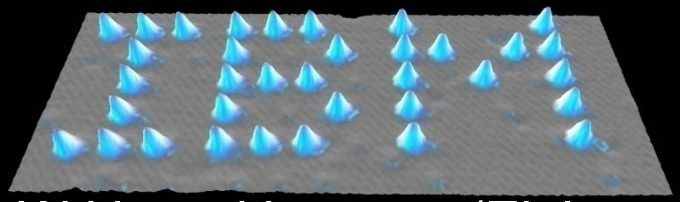
According to current regulations, the two distributions will react identically. Obviously, there is a lot of work needed to find out the actual situation.

Sheer number of chemicals is truly daunting

- OSHA has 40 year-old standards for 600 chemicals.
- **62,526,489** chemical sequences, Chemical Abstract Service on 02/23/11.
- 112 known elements.
- 10^{200} to 10^{900} distinct nanoscale particle possibilities.
- Even larger considering manufacturing process contributions.



Scanning tunneling image of gold atoms



Writing with atoms (Eigler, 1990)

From OSHA Harwood Grant Teaching Module #3, available October 2011

The Challenge

Our current efforts

In understanding safety

This is the immediate need!

What are the Challenges?

- There have only been 10^{17} seconds since the creation of the universe.
- There are more possible combinations of materials to examine than can be accomplished in the next millennium!
- Approval through the FDA takes 7 to 10 years.
- The half-life of a start-up in 18 months.
- Is this a problem?

COURSE DEVELOPMENT

OHSA

In October 2010, OSHA awarded Rice University a grant to “develop and implement a variety of materials and training modules on the safe handling of nanomaterials.”

OSHA Award[1]

- In October 2010, OSHA awarded Rice University a grant to "develop and implement a variety of materials and training modules on the safe handling of nanomaterials."
- Dr. Kristen Kulinowski led a multi-university, including both Texas State and UT Tyler, effort to develop this safety-based training program.
- The final results were a series of presentations in various venues to evaluate the effectiveness of the material developed.

[1] http://news.rice.edu/2010/09/29/osha-bolsters-rice-based-safety-program-on-eve-of-buckyball-discovery-conference/

OSHA Course

- The course: "*Introduction to Nanomaterials and Occupational Health*."
- The focus: Many small companies rely on external consultants to implement workplace safety. Nanomaterials requires specific training.
- The structure: Seven modules that can be taught as either a 4 hour or 8 hour course.
- The implementation: Presentations of the modules at professional conferences demonstrated the need for the 8 hour version.

OSHA Course Content

Introduction to Nanomaterials and Occupational Health

Content:

1. Nanotechnology and Nanomaterials
2. What Workers need to know about Nanomaterial Toxicology
3. Assessing Exposure to Nano
4. Controlling Exposure to Nano
5. Risk Management Approaches
6. Regulations and Standards Relevant to Nanomaterial Workplaces
7. Tools and Resources for Further Study

OSHA Course Content

- The material developed under this grant (# SH-21008-10-60-F-48) is available on the OSHA web site.
- The course, in the initial development state, was tested at professional conferences. At one conference, the no-charge offering of the course was “sold out” in less than 24 hours.
- The evaluation of the short and long versions of the course revealed that the longer version (8 hours) was preferred by the attendees and yielded a better understanding of the material.

NSF

NSF-NUE (Nanotechnology Undergraduate Education) grant titled “NanoTRA- Texas Regional Alliance to Foster Nanotechnology Environment, Health, and Safety Awareness in Tomorrow’s Engineering and Technology Leaders”, which began in January 2013.

NSF Project Goal

To educate engineering and technology undergraduate students in 'nanotechnology safety‘ that includes societal, ethical, environment, health, and safety issues.


Objectives

- Develop two modular undergraduate-level courses dealing with nanotechnology environment, health, and safety awareness. These courses will better prepare undergraduate students to advance to graduate nanotechnology programs and to work with nanomaterials in their future careers;
- Build on pedagogical research by employing a variety of teaching methods to engage students, particularly women and Hispanic students, including hands-on training, socially-relevant case studies, plant tours, videos and guest lectures;
- Elucidate emerging needs in nanotechnology environment, health, and safety, and incorporate them into basic education that can be immediately employed in industry;
- Promote interdisciplinary interactions among engineering, engineering technology, science, and industrial management/technology majors.

