



PREM: Paradigm and Realization of Excellence in Materials

Synergistic Partnership for Research and Education on Nanostructured and Functional Materials

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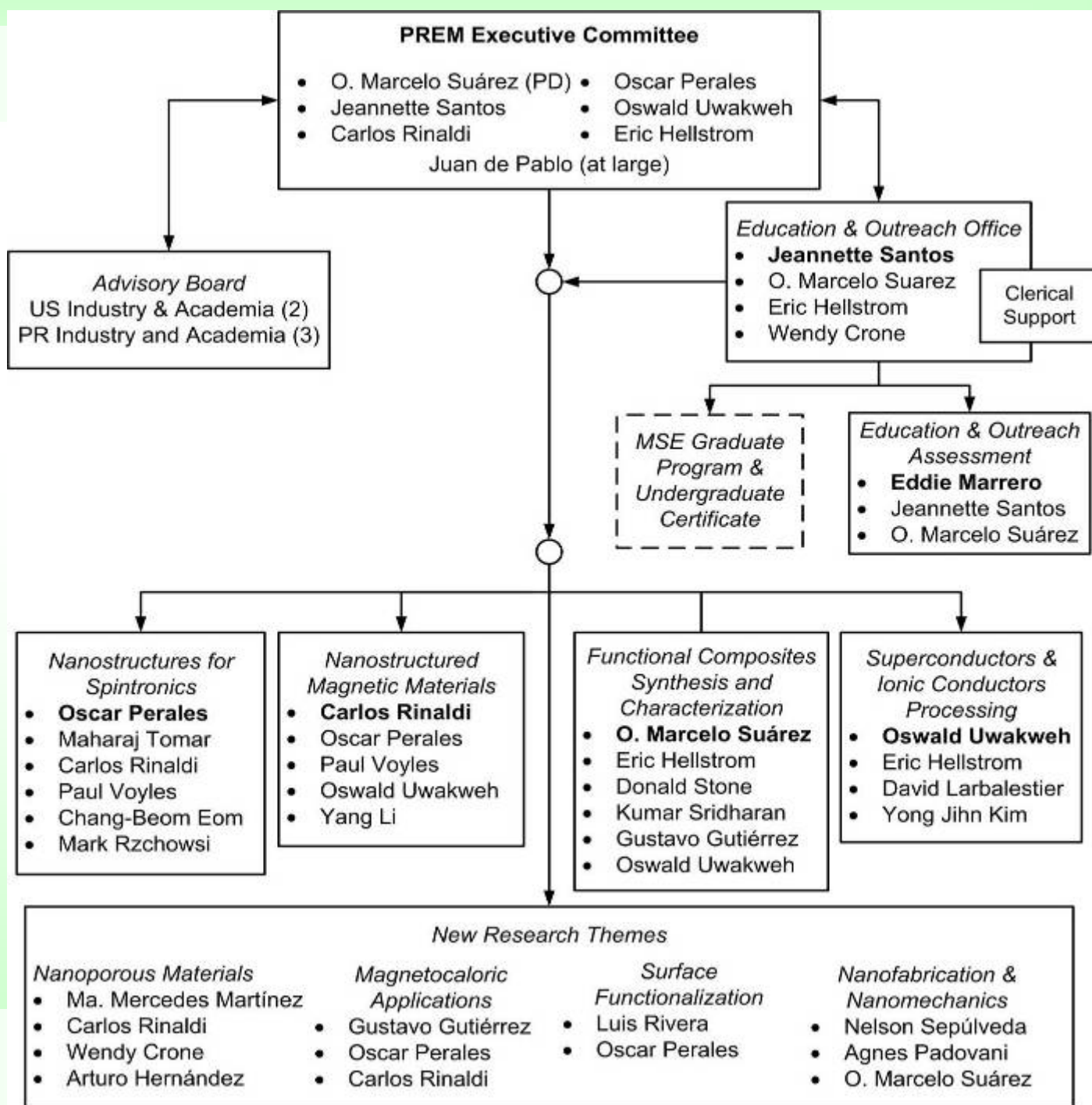
The Story of our PREM

- Circa March 2003: Announcement and Excitement
- Originally, three research thrust areas:
 - Spintronics and nanostructured magnetic materials
 - Al-B-X functional composites
 - Superconductors processing
- Education and outreach activities
- Assessment
- Main UW partnership: MRSEC IRG 2 (Superconductivity), NIRT (Spintronic materials) and MRSEC IEG
- Award: April 1, 2004 – March 31, 2009
- \$ 2.7 M (\$740k+ 4 · \$490,000)





