Markus J. Buehler, Ph.D.

Professor and Head of Department, Civil and Environmental Engineering
Massachusetts Institute of Technology

Laboratory for Atomistic and Molecular Mechanics (LAMM), Center for Materials Science and Engineering, Center for Computational Engineering

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Citizenship: United States of America

Professional Record

Massachusetts Institute of Technology	Civil and Environmental Engineering	Postdoctoral Associate 2005-2006
California Institute of Technology	Chemistry and Chemical Engineering	Postdoctoral Scholar 2004-2005
Max Planck Institute for Metals Research University of Stuttgart	Chemistry (Materials Science)	Dr. rer. nat. (Ph.D. eq.), 2004
	Engineering Mechanics	M.S., 2001
Michigan Technological University University of Stuttgart, Germany	Process and Chemical Engineering	Pre-Diploma (B.S. eq.), 2000

Principal Research Interests: Making bio-inspired nanotechnology sustainable and scalable for large-volume materials applications. Focus on materials science of natural, biological and synthetic materials, focused on mechanical, thermal and optical properties (specifically deformation, plasticity, fracture and failure) and biologically inspired and biomimetic *de novo* material design from atoms to structures in the context of civil and environmental engineering. Specific emphasis on natural and synthetic materials that provide sustainable mechanical functions (e.g. collagen, bone, spider silk, intermediate filaments, amyloid protein, etc.).

Since 2013, serves as the Head of MIT's Department of Civil and Environmental Engineering. From 2011-2013, served as Director of MIT's Computation for Design and Optimization (CDO) program. Since 2010, serves as Director of the MIT-Germany program, part of the MIT International Science and Technology Initiatives (MISTI). Chaired and participated in shaping several MIT-wide initiatives and committees. Organized and chaired several major international conferences, led scholarly workshops, and served as committee chair and member of boards in several professional societies (ASME, MRS, ASCE, and others).

Formal Appointments

July 2013- Department Head, Civil and Environmental Engineering, Massachusetts Institute of Technology

July 2013- Full Professor (with Tenure), Civil and Environmental Engineering, Massachusetts Institute of Technology

2011-2013: Associate Professor (with Tenure), Civil and Environmental Engineering, Massachusetts Institute of Technology
2011-2013: Co-Director, MIT Computation for Design and Optimization Program (CDO)
2010-2013: Group Head, Mechanics and Materials Division in Civil and Environmental Engineering, Massachusetts Institute of Technology
2010- Director, MIT-Germany Program, Massachusetts Institute of Technology
2009-2011: Esther and Harold Edgerton Associate Professor, Civil and Environmental Engineering, Massachusetts Institute of Technology
2007-2009: Esther and Harold Edgerton Assistant Professor, Civil and Environmental Engineering, Massachusetts Institute of Technology
2006-2007: Assistant Professor, Dept. Civil and Environmental Engineering, Massachusetts Institute of Technology
2005-2006: Lecturer and Postdoctoral Associate, Massachusetts Institute of Technology
2004-2005: Postdoctoral Scholar and Director of Multiscale Modeling and Software Integration, Materials and Process Simulation Center, California Institute of Technology, Pasadena
2004: Postdoctoral fellow, Max Planck Institute for Metals Research, Stuttgart, Germany
2001-2004: Research Assistant, Max Planck Institute for Metals Research, Stuttgart, Germany
2000-2001: Graduate Research Assistant, Department of Mechanical Engineering-Engineering Mechanics, Michigan Technological University

Selection of Key Publications (from**: 230+ peer reviewed articles**, 20+ book chapters, 6 books & monographs)

