PO-YU CHEN (陳柏宇)

Assistant Professor

Department of Materials Science and Engineering Institute of Biomedical Engineering National Tsing Hua University

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RESEARCH SUMMARY

Investigate structure-property-function relationships of biological (natural) materials using Materials Science & Engineering principles and synthesize biomimetic/bio-inspired materials.

EDUCATION

Ph.D.	Materials Science & Engineering University of California, San Diego, La Jolla, CA	Dec. 2009	
	Dissertation: "A comparative study of mineralized bio-composites: Hierarchical structure, mechanical behavior and toughening mechanisms"		
	Advisors: Prof. Joanna McKittrick & Prof. Marc A. Meyers		
M.S.	Materials Science & Engineering University of California, San Diego , La Jolla, CA	Dec. 2005	
B.S.	Materials Science & Engineering National Tsing Hua University, Hsinchu, Taiwan	June 2002	

RESEARCH INTERESTS & EXPERTISE

- Biological (Natural) Materials
- Biomimetic/Bio-inspired Materials
- Biomedical Materials
- Biomineralization
- Biomechanics
- Bio-imaging & Structural Characterization
- Green and Energy Related Materials

RESEARCH EXPERIENCE

Postdoctoral Fellow, Materials Science & Engineering, UCSD Mechanical & Aerospace Engineering Nov. 2009 – May 2011

Biological (Natural) Materials

- Investigated structure and mechanical design of piranha teeth and armored fish scales
- Studied hierarchical structure and toughening mechanisms of armadillo carapace
- Comparative study of dynamic mechanical behavior of various biological composites
- Structural and mechanical studies on soft biological tissues/materials using AFM (Collaboration with Prof. Ratnesh Lal in Bioengineering Department, UCSD)

Bone and Mineralized Tissues

- Kinetic studies on demineralization and deproteinization of bone and mineralized tissue
- Investigated multi-scale structural and mechanical properties of bone with varying degree of demineralization/deproteinization
- Studied osteoporosis and bone diseases using Materials science/Mechanical approaches
- Structural characterization and mechanical testing on *in vitro* re-mineralized bone (Collaboration with Prof. Paul Price in Biology Department, UCSD)

Biomineralization

- Studied effects of temperature, acidity, food availability on the growth of abalone shells
- Examined and monitored the growth of abalone shell using Ca²⁺ ion selective electrodes (Collaboration with Prof. Joseph Wang in Nanoengineering Department, UCSD)

Bio-inspired Synthetic Materials

• Synthesized and characterized abalone-inspired organic-inorganic multilayer thin films. (Collaboration with Prof. Gustavo Hirata in Center for Nanoscience & Nanotechnology, Universidad Nacional Autónoma de México)

Research Assistant, Materials Science & Engineering, UCSD	Sept. 2004 - Oct. 2009
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Structure and Mechanical Properties of Biological Materials

- Investigated multi-scale structure-mechanical property relationships and toughening mechanisms of various biological materials
 - Tough ceramic composites: mollusk shells, crab exoskeletons, teeth/tusks
 - Impact resistant biological materials: antler, horn, turtle shell, and armor materials
 - Strong/light weight cellular materials: bird beaks, feathers, and other cellular structures

Fracture Mechanics and Toughening Mechanisms in Bone and Mineralized Tissues

- Studied and compared the toughening mechanisms in antler and bone using *in-situ* SEM (Collaboration with Prof. Robert Ritchie at University of California, Berkeley/LBNL)
- Evaluated dynamic mechanical behavior of mineralized tissues by Hopkinson bar test (Collaboration with Prof. Kenneth Vecchio in NanoEngineering Department, UCSD)

Biological Adhesives

- Discovered the hierarchical structure and functional design of biological adhesives: abalone foot, tree frog toe pads, insect legs, and plants
- Measured the pull-off force of individual fibril using AFM at varying humidity/surface (Collaboration with Prof. Frank Talke in Mechanical Engineering Department, UCSD)

Biomineralization

• Examined the sequential growth of abalone shell and established growth mechanisms

- Developed methods to completely/selectively remove minerals/proteins from bone and mineralized tissues without altering microstructure
- Multi-scale structural characterization on completely demineralized/deproteinized bone
- Mechanical testing and modeling of fully demineralized/deproteinized cancellous bone
- Comparative TEM studies on minerals derived from bone and ferritin-depleted serum (Collaboration with Prof. Paul Price in Biology Department, UCSD)

Research Intern, Ma	terials Science & Engineering, NTHU	Feb. 2001 - June 2002
(Su	pervised by Prof. Jeng-Gong Duh)	

Functional Coating and Thin Film Technology

• Biocompatibility and mechanical properties of (Ti,Al)N thin film coating on dental alloys

TEACHING EXPERIENCE

Materials Science & Engineering, NTHU Assistant Professor	June 2011 - present
 Kinetics of Materials (Graduate Course) (Core class with 120+ graduate students) 	Spring 2012/2013
Introduction to Bioinspired/Biomimetic Materials (Graduate Co	urse) Fall 2011/2012
Materials Science & Engineering (MATS), UCSD Mechanical & Aerospace Engineering (MAE)	Jan. 2005 - May 2011
 Adjunct Instructor MATS 252 Biomaterials & Medical Devices (Graduate Course) 	Spring 2010/2011
 Invited Lecturer MATS 252 Biomaterials (Graduate Course) MATS 227 Structure & Analysis of Solids (Graduate Course) MAE 20 Elements of Materials Science MATS 202 Solid State Diffusion & Reaction Kinetics (Graduate CENG 256 Biomaterials & Biomimetics 	Spring 2009 Fall 2009 Fall 2009 e Course) Winter 2010 Fall 2010
 Teaching Assistant MAE 160 Mechanical Behavior of Materials Win - Prepared teaching materials, instructed discuss sessions and he MAE 156B Sponsored Engineering Projects - Advised undergraduate students on industry-sponsored engineering MAE 171B Advanced Laboratory Course - Supervised undergraduate research/engineering projects 	nter/Spring/Summer 2005 eld office hours Spring 2009 ering projects Spring 2007/Spring 2008
Mentor - Gave informal lectures, directed research plans, provided tutoria and training, edited/revised manuscripts of peer-reviewed journals	2005 - May 2011 Ils for experimental setup
• Ph.D. students: Yen-shan Lin (MAE) – teeth and fish scales Ekaterina Novitskaya (MSE) – horns and bones Irene Chen (MSE) – armadillo carapace	