Current UPRM/UW PREM Organization





2007 Participating Research & Academic Units

- UPRM
 - Dept. of Engineering Science & Materials (formerly *General Engr.*)
 - Dept. of Chemical Engineering
 - Dept. of Physics
 - Others:
 - Dept. of Chemistry
 - Dept. of Mechanical Engineering
- UW
 - Dept. of Materials Science & Engineering
 - Dept. of Engineering Physics
 - Materials Research Science & Engineering Center (MRSEC)
- National High Magnetic Field Laboratory (FRG)

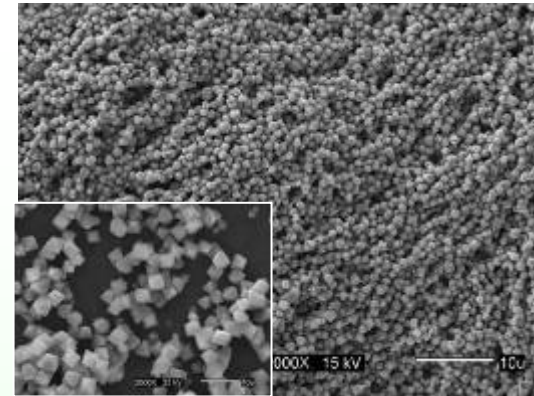




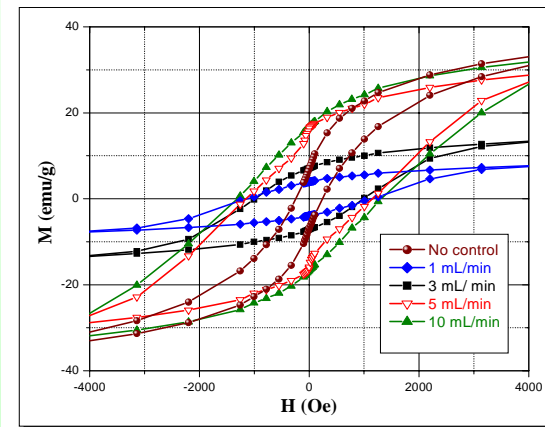
Research

Functional Magnetic Nanostructures

- Formation of monosize particles of metastable ϵ -Co in Trimethylene Glycol reported for the first time.
- Partial ordering of nanocrystalline CoPt is apparent when Co ions are reduced in Trimethylene Glycol (TMEG) in presence of Pt ions and quenched in ice-water.
- Higher coercivity of cobalt ferrite nanocrystals achieved via control of reaction time, heating intensity and flow rate of reactants addition: 1330Oe from 230 Oe, with no flow-rate control.
- Stable suspensions of Fe-ZnO nanocrystals and thin films of Co-Fe doped-ZnO synthesized in ethanol and RF-magnetron sputtering, respectively.
- Nanocrystalline bare and Gd and Eu-doped ZnO were produced via novel low-temperature sol-gel method.
- Optical and magnetic characterization of produced materials is in progress.



SEM image of monodisperse metastable ϵ -Co produced in polyol solutions. The inset shows the morphology of the intermediate; a dissolution-reduction process should have taken place.



M-H loops at 300K for CoFe_2O_4 synthesized at different flow-rates. The coercivity was increased from 230 Oe (non-flow rate controlled) up to 1330 Oe (10 ml/min)