H-index=39 (ISI), **46** (Google Scholar); **7,200+ citations**

1. C.T.-Chen, C. Chuang, J. Cao, V. Ball, M.J. Buehler, "Excitonic Effects from Geometric Order and Disorder Explain Broadband Optical Absorption in Eumelanin," *Nature Communications*, accepted for publication
2. S.W. Chang, M.J. Buehler, "Molecular biomechanics of collagen molecules," *Materials Today*, Vol. 17(2), pp. 70-76, 2014
3. Z. Qin, L. Dimas, D. Adler, G. Bratzel, M.J. Buehler, "Biological materials by design," *J. Phys. Cond. Matter*, 2014
4. T. Giesa, N. Pugni, J.Y. Wong, D.L. Kaplan, M.J. Buehler, What's Inside the Box? – Length-Scales that Govern Fracture Processes of Polymer Fibers, *Advanced Materials*, DOI: 10.1002/adma.201303323, 2014
5. Z. Qin, M.J. Buehler, "Mussel thread networks are impact tolerant due to heterogeneous material distribution," *Nature Communications*, Vol. 4, p. 2187, 2013
6. L. Dimas, G. Bratzel, I. Eylon, M.J. Buehler, "Tough Composites Inspired by Mineralized Natural Materials: Computation, 3D printing and Testing," *Advanced Functional Materials*, Vol. 23(36), pp. 4629-4638, 2013
7. J. Zang, S. Rye, N. Pugno, Q. Wang, Q. Tu, M.J. Buehler, X. Zhao "Multifunctional Crumpling and Unfolding of Large-Area Graphene," *Nature Materials*, Vol. 12(4), pp. 321-325, 2013
8. A. Nair, A. Gautieri, S.W. Chang, M.J. Buehler, "Molecular mechanics of mineralized collagen fibrils in bone," *Nature Communications*, Vol. 4, article # 1724, 2013
9. Z. Qin, M.J. Buehler, "Spider silk: Webs measure up," *Nature Materials*, Vol. 12(3), pp. 185-187, 2013

10. S.W. Cranford, A. Tarakanova, N. Pugno, M.J. Buehler, "Nonlinear constitutive behaviour of spider silk minimizes damage and begets web robustness from the molecules up," *Nature*, Vol. 482, pp. 72-76, 2012 (cover article).
11. S.W. Chang, S. Shefelbine, M.J. Buehler, "Structural and mechanical differences between collagen homo- and heterotrimers: Relevance for the molecular origin of brittle bone disease," *Biophysical Journal*, Vol. 102(3), pp. 640-648, 2012.
12. O. Compton, K. Putz, S. Cranford, Z. An, C. Brinson, M. Buehler, S.B. Ngyen, "Tuning the Mechanical Properties of Graphene Oxide Paper and Its Associated Polymer Nanocomposites by Controlling Cooperative Intersheet Hydrogen Bonding," *ACS Nano*, Vol. 6 (3), pp. 2008–2019, 2012.
13. D. Lau, O. Büyüköztürk, M.J. Buehler, "Characterization of the intrinsic strength between epoxy and silica using a free energy approach," *J. Mat. Res*., Vol. 27(14), 2012
14. C.T. Chen, V. Ball, J.J. de Almeida Gracio, M.K. Singh, V. Taniazzo, D. Ruch, M.J. Buehler, "Self-assembly of tetramers of 5,6 dihydroxyindole explains the primary physical properties of eumelanin: Experiment, simulation and design," *ACS Nano*, Vol. 7(2), pp. 1524-1532, 2013
15. C.C. Chou, M.J. Buehler, "Breaking out of the cage," *Nature Chemistry*, Vol. 3(11), pp. 837-839, 2011.
16. S. Cranford, D. Brommer, M.J. Buehler, "Extended graphynes: simple scaling laws for stiffness, strength and fracture," *Nanoscale*, Vol. 4, pp. 7797-7809, 2012.
17. R. Pellenq, M. Buehler, F. Ulm, S. Yip, K. Van Vliet, H. Jennings., "Set in stone? A perspective on the concrete sustainability challenge," *MRS Bulletin*, Vol. 37(4), pp. 395, 2012
18. D. Spivak, T. Giesa, E. Wood, M.J. Buehler, "Category Theoretic Analysis of Hierarchical Protein Materials and Social Networks," *PLoS ONE,* Vol. 6(9), paper # e23911, 2011.
19. Z. Qin, A. Kalinowski, K. Dahl, M.J. Buehler, "Structure and stability of the lamin A tail domain and HGPS mutant," *Journal of Structural Biology,* Vol. 175, pp. 425–433, 2011.
20. A. Gautieri, S. Vesentini, A. Redaelli, M.J. Buehler , "Hierarchical structure and nanomechanics of collagen microfibrils from the atomistic scale up," *Nano Letters*, Vol. 11(2), pp. 757-766, 2011
21. T. Knowles, M.J. Buehler, "Nanomechanics of functional and pathological amyloid materials," *Nature Nanotechnology*, Vol. 6(7), pp. 469-479, 2011.
22. M.J. Buehler, "Tu(r)ning weakness to strength," *Nano Today*, Vol. 5(5), pp. 379-383, 2010.
23. S. Keten, M.J. Buehler, "Nanostructure and molecular mechanics of dragline spider silk protein assemblies," *Journal of the Royal Society Interface,* Vol. 7(53), pp. 1709-1721, 2010. Paper highlighted in *Science*.
24. S. Keten, Z. Xu, B. Ihle, M.J. Buehler, "Nanoconfinement controls stiffness, strength and mechanical toughness of beta-sheet crystals in silk," *Nature Materials*, Vol. 9, pp. 359-367, 2010.
25. D. Sen, K. Novoselov, P. Reis and M.J. Buehler, "Tearing of graphene sheets from adhesive substrates produces tapered nanoribbons," *Small*, Vol. 6(10), pp. 1108-1116, 2010.
26. Z. Xu, M.J. Buehler, "Hierarchical nanostructures are crucial to mitigate ultrasmall thermal point loads," *Nano Letters*, Vol. 9(5), 2065-2072, 2009. Paper highlighted in *Nature*.
27. Z. Xu, M.J. Buehler, "Nanoengineering heat transfer performance at carbon nanotube interfaces," *ACS Nano*, Vol. 3(9), pp. 2767-2775, 2009.
28. Y.C. Yung, J. Chae, M.J. Buehler, C. Hunter, D. Mooney, "Cyclic tensile strain triggers a sequence of autocrine and paracrine signaling that regulate angiogenesis in human vascular cells," *Proc. Nat'l Acad. Sci. USA*, Vol. 106, pp. 15279-15284, 2009.

