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Structure-Property Relationships in Biomineralized and Bio-mimetic Composites

Current world technologies and environments rely in large measure upon a growing need for the development of new structural materials with high strength and durability, toughness, light weight, low cost, and complete recyclability. Such materials may be derived synthetically, but Nature has evolved efficient strategies, exemplified in the mineralized tissues of numerous species, that have led to low-weight structural materials that exhibit exceptional strength, durability, and other unique and important properties. In these biomineralized systems, minerals and proteins or additional molecules exist in close proximity and at a various length scales, through their hierarchical structure from nano- to microscale dimensions. Interactions at these inorganic-organic interfaces are vital to the functions of a great variety of structural materials and biological tissues found in the biosphere, including, for example, the shells of mollusks and the bones and teeth of vertebrates.

An active and constantly growing area of research explores the structure-mechanical property relationships of these biomineralized composites with the intention of applying this body of knowledge to the study and mimicry of biomimetic composite materials that can play key roles in developing new materials and structures. The resulting materials will offer a new combination of low weight, high strength/toughness and multifunctionality to break traditional engineering paradigms in a radical manner, and they could benefit a wide spectrum of applications including those related to the automotive industry, energy, shipbuilding, defense, and civil and aerospace engineering. Moreover, studies of biological materials, such as bones and teeth, are also of great importance in the health care arena. The development of biomaterials and tissue-engineered materials is crucial for those instances in which tissues and biological materials need to be replaced, repaired or regenerated because of congenital defects of individuals, injury and other forms of external/internal damage, or disease.

The characterization and study of these materials require the use of modern tools such as electron and scanning probe microscopy, small-scale mechanical testing capabilities, and advanced multiscale numerical models and simulation techniques. At the same time, these investigations are best accomplished through multidisciplinary approaches and so require the close collaboration among material scientists, chemists, physicists, mechanicians, bioengineers, clinicians and biologists. The main purpose of Symposium KK held at the 2009 MRS Spring Meeting was to bring together hundreds of scientists and researchers working in the diverse and interdisciplinary areas of biomineralized and biomimetic composite materials. Over 90 oral and poster presentations were given over a period of four days, including those by 20 internationally recognized invited speakers from academia, national laboratories, industries, government, and international institutions. The topics discussed included modeling and simulation of mechanical properties in biomineralized and mimetic systems, experimental design, synthesis and properties in biomineralized and mimetic systems, experimental design, synthesis and properties of biomimetic composites, structure-function properties of biomineralized tissues, biomaterials for tissue engineering, investigation of biomineralized tissue ultrastructure (inorganic and organic), quantitation of the ultrastructural response of the organic and inorganic phases in biological composites to mechanical stresses, and use of high resolution in situ synchrotron and spectroscopic techniques. These specific subjects were categorized and detailed in ten sessions, each demonstrating
the interdisciplinary and distinctive nature of this interesting and significant area of research. A collection of several representative papers is included in the Proceedings Volume 1187.

The organizers acknowledge that the success of Symposium KK depended critically on the full participation of excellent researchers and scientists as well as graduate students. The organizers are also extremely grateful to MRS for making this Symposium possible through its dedicated work before, during and following the Meeting and to the volunteer students who kindly assisted with audio and video help during the sessions. We also thank Gatan UK, the Journal of Materials Chemistry, Nanoforce Technology, Ltd, the Office of Naval Research and the U.S. Department of Energy for their generous and substantial financial support.
Symposium KK: Structure-Property Relationships in Biomineralized and Biomimetic Composites

Structure-Property Relationships in Biomineralized and Biomimetic Composites
April 14 - 17, 2009

Chairs
David Kisailus
Lara Estroff
William Landis
Pablo Zavattieri
Himadri S. Gupta

University of California-Riverside
Cornell University
Northeastern Ohio Universities College of Medicine
GM Research & Development Center
Queen Mary University of London

Symposium Support
Gatan UK
J. Materials Chemistry
Nanoforce Technology Ltd
Office of Naval Research
U. S. Department of Energy

* Invited paper

SESSION KK1: Structure-Function Relationships in Biomineralized Tissues I
Chairs: David Kisailus and Eli Sone
Tuesday Morning, April 14, 2009
Room 3024 (Moscone West)

8:30 AM *KK1.1
Brachiopod Shells Control the Material Properties of Calcite. Maggie Cusack1, Alberto Perez-Huerta1 and Wenzhong Zhu2;
1Geographical & Earth Sciences, University of Glasgow, Glasgow, United Kingdom; 2Scottish Centre for Nanotechnology in Construction Materials, University of the West of Scotland, Paisley, United Kingdom.

9:00 AM KK1.2
Abstract Withdrawn

9:15 AM KK1.3
Nacre Evolution: A Proteomic Approach. Benjamin Marie1, Gilles Luquet1, Arul Marie2, Lionel Dubost2, Milet Christian3, Laurent Bedouet3, Michel Becchi4, Isabelle Zanella-Cleon* and Frédéric Marin1; 1Umr 5561 Biogeosciences, University of Burgundy, Dijon, Burgundy, France; 2Département RDOM, MNHN, Paris, France; 3UMR CNRS 5178, BOME, MNHN, Paris, France; 4UMR 5086 CNRS, IBPC, Lyon, France.

