

## BROCK H MARRS

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### EDUCATION

**Doctor of Philosophy**

Biomedical Engineering  
University of Kentucky  
May 2007

Multiwall Carbon Nanotube Augmentation of a Bone Cement Polymer

**Master of Science**

Biomedical Engineering  
University of Kentucky  
December 2003

Augmenting Bone Cement with Multiwall Carbon Nanotubes

**Bachelor of Science**

Physics-Engineering  
Washington and Lee University  
June 2001.

### PROFESSIONAL POSITIONS

- 2008 – Present      Engineer Research Associate, Center for Applied Energy Research, University of Kentucky, Lexington, KY. (Part Time)
- 2007 – Present      Vice President for Research. NuForm Materials, LLC,      Sadieville, KY. (Part Time)
- 2007 – 2008      Post-Doctoral Scholar. Center for Applied Energy Research, University of Kentucky, Lexington, KY.
- 2006      Visiting Scientist. Finsbury Orthopaedics, Ltd, Surrey, United Kingdom and University of Southampton, Southampton, United Kingdom.
- 2002 – 2007      Graduate Research Assistant, Center for Applied Energy Research, University of Kentucky, Lexington, KY.
- 2000      Summer Research Assistant in Engineering, Washington and Lee University, Lexington, VA.

### PROFESSIONAL MEMBERSHIPS

- 2006 – Present American Carbon Society
- 2008 – Present APMI International

### PEER REVIEWED PUBLICATIONS AND ABSTRACTS

**Marrs B**, Andrews R, Rantell T, and Pienkowski D. “Flexural Properties of Polymethylmethacrylate Reinforced with Multiwalled Carbon Nanotubes.” Transactions of the 49<sup>th</sup> Annual Meeting of the Orthopaedic Research Society, 1461, 2003.

**Marrs B**, Andrews R, Rantell T, and Pienkowski D. "Multiwall Carbon Nanotubes Improve the Fatigue Performance of Bone Cement." Transactions for the International Workshop on Nanomaterials, page 69, 2004.

**Marrs B**, Andrews R, Rantell T, and Pienkowski D. "Multiwall Carbon Nanotubes Enhance the Fatigue Life of Bone Cement." Transactions of the 50<sup>th</sup> Annual Meeting of the Orthopaedic Research Society, 253, 2004.

Shaffer W, Margulies J, Cassidy C, **Marrs B**, Seeley M, Pienkowski D, Shapiro R. "Sacral fracture constructs: how can we understand the complex relationships of the pelvis to the lumbar spine?" 20<sup>th</sup> Annual Meeting of the North American Spine Society, 2005.

Shaffer W, Margulies J, Cassidy C, **Marrs B**, Seeley M, Pienkowski D, Shapiro R. "Sacroiliac Instability: A Novel Study of Scoliosis Constructs." Harrington Spine Symposium, University of Kansas, 2005.

**Marrs B**, Andrews R, Pienkowski D. "Multiwall Carbon Nanotubes Enhance the Fatigue Life of Physiologically Maintained Bone Cement." Carbon 2006: The International Carbon Conference, 2006.

**Marrs B**, Andrews R, Rantell T, Pienkowski D. "Augmentation of Bone Cement with Multiwall Carbon Nanotubes." Journal of Biomedical Materials Research Part A, 2006; 77A(2): 269 – 276.

**Marrs B**, Andrews R, Pienkowski D. "The Fatigue Life of Physiologically Maintained Bone Cement is Enhanced by Multiwall Carbon Nanotubes." Transactions of The International Conference on Carbon, page 19, 2006.

**Marrs B**, Andrews R, Pienkowski D. "Multiwall Carbon Nanotubes Affect the Fatigue Performance of Methyl Methacrylate Copolymer." Transactions for the Society for Biomaterials 2007 Annual Meeting and Exposition, 585, 2007.

Robl T, Groppo J, Perrone R, **Marrs B**. "Characteristics of Classified Fly Ash as Polymer Filler." Transactions of the World of Coal Ash, 2007.

**Marrs B**, Andrews R, Pienkowski D. "Multiwall Carbon Nanotubes Enhance the Fatigue Performance of Physiologically Maintained Methyl Methacrylate – Styrene Copolymer." Carbon, 2007; 45(10): 2098-2104.

**Marrs B**, Sinnott-Jones P, Sinclair I, Andrews R, Pienkowski D. "Multiwall Carbon Nanotubes Affect the Fatigue Crack Propagation of Orthopaedic MMA-co-Sty." Transactions of The International Conference on Carbon, 148, 2007.

**Marrs B**, Weisenberger M, Bortz D. "Fatigue Performance of Multiwall Carbon Nanotube – Polymer Composites" Transactions of The International Conference on Carbon, 147, 2007.

Bortz D, Weisenberger M, **Marrs B**, Andrews R. "Fatigue Performance of Multiwall Carbon Nanotube Composite PMMA and ABS." Proceedings of the International Mechanical Engineering Congress and Exposition, IMECE2008-67578, 2008.