Maria I. Lopez (MSE) – growth of abalone shell

Curriculum Vitae Po-Yu Chen

Conducted weekly discussion sections and held office hours Supervised undergraduate students performing research/engineer	ing projects
rials Science Center, National Tsing Hua University rtment of Materials Science and Engineering earch Assistant Assisted with patent application, technology licensing and indust Involved in research projects on solder joint reliability of microel	Feb. 2004 - Aug. 200 ry cooperation
functional coating/surface modification of materials	een ome puokuge und
Curriculum Vitae Po-Yu Chen	

Visiting scholars: Glaucio Serra & Lilliane Morais (Brazil) - teeth & dental materials Jeremy Peyras (France) – river clam shells Oliver Franke (Germany) - nanoindentation on bone/cartilage Luca Tombolato (Italy) – horns Akira Watanabe (Japan) – biomechanical simulations George Charalambous (UK) – bones & antlers Undergraduate interns: Victor Correa, Jerry Curriel, James Kiang, Fred Sheppard, Robert Urbania, Joshua Vasquaz, Joshua Yee • High school interns: Kadija Amba, Gloria Chukwueke, Erik Hernandez, Judith Inurriaga **Educational Outreach** 2005 - May 2011 • Initiated and organized several open-lab tours for elementary and middle school students • Played an active role in the San Diego Zoo Biomimicry Program by demonstrating current research on biological and bio-inspired materials to general publics WORK EXPERIENCE Materials Science & Engineering/Mechanical & Aerospace Engineering, UCSD **Postdoctoral Fellow** Jan. 2010 - May 2011 • Performed multi-/interdisciplinary research projects • Assisted with grant-writing (NSF, ARO, DOE, DARPA, UC-MEXUS grants) • Supervised graduate and undergraduate students • Managed laboratory facilities **Adjunct Instructor** March 2010 – May 2011 Taught graduate-level course on Biomaterials **Research Assistant** Sept. 2004 - Oct. 2009 • Carried out doctoral research projects Jan. 2005 - June 2008 **Teaching Assistant** Prepared teaching materials Graded assignments and exams • Mater - Aug. 2004 Depar Res on •

Ana B. Castro-Ceseña (Biology) - kinetic studies on bone

Master students: Steve Lee (MSE) – dynamic behavior of biological materials Sandra P. Diaz (MSE) – bio-inspired multilayer composites Andrew Stokes (MSE) – antlers

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Air Cavalry Brigade, Army, Taichung, Taiwan

Logistic 2nd Lieutenant Officer

- Supervised helicopter maintenance, repair, and parts supplies
- Took charge of general logistic supplies

EXPERIMENTAL SKILLS

Biological Specimen Preparation & Fabrication

- Fixation, Dehydration, Polymerization
- Microtome Sectioning
- Critical Point Drying (CPD)
- Controlled Demineralization & Deproteinization

Biological Analysis

- Amino Acid Analysis (AAA)
- Polyacrylamide Gel Electrophoresis (PAGE)
- Lowry Protein Assay
- Protein Sequencing & Analysis

Microstructural Characterization & Chemical Analysis

- Transmission Electron Microscopy (TEM)
- Scanning Electron Microscopy (SEM) with EBSD & EDS
- Atomic Force Microscopy (AFM)
- Optical & Fluorescence Microscopy
- Micro-Computed Tomography (µ-CT scans)
- Stylus Contact Surface Profilometer
- X-ray Diffraction (XRD)
- X-ray Fluorescence Spectroscopy (XRF)
- Raman Spectroscopy
- Fourier Transform Infrared Spectroscopy (FTIR)
- Thermogravimetric Analyzer (TGA)
- Differential Scanning Calorimetry (DSC)

Biological Imaging Techniques

- Stereoscopy & Optical Microscopy
- Laser Confocal Scanning Microscopy (LCSM)
- Clinical/Micro-CT & Synchrotron X-ray CT
- Environmental SEM (ESEM)
- Cryo-TEM
- 3-D TEM Tomography
- 3-D Reconstruction/Visualization
- Ultra High Speed Camera/Video Systems

Mechanical Testing

- Universal Materials Testing System: Tensile, Compressive, Flexure, Fatigue Tests
- Atomic Force Microscopy
- Nanoindentation (dynamic mode in hydrated condition)
- *in-situ* Mechanical Tests under SEM

- Vickers Micro-hardness Tester
- Indentation Scratch Tester
- Split-Hopkinson Pressure Bars (SHPB)
- Charpy & Drop-Weight Impact Testers

Software

- Microsoft Windows/Office
- MATLAB, Origin, KaleidaGraph, UN-SCAN-IT, Photoshop, ImageJ, CorelDRAW
- 3-D visualization/reconstruction Software
- ABAQUS Finite Element Analysis

AWARDS & HONORS

National Tsing Hua University 2011 – present

- 2013 TMS Young Leader Professional Development Award (Structural Materials Division) (March, 2013)
- Distinguished Young Researcher Career Award by National Science Council, Taiwan (April, 2012)
- 2011 Materials Science & Engineering C Young Researcher Award (Nov. 2011)
- Winner, Emerging Researchers in Biomedical Engineering, ASME 2011 International Mechanical Engineering Congress & Exposition Poster Competition (Nov. 2011)

University of California, San Diego 2004 – 2010

- UCSD STARS Award (summer training academy for research in the sciences) (Aug. 2010)
- San Diego Zoo Biomimicry Scholarship (Sept. 2009)
- Acta Biomaterialia Student Award Nominee (March 2009)
- NSF-ARO Travel Award (March 2009)
- UCSD Jacobs School of Engineering Research Expo Best Poster Award (2006 & 2008)
- Army Research Office Assistantship (2009 2010)
- National Science Foundation Assistantship (2005 2011)

National Tsing Hua University 1998 – 2002

- Hsinchu Syue-chu Foundation Scholarship (April 2002)
- 1944 Alumni Memorial Scholarship (Sept. 2001)
- Taiwan Land Bank Scholarship (Feb. 2000)
- Mr. Chi Chen Memorial Scholarship (Sept. 1999)

