W. Craig Carter
Professor of Materials Science and Engineering
Department of Materials Science and Engineering
Secretary of the Faculty, MIT
Massachusetts Institute of Technology
ccarter@mit.edu

Professional Preparation:

Univ. of Calif., Berkeley	Materials Science and Engineering.	B.S. (1983)
Univ. of Calif., Berkeley	Materials Science and Engineering.	M.S. (1987)
Univ. of Calif., Berkeley	Materials Science and Engineering.	Ph.D. (1989)
NRC/NIST	Materials Science	Postdoc (1989-91)

Appointments:

Professor	MIT	June 2003-
Co-Founder and Scientific Consultant	24M Technologies	June 2010-
Visiting Professor	EPFL	2016-2020
Research Scientist	NIST	1992-1998
Staff Scientist	Rockwell International Science Center	1991-1992

Selected Awards

Outstanding Educator Award	American Ceramic Soc.	2017
Miller Visiting Professor	University of California	2013
Wolfram Innovator of the Year	Wolfram Research	2012
MacVicar Distinguished Teaching Fellow	MIT	2008-present
Bose Award ,Excellence in Teaching	MIT, School of Engin.	2008
R.M. Fulrath Award	American Ceramic Soc.	2005
Technology of the Year	Industry Week Magazine	1999
Fellow	American Ceramic Soc.	1999
Federal Civil Service Bronze Medal	Dept. of Commerce	1997
Robert Coble ,Young Scientist Award	American Ceramic Soc.	1996
Ross Coffin Purdy Award	American Ceramic Soc.	1990

Professional Interests:

My research centers on theory and meso-scale modelling of materials properties and processing. I do theory, modeling and simulations of material properties and processes. In particular, I have focused on thermodynamics and kinetics of interfaces, simulations of microstructural evolution, predictions of fracture and reliability in materials, and battery materials. I've co-authored public domain software to model microstructural properties from experimental images. I've co-founded a company, 24M, with Prof. Yet-Ming Chiang. I develop new teaching

methods for science and engineering and have won multiple awards for teaching excellence. As a tangential interest, I've been using numerical methods, additive manufacturing, and numerically controlled machining to produce exhibits in MOMA, the Pompideau, and the Haute Couture Fashion Show in Paris, and http://onemit.mit.edu/one-mit/.

Commercial

As a part of 24M, I developed and managed development of a software package ESWare that was sold to a multinational corporation and is being used to control optimal dispatch and economics of energy storage on the grid.

Publications

Scientific Disciplines in which publications appear:

- Kinetics, Thermodynamics, Battery Materials, Microstructural Evolution, Capillarity, Wetting, Interfaces, Microsctructural characterization, Sintering, Numerical Methods, Stochastic Models for Reliability, Fracture Mechanics, Mathematics, STEM Education, Phase Diagrams, Phase Field Modeling, Composites, Batteries and Electrochemistry, Metallic Glasses, Photonic Crystals, Colloids, Hamaker Forces, Anisotropy, 3D Printing

Books:

- R.W. Balluffi, S.M. Allen, W. C. Carter, "Kinetics of Materials" Published by J. Wiley, ISBN 13 978-0-471-24689-3, TA404.8.B35, 2005.
- W.C. Carter, W.C. Johnson, "Selected Works of John W. Cahn", TMS Publications and John Wiley and Sons, 1998 ISBN:0-87339-416-X

Patents:

- Carter, W. Craig, Marco Ferrara, Michael Goroff, and Maxwell Mann. "Energy storage modeling and control." U.S. Patent Application 17/378,425, filed November 4, 2021.
- Yet-Ming Chiang, William Henry Woodford, Frank Y. Fan, Zheng Li, Nir Baram, Kyle C. Smith, W. Craig Carter, Gareth H. McKinley, Ahmed Helal, ***METAL SULFIDE ELECTRODES AND ENERGY STORAGE DEVICES THEREOF***, ***Publication number:*** *20170200966,* ***Publication date:*** *July 13, 2017*
- *W. Craig Carter, Yet-Ming Chiang, Mihai Duduta, Pimpa Limthongkul,* ***High energy density redox flow device*** ***Patent number:*** *9614231,* ***Date of Patent:*** *April 4, 2017*
- *Alexander H. SLOCUM, Tristan DOHERTY, Ricardo BAZZARELLA, James C. CROSS, III, Pimpa LIMTHONGKUL, Mihai DUDUTA, Jeffry DISKO, Allen YANG, Throop WILDER, William Craig CARTER, Yet-Ming CHIANG,* ***STATIONARY SEMI-SOLID BATTERY MODULE AND METHOD OF MANUFACTURE*** ***Publication number:*** *20160190544,* ***Publication date:*** *June 30, 2016*
- *Brandon James Hopkins, Alexander H. Slocum, Xinwei Chen, Yet-Ming Chiang, Frank Yongzhen Fan, Ahmed Helal, Zheng Li, Kyle C. Smith, W. Craig Carter,* ***GRAVITY INDUCED FLOW CELL*** ***Publication number:*** *20150155585,* **Publication date:** June 4, 2015
- *Kyle Christopher Smith, W. Craig Carter, Yet-Ming Chiang,* ***Flow Battery Using Non-Newtonian Fluids*** ***Publication number:*** *20150125764,* ***Publication date:*** *May 7, 2015*

- *Alexander H. Slocum, Ricardo Bazzarella, William Craig Carter, Yet-Ming Chiang, Mihai Duduta,* ***STACKED FLOW CELL DESIGN AND METHOD*** ***Publication number:*** *20140004437,* ***Publication date:*** *January 2, 2014*

- *Yet-Ming Chiang, William Craig Carter, James C. Cross, III, Ricardo Bazzarella, Naoki Ota,* ***SEMI-SOLID ELECTRODE CELL HAVING A POROUS CURRENT COLLECTOR AND METHODS OF MANUFACTURE*** ***Publication number:*** *20130065122,* ***Publication date:*** *March 14, 2013*

- *Garry R. Maskaly, Yet-Ming Chiang, W. Craig Carter, R. Edwin Garcia,* ***Ionic colloidal crystals*** **, Patent number: 7446130, Date of Patent: November 4, 2008**

Journal publications

1. L'Etoile, Maxwell A., Carl V. Thompson, and W. Craig Carter. "A Level-Set Method for Simulating Solid-State Dewetting in Systems with Strong Crystalline Anisotropy." Acta Materialia 282 (January 2025): 120368. https://doi.org/10.1016/j.actamat.2024.120368.
2. Ramanandan, Santhanu Panikar, Alban Morelle, Michele Masseroni, et al. "Gate-Tunable Hole Transport in In-Plane Ge Nanowires by V-Groove Confined Selective Epitaxy." Advanced Functional Materials 35, no. 32 (2025): 2423734. https://doi.org/10.1002/adfm.202423734.
3. Ye, Matthew, Theodore Hueckel, Perapat P. Gatenil, Keisuke Nagao, W. Craig Carter, and Robert J. Macfarlane. "Nanoparticle Superlattices with Nonequilibrium Crystal Shapes." ACS Nano 18, no. 24 (2024): 15970–77. https://doi.org/10.1021/acsnano.4c04192.
4. Athanasiou, Christos E., Cole D. Fincher, Colin Gilgenbach, et al. "Operando Measurements of Dendrite-Induced Stresses in Ceramic Electrolytes Using Photoelasticity." Matter 7, no. 1 (2024): 95–106. https://doi.org/10.1016/j.matt.2023.10.014
5. Park, Richard J. -Y; Fincher, Cole D; Badel, Andres F; Carter, W. Craig) Chiang, Yet-Ming, *ACS Appl. Mater. Interfaces* 2023, 15, 30, 36117–36123 2023 https://doi.org/10.1021/acsami.3c04297
6. Mac Fhionnlaoich, Niamh and Schrettl, Stephen and Tito, Nicholas B. and Yang, Ye and Nair, Malavika and Serrano, Luis A. and Harkness, Kellen and Silva, Paulo Jacob and Frauenrath, Holger and Serra, Francesca and Carter, W. Craig and Stellacci, Francesco and Guldin, Stefan, "Reversible Microscale Assembly of Nanoparticles Driven by the Phase Transition of a Thermotropic Liquid Crystal***"****ACS Nano 2023, 17, 11, 9906–9918, 2023* ***https://doi.org/10.1021/acsnano.2c09203***
7. Cole D. Fincher , Christos E. Athanasiou , Colin Gilgenbach, Michael Wang ,Brian W Sheldon, , W. Craig Carter [1], Yet-Ming Chiang, "Controlling dendrite propagation in solid-state batteries with engineered stress", Joule, 6(12) 2022, Pages 2794-2809, https://doi.org/10.1016/j.joule.2022.10.011