29. R. Pellenq, A. Kushima, R. Shahsavari, K. Van Vliet, M.J. Buehler, S. Yip , F.-J. Ulm, "A realistic molecular model of cement hydrates," *Proc. Nat'l Acad. Sci. USA*, Vol. 106(36), pp. 15279-15284, 2009.
30. A. Gautieri, S. Uzel, S. Vesentini, A. Redaelli, M.J. Buehler**,** "Molecular and mesoscale disease mechanisms of Osteogenesis Imperfecta," *Biophysical J.,* Vol. 97(3), pp. 857-865, 2009.
31. M.J. Buehler, Y. Yung, "Deformation and failure of protein materials in extreme conditions and disease," *Nature Materials*, Vol. 8(3), pp. 175-188, 2009.
32. Z. Xu, M.J. Buehler, "Strain controlled thermomutability of single-walled carbon nanotubes," *Nanotechnology,* Vol. 20(18), paper # 185701-6, 2009.
33. M.J. Buehler, *Atomistic Modeling of Materials Failure*, Springer (New York), 2008.
34. M.J. Buehler, T. Ackbarow, S. Keten, "Theoretical and computational hierarchical nanomechanics of protein materials: Deformation and fracture," *Progress in Materials Science*, Vol. 53, pp. 1101-1241, 2008.
35. M.J. Buehler, "Defining nascent bone by the molecular nanomechanics of mineralized collagen fibrils," *Nanotechnology,* Vol. 18, paper number 295102, 2007.
36. T. Ackbarow, X. Chen, S. Keten, M.J. Buehler, "From the cover: Hierarchies, multiple energy barriers and robustness govern the fracture mechanics of alpha-helical and beta-sheet protein domains," *P. Natl. Acad. Sci. USA*, Vol. 104(42), pp. 16410-16415, 2007 (cover article).
37. M.J. Buehler and T. Ackbarow, "Fracture mechanics of protein materials," *Materials Today*, Vol. 10(9), pp. 46-58, 2007.
38. M.J. Buehler and S.Y. Wong, "Entropic elasticity controls nanomechanics of single tropocollagen molecules," *Biophys. J.,* Vol. 93(1), pp. 37-43, 2007.
39. M.J. Buehler and H. Gao, "Dynamical fracture instabilities due to local hyperelasticity at crack tips," *Nature*, Vol. 439, pp. 307-310, 2006.
40. M.J. Buehler, "Nature designs tough collagen: Explaining the nanostructure of collagen fibrils," *Proc. Nat'l Acad. Sci. USA,* Vol. 103 (33), pp. 12285–12290, 2006.
41. M.J. Buehler, A.C.T. v. Duin, W.A. Goddard III, "Multi-paradigm modeling of dynamical crack propagation in silicon using a reactive force field," *Phys. Rev. Lett.,* Vol. 96, p. 95505. 2006
42. M.J. Buehler, F.F. Abraham, H. Gao, "Hyperelasticity governs dynamic fracture at a critical length scale," *Nature*, Vol. 426, pp. 141-146, 2003.

