A Multi-Tool Approach to Integrating Nanotechnology and Fuel-Cell Concepts into the Curriculum

Matthew D'Amato, Kenneth Lux
University of Wisconsin – Madison

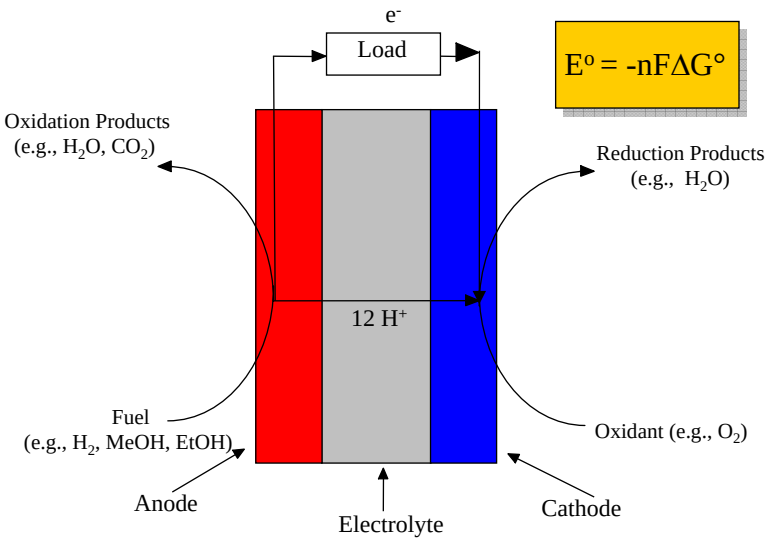
Holly Walter Kerby, Barbara Anderegg, Kenneth A. Walz
Madison Area Technical College

Education and Workforce

"The annual global impact of products where nanotechnology will play a key role has been estimated in 2000 **to exceed $1 trillion by 2015**, which would require **2 million nanotechnology workers**."

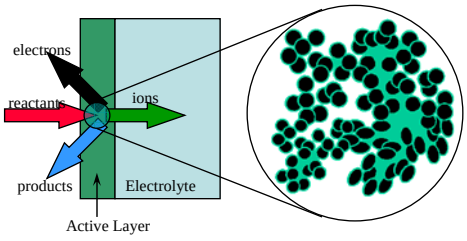
Mihail Roco, Director of the National Nanotechnology Initiative

Fuel Cell Basics



Nanotechnology and Fuel Cells

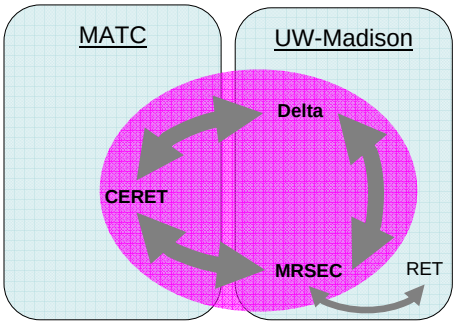
- Nanotechnology enables fuel cells
  - Surface reactivity
  - Surface area to volume ratio
- Fuel cells as a vehicle to teaching nanotechnology
- Can be used in different modules
  - Energy
  - Electrochemistry
  - Thermodynamics
  - Kinetics



Confluence of Programs

Several programs contributed to developing these activities

- Madison Area Technical College (MATC)
  - Consortium for Education in Renewable Energy Technologies (CERET)
- UW-Madison
  - Materials Research Science and Engineering Center (MRSEC)
  - Research Experience for Teachers (RET)
  - Delta Program



MRSEC: Materials Research Science and Engineering Center

- One of ~20 centers funded by NSF nationwide
- UW-MRSEC focuses on Nanostructured Materials and Interfaces
- Organized in 4 groups
  - 3 Interdisciplinary Research Groups (IRGs)
  - Seed projects
  - Interdisciplinary Education Group (IEG)
- Cross-cuts several departments
  - ChemE, MatSci, Eng. Mechanics, Physics, Chemistry, others
- Coordinates with Research Experience for Teachers (RET), Research Experience for Undergraduatess (REU), and Summer Research Experience for Undergraduates (SURE) programs