PROFESSIONAL SOCIETIES

- **TMS** (The Minerals, Metals & Materials Society)
- MRS (Materials Research Society) MRS-T
- **ASM International** (The Materials Information society)
- **ASME** (American Society of Mechanical Engineers)
- ACerS (American Ceramic Society)
- **ISBE** (International Society of Bionic Engineering) Founding member
- **ZSSD** (Zoological Society of San Diego)
- TACT (Taiwan Association for Coatings and Thin Films Technology)

Curriculum Vitae Po-Yu Chen

PROFESSIONAL SERVICE

- **Co-organizer,** Advances in biomineralized ceramics, bioceramics and bioinspired designs. 8th Pacific Rim Conference on Ceramic and Glass Technology, San Diego, CA. (June 2013)
- **Co-organizer,** Biological Materials Science Symposium, TMS 2013 Annual Meeting, San Antonio, TX. (March 2013)
- **Organization Committee,** Multidisciplinary Design, 2012 International Senior Project Conference, Hsinchu, Taiwan. (March 2012)
- **Co-organizer,** Biological Materials Science Symposium, TMS 2012 Annual Meeting, Orlando, FL. (March 2012)
- **Organizer,** Bio-mimetic Materials, Biological Materials Symposium, 12th International Union of Materials Research Society International Conference in Asia (IUMRS-ICA), Taipei, Taiwan. (Sept. 2011)
- **Organizer**, Biomimetic Materials Workshop at San Diego Zoo, TMS 2011 Annual Meeting, San Diego, CA. (Feb. 2011)
- **Co-organizer**, Biological Materials Science Symposium, TMS 2011 Annual Meeting, San Diego, CA. (Feb. 2011)
- **Co-organizer**, The 3rd San Diego Zoo Annual Biomimicry Symposium, San Diego, CA. (April 2011)
- Session Chair, Biological Materials: Soft Tissue and Materials, Biological Materials Science Symposium, TMS 2010 Annual Meeting, Seattle, WA. (Feb. 2010)
- Session Chair, Surfaces, Biocompatibility and Bioactive Ceramics, Advances in Biomineralized Ceramics, Bioceramics, and Bioinspired Designs Symposium, 8th Pacific Rim Conference on Ceramic and Glass Technology, Vancouver, BC, Canada. (June 2009)
- Session Chair, Biological Materials II, Biological Materials Science Symposium, TMS 2009 Annual Meeting, San Francisco, CA. (Feb. 2009)
- **Committee Member**, TMS Biological Materials Science Symposium. (2006 present)

JOURNAL EDITOR

- Editorial Board, Bioinspired, Biomimetic, and Nanobiomaterials (ICE Publishing)
- Advisory Board, Journal of Materials Research and Technology
- **Guest Editor**, Journal of Mechanical Behavior of Biomedical Materials (March 2012) Special Issue on 2011 TMS Biological Materials Science Symposium
- Guest Editor, JOM (April 2012) Special Issue on Biological and Bioinspired Materials

JOURNAL REVIEWER

- Acta Biomaterialia
- Animal: An International Journal of Animal Bioscience
- Bioinspiration and Biomimetics
- Bioinspired, Biomimetic, and Nanobiomaterials
- Journal of Experimental Biology
- Journal of Materials Research
- Journal of Materials Science

- Journal of the Mechanical Behavior of Biomedical Materials
- Journal of the Royal Society Interface
- Journal of Structural Biology
- Materials Science and Engineering C
- Medical Engineering and Physics
- Revista Matéria

GRANTS & PROPOSALS

- **PI**, National Science Council, Taiwan "An investigation into structural design and attachment mechanisms of bio-inspired wet adhesive surfaces" (**NSC Distinguished Young Researcher Career Award**) (Awarded, 8/1/2012-7/31-2015)
- **PI**, National Science Council, Taiwan "Synthesis and characterization of bio-inspired organic/inorganic multilayered coatings" (NSC-100-2218-E-007-016-MY3) (Awarded 9/1/2011-8/31/2014)
- **Co-PI**, National Science Foundation, "Biological Materials Science Symposium, Orlando, March 11–15, 2012." (Awarded, DMR 1212495)
- **Co-PI**, Army Research Office, "Bioinspired Materials Science Workshop at San Diego Zoo, February 27, 2011" (Awarded, ARO 59447-MS-CF)
- **Co-PI**, National Science Foundation, "Biological Materials Science Symposium, San Diego, February 27 March 3, 2011." (Awarded, DMR 1063948)
- Assisted with grant-writing (NSF, ARO, DOE, UC-MEXUS grants)
- Prepared annual reports and research highlights for awarded grants (NSF DMR 0510138, NSF DMR 1006931, ARO W911-08-1-0461)

PUBLICATIONS

Journal Publications

- 1. E. Hamed, E.E. Novitskaya, J. Li, P.-Y. Chen, I. Jasiuk, J. McKittrick, "Correlation of experimental and modeling results on the elastic moduli of untreated, demineralized, and deproteinized trabecular bone", *Acta Biomater*. (in preparation).
- 2. **P.-Y. Chen**, M.I. Lopez, E.E. Novitskaya, J. McKittrick, M. A. Meyers. Structural characterization of the mineral phase in bony tissues: A comparative study. *J. Bone Mineral. Res.* (in preparation).
- 3. M.A. Meyers, J. McKittrick, **P.-Y. Chen**, Structural biological materials: Critical mechanics-materials connections. *Science* 2013;339:773-779.
- 4. **P.-Y. Chen**, J. McKittrick, M.A. Meyers. Structural biological materials: Functional adaptations. *Prog. Mater. Sci.* 2012:57;1492-1704.
- 5. M.A. Meyers, Y.S. Lin, E.A. Olvesky, **P.-Y. Chen**. The scales of the Amazon Araipamas: Bioinspiration for flexible ceramics. Adv. Eng. Mater. 2012:14;279-288.
- 6. J. McKittrick, **P.-Y. Chen**, S.G. Bodde, W. Yang, E.E. Novitskaya, M.A. Meyers. The structure, functions and mechanical properties of keratin. *JOM*, 2012;64:449-468.
- 7. J.A. Nychka, **P.-Y. Chen**. Nature as Inspiration in Materials Science and Engineering. *JOM*, 2012;64:446-448.