Service and Leadership Activities

Academic leadership appointments listed above under "Formal Appointments"

Invited, Keynote and Plenary Talks: More than 200 invited talks, including more than 20 plenary and keynote lectures given in North America, Europe, Asia, Zealandia and Africa; several invited talks at Gordon Research Conferences.

Editorial Activities: Significant expertise and track record in scientific editing and publishing.
- Editor-in-Chief, *BioNanoScience* (Springer): Conceived journal concept and formed editorial board and editorial leadership;
- Section Editor, *Nanotechnology* (Institute of Physics);
- Editorial Board, *Computational Materials Science* (Elsevier);
- Editorial Board, *J. Royal Soc. Interface* (Royal Society);
- Academic Editor, *PLoS ONE* (Public Library of Science);

- Editor, *Acta Mech. Sinica* (Springer);
- Executive Editor, *International Journal of Applied Mechanics* (Imperial College Press);
- Associate Editor, *Journal of Engineering Mechanics* (ASCE);
- Editorial Board, *Mech. Behav. Biomed. Mat.* (Elsevier);
- Editorial Board, *Journal of Nanomechanics and Micromechanics* (ASCE);
- Associate Editor, *J. Comp. Theor. Nanosci.* (Amer. Sci. Publ.);
- Guest Editor, *J. Mater. Sci.* (Springer)
- Guest Editor, *J. Mater. Res.* (Materials Research Society)

Committees and service (selection)

- Chair, Fifth International Conference on Mechanics of Biomaterials & Tissues 2013, Sitges, Spain, 2012-2013
  http://www.mechanicsofbiomaterials.com/
- Co-Chair, NanoEngineering for Medicine and Biology Congress NEMB2013, 2012-2013
  http://www.asmeconferences.org/NEMB2013/index.cfm
- Chair, Fourth International Conference on Mechanics of Biomaterials & Tissues 2011, Hawai'i, 2010-2011.
- Symposium organizer of several Materials Research Society Symposia
  - MRS Spring Meeting 2010: Symposium QQ: Biological Materials and Structures in Physiologically Extreme Conditions and Disease (with J. Spatz, D. Kaplan, C.T. Lim)
  - MRS Fall 2010 "Multiscale Mechanics of Hierarchical Biological, Bioinspired, and Biomedical Materials" (with U. Wegst, R. Narayan, C. Hellmich)
  - MRS Fall Meeting 2011: Symposium OO: Multiscale Mechanics of Hierarchical Materials (with H. Espinosa, U. Wegst, T. Benson-Tolle, M. Landingham)
  - MRS Spring Meeting 2012: *De novo* graphene and carbon nanomaterials (with: C. Ozkan, N. Pugno, Y. Gogotsi) & others
- Chair, Biomechanics Committee at the ASCE Engineering Mechanics Institute (EMI), since 2008. Established new student award: "*Y.C. Fung Student Paper Competition on Biomechanics and Biophysics*" (held for the first time at the EMI 2011 Conference at Northeastern University, Boston, MA).
- Co-Chair, NanoEngineering for Medicine and Biology Congress Steering Committee of ASME, since 2010.
- Member, Nanoengineering Council Executive Committee, since 2010.
- At MIT:
  - Chair, Faculty Search Committee in Civil and Environmental Engineering, 2011-2012;
  - Member, Department Council in Civil and Environmental Engineering, since 2010;
  - Faculty Advisor to the Everett Moore Baker Memorial Foundation, since 2009;
  - Member, Editorial Board of the Faculty Newsletter, 2009-2012;
  - Member, Undergraduate Association (UA) Advisory Committee, 2010-2012;
  - Chair, Search for the Director of the MIT Initiative on the Environment (2014); and member of strategic committee in the School of Engineering and beyond.