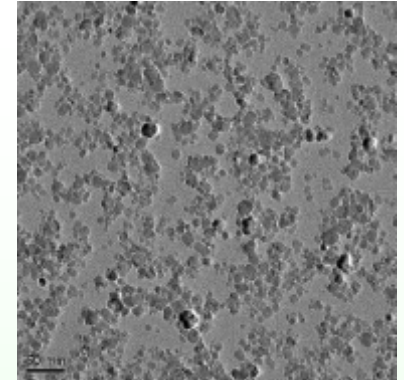




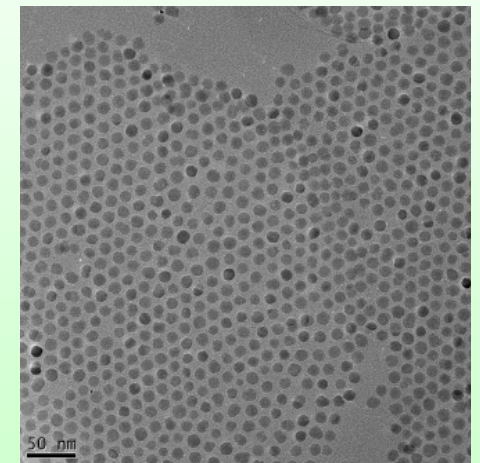
Research

Magnetic Nanoparticle-Based Sensors

- Quantitative comparison of magnetic nanoparticle-based sensors to rotational Brownian motion model
- Efforts focused on particle synthesis and functionalization
 - Cobalt ferrite (CoFe_2O_4) nanoparticles prepared by co-precipitation were functionalized with dimercaptosuccinic acid (DMSA). The particles had a ~ 12 nm in crystal diameter. But were too polydisperse.
 - To improve monodispersity, nanoparticle synthesis done via thermal decomposition of $\text{Fe}(\text{acac})_3$ and $\text{Co}(\text{acac})_2$. Highly monodisperse CoFe_2O_4 nanoparticles were obtained, with diameters from 6 to 14 nm, controllable by varying the synthesis conditions.
 - Resulting nanoparticles are coated with oleic acid and we are currently in the process of replacing this with DMSA.
- Current efforts are focused on building an AC susceptometer for liquid samples capable of measurements in the 10kHz to 2MHz frequency range.



TEM image of co-precipitation with wide particle size distribution



TEM image of thermal decomposition showing monodisperse particles in hexagonal arrays

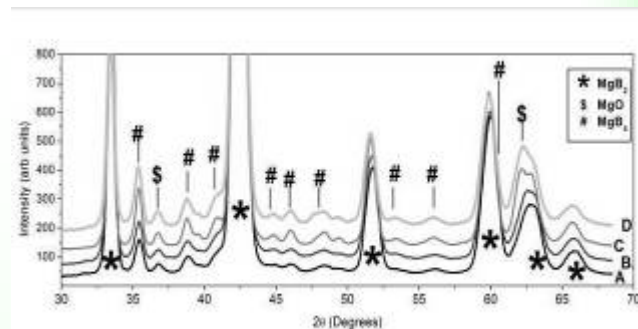




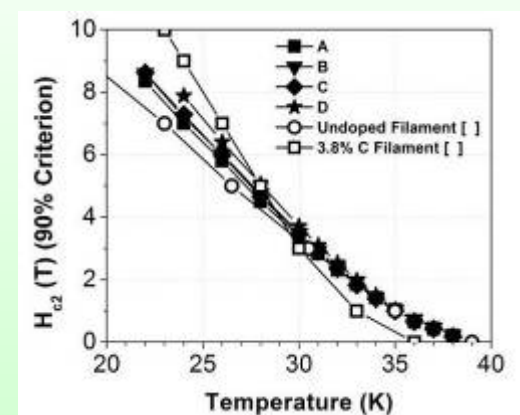
Research

High Energy Processing of MgB_2 -Based Superconductors

- Variable atmospheric processing conditions of undoped MgB_2 during ball milling partly explains reported variations in reported properties
- Formation of MgO and MgB_4 phases in small amounts result during ball milling (from precursor powders, or during ball milling/sintering etc.)
- MgB_2 is found to be highly sensitive to CO_2 and O_2 atmospheres based on measured residual relative resistivity, T_c , and H_{c2}
- MgO and MgB_4 formation in O_2 atmospheres led to reduction in current flow, and, was largely responsible for the wide variations in connectivity and differences in T_c , resistivity, and H_{c2} , reported in the literature for "pure" MgB_2 based on comparative analysis of atmospheric humidity effect between Mayaguez, PR and dry winter conditions in Madison, WI
- Upcoming work includes:
 - Site specific dopings with transition metal and refractory metal borides and carbides
 - Large scale processing for making magnets in collaboration with a company for MRI purposes.