The University of Wisconsin – Madison
Materials Research Science and Engineering Center on Nanostructured Materials and Interfaces

RET: Research Experience for Teachers

- Managed by UW-MRSEC
- K-12 teachers spend several weeks at UW
  - Work with UW education and research personnel
  - Teachers meet regularly together to compare progress
- Bring cutting-edge nanotechnology back to the classroom
- Utilize teachers' expertise to translate research into teaching tools

RET participant Bruce Swanson explains to students features of a silicon wafer.

Memorial High School students discuss how common refrigerator magnets mimic a scanning probe microscope.

The University of Wisconsin – Madison
Materials Research Science and Engineering Center on Nanostructured Materials and Interfaces

CERET: Consortium for Education in Renewable Energy Technology

- Interdisciplinary approach to technical education in renewable energy technologies.
- Develop a technically-competent renewable energy industry workforce

•Foster the production of more energy from Wisconsin grown agriculture products and by-products

•Encourage the use of distributed energy generation sources

•Promote applied renewable energy understanding and knowledge.

The Delta Program

Preparing UW graduate students and post-docs for successful careers that *integrate* forefront research and superb teaching and learning

STEM professor as Change Agent: Teaching-as-Research
- Hypothesize, experiment, observe, analyze, improve
- Self-sustained improvement of STEM education

Learning Community
- Support growth in teaching and learning
- Graduate student, post-doc, faculty community
- Foundation for institutional change

Learning-through-Diversity
- Excellence and diversity are necessarily intertwined
- Students bring a rich array of experiences and skills
- Learning of all students is enhanced if all are engaged

DELTA Integrating Research, Teaching, and Learning

www.delta.wisc.edu

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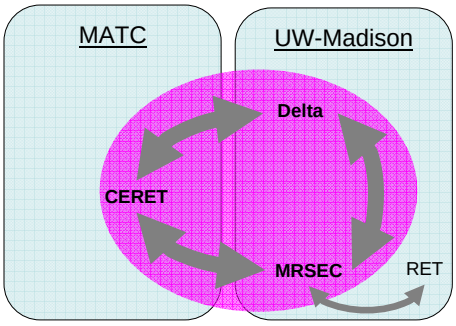
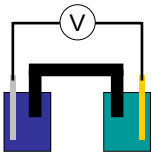


Teaching Fuel-Cell Technology: A Multi-Tool Approach

- Implemented in chemistry courses at MATC
  - Non-majors course
  - General chemistry course (transferable to UW)
- Traditional lectures – Auditory learners
- Web-based learning objects – Visual learners
- Fuel-cell laboratory module – Tactile learners
- Assessed effectiveness with pre/post quiz and surveys (strengths, improvements, insights)



Traditional Lectures

- Electrochemistry
  - Redox reactions
  - Electrochemical cells
- Batteries
- Fuel cells
  - Basics
  - Types of fuel cells
  - Advantages/disadvantages
  - Cost components
- Assessment
  - Student feedback
  - Focused on guest instructor's teaching

Web-Based Learning Objects

- *Effective* learning objects can help enhance student learning
  - Interactive
  - Self-paced
  - Addresses visual and auditory learners
- Utilized both before and after lectures
  - Before: To test effectiveness of learning objects
  - After: To enhance impact of lectures
- Assessment
  - Pre- and post-quizes
  - Student feedback

Learning Objects

Definition: brief, web-based, interactive tutorial, designed to convey a "nugget" of information

Many Applications:

- stand-alone or part of larger unit
- applicable to various courses (depending on content)
- distance learning
- easily adapted for diverse students (including those with disabilities, various learning styles, language barriers, etc.)

"Heart of a Fuel Cell"

Exploring technological issues in fuel cells with a learning object

Cost	Performance	Durability
Why are FCs expensive? When will they be cost effective?	What affects performance of FCs? What research problems are involved?	What affects lifetime of FCs? How can we test long-term performance?