- 8. J.J. Kruzic, N. Rahbar, **P.-Y. Chen**, C. Tamerler. Editorial on the special issue-7th TMS Symposium on Biological Materials Science. *J. Mech. Behav. Biomed. Mater.* 2012;7:1-2 Sp. Iss. SI MAR 2012.
- 9. E. Hamed, E.E. Novitskaya, J. Li, **P.-Y. Chen**, I. Jasiuk, J. McKittrick. Elastic moduli of untreated, demineralized and deproteinated cortical bone: Validation of a theoretical model of bone as an interpenetrating composite material. *Acta Biomater*.2012:8;1080-1092. (2)
- 10. **P.-Y. Chen**, J. Schirer, A. Simpson. R. Nay. Y.-S. Lin. W. Yang, M.I. Lopez, J. Li, E.A. Olevsky, M.A. Meyers. Predation vs. Protection: Fish teeth and scales evaluated by nanoindentation. *J Mater. Res.* 2012:27:100-112. (2)
- 11. V.A. Lubarda, E.E. Novitskaya, J. McKittrick, S.G. Bodde, **P.-Y. Chen**. Elastic properties of cancellous bone in terms of elastic properties of its mineral and protein phase with application to their osteoporotic deterioration. *Mechanics of Materials* 2012;44:139-150.
- 12. E.E. Novitskaya, **P.-Y. Chen**, E. Hamed, J. Li, V.A. Lubarda, I. Jasiuk, J. McKittrick. Review: Recent advances in the measurement and modeling of the Young's modulus of cortical bone. *J. Theo. Appl. Mech.* 2011;38:209-297.
- E.E. Novitskaya, P.-Y. Chen, S. Lee, A.B. Castro-Ceseña, G.A. Hirata, V.A. Lubarda, J. McKittrick. Anisotropy in the compressive mechanical properties of bovine cortical bone: Mineral and protein constituents compared with untreated bone. *Acta Biomater*. 2011;7:3170-3177. (4)
- 14. P.-Y. Chen, J. McKittrick. Compressive mechanical properties of demineralized and deproteinized cancellous bone. J. Mech. Behav. Biomed. Mater. 2011;4:961-973. (4)
- 15. R.M. Kulin, **P.-Y. Chen**, F. Jiang, K.S. Vecchio. A study of the dynamic compressive behavior of Elk antler. *Mater. Sci. Eng. C* 2011:31:1030-1041.
- 16. **P.-Y. Chen** and J.A. Nychka, Inspiration from Nature—Biomimetic Materials Workshop at the San Diego Zoo", JOM, 2011;63:19-20.
- 17. I.H. Chen, J.H. Kiang, V. Correa, M.I. Lopez, **P.-Y. Chen**, J. McKittrick, M.A. Meyers. Armadillo armor: Mechanical testing and micro-structural evaluation. *Journal of the J. Mech. Behav. Biomed. Mater.* 2011;4:713-722. (2)
- M.A. Meyers, P.-Y. Chen, M.I. Lopez, Y. Seki, A.Y.M. Lin. Biological materials: A materials science approach. *J. Mech. Behav. Biomed. Mater.* 2011;4:626-657. (Ranked the 2nd most downloaded paper in the journal according to ScienceDirect[®]) (4)
- 19. P.-Y. Chen, D. Toroian, P.A. Price, J. McKittrick. Minerals form a continuum phase in mature cancellous bone. *Calcif. Tiss. Inter.* 2011;88:351-361. (10)
- 20. S. Lee, E.E. Novitskaya, B. Reyante, J. Vasquez, R. Urbaniak, T. Takahashi, E. Woolley, L. Tombolato, **P.-Y. Chen**, J. McKittrick. Impact testing of structural biological materials. *Mater. Sci. Eng. C* 2011;31:730-739. (5)
- 21. A.B. Castro-Ceseña, E.E. Novitskaya, **P.-Y. Chen**, G.A. Hirata, J. McKittrick. Kinetic studies of bone demineralization at different HCl concentrations and temperatures. *Mater. Sci. Eng. C* 2011; 31:523-530. (7)
- 22. M.I. Lopez, **P.-Y. Chen**, J. McKittrick, M.A. Meyers. Growth of nacre in abalone: Seasonal and Feeding Effect. *Mater. Sci. Eng. C* 2011;31:238-245. (4)
- 23. J. McKittrick, **P.-Y. Chen**, L. Tombolato, E.E. Novitskaya, W. Trim, Y.S. Lin, G.A. Hirata, E.A. Olevsky, M.A. Meyers, M.F. Horstemeyer. Energy absorbent natural materials and bio-inspired design strategies: A review. *Mater. Sci. Eng. C* 2010; 30:331-342. (13)
- 24. M.E. Launey, **P.-Y. Chen**, J. McKittrick, R.O. Ritchie. Mechanistic aspects of the fracture toughness of elk antler bone. *Acta Biomater*. 2010;6:1505-1514. (20)

- 25. R.M. Kulin, **P.-Y. Chen**, F. Jiang, J. McKittrick, and K.S. Vecchio. Dynamic Fracture Resilience of Elk Antler: Biomimetic Inspiration for Improved Crashworthiness. *JOM* 2010;62:41-46. (4)
- 26. L. Tombolato, E.E. Novitskaya, **P.-Y. Chen**, F.A. Sheppard, J. McKittrick. Microstructure, elastic and fracture properties of horn keratin. *Acta Biomater*. 2010;6:319-330. (10)
- 27. P.-Y. Chen, A.G. Stokes, J. McKittrick. Comparison of structure and mechanical properties of bovine femur bone and antlers of the North American elk (*Cervus canadensis*). Acta Biomater. 2009;5:693-706. (24)
- 28. A.Y.M. Lin, R. Brunner, **P.-Y. Chen**, F.E. Talke, M.A. Meyers. Underwater adhesion of abalone: The role of van der Waals and capillary forces. *Acta Mater*. 2009;57:4178-85. (2)
- P.-Y. Chen, A.Y.M. Lin, Y.S. Lin, Y. Seki, A.G. Stokes, J. Peyras, E.A. Olevsky, M.A. Meyers, J. McKittrick. Structure and mechanical properties of selected biological materials. *J. Mech. Behav. Biomed. Mater.* 2008;1:208-226. (Ranked the 2nd most downloaded paper in the journal according to ScienceDirect[®]) (50)
- 30. **P.-Y. Chen**, A.Y.M. Lin, Y. Seki, S.G. Bodde, A.G. Stokes, J. McKittrick, M.A. Meyers. Structural biological materials: Overview of current research. *JOM* 2008;60:23-32. (7)
- 31. P.-Y. Chen, A.Y.M. Lin, J. McKittrick, M.A.Meyers. Structure and mechanical properties of crab exoskeletons. *Acta Biomater*.2008;4:587-596. (28)
- 32. M.A. Meyers, **P.-Y. Chen**, A.Y.M. Lin, Y. Seki. Biological materials: structure and mechanical properties. *Prog. Mater. Sci.* 2008;53:1-206. (Ranked the 9th most downloaded paper in the Materials Science area according to ScienceDirect[®]) (262)
- 33. A.Y.M. Lin, **P.-Y. Chen**, M.A. Meyers. The growth of nacre in the abalone shell. *Acta Biomater*. 2008;4:131-138. (29)
- 34. M.A. Meyers, A.Y.M. Lin, **P.-Y. Chen**, J. Muyco. Mechanical strength of abalone nacre: role of the soft organic layer. J. Mech. Behav. Biomed. Mater. 2008;1:76-85. (44)
- 35. M.A. Meyers, A.Y.M. Lin, Y. Seki, **P.-Y. Chen**, B. Kad, S.G. Bodde. Structural biological composites: An overview. *JOM* 2006;58:35-41. (28)