9:30 AM KK1.4

9:45 AM KK1.5
Mechanical Function of a Complex Three-dimensional Suture Joining the Bony Elements in the Shell of the Red-eared Slider Turtle. Ron Shahar1, Stefanie Krauss3, Efraim Monsonoge3 and Peter Fratzl2; 1Koret school of Veterinary Medicine, The Hebrew University of Jerusalem, Rehovot, Israel; 2Department of Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; 3Institute of Biochemistry and Nutrition, The Hebrew University of Jerusalem, Rehovot, Israel.

10:00 AM BREAK
10:30 AM *KK1.6
Glass in Sponges. Joanna Aizenberg1, Peter Fratzl2 and James C Weaver3; 1Harvard University, Cambridge, Massachusetts; 2MPI, Golm, Germany; 3UC Riverside, Riverside, California.

11:00 AM KK1.7
Functional Biomimetics - Structure-Property Correlations in Hybrid Biological Tissues Mehmet Sankaya1,2, Hanson Fong1,2,4, Malcolm L Sneed1,4 and Martha Somerman5; 1Genetically Engineered Materials Science and Engineering Center, University of Washington, Seattle, Washington; 2Materials Science and Engineering, University of Washington, Seattle, Washington; 3Dental School, University of Washington, Seattle, Washington; 4Craniofacial Molecular Genetics, University of Southern California, Los Angeles, California.

11:15 AM KK1.8
High Performance Impact-Tolerant and Abrasion-Resistant Materials: Lessons From Nature James C Weaver3, Anthony Tanliucio1,2, Jie Lian2, Sabrina Louie1, Junian Wang2 and David Kisailus1; 1Chemical and Environmental Engineering, UC Riverside, Riverside, California; 2Mechanical Engineering, UC Riverside, Riverside, California; 3Chemical Engineering, The Cooper Union for the Advancement of Science and Art, New York, New York.

11:30 AM KK1.9
Effect of Alport Syndrome Mutations in Tropocollagen on Molecular and Microfibrillar Mechanical Properties. Maya Srinivasan1,2, Sinan Kelen2, Alfonso Gautieri1,2 and Markus J Buehler2; 1Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey; 2Laboratory for Atomistic and Molecular Mechanics, Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts; 3Cellular and Molecular Biomechanics Research Group, Department of Bioengineering, Politecnico di Milano, Milan, Italy.

11:45 AM KK1.10
Influence of Scaffold Composition on Gene Expression and Cellular Organization in Tissue-engineered Middle Phalanx Models of Human Digits. William Joel Lands1, Yoshitaka Wada1,2,3, Robin Jacquet1, Elizabeth Lowder1 and Noritaka Isogai2,1; 1Integrative Medical Sciences, Northeastern Ohio Universities Colleges of Medicine and Pharmacy, Rootstown, Ohio; 2Plastic and Reconstructive Surgery, Kinki University Medical School, Osaka, Japan.

SESSION KK2: Structure-Function Relationships in Biomineralized Tissues II
Chairs: Lara Estroff and Christine Orme
Tuesday Afternoon, April 14, 2009
Room 3024 (Moscone West)

1:30 PM *KK2.1
Alternative to DOPA in a Mussel Adhesive Protein. Herbert Waite, Marine Science Institute, UCSB, Santa Barbara, California.

2:00 PM *KK2.2
Plant Actuation by the Swelling of Cellulose Nanocomposite Architectures. Peter Fratzl and Ingo Burgert; Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Germany.

2:30 PM KK2.3
Adhesive Structure of the Freshwater Zebra Mussel, Dreissena polymorpha. Nikroz Farsad1, Trevor W Gilbert2 and Eli D Sone1,2,3; 1Materials Science & Engineering, University of Toronto, Toronto, Ontario, Canada; 2Institute of Biomaterials & Biomedical Engineering, University of Toronto, Toronto, Ontario, Canada; 3Faculty of Dentistry, University of Toronto, Toronto, Ontario, Canada.

2:45 PM KK2.4
Nano-Porous Sucker Rings from Dosidicus gigas. Miserez AN1,2,3, James C Weaver4, Peter B Pedersen5, Todd Schneeberk2, Roger Hanlon5, David Kisailus1 and Henrik Birkedal1; 1Department of Chemistry & Interdisciplinary Nanoscience Center, Aarhus University, Aarhus, Denmark; 2Department of Molecular, Cellular, and Developmental Biology, University of California, Santa Barbara, Santa Barbara, California; 3Materials Department, University of California, Santa Barbara, Santa Barbara, California; 4Department of Chemical and Environmental Engineering, University of California, Riverside, Riverside, California; 5Marine Biological Laboratory, Woods Hole, Massachusetts.

