Markus J. Buehler, Ph.D.
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SUMMARY

Markus J. Buehler is the McAfee Professor of Engineering at MIT, a member of the Center for Materials Science and Engineering, and the Center for Computational Science and Engineering at the Schwarzman College of Computing. In his research, Professor Buehler pursues new modeling, design and manufacturing approaches for advanced biomaterials that offer greater resilience and a wide range of controllable properties from the nano- to the macroscale. His interests include a variety of functional material properties including mechanical, optical and biological, linking chemical features, hierarchical and multiscale structures, to performance in the context of physiological, pathological and other extreme conditions. His methods include molecular and multiscale modeling, design, as well as experimental synthesis and characterization. His particular interest lies in the mechanics of complex hierarchical materials with features across scales (e.g. nanotubes, graphene and natural biomaterial nanostructures).

His recent research has resulted in a new paradigm for the analysis of bio-inspired materials and structures to devise new biomaterial platforms, and using a mathematical categorization approach that connects insights from disparate fields such as materials, structures to music and language. His work also includes the introduction of AI methods in materials modeling and design, especially fracture mechanics, featuring a novel perspective to connect datasets form experiment and simulation to develop multiscale models. He has applied these methods to wide ranging areas of application including protein folding, fracture, and composite design, and coupled the *de novo* design methods with additive manufacturing approaches. He is well-known for his research on mechanically relevant proteins, especially silk, elastin, intermediate filaments, and collagen.

Prof. Buehler has authored more than 450 peer-reviewed publications (H-index=89), which have been cited around 30,000 times, and authored two monographs (as well as several edited books). He has given more than 400 invited/keynote/plenary talks around the world, and given several highly-praised TED talks. His technical innovations have resulted in several patents.

He is the Editor in Chief of the *Journal of the Mechanical Behavior of Biomedical Materials*, was recently elected as the Section Editor of *MRS Bulletin Impact* by the Materials Research Society, and is active on the editorial board of many other peer-reviewed journals. Buehler is an elected member of the Board of Directors of the Society of Engineering Science (SES), and between 2018 and 2020 served a three-year term as President-elect, President and Past President of the SES. He served as the chair of several conferences (including the ASME Global Congress on NanoEngineering for Medicine and Biology meeting in 2011), various societal committees in professional organizations, and is actively involved in public outreach (including an annual materials research camp at MIT with local middle and high schools). He was recently elected as MRS Fall 2021 Meeting Chair, one of the largest materials research conferences.

He is the recipient of many awards including the Harold E. Edgerton Faculty Achievement Award, the Alfred Noble Prize, the Feynman Prize in Nanotechnology, the Leonardo da Vinci Award, and the Thomas J.R. Hughes Young Investigator Award. He is a recipient of the National Science Foundation CAREER award, the United States Air Force Young Investigator Award, the Navy Young Investigator Award, and the Defense Advanced Research Projects Agency (DARPA) Young Faculty Award, as well as the Presidential Early Career Award for Scientists and Engineers (PECASE). In 2016 he was awarded the Foresight Institute Feynman Prize for his advances in nanotechnology. In 2018, he was selected as a Clarivate Highly Cited Researcher. In 2020, he was named as one of the global top 0.09% of all researchers worldwide in the nanoscience category in a study from Stanford University.

In addition to his teaching at MIT, he offers an annual Professional Education course "*Predictive Multiscale Materials Design*". As an active composer of classical and experimental music, he is active in scientific outreach and the intersection of art and science, and a member of the Executive Committee of MIT's Center for Art, Science and Technology (CAST). Based on his record in the translation of basic research into practice through entrepreneurship, Buehler is heavily involved with startups and innovation, such as through his role on the Board of Directors of Sweetwater Energy, Inc. and as a member of the Scientific Advisor Board of Safar Partners (A Technology Venture Fund with Private Equity Vision). He has extensive experience in scientific and engineering consulting for industry and law firms as expert witness.