Multidisciplinary and Ethnically Diverse NSF-NUE Team of Investigators

- Dr. Jitendra S. Tate, Principal Investigator, Ingram School of Engineering, Texas State
- Dr. Dominick E. Fazarro, Department of Human Resource Development and Technology, University of Texas at Tyler
- Dr. Craig Hanks, Department of Philosophy, Texas State
- Mr. Satyajit Dutta, Ingram School of Engineering, Texas State
- Dr. Walt Trybula, Ingram School of Engineering, Texas State
- Dr. Robert McLean, Department of Biology, Texas State
- Dr. Fritz Allhoff, Department of Philosophy, Western Michigan University
- Graduate Researcher: Mr. Lucio Andres Alvarez Andrade, Texas State; Mr. Adam Mokhtari, UT Tyler
- Undergraduate Researcher: Mr. Sergio Espinoza, Ms. Luna Wilson, Texas State

Nanotechnology Advisory Council (NAC)

This project is being advised by a forward-thinking team of experts from academia and industry. The NAC will assist in improving the quality of the contents in each course

- Ms. Christie Sayes, RTI International
- Dr. Greg Marshall, Chair, Department of Respirator Care, Texas State
- Ms. Deb Newberry, Director, NFS-Nanolink Center
- Ms. Barbara Foster, MIP (Microscopy and Imaging)
- Dr. Chuck Geraci, NIOSH
- Dr. Mark Wiesner, Director, CEINT (Center for Environmental Implications of Nanotechnology) at Duke University

Government Agencies Involved in Nanotechnology

Safety and Ethics

- A significant challenge in working with unknowns is the fact that some information will not be available until after the fact.
- It was obvious that there was a need for the introduction of ethics into the curriculum.
- Establishing an understanding of implications is critical for the students to develop critical thinking.

Safety and Risk

- The world has rapidly developing technologies.
- There is nothing that is risk free.
- Judgments are made daily on the basis of incomplete information through the analysis of the potential outcomes.
- Providing the students with the ability to evaluate potential risks and make informed decisions is a component to being good stewards.

Understandings

- Applying nanomaterials can provide beneficial results that improve the quality of life.
- The same nanomaterials can be harmful is not handled adequately.
- Risk analysis provides a basis for good judgment, but does not guarantee it.
  - Bikini Atoll was “cleaned” of most radioactive materials to save one potential death at the cost of two lives.
- We understood these elements, Ethics and Risk, had to be included.

Two Courses Developed

The NSF grant was to develop:

- The first (introductory) course:
  - *"Introduction to Nanotechnology Safety".*
  - Consists of 10 modules plus all related course material.
- The second (advanced) course:
  - *"Principles of Risk Management for Nanoscale Materials".*
  - Also consists of 10 modules and materials.

Intro to Nanotech Safety

1. What is Nanotechnology and Nano-Ethics
2. Ethics of Science and Technology
3. Societal Impacts
4. Ethical Methods and Processes
5. Nanomaterials and Manufacturing

Intro to Nanotech Safety

6. Environmental Sustainability
7. Nanotechnology in Health and Medicine
8. Military and National Security Implications
9. Nanotechnology Issues in the Future
10. Guest lecturers from Industry and Governmental Agencies & Project presentations

Nanoscale Risk Management

1. Overview of Occupational Health & Safety
2. Applications of Nanotechnology
3. Assessing Nanotechnology Health Risks
4. Sustainable Nanotechnology Development
5. Environmental Risk Assessment