3:00 PM BREAK

3:30 PM *KK2.5
In-vitro Mechanical Testing of Single Collagen Nanofibrils. Steven Eppell1, Zhilei Liu Shen1, Reza Daj1, Harold Kahn2 and Roberto Ballarin3; 1Biomedical Engineering, Case Western Reserve University, Cleveland, Ohio; 2Materials Science and Engineering, Case Western Reserve University, Cleveland, Ohio; 3Civil Engineering, University of Minnesota, Minneapolis, Minnesota.

4:00 PM *KK2.6
Cement Lines and Bone Quality - A Lesson from Studies of Long-lasting Cement Lines in Osteopetrotic Bones of Aging c-sgc Deficient Mice. Yoshiro Takano, Biostructural Science, Dept. of Hard Tissue Engineering, Tokyo Medical and Dental School, Tokyo, Japan.

4:30 PM KK2.7

4:45 PM **KK2.8**
Damage and Crack Evolution in Mammalian Enamel **James Jin-Wu Lee**1,2, Brian R Lawn1, Paul Constantino2 and Peter Lucas2; 1Ceramics Division, National Institute of Standards and Technology, Gaithersburg, Maryland; 2George Washington University, Washington, District of Columbia.

SESSION KK3: Structure-Property Relationships in Biomimetic Composites I

8:30 AM **KK3.1**
Spider Silk as a Novel High Performance Biomimetic Muscle Driven by Humidity. **Ingi Agnarsson**2, **Ali Dhinoiwala**1, Vasav Sahni1 and Todd Blackledge2; 1Polymer Science, The University of Akron, Akron, Ohio; 2Intergrated Bioscience Program, The University of Akron, Akron, Ohio.

9:00 AM **KK3.2**
Silk/Silica Biomaterials for Bone Remodeling **Aneta Joanna Mieszawska**1, Carole C Perry2 and David L Kaplan1; 1Biomedical Engineering, Tufts University, Medford, Massachusetts; 2School of Science and Technology, Nottingham Trent University, Nottingham, United Kingdom.

9:15 AM **KK3.3**
Genetically Engineered Chimeric silk/ Metal Binding Proteins. **Heather Currie**1, Rajesh R Naik2, Carole C Perry3 and David L Kaplan1; 1Department of Biomedical Engineering, Tufts University, Medford, Massachusetts; 2Materials and Manufacturing Directorate, Air Force Research Laboratory, Wright-Patterson Air Force Base, Dayton, Ohio; 3School of Science and Technology, Nottingham Trent University, Nottingham, United Kingdom.

9:30 AM **KK3.4**
Effect of CaSiO3 structure and texture on the in vitro behavior of Human Mesenchymal Stem Cells. **Nianli Zhang**1, Nita Sahai1,3, Jim Molenda2 and William Murphy2; 1Department of Geology and Geophysics, University of Wisconsin - Madison, Madison, Wisconsin; 2Department of Biomedical Engineering, University of Wisconsin - Madison, Madison, Wisconsin; 3Department of Chemistry, University of Wisconsin - Madison, Madison, Wisconsin.

9:45 AM **KK3.5**
Modeling the Mechanical Properties of a Soft Matrix in Biological Composites. **Markus A. Hartmann** and Peter Fratzl; Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany.

10:00 AM BREAK

10:30 AM **KK3.6**
Biologically inspired Strategies for Interfacial Control in Polymer Nanocomposites. **Phillip Messersmith**, Biomedical Engineering, Northwestern University, Evanston, Illinois.

11:00 AM **KK3.7**

11:15 AM **KK3.8**
Controlled Magnetite Formation by Mimic Peptides from the Mms6 Protein of Magnetotactic Bacteria. **Atsushi Arakaki**, Fukashi Masuda, Yosuke Amemiya and Tadashi Matsuana; Life Science and Biotechnology, Tokyo university of Agriculture and Technology, Tokyo, Japan.

11:30 AM **KK3.9**
Abstract Withdrawn

SESSION KK4: Structure-Property Relationships in Biomimetic Composites II

Chairs: Himadri Gupta and Nico Sommerdijk
Wednesday Afternoon, April 15, 2009
Room 3024 (Moscone West)

1:30 PM **KK4.1**

2:00 PM **KK4.2**
2:30 PM KK4.3
Single Crystals with Incorporated Polymer Networks: Hierarchical Structures and Improved Mechanical Properties.

Hanyou Li1, Huolin L Xin2, David A Muller3 and Lara A Estroff1; 1Material Science and Engineering, Cornell University, Ithaca, New York; 2Department of Physics, Cornell University, Ithaca, New York; 3School of Applied and Engineering Physics, Cornell University, Ithaca, New York.

2:45 PM KK4.4
Crystallisation of Calcium Carbonate within Controlled Microenvironments Yi-Yeoun Kim1, Chris Stephens2, Nicola B Hetherington1, Ana-Paula Ramos1, Hugo K Christensen2 and Fiona C Meldrum1; 1Chemistry, University of Bristol, Bristol, United Kingdom; 2Physics, University of Leeds, Leeds, Yorkshire, United Kingdom.