Conference Proceedings

- 36. S. Lee, M. Porter, S. Waskoa, G. Laua, **P.-Y. Chen**, E.E. Novitskaya, A.P. Tomsia, A. Almutairi, M.A. Meyers, J. McKittrick. Potential Bone Replacement Materials Prepared by Two Methods. Materials Research Society Symposium Proceeding, Fall 2011, Volume 1418, Symposium MM6.2.
- 37. E.E. Novitskaya, A.B. Castro-Ceseña, **P.-Y. Chen**, J. Vasquez, R. Urbaniak, S. Lee, G.A. Hirata, J. McKittrick. Investigations into demineralized cortical bone. Materials Research Society Symposium Proceeding, Fall 2010, Volume 1301, Symposium NN1.7.
- 38. A.B. Castro-Ceseña, E.E. Novitskaya, **P.-Y. Chen**, M.P. Sánchez-Saavedra, G.A. Hirata, J. McKittrick. Comparison of demineralized and deproteinized bone. Materials Research Society Symposium Proceeding, Fall 2010, Volume 1301, Symposium NN1.8.
- 39. G.A. Hirata, S.P. Diaz, **P.-Y. Chen**, M.A. Meyers, J. McKittrick. Bio-inspired inorganic/polymer thin films. Materials Research Society Symposium Proceeding, Fall 2009, Volume 1239, Symposium VV1.5.
- 40. **P.-Y. Chen**, D. Toroian, P.A. Price, J. McKittrick. Bone: A natural nanocomposite. 2009 The 17th International Conference on Composites/Nano Engineering, Honolulu, HI.

- 41. **P.-Y. Chen**, D. Toroian, P.A. Price, J. McKittrick. Structural and mechanical properties of the collagen-mineral nano-constituents in cancellous bone. 2009 The 1st International Conference on Nanostructured Materials and Nanocomposites, Kottayam, India.
- 42. **P.-Y. Chen**, F.A. Sheppard, J.M. Curiel, J. McKittrick. Fracture mechanisms of bone: A comparative study between antler and bovine femur bone. Materials Research Society Symposium Proceeding, Fall 2008, Volume 1132E, Symposium Z1.4.
- 43. G.A. Hirata, J.H. Tao, **P.-Y. Chen**, K.C. Mishra, J. McKittrick. A new method to produce rare earth-doped gallium nitride phosphor powders. Materials Research Society Symposium Proceeding, Spring 2005, Volume 866, Symposium V6.9.

Textbook

44. M.A. Meyers and **P.-Y. Chen**. Biological and Bioinspired Materials. Cambridge University Press, in progress 2013.

中文期刊著作

45. **陳柏宇 P.-Y. Chen**. 利用參考點壓痕量測技術檢測活體內骨骼組織之機械性質 Probing in vivo Mechanical Properties of Bone Tissues by Reference Point Indentation Technique. 科 儀新知第三十四卷第二期 2012 年 10 月, pp.20-27.

PRESENTATIONS

Invited Talks

- 1. Department of Physics, National Chung Hsing University, Taichung, Taiwan. (March 28, 2013)
- 2. School of Materials Science and Engineering, Shanghai Jiaotong University, Shanghai, China. (January 8, 2012)
- 3. Department of Mechanical and Electro-Mechanical Engineering, National Sun Yat-Sen University, Kaohsiung, Taiwan (December 20, 2012)
- 4. Department of Materials Science and Engineering, National United University, Miaoli, Taiwan. (December 12, 2012)
- 5. Department of Materials Science and Engineering, Feng Chia University, Taichung, Taiwan. (October 17, 2012)
- 6. College of Life Science, National Tsing Hua University, Hsinchu, Taiwan (October 4, 2012)
- 7. **P.-Y. Chen**, "Biological materials: Lessons from nature." Department of Physics, National Tsing Hua University, Hsinchu, Taiwan. (June 12, 2012)
- 8. **P.-Y. Chen**, "Biological and bioinspired materials: Recent development and future perspectives." Department of Materials Science and Engineering, National Tsing Hua University, Hsinchu, Taiwan. (April 13, 2012)
- 9. **P.-Y. Chen**, "Lessons from nature: Biological and bioinspired materials." Department of Materials Science and Engineering, National Chung Hsin University, Taichung, Taiwan. (April 11, 2012)
- 10. **P.-Y. Chen**, "Overview on biological and bio-inspired materials." China Steel Corporation Materials Science Forum, Hsinchu, Taiwan. (February 17, 2012)
- P.-Y. Chen, "Bridging life science and engineering interdisciplinary research on biological materials" College of Engineering, National Tsing Hua University, Hsinchu, Taiwan. (February 4, 2012)