PROFESSIONAL TRAINING

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

PROFESSIONAL APPOINTMENTS

2019	President, Society for Engineering Science (SES)
2018-present	Safar Partners Equity Fund, Scientific Advisory Board
2017-present	Member of the Board of Directors, Sweetwater Energy, Inc.
2015-present	McAfee Professor of Engineering (Institute-wide Endowed Chair Professorship), MIT
2013-2020	Head of Department, Dept. Civil and Environmental Engineering, MIT
2013-present	Professor (with tenure), Dept. Civil and Environmental Engineering, MIT
2011-2013	Co-Director, MIT Computation for Design and Optimization Program
2011-2013	Associate Professor with Tenure, Dept. Civil and Environmental Engineering, MIT
2010-2013	Group Leader, Mechanics and Materials Division in Civil & Environmental Engineering, MIT
2010-present	Director, MIT-Germany Program, MIT
2009-2010	Esther and Harold Edgerton Associate Professor, Civil and Environmental Engineering, MIT
2007-2009	Esther and Harold Edgerton Assistant Professor, Civil and Environmental Engineering, MIT
2006-2007	Assistant Professor, Dept. Civil and Environmental Engineering, MIT
2005-2006	Lecturer and Postdoctoral Associate, MIT
2004-2005	Director of Multiscale Modeling and Software Integration, Materials and Process Simulation Center, California Institute of Technology, Pasadena
2004-2005	Postdoctoral Scholar, 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
2001	Internship at Bosch, CR/AP1&APP2, Auslegung von Kunststoffbauteilen, Waibilingen
2000-2001	Graduate Research Assistant, Department of Mechanical Engineering-Engineering Mechanics, Michigan Technological University

SELECTED PUBPLICATIONS (total: 450+ peer reviewed articles, several books and book chapters; H-index 89 (Google Scholar), Clarivate Highly Cited Researcher)

- E. Khare, N. Holten-Andersen, M.J. Buehler, "Transition metal-coordinate bonds in protein-inspired materials and engineered polymer hydrogels for tunable mechanical properties," *Nature Reviews Materials*, in press (2020)
- T. Sapra, Z Qin, A. Dubrokvsky-Gaupp, U. Aebi, D. Muller, M.J. Buehler, O. Medala, "Nonlinear mechanics of lamin filaments and the meshwork topology build an emergent nuclear lamina," *Nature Communications*, in press
- K. Guo, M.J. Buehler, "A semi-supervised approach to architected materials design using graph neural networks," *Extreme Mechanics Letters*, Vol. 41, pp. 101029, 2020
- I. Su, M.J. Buehler, "Mesomechanics of a Three-Dimensional Spider Web," *Journal of the Mechanics and Physics of Solids*, Vol. 144, p. 104096, 2020
- M.J. Buehler, "Liquified protein vibrations, classification and cross-paradigm *de novo* image generation using deep neural networks," *Nano Futures*, p. 035004, Vol. 4(3), 2020
- M. Hsu, C.H. Yu, M.J. Buehler, "Using Deep Learning to Predict Fracture Patterns in Crystalline Solids," *Cell Matter*, Vol. 3, 1-15, 2020