3:00 PM BREAK

3:30 PM *KK4.5
Overview of Biomimetic Composites for Morphing Wing Skins Christopher Henry and Geoff McKeilent; Active Materials and Adaptive Structures, HRL Laboratories LLC, Malibu, California.

4:00 PM *KK4.6

4:30 PM KK4.7
Mechanical Analysis of Macromodels of Biomimetic Composite Materials using Rapid Prototyping Techniques Mark Cooper1, Katherine Frank1, Phillip Russel1, Michael Waters1, Alejandro H Strachan1 and Pablo D. Zavattieri2; 1School of Materials Engineering, Purdue University, West Lafayette, Indiana; 2General Motors Research and Development Center, Warren, Michigan.

4:45 PM KK4.8
Structure and Stability of Bio-Inspired Calcite Crystals Studied by X-Ray Techniques Anna Sophia Schenk1, Barbara Aichmayer1, Oskar Paris3, Helmut Köffler2, Christine Lausser2 and Peter Fratzl2; 1Department of Biocatastic Materials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; 2Department of Chemistry, University of Aarhus, Aarhus, Denmark; 3Marine Biological Laboratory, Woods Hole, Massachusetts.

SESSION KK5: Poster Session: Structure-Property Relationships in Biomimeralized and Biomimetic Composites

Chairs: Lara Estroff, Himadi Gupta, David Kisailus, William Landis and Pablo Zavattieri
Wednesday Evening, April 15, 2009
8:00 PM
Salon Level (Marriott)

KK5.1
Microstructural and Biochemical Characterization of the Nano-porous Sucker Rings from Dosidicus gigas James C. Weaver1, Ali Miserez2, Peter B Pedersen3, Todd Schneeberk2, Roger T Hamon4, Henrik Birkedal5 and David Kisailus6; 1Department of Chemical and Environmental Engineering, University of California, Riverside, Riverside, California; 2Materials Department, University of California, Santa Barbara, Santa Barbara, California; 3Department of Chemistry, University of Aarhus, Aarhus, Denmark; 4Marine Biological Laboratory, Woods Hole, Massachusetts.

KK5.2
Osteogenesis Imperfecta Mutations In Tropocollagen Protein Domains Lead to Molecular Softening and Reduced Intermolecular Adhesion. Alfonso Gautieri2, Maya Strinivasan1, Sinan Keten1, Mark Buehler2, 1Mechanical and Aerospace Engineering, Princeton University, Princeton, New Jersey; 2Laboratory for Atomic and Molecular Mechanics, Department of Civil and Environmental Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts; 3Cellular and Molecular Biomechanics Research Group, Department of Bioengineering, Politecnico di Milano, Milan, Italy.

KK5.3
Characterization of Crustacyanin A2 Subunit as a Component of the Organic Matrix of the Cherax quadricarinatus Gastroliths Gilles Lucquet1, Nathalie Le Roy1, Sergio Bucarey2, Isabelle Zanella-Cléon3, Michel Becchi3, Maria Soledad Fernandez2, Jose Luis Arias2, Nathalie Guichard1, Benjamin Marie1 and Frédéric Marin1; 1UMR 5561 CNRS-Université de Bourgogne, Laboratoire de Biogéosciences, Dijon, France; 2Faculty of Veterinary and Animal Sciences, University of Chile, and Centre for Advanced Interdisciplinary Research in Materials (CIMAT), Santiago, Chile; 3Institut de Biologie et Chimie des Protéines, UMR 5086 CNRS-Université Lyon 1, Laboratoire de Spectrométrie de Masse, Lyon, France.

KK5.4
Mechanical Properties and Surface Characterization of Calcium Carbonate Platelets Extracted from Freshwater Pearl Shell. Xing Chen. NUANCE Center, Northwestern University, Evanston, Illinois.

KK5.5
Extreme Mechanical Anisotropy in Bone at the Mesoscale. Jong Sato1, Himadi S. Gupta2, Paul Zasiansky1, H. D Wagner2 and Peter Fratzl3; 1Department of Biocatastic Materials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; 2Materials and Interfaces, Weizmann Institute of Science, Rehovot, Israel; 3Queen Mary University of London, School of Engineering and
KK5.6
Effects of fetuin-A Deficiency on the Material Bone. Jong S. Seto1, Himadri S. Gupta3, Stefanie Krauss1, John Dunlop1, Admir Masic1, Willi Jahnen-Dechent2 and Peter Fritz1; 1Department of Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; 2Biomedical Engineering, Biointerface Group, RWTH Aachen University, Aachen, Germany; 3Queen Mary University of London, School of Engineering and Materials Science, London, United Kingdom.

KK5.7
Abstract Withdrawn

KK5.8
In Vitro Human Osteoblast Responses to Titanium Oxide-Based Surfaces with Varying Topology and Composition. Charles Andrew Collier1, Helen J Griffiths1, Athina E Markaki2, James A Curran1 and T. W Clyne1; 1Materials Science and Metallurgy, University of Cambridge, Cambridge, Cambridgeshire, United Kingdom; 2Department of Engineering, University of Cambridge, Cambridge, Cambridgeshire, United Kingdom.