- 12. **P.-Y. Chen**, "Multi-scale structural characterization and mechanical testing of biological materials" National Science Council Bio-nanomechanics Workshop, Taipei, Taiwan. (December 2, 2011)
- 13. **P.-Y. Chen**, "Biological materials: Functional adaptation and bio-inspired design." Department of Mechanical Engineering, Mingchi University, Taipei, Taiwan (October 19, 2011)
- 14. **P.-Y. Chen**, "Mollusks, crabs, and sharks Bio-inspired design of novel materials." College of Engineering, National Taiwan Ocean University, Keelong, Taiwan. (October 14, 2011)
- 15. **P.-Y. Chen**, "Bone and mineralized tissues: hierarchical structure, mechanical properties and toughening mechanisms." National Taiwan University Hospital, Hsinchu, Taiwan. (October 13, 2011)
- 16. **P.-Y. Chen**, "Biological and bio-inspired materials: Materials scientists' approaches" Department of Materials Science and Engineering, National Chao Tung University. (October 12, 2011)
- P.-Y. Chen, "Biological and bioinspired materials: An overview" Department of Materials Science and Engineering, National Tsing Hua University, Hsinchu, Taiwan. (September 30, 2010)
- 18. **P.-Y. Chen**, "Structural and mechanical design of selected biological materials." Nanjing University of Aeronautics and Astronautics, Nanjing, China. (September 18, 2010)
- 19. **P.-Y. Chen**, "Learning from the abalone: Tough laminated composites and underwater attachment devices." 3rd International Conference of Bionic Engineering, Zhuhai, China. (September 15, 2010)
- 20. **P.-Y. Chen**, J. McKittrick, M.A. Meyers. "Biological and bioinspired materials: A materials science approach." The Brazilian Center for Physics Research (CPBF) and Military Institute of Engineering (IME), Rio de Janeiro, Brazil. (August 3, 2010)
- 21. **P.-Y. Chen**, J. McKittrick, M.A. Meyers. "Mechanical design and toughening mechanisms of mineralized biological materials." 1st TMS-ABM International Materials Congress, Rio de Janeiro, Brazil. (July 26, 2010)
- 22. **P.-Y. Chen**, "Learning from nature: Biological and bioinspired materials." Department of Engineering and System Science, National Tsing Hua University, Hsinchu, Taiwan. (March 25, 2010)
- P.-Y. Chen, M.E. Launey, R.M. Kulin, F. Jiang, K.S. Vecchio, R.O. Ritchie, M.A. Meyers, J. McKittrick. "Comparative study of the structure and mechanical properties of antler and bone." The 8th Pacific Rim Conference on Ceramic and Glass Technology, Vancouver, BC, Canada. (June 4, 2009)
- 24. **P.-Y. Chen**, "Biological materials: Structure and mechanical properties." UCLA-Hysitron Nanomechanical Testing Workshop, University of California, Los Angeles, CA, USA (June 10, 2008)
- 25. **P.-Y. Chen**, "Learning from nature: Biology inspiring the design of future materials." Centro de Ciencias de la Materia Condensada, Universidad Nacional Autónoma de México, Ensenada, México. (September 26, 2007)

Oral Presentations

- 26. C.-Y. Sun, H.-J. Fang, Pei-Chun, Chou, **P.-Y. Chen**. "Mechanical and functional design of natural dermal armors", 10th Pacific Rim Conference on Ceramic and Glass Technology, June 2-7, 2013, San Diego, CA, USA.
- 27. Y.-T. Ku, W.-G. Liu, Y.-H. Lee, C.-C. Chiao, **P.-Y. Chen**. "Cuttlebone: A multifunctional buoyancy control device", 10th Pacific Rim Conference on Ceramic and Glass Technology, June 2-7, 2013, San Diego, CA, USA.
- 28. P.-C. Chou, M. Porter, J. McKittrick, **P.-Y. Chen**. "Vapor deposition polymerization as an alternative method to enhance the mechanical performance of bio-Inspired scaffolds", 10th Pacific Rim Conference on Ceramic and Glass Technology, June 2-7, 2013, San Diego, CA, USA.
- 29. C.-Y. Sun, Y.-C. Chan, J.-W. Lee, J.-G. Duh, **P.-Y. Chen**. "Microstructural and Mechanical Evaluations of Innovative Hybrid Multilayer Coatings Inspired by Abalone Nacre", 10th Pacific Rim Conference on Ceramic and Glass Technology, June 2-7, 2013, San Diego, CA, USA.
- 30. H.-J. Fang, Y.-C. Chan, T.-C. Tseng, J.-G. Duh, J.-W. Lee, **P.-Y. Chen** "Structural Characterization and Mechanical Performance of Durophagous Fish: A Comparative Study" 142th TMS Annual Meeting & Exhibition, March 2-7, 2013, San Antonio, TX, USA.
- 31. C.-Y. Sun, **P.-Y. Chen** "Hierarchical Structure and Mechanical Design of Natural Dermal Armors" 142th TMS Annual Meeting & Exhibition, March 2-7, 2013, San Antonio, TX, USA.
- C.-Y. Sun, Y.-C. Chan, J.-W. Lee, J.-G. Duh, P.-Y. Chen "Structural Characterization and Mechanical Evaluations of Abalone Nacre-inspired Multilayer Coatings Synthesized by RF sputtering and Pulsed Laser Deposition" 142th TMS Annual Meeting & Exhibition, March 2-7, 2013, San Antonio, TX, USA.
- 33. Y.-T. Ku, Y.-H. Lee, C.-C. Chiao, **P.-Y. Chen** "On the Structural and Mechanical Design of Cuttlebone" 142th TMS Annual Meeting & Exhibition, March 2-7, 2013, San Antonio, TX, USA.
- P.-C. Chou, P.-Y. Chen "Investigation of the Microscopic Mineral Content Variation in Bone by Electron Probe Microanalyzer (EPMA)" 142th TMS Annual Meeting & Exhibition, March 2-7, 2013, San Antonio, TX, USA.
- 35. C.-P. Hsu, P.-Y. Chen "Water-lubricated Surface as Deadly Trap: Composite Structure and Surface Properties of Insect-eating Pitcher Plants" 142th TMS Annual Meeting & Exhibition, March 2-7, 2013, San Antonio, TX, USA.
- 36. J. McKittrick, M.M. Porter, E.E. Novitskaya, M.A. Meyers, **P.-Y. Chen** "Bioinspired ceramic scaffolds for bone replacement" Innovations in Biomedical Materials 2012, September 11, 2012, Raleigh, NC, USA.
- 37. **P.-Y. Chen**, E.E. Novitskaya, J. McKittrick "Toward a Better Understanding of the Structure of Bone Mineral by Deproteinization." International Conference of Young Researchers on Advanced Materials, July 1-6, 2012, Singapore.
- 38. **P.-Y. Chen**, C.-Y. Sun, Y.-C. Chan, J.-W. Lee, J.-G. Duh "Synthesis of Bio-inspired Organic/inorganic Multi-layer Composites." International Conference of Young Researchers on Advanced Materials, July 1-6, 2012, Singapore.
- P.-Y. Chen, M.E. Launey, R.O.Ritchie, J. McKittrick, "On the exceptional facture toughness of antler bone." 141th TMS Annual Meeting & Exhibition, March 12-15, 2012, Orlando, FL, USA.