XRD of Ball Milled MgB_2



Temperature Dependence of lower critical field, H_{c2}

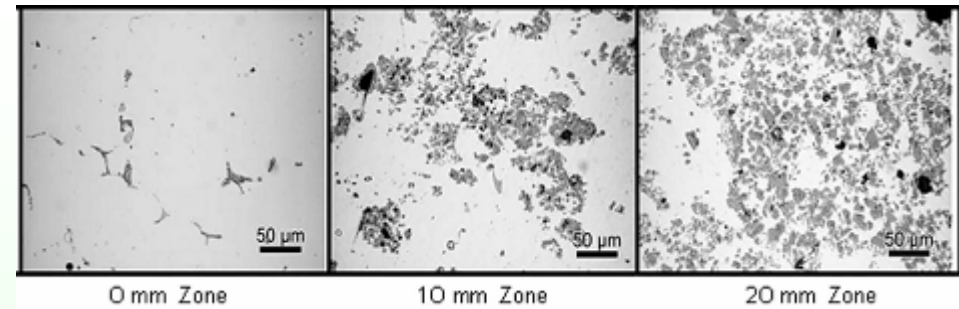


Research

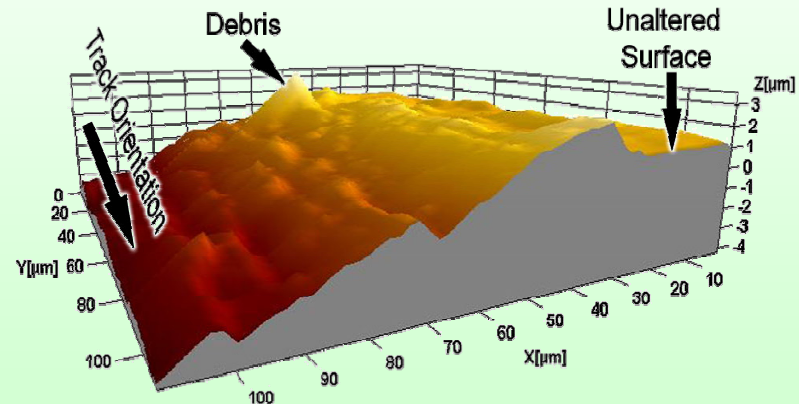
Functional Al-B-X Composites

Functionally-Graded Aluminum Matrix Composites

- Functionally-graded Al matrix composites (FG-AMC) synthesized via centrifugal casting (low-cost processing)
- Much larger volume fractions of AlB_2 or $\text{Al}_x\text{Mg}_{1-x}\text{B}_2$ on the external regions were attained
- Resulting high wear-strength, lightweight composite is being proposed as lunar regolith abrasion resistant material.



Microstructure of centrifugally cast FG-AMC



AFM image of pin-on-disk track in FG-AMC Al-5wt%B internal zone

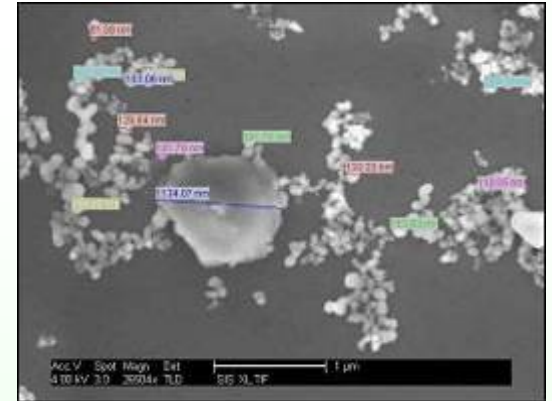


Research

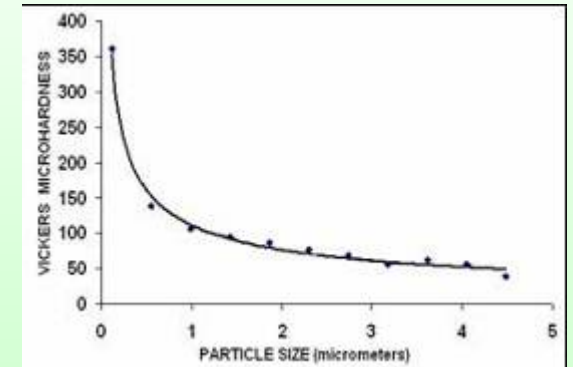
Functional Al-B-X Composites (cont.)

Alternative Processing Routes for Al-B-X Composites

- Successful mechanical alloying of aluminum matrix composite using pure Al pellets with different loadings of MgB_2 powder ($\sim 40\mu m$)
- Mechanical alloying was followed by vacuum partial melting (Al matrix) at $900^\circ C$
- The resulting material contained $Al_xMg_{1-x}B_2$ particles with a bimodal size distribution:
 - large particles (average size of $4.91\mu m$)
 - nanosized ones ($< 80\text{ nm.}$)
- Bulk and microhardness are affected by particle size
- Directional solidification studies of Al-B-Cu composites
- AlB_2 catalytic potency in the heterogeneous nucleation of Al was revealed
- Upcoming research will couple both projects to propose alternative grain refiners for the Al industry



High resolution SEM image of $Al_xMg_{1-x}B_2$ particles embedded in an Al matrix.