KK5.9
Phases, Composition and Microstrain in the Mineralized Byssus of Anomia. Henrik Birkedal and Jakob R Eltzholtz; Department of Chemistry & Interdisciplinary Nanoscience Center, Aarhus University, Aarhus, Denmark.

KK5.10
Shell Recovery Process In the Clam Ruditapes Phillippinarum, Affected by the Brown Ring Disease (BRD): a Biochemical Study. Notwenn Trinkler1, Frederic Marin2, Nathalie Guichard2, Maylis Labonne1, Christine Paillard1 and Jean-Francois Bardeau2; 1LEMAR UMR CNRS 6539, IUEM UBO, Plouzané, France; 2Laboratoire de Biogéoscience UMR 5561, UB, Dijon, France.

KK5.11
Abstract Withdrawn

KK5.12
Abstract Withdrawn

KK5.13
Novel Dental Restorative Composites having Excellent Mechanical Properties and Reduced Volumetric Shrinkage during Polymerization. Sun H Yoo, You S Chung and Chang Keun Kim; School of Chemical Engineering & Materials Science, Chung-Ang University, Seoul, Korea, South.

KK5.14
Molecular Recognition at the Organo-Mineral Interface between Protein and Bone. Jonathan James Phillips1,2 and Seung-Wuk Lee1,2; 1Bioengineering, UC, Berkeley, Berkeley, California; 2Physical Biosciences, Lawrence Berkeley National Laboratory, Berkeley, California.

KK5.15
Abstract Withdrawn

KK5.16
Nanosilica Formation at Lipid Membranes Induced by Silaffin Peptides. Michael Kent1, Jaclyn Murton1, Frank Zendejas2, Huu Tran3, Blake Simmons2, Sushil Satija4 and Ivan Kuzmenko5; 1Sandia National Labs, Albuquerque, New Mexico; 2Sandia National Labs, Livermore, California; 3National Institute of Standards and Technology, Gaithersburg, Maryland; 4Argonne National Labs, Argonne, Illinois.

KK5.17
Synthesis Of Porous Calcium Phosphate Nanotubes. Deepa Khushalani1, Dept. of Chemical Sciences, TIFR, Mumbai, MH, India.

KK5.18
The Effect of Silk Fibroin Hydrogels, Peptides, and β-chitin on Calcium Carbonate Crystallization: A Synthetic Model for Nacre Formation. Ellen C Keene1, John S Evans2 and Lara A Estroff3; 1Material Science & Engineering, Cornell University, Ithaca, New York; 2Laboratory of Chemical Physics, New York University, New York City, New York.

KK5.19
Abstract Withdrawn

KK5.20
Electrical Characterization of Functionalized Diatom Pinnularia sp. Biosilica. Timothy Gutu1, Clayton Jeffryes2, Gregory L Rorrer2 and Jun Jiao1; 1Department of Physics, Portland State University, Portland, Oregon; 2Department of Chemical Engineering, Oregon State University, Corvallis, Oregon.

KK5.21
Numerical Studies and Dimensional Analysis for Designing Bio-Inspired Composite Materials. Jee E Rim1, Pablo D.
Zavattieri\textsuperscript{2} and Horacio D Espinosa\textsuperscript{1}; \textsuperscript{1}Department of Mechanical Engineering, Northwestern University, Evanston, Illinois; \textsuperscript{2}General Motors Research and Development Center, Warren, Michigan.

KK5.22
Abstract Withdrawn

KK5.23
Composite Biomaterial of Ceramic-polymer: Development and Characterization. Miriam Estevez, Rogelio Rodriguez, Angel M Escamilla and Ana Leonor Rivera; Centro de Física Aplicada y Tecnología Avanzada, Universidad Nacional Autonoma de México, Queretaro, Gro, Queretaro, Mexico.

KK5.24
Coating Electrospun Poly(ε-caprolactone) Fibers with Gelatin and Calcium Phosphate for Bone Tissue Engineering Xiaoran Li\textsuperscript{1,2}, Jingwei Xie\textsuperscript{1}, Xiaoyan Yuan\textsuperscript{2} and Younan Xia\textsuperscript{1}; \textsuperscript{1}Department of Biomedical Engineering, Washington University in St. Louis, St. Louis, Missouri; \textsuperscript{2}School of Materials Science and Engineering, Tianjin University, Tianjin, China.

KK5.25
Transferred to KK3.4

KK5.26
Self-healable Biopolymers for Drug Delivery and Tissue Engineering Xuanhe Zhao, Nathaniel D Huebsch, David J Mooney and Zhigang Suo; School of Engineering and Applied Science, Harvard University, Cambridge, Massachusetts.

KK5.27
Thermal and Melt Property Characterization of Biodegradable Polyesters for Batch-Foaming. Qi Liao and Curt W Frank; Department of Chemical Engineering, Stanford University, Stanford, California.