- 40. H.-J. Fang, C.-Y. Sun, Y.-T. Ku, **P.-Y. Chen**, "Structural and mechanical design of zebra shark teeth." 141th TMS Annual Meeting & Exhibition, March 12-15, 2012, Orlando, FL, USA.
- 41. Y.-C. Chan, L.-W. Ho, J.-W. Lee, J.-G. Duh, and **P.-Y. Chen**, "Synthesis of nacre-like structure by RF sputtering and pulsed laser deposition", 141th TMS Annual Meeting & Exhibition, March 12-15, 2012, Orlando, FL, USA.
- 42. **P.-Y. Chen**, E.E. Novitskaya, M.I. Lopez, M.A. Meyers, and J. McKittrick. "Multi-scale structure and mechanical properties of the mineral constituents in some unique bony tissues", 4th International Conference on Mechanics of Biomaterials & Tissues, Big Island, HI, USA. (December 13, 2011)
- 43. Y.-C. Chan, L.-W. Ho, J.-W. Lee, J.-G. Duh, and **P.-Y. Chen**, "Bio-inspired organic/inorganic multilayer coatings synthesized by DC-magnetron sputtering and pulsed laser deposition", TACT 2011 International Conference in Taiwan, November 20-23, 2011, Kenting, Taiwan. (November 20-23, 2011)
- 44. **P.-Y. Chen**, M.I. Lopez, E.E. Novitskaya, M.A. Meyers, J. McKittrick. "Structural characterization of the mineral phase in bony tissues: A comparative study." 140th TMS Annual Meeting, San Diego, CA, USA (February 28 March 3, 2011)
- 45. **P.-Y. Chen**, G.A. Hirata, S.P. Diaz, Y.-C. Chan, J.-G. Duh, J. McKittrick. "Structure and mechanical properties of bioinspired inorganic/polymer multilayer composites." 140th TMS Annual Meeting, San Diego, CA, USA (February 28 March 3, 2011)
- 46. **P.-Y. Chen**, G.A. Hirata, S.P. Diaz, M.A. Meyers, J. McKittrick. "Bioinspired synthetic laminates." 139th TMS Annual Meeting, Seattle, WA, USA (February 15, 2010)
- 47. P.-Y. Chen, M.E. Launey, R.M. Kulin, F. Jiang, K.S. Vecchio, R.O. Ritchie, and J. McKittrick. "Toughening mechanisms in antler: a new light on bone fracture." 3rd International Conference on Mechanics of Biomaterials & Tissues, Clearwater Beach, FL, USA (December 16, 2009)
- 48. **P.-Y. Chen**, E.E. Novitskaya, L. Tombolato, F.A. Sheppard, J. McKittrick. "Why is horn so tough?" 3rd International Conference on Mechanics of Biomaterials & Tissues, Clearwater Beach, FL, USA (December 14, 2009)
- 49. **P.-Y. Chen**, D.A. Toroian, P.A. Price, J. McKittrick. "Structural and mechanical properties of the mineral and protein phases in bone." 2009 MRS Spring Meeting, San Francisco, CA, USA (April 17, 2009)
- 50. **P.-Y. Chen**, R.M. Kulin, F. Jiang, J.M. Curiel, F.A. Sheppard, K.S. Vecchio, J. McKittrick. "Quasi-static and dynamic fracture behavior of elk antler and bovine femur bone." 2009 MRS Spring Meeting, San Francisco, CA, USA (April 16, 2009)
- 51. **P.-Y. Chen**, D.A. Toroian, P.A. Price, J. McKittrick. "Synergistic effect between the Biomineral and Biopolymer Phases in Bone." 138th TMS Annual Meeting, San Francisco, CA, USA (February 17, 2009)
- 52. **P.-Y. Chen**, M.E. Launey, F.A. Sheppard, J.M. Curiel, R.O. Ritchie, J. McKittrick. "Fracture mechanisms of bone: A comparative study between antler and bovine femur bone." 2008 MRS Fall Meeting, Boston, MA, USA (December 2, 2008)
- 53. **P.-Y. Chen**, O. Franke, M.A. Meyers, J. McKittrick. "Mechanical properties of elk antler and bovine femur measured by nanoindentation." 2008 ASME International Mechanical Engineering Congress & Exposition, Boston, MA, USA (November 6, 2008)

- 54. **P.-Y. Chen**, A.Y.M. Lin, R. Brunner, F.E. Talke, M.A. Meyers. "Evidence of van der Waals adhesion found in abalone foot." 137th TMS Annual Meeting, New Orleans, LA, USA (March 12, 2008)
- 55. **P.-Y. Chen**, A.G. Stokes, J. McKittrick. "Structure and mechanical properties of the North American elk antlers." 137th TMS Annual Meeting, New Orleans, LA, USA (March 10, 2008)
- 56. **P.-Y. Chen**, A.Y.M. Lin, J. McKittrick, M.A. Meyers. "Structure and mechanical properties of horseshoe crab exoskeletons." 2nd International Conference on Mechanics of Biomaterials & Tissues, Kuaui, HI, USA (December 12, 2007)
- 57. **P.-Y. Chen**, A.Y.M. Lin, J. McKittrick, M.A. Meyers. "Structure and mechanical properties of crab exoskeletons." 136th TMS Annual Meeting, Orlando, FL, USA (February 27, 2007)