Effect of diboride particles size on the hardness of the Al-based composite

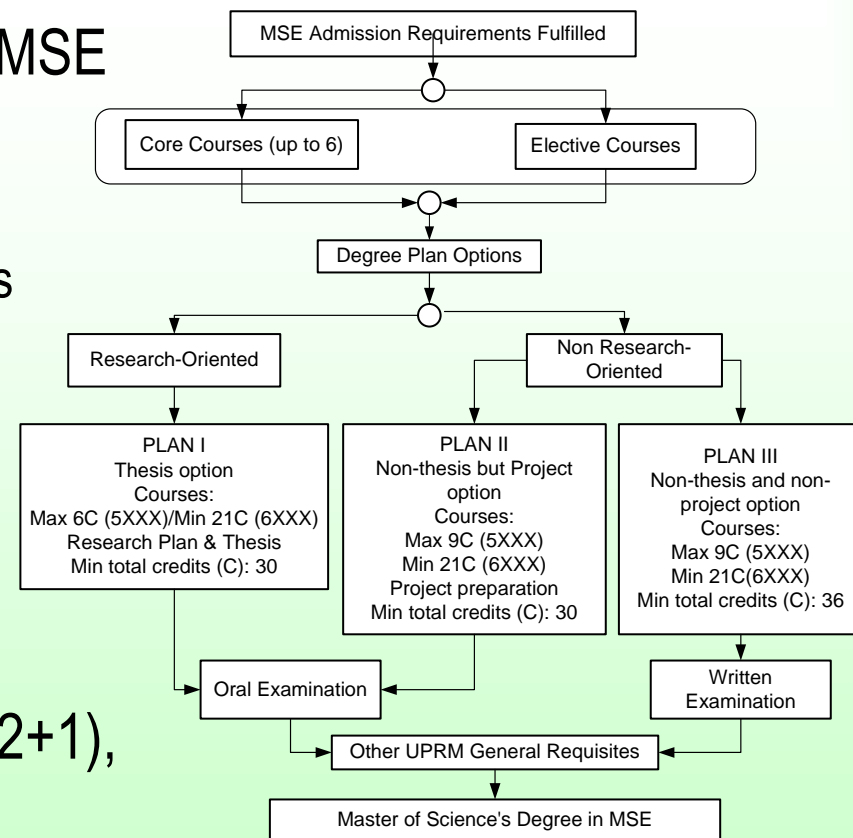




Education & Outreach

Education in Materials Science & Engineering Curriculum Development

- Status of the MS graduate program in MSE
 - Approved by UPRM Academic Senate
 - Approved by UPRM Administration Board
 - At the University System Board of Regents
- Certificate in Materials Science and Engineering
 - Advanced synthesis and characterization
 - Undergraduate research in MSE
 - Curricular Development
- New MSE faculty hired by the ESMat (2+1), ChemE.(2), and ECE (1)





Education & Outreach

Materials Science & Engineering in Public Schools

- Teachers Summer Activities (training on MSE)
 - 2005: two (Mayagüez public schools)
 - 2006: five (Mayagüez, Aguada & Cabo Rojo public schools)
- Materials Science and Engineering clubs
 - Three in Mayagüez schools with 60 members
 - One in Aguada intermediate school with 25 members
 - One in Cabo Rojo high school with 51 members
- High school students participating in PREM
 - 2004-5: two (one is now a UPRM Chemistry student) from one Mayagüez school
 - 2005-6: four from two Mayagüez schools
 - 2006-7: Mayagüez schools (13) and Aguada school (1).
- PREM students participate in **materials science demonstrations** during MSE club meetings and science fairs.



Summer 2006 participating teachers



MSE Club initiation at Hostos High School.



Prof. Perales presents his work on nanomaterials to prospective PREM high school participants



Claribel Acevedo (currently a UW ChemE doctoral student) demonstrates the properties of ferrofluids to E. Rosado Báez Middle School students





Education & Outreach

Materials Science & Engineering in Public Schools (cont.)

- Translation and adaptation of demonstration modules developed at UW MRSEC IEG.
 - Exploring the Nanoworld (*Explorando el Nanomundo*)
 - New modules on diodes and other materials and devices
- Implementation of module developed at Northwestern Univ. MRSEC:
 - Concrete fabrication



Teaching the teacher

Ms. Marisol Colón, one of the first teachers to join PREM in 2005, worked in Prof. María Mercedes Martínez-Iñesta's laboratory on the synthesis of metallic nanowires as part of PREM Teachers' Summer Activities in 2006.

Prof. Martínez-Iñesta joined our Chemical Engineering faculty in 2005 after obtaining her PhD from the University of Delaware. A native of Mayagüez, she had a Chemistry teacher that helped her defined her career path: Mrs. Colón.

Ms Colón: *"This is a teacher's duty: That her student accomplishes much more than herself."*



Ms. Marisol Colón and Prof. María Mercedes Martínez during the closing ceremony of the 2006 Teachers' Summer Activities





Education & Outreach

Materials Science & Engineering in Public Schools (cont.)