KK5.28
Amino- and Carboxy-functionalized Nano- and Microstructured Surfaces for Evaluating the Impact of Non-biological Stimuli on Adhesion, Proliferation and Differentiation of Primary Skin-cells. Petra Kluger\textsuperscript{2}, Kirsten Borchers\textsuperscript{1}, Achim Weber\textsuperscript{1}, Guenter E Tovar\textsuperscript{1,2} and Heike Mertsching\textsuperscript{1}; \textsuperscript{1}Biomimetic Interfaces, Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, Stuttgart, Germany; \textsuperscript{2}Cell Systems, Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB, Stuttgart, Germany; \textsuperscript{3}Institute for Interfacial Engineering, University of Stuttgart, Stuttgart, Germany.

KK5.29
Synthesis and Characterization of Novel Biodegradable and Injectable Hydrogels for Tissue Engineering based on PLA-PEG-PLA Block Copolymers. Kevin W. Worrell and Karl I Jacob; Polymere, Textile & Fiber Engineering, Georgia Institute of Technology, Atlanta, Georgia.

KK5.30
P(LL-lactide) / pseudowollastonite-based Composites : New Biomimetic Materials for Bone Regeneration. Deborah Therese-Joséphine Barone\textsuperscript{1}, Pascal Viville\textsuperscript{2}, Jean-Marie Raquez\textsuperscript{1}, Alexandra Belayew\textsuperscript{2} and Philippe Dubois\textsuperscript{1}; \textsuperscript{1}Laboratory of Polymers and Composite Materials, University of Mons-Hainaut, Mons, Belgium; \textsuperscript{2}Laboratory for Chemistry of Novel Materials, University of Mons-Hainaut, Mons, Belgium; \textsuperscript{3}Laboratory of Molecular Biology, University of Mons-Hainaut, Mons, Belgium.

KK5.31
Enhancement of Osteoclastic Differentiation of Mouse Bone Marrow Cells Cultured on Hydroxyapatite/collagen Bone-like Nanocomposite. Masanori Kikuchi\textsuperscript{1} and Atsushi Irie\textsuperscript{2}; \textsuperscript{1}Biomaterials Center, National Institute for Materials Science, Tsukuba, Japan; \textsuperscript{2}Biomembrane Signaling Project, Tokyo Metropolitan Institute of Medical Science, Tokyo, Japan.

KK5.32
Digital Image Correlation shows Localized Deformation Bands in Inelastic Tensile Loading of Fibrolamellar Bone. Michael Kerschnitzki\textsuperscript{1}, Gunthard Benecke\textsuperscript{1}, Peter Fratzl\textsuperscript{1} and Himadri S Gupta\textsuperscript{2}; \textsuperscript{1}Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Brandenburg, Germany; \textsuperscript{2}School of Engineering and Materials Science, Queen Mary, University of London, London, United Kingdom.

KK5.33
Abstract Withdrawn

KK5.34
In vitro Studies of DSS-8 Peptide on Nano-mechanical Behaviors for Remineralized Human Dentin Chia-Chan Hsu\textsuperscript{1}, Hsuyiung Chung\textsuperscript{1}, Elizabeth Marie Hagerman\textsuperscript{2}, Jenn - Ming Yang\textsuperscript{1} and Benjamin M Wu\textsuperscript{1,2}; \textsuperscript{1}Materials Science and Engineering, UCLA, Los Angeles, California; \textsuperscript{2}Department of Bioengineering, UCLA, Los Angeles, California.

KK5.35

KK5.36
The Substrate Effect on the Cell Properties from Indentation Measurement. Guoxin Cao and Names Chandra; University of
Nebraska-Lincoln, Lincoln, Nebraska.

KK5.37
Abstract Withdrawn

KK5.38
Indentation and Uniaxial Compression Study of Enamel’s Elastic/plastic Behavior from Nanometer to Millimeter Length Scale. Siang Fung Ang1, Stefan Habelitz2, Arndt Klocke3,4, Mike Swain5,6 and Gerold A Schneider1; 1Institute of Advanced Ceramics, Hamburg University of Technology, Hamburg, Germany; 2Division of Biomaterials and Bioengineering, Department of Preventive and Restorative Dental Sciences, University of California, San Francisco, San Francisco, California; 3Division of Orthodontics, Department of Orofacial Sciences, University of California, San Francisco, San Francisco, California; 4Department of Orthodontics, University Medical Center Hamburg-Eppendorf, Hamburg, Germany; 5Faculty of Dentistry, The University of Sydney, Sydney, New South Wales, Australia; 6University of Otago, Dunedin, Otago, New Zealand.

KK5.39

KK5.40
Structure and Mechanical Properties of Horn Keratin. Ekaterina Evdokimenko1, Luca Tombolato1, Jerry Curiel1, Po-Yu Chen2 and Joanna McKittrick1, 2; 1Mechanical and Aerospace Engineering, University of California, San Diego, La Jolla, California; 2Materials Science and Engineering, University of California, San Diego, La Jolla, California.