Poster Presentations

- 58. C.-Y. Sun, Y.-C. Chan, J.-G. Duh, **P.-Y. Chen** "Structural characterization, mechanical evaluations and design principles of alligator osteoderm" 2012 MRS-T Annual Meeting, Huwei, Yunlin, Taiwan. (November 23, 2012)
- 59. H.-J. Fang, Y.-C. Chan, T.-C. Tseng, J.-G. Duh, J.-W. Lee, **P.-Y. Chen** "Ultra-hard, wear resistant fish teeth: A Comparative Study" 2012 MRS-T Annual Meeting, Huwei, Yunlin, Taiwan. (November 23, 2012)
- 60. Y.-T. Ku, W.-G. Liu, Y.-H. Lee, C.-C. Chiao, **P.-Y. Chen**. "On the structural and mechanical design of cuttlebone" 2012 MRS-T Annual Meeting, Huwei, Yunlin, Taiwan. (November 23, 2012)
- 61. C.-Y. Sun, Y.-C. Chan, J.-G. Duh, **P.-Y. Chen**. "Mechanical behavior of novel multilayered coatings inspired by abalone nacre", 2012 Taiwan Association for Coatings and Thin Films Technology, New Taipei City, Taiwan. (November 10, 2012)
- 62. **P.-Y. Chen**, A.Y.M. Lin, M.A. Meyers. "Underwater adhesion of abalone: The role of van der Waals and capillary forces." 1st Anthony G. Evans Memorial Conference, University of California, Santa Barbara, CA. (September 7, 2010)
- 63. P.-Y. Chen, A.B. Castro-Ceseña, D.A. Toroian, P.A. Price, G.A. Hirata, J. McKittrick. "Nano and microscopic investigations on demineralized and deproteinated bone." 2009 The 3rd International Conference on Mechanics of Biomaterials & Tissues, Clearwater Beach, FL. (December 14, 2009)
- 64. **P.-Y. Chen**, E.E. Novitskaya, L. Tombolato, F.A. Sheppard, J. McKittrick. "Structure and mechanical properties of horn keratin." MRS 2009 Spring Meeting, San Francisco, CA. (April 15, 2009)
- 65. **P.-Y. Chen**, D.A. Toroian, P.A. Price, J. McKittrick. "Structural and mechanical properties of the mineral and protein phases in bone." 138th TMS Annual Meeting, San Francisco, CA. (February 16, 2009)
- 66. **P.-Y. Chen**, R.M. Kulin, F. Jiang, J. McKittrick, K.S. Vecchio. "Dynamic fracture behavior of mineralized biological materials." 138th TMS Annual Meeting, San Francisco, CA. (February 16, 2009)
- 67. **P.-Y. Chen**, A.Y.M. Lin, R. Brunner, F.E. Talke, M.A. Meyers. "A natural reusable adhesive device: The abalone foot." 2008 ASME International Mechanical Engineering Congress & Exposition, Boston, MA. (November 6, 2008)
- 68. **P.-Y. Chen**, A.Y.M. Lin, M.A. Meyers. "The sequential growth of nacre in the abalone shell." 2nd International Conference on Mechanics of Biomaterials & Tissues, Kuaui, HI. (December 10, 2007)

COLLABORATORS

University of California, San Diego

- Prof. Marc A. Meyers (Mechanical & Aerospace Engineering): Biological materials
- Prof. Joanna McKittrick (Mechanical & Aerospace Engineering): Bioinspired materials
- Prof. Paul A. Price (Biology): Biomineralization, bone & mineralized tissues
- Prof. Frank Talke (Mechanical & Aerospace Engineering): AFM, Nanomechanics
- Prof. Vlado Lubarda (Mechanical & Aerospace Engineering): Biomechanics

University of California, Berkeley/Lawrence Berkeley National Lab

- Prof. Robert O. Ritchie (Materials Science & Engineering): Bone & mineralized tissues **University of Illinois, Urbana-Champaign**
- Prof. Iwona Jasiuk (Engineering): Multi-scale mechanical modeling of bone

Universidad Nacional Autónoma de México, México

- Prof. Gustavo Hirata (Nanoscience & Nanotechnology): Bio-inspired thin film synthesis **Tsing Hua University (Bejing)**
- Prof. Qing Ling Feng (MSE): Biomineralization & biomaterials

Nanjing University of Aeronautics and Astronautics, China

• Prof. Zhendong Dai (Engineering): Biomechanics & Biomimetics

Nantional Taiwan University Hospital

- Dr. Jui-Sheng Sun (Orthopaedics): Investigation of diseased bones and hard tissues Nantional Tsing Hua University
- Prof. Jenq-Gong Duh (MSE): Thin film & Coating Technology
- Prof. Chuan-Chin Chiao (Life Science): Cuttlebone, Biomineralization

NOTABLE PUBLICITY

The biological materials research conducted at UCSD has been featured in:

- Science Now (Feb. 2012) - Piranha Proof Fish
- NOVA Nature (March, 2011)
 - Nature's Toughest Materials
- Pulse: UCSD Jacobs School of Engineering Newsletter (Spring 2010)
 - Geckos of the sea
- Science Nation (July, 2009)
 - Antlers, Shells, and Beaks What nature can teach us about making things stronger, lighter, and sharper?
- **History Channel** Modern Marvels (March 12, 2008) - *The World's Sharpest*
- Materials News, UC San Diego
 - Cutting Edge Biomimetics Research on Elk Antler (Fall 2008)
 - Learning from Nature Bio-inspired Design for Future Materials (Fall 2005)
- National Geographic (December, 2006)

Curriculum Vitae Po-Yu Chen

- Wildlife Power Beak
- San Diego Union Tribune (June 7, 2006) - Nature's Lab: Imitation of Life for New Ideas in Materials and Engineering Solutions
- Science News (March 25, 2006)
 Making the Most of It: How Nature Turns Weakness into Strength
- Ens-NewSwire.com (December 17, 2005) - Abalone Shell Eyed as Guide for More Effective Body Armor
- **Discovery Channel Canada** Daily Planet (December 1, 2005) - Uncovering the Secrets of Abalone Body Armor
- Science Daily (November 30, 2005) - Engineers Discover Why Toucan Beaks Are Models of Lightweight Strength
- The New York Times (March 22, 2005) - Materials as Tough as Steel? The Abalone Fits the Bills
- JOM News & Update (March 2005)
 Abalone Shell Inspires Lightweight Body Armor
- UCSD Jacobs Engineering News (Spring 2005) - *Biomimetics*
- Science News (February 12, 2005) - Tile Stack for Shell Strength in Abalone
- **Physorg.com** (January 14, 2005) - Uncovering Secrets of Abalone Body Armor

REFERENCES

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