“Nanotubes for the Future”

- UPRM PREM hosted **more than 100 students**, members of our **five Materials Science and Engineering clubs** formed in public schools
- It took place in the Rafael A. Mangual Coliseum, the largest UPRM venue.
- The students were welcome by our Chancellor, Dr. Jorge I. Vélez Arocho, and our Dean of Engineering, Dr. Ramón Vázquez
- PREM high school students, Coraly Sotomayor and Nayomi Plaza were the MCs.
- The students were briefly introduced to the basics of carbon nanotubes by Prof. Oscar Perales and to the geometry of the construct by Prof. Luis A. Rivera (Engineering Graphics professor).
- The activity was originally developed by UW MRSEC IEG.





Education & Outreach

Materials Science & Engineering in Public Schools (cont.)

“Nanotubes for the Future”

- Each Materials Science & Engineering club was assisted by two or three PREM students and supervised by their corresponding teacher mentors.
- Tube frames hold the construct from ropes
- Two air compressors helped participants inflate the black balloons. Conveniently attached to each other to form the hexagons, they were then hanged from the steel frames.
- To complete this task a real teamwork was necessary. The enthusiasm and the energy of the teams were apparent at all times to build five 2-story high nanotubes!!





The Outcomes

Our Research Throughput

- More than thirty publications in peer-reviewed journals:
 - *Nanotechnology*
 - *Journal of Microelectronics*
 - *Journal of Magnetism & Magnetic Materials*
 - *Physical Review B*
 - *Materials Characterization*
 - *Journal of Experimental Nanoscience*
 - *Applied Catalysis B: Environmental*
 - *Journal of Applied Physics*
 - *Scripta Materialia*
 - *Journal of Materials Science*
 - *Journal of Materials Education*
 - *IEEE Transactions on Magnetism*
 - *Composites Part A*
 - *etc.*
- One book chapter in *Encyclopedia of Sensors*
- Twelve conference proceedings
- Almost 300 oral and poster presentations
- More than twenty invited seminars





The Outcomes

Our Research Throughput (cont.)

Additional External Funds Resulting from PREM Activities

Almost \$3M in additional funds attracted by PREM participants from different agencies and programs:

- NSF CAREER (2)
- NSF NIRT
- NSF REU
- NSF MRI (two, one with UW)
- NSF-DMR
- NASA IDEAS (3)
- DoD EPSCoR
- PR EPSCoR
- DoD HBCU
- Etc.

Success rate is higher than 70%.





The Outcomes

Development of Human Resources

UPRM Undergraduates

38 Hispanic students, 19 female students from MechE, ChemE, IndE, ECE, Phys and Social Sci.

UPRM Graduates

23, 4 Hispanic students, 9 female students from MechE, ChemE, Chem and Phys.

UW Graduates

6, 5 Hispanic students, 2 female students MatSci and ChemE.

High School

9 Hispanic students, 5 female students





The Outcomes

Awards & Recognitions Undergraduate Students



2005 AIChE Poster Competition: **Two first prizes** for Claribel Acevedo (currently UW ChemE doctoral student) and Richard Lorenzo

AIChE

TMS 2006 Annual Scholarships
awardee: Ruth Hidalgo (one of thirteen awards) given by the Light Metals Division



2007 TMS Annual Meeting Poster Competition: **First Prize** for Carlos Báez from TMS Materials Processing & Manufacturing Division

TMS

2007 TMS Annual Meeting Poster Competition: **First Prize** for José Vázquez from TMS Light Metals Division





The Outcomes

Awards & Recognitions (cont.)

PREM Faculty

Five PREM professors awarded **Distinguished Professor Awards** by the UPRM College of Engineering:

- 2004: O. Perales, C. Rinaldi, O. M. Suárez
- 2005: C. Rinaldi, J. Santos, A. Hernández
- 2006: O. Perales

2006 NSF CAREER Awards: C. Rinaldi,
A. Hernández





The Outcomes

Awards & Recognitions (cont.)

PREM Faculty

2006 National Defense Science and Engineering Graduate Fellowship from DoD and the Air Force Office of Scientific Research to Bárbara Calcagno (UPRM Prof. and UW PhD candidate working with Dr. W. Crone)



Article selected by the editorial board as **one of the 32 best works published in 2006** in the *Superconductor Science & Technology*. "Atmospheric conditions and their effect on ball-milled magnesium diboride," B. J. Senkowicz, R. Pérez Moyet, R. J. Mungall, J. Hedstrom, O. N. C. Uwakweh, E. E. Hellstrom and D. C. Larbalestier, *Supercond. Sci. & Tech.*, Vol. 19, No. 11, (2006): pp. 1173-1177.