- C.H. Yu; M.J. Buehler, "Sonification based de novo protein design using artificial intelligence, structure prediction, and analysis using molecular modeling," *APL Bioengineering*, Vol. 4(1), p. 016108, 2020.
- J. Yeo; G. Jung; F. Martin-Martinez; J. Beem; Z. Qin; M. Buehler, "Multiscale design of graphyne-based materials for high-performance separation membranes," *Advanced Materials*, https://doi.org/10.1002/adma.201805665, 2019
- E. Beniash, C. Stifler, C.-Y. Sun, G.S. Jung, Z.Qin, M.J. Buehler, P. Gilbert, "The hidden structure of human enamel," *Nature Communications*, paper #: 4383, 2019
- M. d'Ischia, A. Napolitano, A. Pezzella, P. Meredith, M.J. Buehler "Melanin biopolymers: Tailoring chemical complexity for materials design," *Angewandte Chemie International Edition*, DOI: 10.1002/anie.201914276, 2019
- W. S. Leong, H. Wang, J. Yeo, F. J. Martin-Martinez, A. Zubair, P.-C. Shen, Y. Mao, T. Palacios, M. J. Buehler, J.-Y. Hong, and J. Kong, "Paraffin-enabled graphene transfer," *Nat. Commun.*, Vol. 10, p. 867, 2019.
- D. Liu, A. Tarakanova, C. C. Hsu, M. Yu, S. Zheng, L. Yu, J. Liu, Y. He, D. J. Dunstan, and M. J. Buehler, "Spider dragline silk as torsional actuator driven by humidity," *Science Adv.*, Vol. 5, no. 3, 2019
- M. Buehler; A. Misra, "Mechanical behavior of nanocomposites," *MRS Bulletin*, Volume 44, 19-23, doi:10.1557/mrs.2018.323, 2019
- G.X. Gu, C.-T. Chen, M.J. Buehler "*De novo* composite design based on machine learning algorithm", *Extreme Mechanics Letters* 18, p. 19-28, 2018
- Y. Han, M. Li, G. Jung, M. A. Marsalis, Z. Qin, M. J. Buehler, L. Li, D. A. Muller "Sub-nanometre channels embedded in two-dimensional materials" *Nature Materials* (cover article), Vol. 17.2, pp. 129-133, 2018
- G. X. Gu, C.-T. Chen, D. J. Richmond, and M. J. Buehler, "Bioinspired hierarchical composite design using machine learning: simulation, additive manufacturing, and experiment," *Mater. Horizons*, vol. 5, no. 5, pp. 939–945, Aug. 2018 (Selected as 2018 Outstanding Paper Prize winner)
- A. Tarakanova, G. Yeo, C. Baldock, A. Weiss, M.J. Buehler, "Molecular model of human tropoelastin and implications of associated mutations", *Proceedings of the National Academy of Sciences (PNAS)*, Vol. 115 (28) 7338-7343, 2018
- Z. Qin, G.S. Jung, M.J. Kang, M.J. Buehler, "The mechanics and design of a lightweight three-dimensional graphene assembly," *Science Advances* 3 (1), e1601536SD, 2017
- S. Ling; Z. Qin; W. Huang; S. Cao; D. L. Kaplan; M. J. Buehler, "Design and function of biomimetic multilayer water purification membranes," *Science Advances*, DOI: 10.1126/sciadv.1601939, 3 (4), e1601939, 2017
- S. Ling, D. Kaplan, M. Buehler, "Universal material design strategies of biopolymer nanofibrils in nature and engineering," *Nature Reviews Materials* 3, Article number: 18016, 2018- Z. Qin, G.S. Jung, M.J. Kang,
- M.J. Buehler, "The mechanics and design of a lightweight three-dimensional graphene assembly," *Science Advance*s 3 (1), e1601536SD, 2017
- G. X. Gu; M. Takaffoli; M. J. Buehler, "Hierarchically Enhanced Impact Resistance of Bioinspired Composites," *Advanced Materials*, DOI: 10.1002/adma.201700060, 29 (28), 1700060, 2017
- M.J. Abdolhosseini Qomi, M.J. Buehler, S. Yip, F.-J. Ulm, K.J. Van Vliet, R.J-M. Pellenq, *et al.* "Combinatorial molecular optimization of cement hydrates," *Nature Communications* 5, p. 4960, 2014
- M.J. Buehler, "Materials by design-A perspective from atoms to structures," *MRS Bulletin*, 38 (2), 169-176, 2013
- A.K. Nair; A. Gautieri; S. Chang; et al., "Molecular mechanics of mineralized collagen fibrils in bone," *Nature Communications*, 4, 1724, 2013
- 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* 37(4), 395 2012.
- 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)
- T. Knowles, M.J. Buehler, "Nanomechanics of functional and pathological amyloid materials," *Nature Nanotechnology* 6(7), pp. 469-479, 2011.
- D. Sen, K. Novoselov, P. Reis and M.J. Buehler, "Tearing of graphene sheets from adhesive substrates produces tapered nanoribbons," *Small* 6(10), 1108-1116, 2010 (cover article).
- 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
- M.J. Buehler and H. Gao, "Dynamical fracture instabilities due to local hyperelasticity at crack tips," *Nature*, Vol. 439, pp. 307-310, 2006