KK5.41
Exploring Nucleation in Biomimetic Systems Through In Situ, Fluid Cell TEM. Michael H Nielsen1,2, Jonathan R Lee2 and James J De Yoreo1; 1Lawrence Berkeley Lab, Berkeley, California; 2Lawrence Livermore National Lab, Livermore, California.

SESSION KK6: Reversible Deformation and Fracture Mechanics of Biological Composites I
Chairs: Himadri Gupta and William Landis
Thursday Morning, April 16, 2009
Room 3024 (Moscone West)

8:30 AM *KK6.1
Phosphorylated Proteins May Play a Significant Role in the Fracture Resistance of Bone. Paul Hansma, University of California, Santa Barbara, California.

9:00 AM KK6.2
Statistical Model of the Dynamic Mechanical Response of Nacre. Mark H. Jhon1,2 and Daryl C Chrzan1,2; 1Department of Materials Science and Engineering, University of California, Berkeley, Berkeley, California; 2Materials Sciences Division, Lawrence Berkeley National Laboratory, Berkeley, California.

9:15 AM KK6.3
The Structural and Mechanical Design of Interfaces in Palms and Reeds. Markus Ruegeberg1,2, Thomas Speck1 and Ingo Burgert1; 1Biomaterials, Max-Planck-Institute of Colloids and Interfaces, Potsdam, Germany; 2Botanic Garden, Faculty of Biology, University of Freiburg, Freiburg, Germany.

9:30 AM KK6.4
Nano-/micro-structural Response of the Collagen/matrix Composite in Human Arterial Adventitia Links to Mechanical Properties. Americhsch Hejn1, Fernando Cacho-Nerin1, Fabian Schmid1, Barbara Sartori1, Michael Rappol1, Gerhard A Holzapfel2 and Peter Laggner1; 1Institute of Biophysics and Nanosystems Research, Austrian Academy of Sciences, Graz, Austria; 2Institute for Biomechanics, Graz University of Technology, Graz, Austria.

9:45 AM KK6.5
AFM and PFM measurements of Enamel in order to Determine the Crack Tip Toughness and Cohesive Zone of Enamel. Siang Fung Ang and Rodrigo Pacher Fernandes; Institute of Advanced Ceramics, Hamburg University of Technology, Hamburg, Germany.

10:00 AM BREAK

10:30 AM *KK6.6
Probing Nanomechanical Behavior of Biological Fibrous Materials using Combination AFM-SEM. Asa H Barber, Fei Hang and Dun Lu; Department of Materials, Queen Mary, University of London, London, United Kingdom.

11:00 AM KK6.7
Transferred to *KK9.1

11:15 AM KK6.8
Unique Structural Designs Leading to the Inelastic Deformation of Haversian Bone. Vincent Ebacher and Rizhi Wang:

Quasi-static and Dynamic Fracture Behavior of Elk Antler and Bovine Femur Bone. Po-Yu Chen, Robb M. Kulin, Fengchun Jiang, Jerry Curie, Fred A Sheppard, Kenneth S. Vecchio, and Joanna McKittrick. Materials Science and Engineering, University of California, San Diego, La Jolla, California; Mechanical and Aerospace Engineering, University of California, San Diego, La Jolla, California; Nanoengineering, University of California, San Diego, La Jolla, California.


3D High-resolution and High-sensitivity X-ray and Neutron Imaging of Wet Dentine in Teeth. Paul Zaslansky. Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Brandenburg, Germany.


Micropillar Compression of Individual Osteoarthritic Bone Trabeculae. Andy Bushby, F. Ahmed and H. S Gupta; Centre for Materials Research, Queen Mary, University of London, London, United Kingdom.

Does the Incorporation of Calcium or Phosphate Control the Rate of Brushite Mineralization? Jennifer L Giocondi, George H Nancollas, Alex A Chernov, and Christine Orme. LLNL, Livermore, California; SUNY, Buffalo, New York.


A New Multilayered Composite Bioceramic for Bone Graft. José I Arias, Andrónico Neira-Carrillo, Mehrad Yazdani-Pedram, María S Fernandez and José Luis Arias. Instituto Ciencias Clinicas Veterinarias, Universidad Austral de Chile, Valdivia, Chile; Animal Biology, Universidad de Chile and CIMAT, Santiago, Chile.
glycel) Hydrogel, Wonjae Lee, Nam-joon Cho, Menashe Elazar, Jeffrey S Glenn and Curtis W Frank; 1Mechanical Engineering, Stanford University, Stanford, California; 2Chemical Engineering, Stanford University, Stanford, California; 3Medicine, Stanford University, Stanford, California.

9:30 AM KK9.4
Abstract Withdrawn

9:45 AM BREAK

10:15 AM *KK9.5
Self-Assembling Peptide Nanofiber Hydrogels Targeted for Dental Tissue Regeneration. Kerstin M Galler, Lorenzo Aulisa, Adriana C Cavender, Schmalz Gottfried, Rena N D’Souza and Jeffrey D Hartgerink; 1Bioengineering, Rice University, Houston, Texas; 2Biomedical Sciences, Baylor College of Dentistry, Dallas, Texas; 3Restorative Dentistry and Periodontology, University of Regensburg, Regensburg, Germany.