**Marrs B**. "Improving the Performance of Medical Implants with Carbon Nanotubes." *Energeia*, 2008; 19 (3).

Tickle A, **Marrs B**, Giordani M, Andrews R, Pienkowski D. "Multiwall Carbon Nanotubes Alter the Polymerization Kinetics of Bone Cement." Transactions of the 55<sup>th</sup> Annual Meeting of the Orthopaedic Research Society, 561, 2009.

Tickle A, **Marrs B**, Giordani M, Andrews R, Pienkowski D. "Multiwall Carbon Nanotubes and Tobramycin Affect the Polymerization of Bone Cement." Transactions of The Society for Biomaterials 2009 Annual Meeting and Exposition, 2009.

**Marrs B**, Tickle A, Giordani M, Andrews R, Pienkowski D. "Multiwall Carbon Nanotubes Alter the Heat Flow Associated with Curing Bone Cement." Transactions of The Annual World Conference on Carbon, B11-2, 2009.

Bortz D, Weisenberger M, **Marrs B**, Andrews R. "Fatigue Performance of Multiwall Carbon Nanotube – Polymer Composites." Transactions of The Annual World Conference on Carbon, P3-95, 2009.

## **PATENTS AND INTELLECTUAL PROPERTIES**

**Marrs B**, Andrews R, Cunningham L. "Carbon Fiber Reinforced Carbon Foams for Repair and Reconstruction of Bone Defects" Serial No. 12/057,980. Filed March 28, 2008.

**Marrs B**, Andrews R. "A Multi-Component, Composite Intervertebral Disk System for Implantation." Case 1299, University of Kentucky, 30 September 2004.

**Marrs B**, Andrews R, Crocker M. "Changing the Radiopacity of Otherwise Radiolucent Material Systems by the Addition of Carbon Nanotubes Containing Radiopaque Particles Embedded on their Surface." Case 1300, University of Kentucky, 30 September 2004.

Shaffer W, Pienkowski D, Andrews R, **Marrs B**. "Method and Material for Using Nanomaterials to Treat Metastatic Tumors." Case 1365, University of Kentucky, 13 October 2005.

Pienkowski D, **Marrs B**. "Thermal Induced Biological Benefits of Carbon Nanotube Augmentation of Bone Cement." Case 1641, University of Kentucky, 22 January 2009.

## **PRESENTATIONS**

"Augmenting Bone Cement with Multiwall Carbon Nanotubes." Biomedical Engineering Departmental Seminar, University of Kentucky, Lexington, KY. 28 April 2003.

"Multiwall Carbon Nanotubes Enhance the Fatigue Life of Bone Cement." Podium Presentation, 50<sup>th</sup> Annual Meeting of the Orthopaedic Research Society, San Francisco, CA. 9 March 2004.

"Multiwall Carbon Nanotubes and Orthopaedic Prostheses." Invited presentation Surgery Research Colloquium, University of Kentucky, Lexington, KY. 19 January 2005.

"Multiwall Carbon Nanotubes Enhance the Fatigue Performance of Physiologically Maintained Bone Cement." Podium Presentation, Carbon 2006: The International Conference on Carbon, Aberdeen, Scotland. 16-21 July 2006.

“On the Path to Realization of High Performance Implantable Materials: MWNT – Bone Cement Composites.” Biomedical Engineering Departmental Seminar, University of Kentucky, Lexington, KY. 15 September 2006.

“Characteristics of Classified Fly Ash as Polymer Filler.” Podium Presentation, World of Coal Ash, Northern Kentucky Convention Center, South Side of Cincinnati, OH. 9 May 2007.

“Thermal and Mechanical Properties of Carbon Nanotube Composites.” Keynote Presentation, NanoComposites Workshop, Composites at Lake Louise, Alberta, Canada. 30 October 2007.

“Multiwall Carbon Nanotubes Alter the Heat Flow Associated with Curing Bone Cement.” Podium Presentation, The Annual World Conference on Carbon, Biarritz, France. 17 June 2009.

## **GRANTS AND CONTRACTS**

### **Active**

Marrs B (PI). “NSF SBIR Phase II: Improved Manufacturing Methodology for Aluminum Ash Metal Matrix Composite Materials.” National Science Foundation, \$499,376, 7/15/2009 – 6/30/2011.

### **Completed**

Marrs B (PI). “Improved Manufacturing Methodology for Aluminum Ash Metal Matrix Composite, MMC, Materials from Powder Metallurgy, P/M.” Kentucky Cabinet for Economic Development Department of Commercialization and Innovation, \$98,602, 3/1/2007 – 6/30/2009.

Marrs B (PI). “NSF SBIR Phase I: Improved Manufacturing Methodology for Aluminum Ash Metal Matrix Composite Materials.” National Science Foundation, \$123,530, 1/1/2008 – 12/31/2008.

Marrs B (PI). “Carbon Fiber Reinforced Carbon Foams for the Repair of Bone Defects.” Kentucky Science and Engineering Foundation, \$4,000, 10/5/2007 – 11/8/2007.