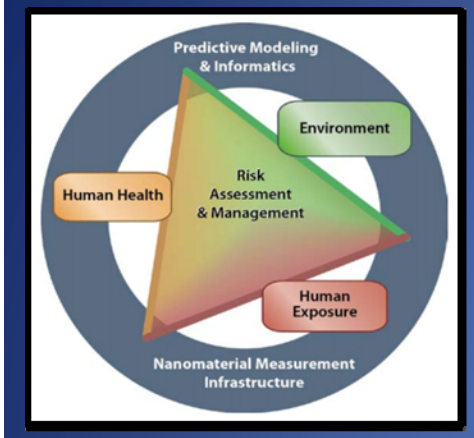
Nanoscale Risk Management

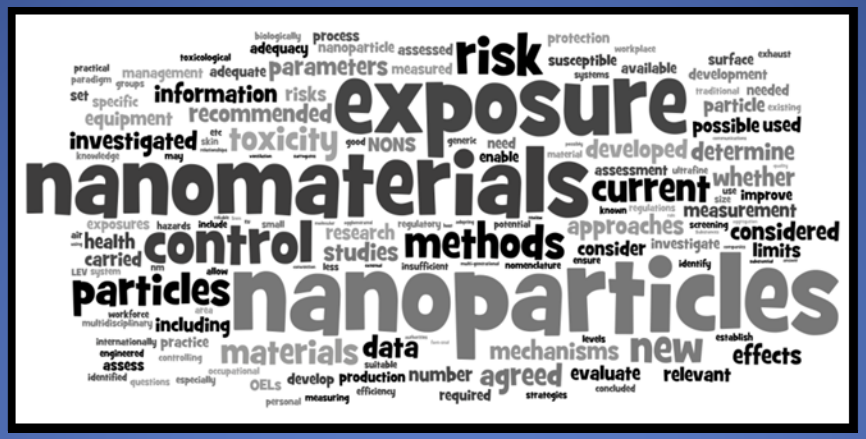
6. Ethical and Legal Aspects of Nanotechnology
7. Developing a Risk Management Program
8. Presentations of Research Projects plus Guest lecturers from various organizations.
9. Hands-on lab efforts in the specially designed lab
10. Corporate visits to leading organizations who are implementing various type of nanotechnology controls

Expected Impact on Undergraduate Minorities

- Total enrollment in Engineering and Engineering Technology programs at Texas State 1,100+ students, more than 35% are minorities (10% women, 23% Hispanic, and 5% African-American). The majority of students in these programs will be impacted, either by taking required courses that include new modules developed on this project or by taking the semester-long courses.
- Total enrollment at Texas State is over 36,000 students with over 33% of the student body of Hispanic background. The Ingram School of Engineering, which began course work in 2008, is the fasting growing school in the University.

Nanotechnology Safety





- The physicochemical properties that make nanomaterials, industrial or engineered, attractive technologically also raise questions and concerns from industry, consumers and regulators regarding their toxicity and potential for exposure. Engineered particles such as carbon nanotubes require certain safety protocol while working with them. Medicine nanoparticles in the industry may pose threats to human heart and lung functions. Therefore it is required for engineers to develop and implement safe handling practices that are included in modules such as, nanoparticle transport, administrative controls, theories of accident causation, and use of ASTM/OSHA guidelines for working with nanomaterials.

Nanotechnology Safety Course Contents

Course 1: Introduction to Nanotechnology Safety		Course 2: Principles of Risk Management for Nanoscale Materials	
Module	**Theme of the Module**		**Theme of the Module**
1A	What is nanotechnology and nano-ethics?	1B	Overview of Occupational Health & Safety
2A	Ethics of Science and Technology	2B	Applications of Nanotechnology
3A	Social Impacts	3B	Assessing Nanotechnology Health Risks
4A	Ethical Methods and Processes	4B	Sustainable Nanotechnology Development
5A	Nanomaterials and Manufacturing	5B	Environmental Risks Assessment
6A	Environmental Sustainability	6B	Ethical and Legal Aspects of Nanotechnology
7A	Nanotechnology in Health and Medicine	7B	Developing a Risk Management Program
8A	Military and National Security Implications	8B	Presentations of Papers or Case Studies
9A	Nanotechnology Issues in the distant Future	9B	Hands-on Training on Using Safety Gear in Non-manufacturing