- Buehler, M.J., J. Balk, H. Gao and E. Arzt, "Constrained grain boundary diffusion in thin copper films," In: *Handbook of Theoretical and Computational Nanotechnology,* Volume 5, Chapter 4, pp. 215-249, Eds. W. Schommers and M. Rieth, American Scientific Publishers, 2006.
- Hartmaier, A., M.J. Buehler, and H. Gao, "Multiscale Modeling of Deformation in Polycrystalline Thin Metal Films," *Advanced Engineering Materials* 7(3), 165-169, 2005
- M.J. Buehler, Y. Kong, and H. Gao, "Deformation mechanisms of very long singlewall carbon nanotubes subject to compressive loading," *Journal of Engineering Materials and Technology* 126, 245-249, 2004
- Buehler, M.J., F.F. Abraham, H. Gao, "Hyperelasticity governs dynamic fracture at a critical length scale," *Nature* 426, 141-146, 2003
- M.J. Buehler, B. Bettig, G. Parker, "Homogenization of Smart Material Cells for Finite Element Simulations," *Communications in Numerical Methods in Engineering,* Vol. 19, pp. 977–989, 2003

OTHER ACTIVITIES, SERVICE AND LEADERSHIP

1. **Invited, Keynote and Plenary Talks**:
   More than 400 invited talks, including many plenary and keynote lectures given around the world, at major conferences, workshops, and various research institutions and industry. His set of presentations also includes several TED talks and broad-impact general audience lectures.

2. **Editorial Activities:**
   Editor-in-Chief, J. Mech. Behav. Biomed. Mat. (Elsevier); Section Editor, MRS Bulletin Impact; Editor-in-Chief, BioNanoScience (Springer); Cell Matter, Member of the Editorial Advisory Board (Cell Press); Editorial Advisory Board, ACS Biomaterials Science and Engineering (American Chemical Society); Proceedings of the National Academy of Sciences (PNAS), Handling Editor; Editorial Board Member, Extreme Mechanics Letters (Elsevier); Editor Board Member, Scientific Reports (Nature Publishing Group); Editorial Board, Computational Materials Science (Elsevier); Academic Editor, PLoS ONE (Public Library of Science); Associate Editorial Board, Frontiers in Mechanics of Materials (Frontiers); Guest Editor, MRS Bulletin (MRS); Executive Editor, International Journal of Applied Mechanics (Imperial College Press); Associate Editor, Journal of Engineering Mechanics (ASCE); Editorial Board, Journal of Nanomechanics and Micromechanics (ASCE); Associate Editor, J. Comp. Theor. Nanosci. (Amer. Sci. Publ.); Editor, Acta Mech. Sinica (Springer); Guest Editor of J. Mater. Res. (Cambridge Univ. Press).

3. **Committees and Service** (selection)
   Chair, MRS Fall 2021 Meeting, 2019-2021; Member, Core Committee of New Engineering Education Transformation (NEET), MIT, 2017-2019; MIT Refugee ACTion (ReACT) Senior Advisory Committee, 2017-now; MIT Center for Computational Engineering Advisory Council, 2019-now; 2018-19, Co-Chair Eighth International Conference on Mechanics of Biomaterials & Tissues; Co-Chair, NanoEngineering in Medicine and Biology (NEMB) Congress 2013, Boston, 2013; Chair, Fourth International Conference on Mechanics of Biomaterials & Tissues 2011, Hawai'i; Chair, Biomechanics Committee at the ASCE Engineering Mechanics Institute (EMI), since 2008; Co-Chair, NanoEngineering for Medicine & Biology Congress Steering Committee of ASME, since 2010; Member, Nanoengineering Council Executive Committee, 2010.