10:45 AM KK9.6
Histological and Mechanical Evaluation of the in vivo Bone-bonding Ability on the K2TiO2N+1/β-Ti Alloy as a Novel Bioactive Material. Chuxiang Cui, Yumin Qi, Shuangjin Liu, Mingfang Zhang, Xuelian Xue and Nan Huang; 1School of Materials Science and Engineering, Hebe University of Technology, Tianjin, Tianjin, China; 2Department of Pathology, Tianjin Medical University, Tianjin, Tianjin, China.

11:00 AM KK9.7
Enamel Matrix Guided Growth of Apatite. Vuk Uskokovic, Li Zhu, Wu Li and Stefan Habeltz; 1Department of Preventive and Restorative Dental Sciences, University of California, San Francisco, San Francisco, California; 2Department of Oral and Craniofacial Sciences, University of California, San Francisco, San Francisco, California.

11:15 AM KK9.8
Early Stages of Collagen Mineralization Studied by Cryo-TEM: Starting at the Overlap Region? Fabio Nudelman, Paul Bomans, Koen Pieterse, Laura Brykaj, GJbertus de With and Nico Sommerdijk; 1Laboratory for Materials Science and Interface Chemistry and Soft Matter Cryo-TEM Research Unit, Dept. of Chemical Engineering and Chemistry, Eindhoven University of Technology, Eindhoven, Netherlands; 2Biomodeling and Bioinformatics, Department of Bioengineering, Eindhoven University of Technology, Eindhoven, Netherlands.

11:30 AM KK9.9
Structural and Mechanical Properties of the Mineral and Protein Phases in Bone. Po-Yu Chen, Damon Torolainen, Paul A Price, Fred A Sheppard and Joanna McKittrick; 1Materials Science and Engineering, University of California, San Diego, La Jolla, California; 2Biology, University of California, San Diego, La Jolla, California; 3Mechanical and Aerospace Engineering, University of California, San Diego, La Jolla, California.

SESSION KK10: High Resolution Imaging Techniques for Characterizing Organic-Inorganic Composites
Chairs: David Kisailus and Ulrike Wegst
Friday Afternoon, April 17, 2009
Room 3024 (Moscone West)

1:30 PM *KK10.1

2:00 PM *KK10.2
Biomimetic Ultrastructure. Pupa Gilbert, Rebecca A Metzler, Christopher E Killian, Susan Coppersmith, Yurong Ma, Yael Politi, Steve Weiner and Lia Addadi; 1Physics, University of Wisconsin, Madison, Wisconsin; 2Weizmann Institute of Science, Rehovot, Israel.

2:30 PM KK10.3

2:45 PM KK10.4
Collagen Fibril Orientation Mapping of Mineralized Tissue by Polarized Raman Spectroscopy. Admir Masic, John W Dunlop, Markus A Hartmann, Jong Seo, Sonja Gamsjäger, Paul Zaslansky and Peter Fratzl; 1Department of Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Germany; 24th Medical Department, Ludwig Boltzmann Institute of Osteology at the Hanusch Hospital of WOKK and AUVA Trauma Centre Meidling, Vienna, Austria.

3:00 PM BREAK

3:30 PM *KK10.5
Quantitative Mechanical/Chemical Imaging of Bone from Dmp1 Null Mice. Xiaomei Yao, Lynda Bonewald, J David Eick and

Yong Wang; University of Missouri Kansas City School of Dentistry, Kansas City, Missouri.

4:00 PM *KK10.6
Probing the Molecular-level Structure of Biominerals. Melinda J Duer1, David G Reid1, Erica R Wise1, Serena M Best2, David Zou2, Christian Jaeger3, Catherine M Shanahan4 and Michael Schoppet5; 1Chemistry, University of Cambridge, Cambridge, United Kingdom; 2Materials, University of Cambridge, Cambridge, United Kingdom; 3Federal Institute for Materials Research and Testing, Berlin, Germany; 4Cardiovascular Division, Kings College London, London, United Kingdom; 5Internal Medicine and Cardiology, Philipps University, Marburg, Germany.

4:30 PM KK10.7
Compressive Failure of Human Trabecular Bone Studied by X-ray Microtomography. Farhat Ahmed1,2, Graham R Davis2 and Andy J Bushby1; 1Centre of Materials Research, Queen Mary University of London, London, United Kingdom; 2Dental Biophysics, Queen Mary University of London, London, United Kingdom.

4:45 PM KK10.8
Transmission X-ray Microscopy of the Nanostructure of Bone Trabeculae. Joy Andrews1, Eduardo Almeida2, Josh Alwood3, Marjolein van der Meulen4, Jie Chen5 and Piero Pianetta1,2; 1SSRL, SLAC, Menlo Park, California; 2NASA Ames Res Ctr, Moffett Field, California; 3Stanford University, Stanford, California; 4Mechanical & Aerospace Eng, Cornell University, Ithaca, New York; 5IHEP, Beijing, China.