Nanotechnology Safety Module Application

Incorporation of Nanotechnology Safety Courses in Curriculum or Modules into Existing Courses			
Location	Program	Course # and Title	Course/ Module
UT-Tyler	BS (Industrial Technology): Focus: Nanotechnology Management	TECH 4350: Introduction to Nanotechnology Safety (Online)	FULL COURSE
Texas State	BS (Industrial Technology): Focus: Nanotechnology Management	TECH 4330-Principles of Risk Management for Nanoscale Materials	FULL COURSE
Texas State	BS(MFGE), BS(IE), BS(EE), BS(ET), BS(IT), BS(CIM), BS(CSM)	PHIL. 1320: Society and Ethics	1A-4A, 6A-8A
Texas State	BS(MFGE), BS(IE), BS (IT), BS(ET)	IE 4380: Industrial Safety	1A, 3B, 4B, 6B, 7B
Texas State	BS(MFGE), BS(IE),BS(EE),BS(ET)	ENGR 2300: Materials Engineering	1A, 3A
Texas State	BS(MFGE), BS(IE)	ENGR 2332: Materials Selection and Manufacturing Processes	6A, 8A
Texas State	BS(MFGE), BS(EE), BS(ET)	MFGE/EE/TECH 4392: Microelectronics Manufacturing-I	3B, 4B
Texas State	BS(MFGE), BS(EE), BS(ET)	MFGE/EE/TECH 4394: Microelectronics manufacturing-II	5A, 9A
Texas State	BS(MFGE)	MFGE 4399: Polymer Nanocomposites	2B, 4B, 5B, 9B, Guest

CERTIFICATION

PURPOSE

- The “world” of nanotechnology is rapidly developing and students will need to keep up to date.
- There are a large number of people who will not have been exposed to the nano-safety education while in school.
- There needs to be a recognized measurement of Nano-Safety understanding.
- The development of Nano-Safety Certification has been developing since 2012.

Certification Program

- University of Texas at Tyler has developed a certification program, the elements of which are shown on the next slide.
- The evaluation of developing any certification program requires testing before being finalized.
- The NSF Nano-Link Center at Dakota County Technical College has a Nano Technician program. Students from this program have been used as the initial test subject.

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About CBT

The University of Texas at Tyler College of Business and Technology (CBT) provides high quality education to the citizens of East Texas and beyond through a strategic mix of face-to-face, hybrid, and online courses.

The CBT prides itself on creating a vibrant learning atmosphere to help UT Tyler students attain the knowledge and skills to be successful professionals.

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- Industrial Engineer
- Manufacturing Engineer
- Inventory Manager
- Project Engineer
- Technical Salesperson

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Program Courses

Core Curriculum - 42 Hours
Students are required to complete the core curriculum before receiving an academic undergraduate degree. For more information: www.uttyler.edu/admissions/core-curriculum/.

Technology Coursework - 36 Hours
TECH 1303: Engineering Graphics
TECH 1320: Industrial Materials
TECH 2311: Electrical & Fluid Systems
TECH 2319: Programmable Logic Controllers
TECH 2323: Intro to Computer Applications
TECH 3311: Manufacturing Processes
TECH 3324: Plant Layout & Facilities Planning
TECH 3333: Polymer Processing
TECH 3344: Industrial Safety
TECH 4317: Computer Integrated Mfg.
TECH 4323: Lean Production
TECH 4343: Adv. Manufacturing Processes

Professional Coursework - 10 Hours
TECH 4301: Supervision
TECH 4310: Total Quality Management
TECH 4372: Capstone Experience
TECH 4173: E-Portfolio

Business Administration Minor - 18 Hours
ACCT 3300/FINA 3300: ACCT/FINA Small Bus
FINA 3315: Personal Finance
MANA 3305: Operations Management
MANA 3311: Fundamentals of Management
MARK 3311: Principles of Marketing
TECH 3355: Supply Chain Management

Approved Electives - 14 Hours

Nano/Adv. Materials Safety Certification
TECH 3303: Intro to Nanotechnology
TECH 3304: Intro to Nanotechnology Safety
TECH 3344: Industrial Safety
TECH 4313: Risk Mgmt. of Nanomaterials

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Certification

- Currently under development is a Nano-Safety Certification program for the Association of Technology, Management, and Applied Engineering (ATMAE) Society.
- This certification is planned on being offered beginning in 2016.
- This is only the beginning of the efforts to ensure that the application of nanotechnology addresses potential issues impacting everyone.