4. **Teaching**
   3.021J Introduction to Modeling and Simulation (undergraduate)
   1.454 Atomistic Modeling and Simulation of Materials (graduate)
   1.050 Engineering Mechanics (undergraduate)
   "Predictive Multiscale Materials Design" (professional education summer course)

HONORS AND AWARDS (selection of major awards)

Materials Horizons - Outstanding Paper Prize (Royal Society of Chemistry), 2019; Highly Cited Researcher (Clarivate Analytics), recognizing exceptional research performance demonstrated by production of multiple highly cited papers that rank in the top 1% by citations for field and year in Web of Science, 2018; Elected as President, Society for Engineering Science (SES), 2017; Feynman Prize, Theory, 2016; Outstanding Young Scientist Award, NANOSMAT Society, 2016; Fellow, NANOSMAT Society, 2016; Most Cited Paper Award (2009-2015), International Journal of Applied Mechanics (IJAM), 2016; Elected Member, Board of Directors of the Society for

Engineering Science (SES), 2016; Elected Member, ASME Materials Division Executive Committee, 2015; Fellow, AIMBE, 2015; ASME Journal of Applied Mechanics Award 2014; Robert Lansing Hardy Award 2013 (TMS); TMS Structural Materials Division Best Paper Award 2013; MRS Outstanding Young Investigator Award 2012; IEEE Holm Conference Antler Lecture Award 2012; SES Young Investigator Medal 2012; Alfred Noble Prize 2011; Thomas J.R. Hughes Young Investigator Award 2011; Leonardo Da Vinci Award 2011 (ASCE); Stephen Brunauer Award 2011 (ACS); Rossiter W. Raymond Memorial Award 2011 (AIME); 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; Presidential Early Career Award for Scientists and Engineers (PECASE) 2009; United States Navy Young Investigator Award 2008; DARPA Young Faculty Award 2008; Air Force Office of Scientific Research Young Investigator Award 2008; National Science Foundation CAREER Award 2007; Materials Research Society Gold Graduate Student Award, 2004.

STUDENTS AND POSTDOCS

Many of his former students are now graduate students at major universities, and/or faculty at top universities around the world (Northwestern, Berkeley University, Tsinghua University, KAIST, and others), and other leading organizations. Selection of former students and current affiliation:

- Sinan Keten (Professor at Northwestern University)
- Zhao Qin (Assistant Professor, Syracuse University)
- Shengjie Ling (Assistant Professor, ShanghaiTech)
- Grace Gu (Assistant Professor, University of California, Berkeley)
- Jingjie Yeo (Assistant Professor, Cornell University)
- Anna Tarakanova (Assistant Professor, University of Connecticut)
- Chi-Hua Yu (Assistant Professor, National Cheng Kung University)
- Zhiping Xu (Professor, Tsinghua University)
- Reza Mirzaeifar (Assistant Professor, Virginia Tech)
- Shu-Wei Chang (Associate Professor, National Taiwan University)
- Arun Nair (Associate Professor, University of Arkansas)
- Evripides Loukaides (Lecturer, University of Bath)
- Flavia Libonati (Assistant Professor, University of Genoa)
- Steven Cranford (Editor-in-Chief, Cell Press, Matter)
- Chia-Ching Chou (Assistant Professor, National Taiwan University)
- GangSeob Jung (Distinguished Staff Fellow, Oak Ridge National Laboratory)
- Alfonso Gautieri (Assistant Professor, Politecnico di Milano)
- Seunghwa Ryu (Associate Professor, KAIST)
- Francisco Martin-Martinez (Lecturer, Swansea University)
- Tristan Giesa (Exponent, Inc.)