The Outcomes

Awards & Recognitions (cont.)

Public High School Students

Mayagüez School District Scientific Fair (February 2006)

Coraly Sotomayor (E. M. Hostos High School): “Hydrogen...Future Energy Source.” **First Prize in Chemistry**. Advisor: Prof. O. Perales

Eric Sánchez (E. M. Hostos High School): “Conductive Properties of Polymers.” **Second Prize in Chemistry**. Advisor: Prof. O. Perales

Nayomi Plaza (E. M. Hostos High School): “Low-Cycle Fatigue of Heat-Treated Al-Mg Alloys.” **First Prize in Engineering**. Advisor: Prof. O. M. Suárez

Ismael Ramírez (J. de Diego High School): “Superconducting MgB_2 .” **Second Prize in Physics**. Advisor: Prof. O. Uwakweh.



Coraly Ruiz and Nayomi Plaza



From left to right: Coraly Ruiz, Eric Sánchez, Nayomi Plaza and Ismael Ramírez

Nayomi Plaza was selected to represent the regional high schools participated in the *Intel International Science & Engineering Fair* held in Indianapolis, IN.





The Outcomes

Awards & Recognitions (cont.)

Public High School Students

Mayagüez School District Scientific Fair (February 2007)

Coraly Sotomayor (E. M. Hostos High School): “*Zinc Oxide Nanocrystals... A Step to the Future.*” **First Prize in Engineering.** Advisor: O. Perales

Fabiola Robles (C. R. O. E. M.): “*Recycled Rubber Use in Roadside Safety Guardrails.*” **Second Prize in Engineering.** Advisor: O. M. Suárez

Nayomi Plaza (E. M. Hostos High School): “*Fatigue in AA 5182 Aluminum Alloys.*” **Third Prize in Engineering.** Advisor: O. M. Suárez

Armando Olivero and **Starlyn Gómez** (Dr. P. Fajardo High School): “*Comparative Study of Cadmium Sulfide Nanocrystals Optical Properties.*” **Second Prize in Physics** (Team Project). Advisor: O. Perales

Aguada School District Scientific Fair (February 2007)

Wilfred Galloza (Dr. C. González, Aguada): “*Hydrogen Embrittlement of Squeeze Cast Aluminum Composite.*” **First Prize in Engineering.** Advisor: O. M. Suárez





The Outcomes

Awards & Recognitions (cont.)

Public High School Students

Western Puerto Rico Regional Scientific Fair (March 2007)

Coraly Sotomayor (E. M. Hostos High School): “*Zinc Oxide Nanocrystals... A Step to the Future.*” **First Prize in Engineering.** Advisor: O. Perales

Nayomi Plaza (E. M. Hostos High School): “*Fatigue in AA 5182 Aluminum Alloys.*” **Second Prize in Engineering.** Advisor: O. M. Suárez

Fabiola Robles (C. R. O. E. M.): “*Recycled Rubber Use in Sideroad Safety Guardrails.*” **Third Prize in Engineering.** Advisor: O. M. Suárez

Armando Olivero and Starlyn Gómez (Dr. P. Fajardo High School): “*Comparative Study of Cadmium Sulfide Nanocrystals Optical Properties.*” **First Prize in Physics** (Team Project). Advisor: O. Perales



Armando Olivero and Starlyn Gómez were **selected to represent Western Puerto Rico in the International Scientific Fair in New Mexico, in May 2007.**



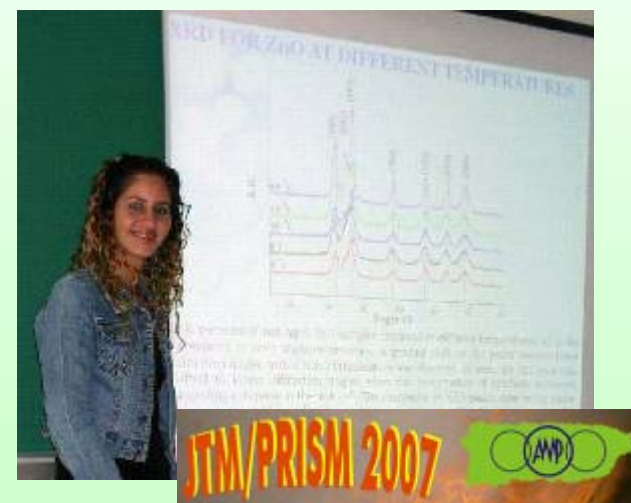


The Outcomes

Awards & Recognitions (cont.)