## **TECHNICAL EXPERIENCE**

**Doctoral Research**, University of Kentucky, September 2003 – April 2007.

Manufactured and processed composite materials comprised of acrylic bone cement reinforced with various concentrations of multiwall carbon nanotubes. Established and executed protocols for fatigue testing carbon nanotube – bone cement composites using a servohydraulic testing system in a variety of testing modes and environments. Analyzed fatigue data using the two- and three-parameter Weibull models. Collaborated with the University of Southampton to characterize the fatigue crack behavior of carbon nanotube – bone cement composites. Investigated fatigue cracking in carbon nanotube – bone cement composites using 3-dimensional x-ray tomography at the European Synchrotron Radiation Facility (ESRF) as part of an international collaboration. Characterized the fracture toughness and fracture properties of carbon nanotube – bone cement composites. Performed fractographic analysis on the fracture surfaces of mechanically tested specimens using scanning electron microscopy. Studied the effects of carbon nanotubes on the thermal/polymerization properties of bone cement using differential scanning calorimetry (DSC), thermogravimetric analysis (TGA), dynamic mechanical analysis (DMA), and laser flash analysis (LFA). Performed chemical functionalization treatments on carbon nanotubes to optimize interactions between phases of the composites.

**Graduate Research Assistant**, Center for Applied Energy Research, University of Kentucky, November 2002 – Present.

Worked extensively with thermoplastics, thermosets, and thermoplastic elastomers. Used polymer processing techniques to produce composite materials reinforced with various carbon materials. Utilized a variety of material characterization techniques including TGA, DSC, DMA, LFA, surface resistivity, quasi-static and dynamic mechanical testing (electro-mechanical and servohydraulic systems), and optical and scanning electron microscopy. Studied and determined the reinforcing mechanisms of carbon nanotubes in a variety of polymer matrices. Utilized an array of techniques and reactions to change the surface chemistry of carbon nanotubes. Developed proposals for government funding agencies and industry. Presented results from ongoing research in regularly scheduled group meetings. Regularly participated in administrative and advisory board meetings.

**Visiting Scientist**, Finsbury Orthopaedics Ltd., United Kingdom, March 2006 – August 2006.

Invited by Finsbury Orthopaedics Ltd to lead a six month research effort focused on developing carbon nanotube – bone cement composites. Established and presented the goals of the project to managerial staff including the Managing Director, Research & Development Director, design engineers, and financial and regulatory advisors, among others. Coordinated and directed meetings with the financial and R&D divisions of Finsbury Orthopaedics, Ltd and faculty from the University of Southampton (United Kingdom). Developed carbon nanotube – bone cement composites and characterized their handling, thermal, and mechanical properties. Collaborated with faculty, staff, and students at the University of Southampton to achieve the goals of the Finsbury project. Established, followed, and met project deadlines and reporting periods. Reported results periodically to Finsbury Orthopaedics, Ltd as well as to the Department of Trade and Industry (United Kingdom).

**Consultant/Researcher**, University of Kentucky, 2003 – present

Collaborated with faculty from the Department of Orthopaedics at the University of Kentucky to characterize and compare the mechanical performance of five clinically used lumbo-pelvic fixation devices instrumented on anatomically correct polymer models. Designed a custom fixture to anatomically fit pelvic models and mimic one legged stance. Developed and implemented protocol for measuring quasi-static and dynamic performance of each device using a servohydraulic system. Collaborated with faculty, staff, and students from Oral and Maxillofacial Surgery to characterize and compare the mechanical performance of mandible fracture fixation devices on polyurethane mandible models. Performed mechanical testing, statistical analysis, and contributed to the conclusions of the study. Performed mechanical testing on two spinal fixation devices (one anterior, one posterior) on behalf of Scient'x USA. Designed and modified test fixtures to complete compression, torsion, and fatigue testing of the 1.95 mm Stella low profile cervical plate (which is now on the market) to meet the requirements of the Spinal System 510(k)s.

**Masters Research**, University of Kentucky, August 2001 – August 2003.

Manufactured and processed carbon nanotube – bone cement composite materials using clinical and non-clinical techniques. Characterized the quasi-static mechanical performance of carbon nanotube – bone cement composites in tension, 3-point, and 4-point bending. Performed fractographic analysis with scanning electron microscopy.

**Research Assistant**, Washington and Lee University, June 2000 – August 2000.

Designed and implemented a variety of test fixtures for use with dynamic mechanical analysis. Investigated the efficacy of the test fixtures for measuring the dynamic properties of plasma during clotting.

## **TEACHING EXPERIENCE**

**Course Instructor**, BME 501 Foundations of Biomedical Engineering, University of Kentucky, November 2003 – December 2003.

Lectured and tested on musculoskeletal biomechanics. Wrote and graded exams.

**Lab Assistant**, BME 530 Biomedical Instrumentation, UK, April 2003, 2005.

Designed and conducted experiments for class. Demonstrated techniques and assisted students in the laboratory.

**Guest Lecturer**, Orthopaedic Basic Science Lecture Series, UK, November 2003.

Lectured on biomaterials used in orthopaedics, especially polymers. Orthopaedic Residency Basic Science Education Program.