Summary

- Nanotechnology Safety (Nano-Safety) needs to be everyone's concern.
- We have been working on all four key focal points to address safety in the emerging technology.
- The initial courses have been well received.
- The certification programs will ensure that more people are capable of correctly working with nanomaterials.
- We are looking for advice on what other items should be included in Nano-Safety Education.

Team Contact Info

JITENDRA TATE, PH.D.

Associate Professor of Manufacturing Engineering

BS, MS, Mechanical Engineering: University of Pune, India
PhD,Mechanical Engineering: North Carolina A&T State University

Texas State wins NSF-NUE 2012 (Nanotechnology Undergraduate Education) grant, PI Dr. Jitendra Tate

NSF-NUE NanoTRA Website
Dr. Jitendra Tate Wins the Dow Chemical Educator of the Year 2009 Award

Contact Info:

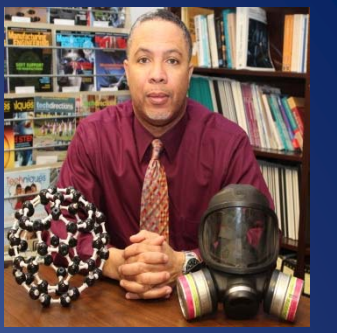
- Email: JT31@txstate.edu
- Office: RF Mitte Building Room 2218; Phone: 512-245-4872
- Composites Lab: RF Mitte Building Room 1218; Phone: 512-245-6782

Awards

- National-level Dow Chemical Educator of the Year 2009 by Composites Division of Society of Plastics Engineers
- College of Science and Engineering, 2009 Dean Nominee for the Presidential Award for Excellence in Teaching
- The Alfred H. Nolle Chapter of the Alpha Chi National College Honor Society, 'Favorite Professor for 2012'

Dominick E. Fazarro, Ph.D., CSTM

IEEE Senior Member
IEEE Nanotechnology Column Editor



- Associate Professor-Department of Technology at the University of Texas at Tyler
- OSHA Outreach Authorized Trainer
- Published numerous articles, book chapters, proceedings, & presented papers on nanotechnology safety and nanoworkforce
- Received federal funding for OSHA and NSF for Nanotechnology Safety Education & Training

– Past member of the Nanomaterials Application Center, Texas State

– Past member of the Texas-Israel Nanotechnology Committee

- Developed curricula on nanotechnology safety and risk management of nanomaterials
- 2013 University of Texas Research Award
- 10 years of Industry experience (Army logistics & NBC)

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Craig Hanks, Ph.D.

Professor Craig Hanks
NEH Distinguished Teaching Professor 2009-2012

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Teaching and Research Specialties:

- Philosophy of Technology, Critical Theory, American Pragmatism, Applied Philosophy (including: Environmental Philosophy, Professional Ethics, Bioethics).

Walt Trybula, Ph.D.

IEEE Fellow & SPIE Fellow
IEEE CPMT Distinguished Lecturer

- Director of the Trybula Foundation, Inc. (Austin, Texas)
- Adjunct Professor, Ingram School of Engineering
  Texas State University (San Marcos, Texas)
- Past Director
  - Center for Emerging Technology Commercialization, The University of Texas at Austin
  - Nanomaterials Application Center, Texas State University
- 13 years at SEMATECH, Senior Fellow of the Technical Staff
- 12 years at GE, nine on Corporate Staff (manufacturing/technology)
- Founded two companies, Director at a third start-up
- Technology Futurist:
  - Nanotechnology: single digit nanometer materials, nanotechnology safety, education
  - Energy: nanoelectronics, nanosensors, nanosystems, picoWatt systems
  - Semiconductors: advanced lithography, med-bio
- Business: emerging technologies, commercialization, mentoring

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