Public High School Students

- Nayomi Plaza was **the first high school student** to present at the LACCEI conference (June 2006). Nayomi was the only PR student selected to participate in the ASM Summer Materials Camp in U. Missouri-Rolla (July 2006).
- Coraly Sotomayor presented her work on ZnO nanocrystals in the **Puerto Rico Interdisciplinary Scientific Meeting (PRISM)**, the largest forum for undergraduate science, technology, engineering and math students in the island (March 2007). She also received the **Innovative Engineering Award** by The Nat. Soc. of Professional Engineers, and **The Most Outstanding Exhibit Award** by The ASM Materials Education Foundation
- Coraly and Nayomi have just been admitted in the UPRM Mechanical Engineering program. They will continue to work with PREM.





Partnership

The Partnership with Univ. of Wisconsin

- Research:
 - Connections with [UW MRSEC](#) via: C. Rinaldi (de Pablo/Nealey) on nanomagnetic particle synthesis, O. M. Suárez (Stone, Hellstrom, Voyles) on FIB of Al-B-X composites.
 - Instrumentation: O. Perales (Voyles, [MRI STEM](#) *remotely operated*)
 - Connections through [FRG](#): O. Uwakweh (Hellstrom, Rzchowski, Larbalestier at FSU)
 - UW [Summer Undergraduate Research Experience](#) is extremely successful with major representation from PREM and UPRM students
 - Others: O. M. Suárez, G. Gutiérrez, O. Perales (Sridharan, UW Nuclear Engineering)
- Human resource development:
 - Graduate students (seminars, workshops, PhD students in MSP and ChemE)
 - Undergraduate students (SURE)
 - Faculty members (workshops, PhD candidate)
 - Adjunct fellow status at UW MS&E Dept. allows for UW library resource access
- Outreach and education (in collaboration with Crone MRSEC-IEG):
 - Implementation of demonstrations/experiments developed at UW.
 - Guidance in teachers' training.





Dissemination

Co-Organization of International Conferences

- Co-organization of **Southeastern Conference on Theoretical and Applied Mechanics (SECTAM XXIII)** held on campus in May 2006. Dr. Harsh Chopra was the keynote speaker
- Co-organization and sponsorship of the **International Conference on Engineering Education ICEE 2006** held in San Juan in July 2006. Dr. Arden Bement was the first keynote speaker of the conference with more than 500 attendees



Dr. Jeannette Santos and Dr. Arden Bement in ICEE 2006 PREM / UW MRSEC booth





The Future

Vision of PREM for the Next Two Years

- Premise: We have created a robust platform on research, education and outreach on diverse areas related to MSE: nanomagnetic materials, superconductors' processing, functional composites, etc. **PREM is the foundation of major crosscutting efforts either existing or upcoming.**
- Main objectives:
 - Strengthen the research production in terms of peer-reviewed publications
 - Keep on the quest for external funding, incorporating new faculty in the major initiatives
 - Seek for partners / collaborators in the main areas related to PREM (add on new faculty's expertise/contacts)
 - Involve more senior personnel and obtain more external support for the outreach efforts (spreading thin) → RET / REU / private funds
 - Keep pressing for a prompt realization of the proposed curricular development (MS program and Undergraduate Certificate in MSE)
 - Conduct a feasibility study of a PhD degree in MSE





The Future

The Expansion of PREM

- Industrial collaborators:
 - Boeing (Everett & St. Louis)
 - Columbus Superconductors
 - KB Alloys
 - Hewlett Packard
 - Rolls Royce (Indiana)
- Federal agencies (major initiatives):
 - NSF:
 - **CREST** proposal on nanoengineered materials
 - **MRI** proposal for nanofabrication facilities
 - **IGERT**, etc.
 - DoD:
 - **DEPSCoR** proposal on multiscale study from nano to megastructures
 - **Infrastructure Support Program** proposal for a thermomechanometry lab
- Universities:
 - Georgia Tech
 - Iowa State Univ.
 - Florida State Univ.
- Federal laboratories:
 - National High Magnetic Field Laboratory
 - Oak Ridge National Laboratory





The Future

The Expansion of PREM (cont.)

UPR NanoScience and Technology Institute

UPR – NASA URC

Center for Nanoscale
Materials

UPR-RP

NASA-\$6M

NSF-PREM

Synergistic Partnership
on Functional and
Nanostructured Materials

NSF-\$2.7M

Other Centers

Center for Materials for
Energy Storage and
Production at the
Nanoscale

Others





premm.uprm.edu