Renewable Energy Learning Objects available at:
http://ceret.us/l_objects.htm

Fuel-Cell Learning Object Results

Student Feedback

Positive feedback from the majority:

"makes it more hands-on"

"better than reading pages in a book"

"short explanations and visual aids"

"easier to learn hearing it and seeing it at the same time"

- Not overdone but simple enough to clearly understand
- Some expressed interest in related issues (energy policy, for example)

Instructor Feedback

- Encouraged to use objects in future courses
- Consider *how* you introduce LOs

More rigorous assessment of particular learning goals is underway.

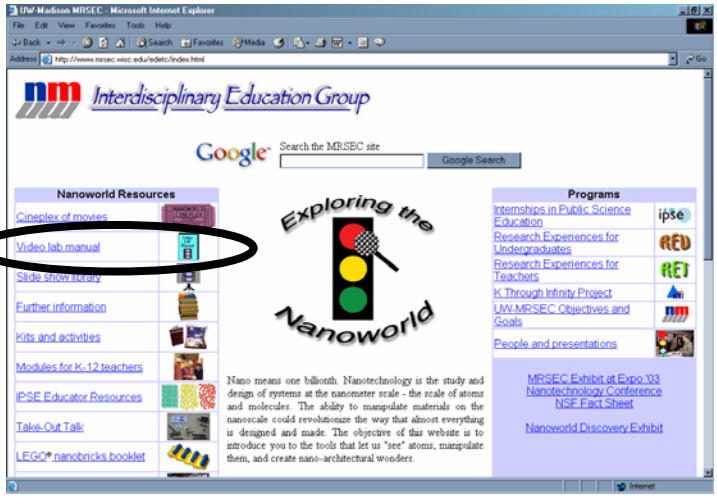
Learning Object

UW MRSEC Web-Based Education Tools

Nanotechnology Lab Manuals

Nanoworld Cineplex Demonstrations

www.mrsec.wisc.edu/nano



Fuel-Cell Laboratory Activity

- Students build their own PEM fuel cells
  - Groups of 4-5 students
  - Instructor provides platinized Ni-Cr mesh
- Measure performance of cells
  - Open-circuit voltage (OCV)
  - Short-circuit current (SSC)
  - Polarization curves
  - $NaBH_4$, MeOH, EtOH solutions for fuel
- Assessment
  - Success rates
  - Power densities
  - Student feedback

Fuel Cell Laboratory Activity

Electroplate wire mesh to form electrodes.

(Prepare ahead of time and demo)

Seal syringe ends with mesh by melting syringe around mesh to form gas chambers.

Use 5-minute epoxy to glue Nafion® membrane between electrodes.

(need to hold still and tight for 5 minutes)

Test fuel cell with $NaBH_4$, MeOH, and/or EtOH

Possible Modifications

- Different electrocatalyst (PtRu)
- Link performance of different sized mesh to surface area
- Use vacuum grease instead of epoxy

Issues

- Need smooth surface for epoxy to bond well
- Need to hold fuel cell tightly in place during epoxy cure
- $NaBH_4$ neutralizes Nafion® - need to re-acidify

Fuel-Cell Video Lab Manual

Results

- Lectures
  - Focused on Delta Intern's teaching performance
  - No data collected specifically on lecture impact on learning outcomes
- Learning Object
  - Re-emphasized concepts in lecture
  - LO alone resulted improvement in pre/post quiz results
  - Pre:42%, Post:80%, n=35
- Fuel-Cell Laboratory Activity
  - Helped bring concepts together
  - Addressed needs of tactile learners
  - Incorporated in MRSEC video lab manual

Conclusions

- An example of leveraging several programs together
- An example of different institutions working together
- Multiple tools to address multiple learning styles
  - Lectures
  - Learning objects
  - Laboratory activites
- Can help to bring nanotechnology into the classroom

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