Outreach and Broader Impact: Broad interest in public outreach

- Research advisor for various undergraduate and high school programs, e.g.: *Research Experience for Teachers* at *MIT's Center for Materials Science* (program for high school teachers to be exposed to science and engineering research); *MIT's Summer Research Program* (MSRP), tailored to recruit

underrepresented groups to MIT graduate schools; research mentor at the *Research Scholar Institute (RSI)* for high school students, others.
- Published lecture notes for most courses taught and made freely available on MIT's *OpenCourseWare*
- Given public lectures on nanotechnology for broad audiences, incl. outreach programs at local high schools, and other venues to promote science and engineering to the general public. Appeared on numerous TV and radio shows to explain the impact of his research to broad audiences (including BBC, Fox News, National Public Radio, and many others).
- Participant in several career panels for undergraduate & graduate students, postdocs
- Developed web-based suite of simulation applets "SIMS" (http://mit.edu/cranford/www/SIMS) and nanoHUB tools for classroom teaching and outreach and to increase the use of computational methods in materials science

Major Honors and Awards (selection)
- ASME Journal of Applied Mechanics Award 2014;
- Robert Lansing Hardy Award 2013 (TMS);
- TMS Structural Materials Division JOM Best Paper Award of TMS 2013;
- Materials Research Society Outstanding Young Investigator Award 2012;
- IEEE Holm Conference Antler Lecture Award 2012;
- Society of Engineering Science Young Investigator Medal 2012;
- Alfred Noble Prize 2011 (awarded by the combined engineering societies of the United States);
- Thomas J.R. Hughes Young Investigator Award 2011 (for special achievements in Applied Mechanics for researchers under the age of 40, given by ASME's Applied Mechanics Division);
- Leonardo Da Vinci Award 2011 (Engineering Mechanics Institute of ASCE);
- Stephen Brunauer Award 2011 (ACS);
- Rossiter W. Raymond Memorial Award 2011 (AIME);
- Best Paper Award, International Journal of Applied Mechanics (Imperial College Press) 2010;
- Sia Nemat Nasser Award 2010 (given by ASME for research excellence in the areas of experimental, computational, and theoretical mechanics and materials);
- Harold E. Edgerton Faculty Achievement Award 2010 (highest honor bestowed upon young MIT faculty for exceptional distinction in teaching and research scholarship);
- Presidential Early Career Award for Scientists and Engineers (PECASE) 2009 (highest honor bestowed by the United States government on outstanding scientists and engineers beginning their independent careers);
- United States Navy Young Investigator Award 2008;
- DARPA Young Faculty Award 2008;
- Air Force Office of Scientific Research Young Investigator Award 2008;
- National Academy of Engineering–Frontiers of Engineering 2007 (invited participant) & 2008, 2013 (plenary speaker);
- Esther and Harold E. Edgerton Career Development Chair Professorship 2007;
- National Science Foundation CAREER Award 2007;
- First Prize Materials Research Society Gold Graduate Student Award, 2004;
- Merit Award, Mathematical Science Department & Graduate Fellowship Michigan Tech, 200-2001.

Teaching and Educational Activities
- *Spring 2006-2013 1.021J "*Introduction to Modeling and Simulation*" (with J.

Grossman/Department of Materials Science and Engineering since 2010); undergraduate
- Spring 2006, 3.22 "*Mechanical Properties of Materials*"; graduate
- IAP 2006, 2007 1.978 PDF "*From nano to macro: Introduction to atomistic modeling techniques*"; graduate
- Fall 2007, 2010, 2012, 1.050 "*Engineering Mechanics I*"; undergraduate
- *Fall 2008, 2011 1.545 "Atomistic Modeling of Materials and Structures"; graduate
- MIT Professional Education: Materials By Design (http://web.mit.edu/professional/short-programs/courses/materials_by_design.html)
- Lecturer at several winter/summer schools, including: *Global Enterprise for Molecular Medicine and Molecular Mechanics (GEM4),* in 2007, 2008, 2009, 2010; *International Centre for Mechanical Sciences (CISM)* in 2012, etc..

*Developed computational materials science methods into undergraduate classroom teaching via a web interface nanoHUB (http://web.mit.edu/star/molsim/nanohub/index.html).

Student and Postdoctoral Supervision

Supervised 9 postdoctoral researchers, 12 Ph.D. students (principal supervisor), 10+ additional Ph.D. students as committee member/co-advisor), 40+ undergraduate students (Undergraduate Research Opportunities Program (UROP), MSRP, National Science Foundation REU, etc.). Several former students and postdocs now faculty members at leading research universities.

Funding and scientific leadership

Maintains and directs a large research program at MIT, the Laboratory for Atomistic and Molecular Mechanics. Major grants from the National Institutes of Health, Department of Defense, and the National Science Foundation. Includes grants from industry and governmental agencies within the US and abroad. Several projects include multiple PIs that stretch across multiple universities and countries.