8. L'Etoile, Maxwell A. and Wang, Baoming and Cumston, Quintin and Warren, Andrew P. and Ginn, James C. and Barmak, Katayun and Coffey, Kevin R. and Carter, W. Craig and Thompson, Carl V., "*Experimental and Computational Study of the Orientation Dependence of Single-Crystal Ruthenium Nanowire Stability* , Nano Letters 22(24) 9958—9963 2022 doi:10.1021/acs.nanolett.2c03529
9. Giovanna Bucci[1], Tushar Swamy[2], W. Craig Carter[3] and Morad Behandish[1] "Modeling of Porous Lithium Metal Electrodes: Turning the Li-Dendrite Problem Around," Journal of The Electrochemical Society, Volume 169, Number 7 Giovanna 2022 *J. Electrochem. Soc.* **169** 070501
10. Park, R.JY., Eschler, C.M., Fincher, C.D. *et al.* Semi-solid alkali metal electrodes enabling high critical current densities in solid electrolyte batteries. *Nat Energy* **6,** 314–322 (2021). https://doi.org/10.1038/s41560-021-00786-w
11. Güniat, Lucas, Lea Ghisalberti, Li Wang, Christian Dais, Nicholas Morgan, Didem Dede, Wonjong Kim et al. "GaAs Nanowires on Si Nanopillars: Towards Large Scale, Phase-engineered Arrays." *Nanoscale Horizons* (2022).
12. Varnavides, G., Mortensen, A. and Carter, W.C., 2021. Simulating Infiltration as a Sequence of Pinning and De-pinning Processes. *Acta Materialia*, *210*, p.116831.
13. Bucci, Giovanna, Karim Gadelrab, and W. Craig Carter. "Mesoscale Model for Ostwald Ripening of Catalyst Nanoparticles." *Journal of The Electrochemical Society* 168, no. 5 (2021): 054
14. Growth of nanowire arrays from micron-feature templates C Jürgensen[1], D Mikulik[1], W Kim[1], L Ghisalberti[1], G Bernard[1], M Friedl[1], W Craig Carter[2], A Fontcuberta i Morral[1,3] and P Romero-Gomez[1] April 2019 Nanotechnology, Volume 30, Number 28
15. Escobar Steinvall, S., Ghisalberti, L., Zamani, R. R., Tappy, N., Hage, F. S., Stutz, E. Z., et al *Heterotwin Zn 3P 2superlattice nanowires: the role of indium insertion in the superlattice formation mechanism and their optical properties*. Nanoscale, 12(44), 22534–22540. doi:10.1039/D0NR05852A . (2020*).*
16. Questioning liquid droplet stability on nanowire tips: from theory to experiment Lea Ghisalberti[1], Heidi Potts[1], Martin Friedl[1], Mahdi Zamani[1], Lucas Güniat[1], Gözde Tütüncüoglu[1], W Craig Carter[1,2] and Anna Fontcuberta i Morral[3,1] Published 25 April 2019 Nanotechnology, Volume 30, Number 28
17. Swamy, T; Park, R; Sheldon, BW; Rettenwander, D; Porz, L; Berendts, S; Uecker, R; Carter, WC; Chiang, YM, *Lithium Metal Penetration Induced by Electrodeposition through Solid Electrolytes: Example in Single-Crystal Li6La3ZrTaO12*, JOURNAL OF THE ELECTROCHEMICAL SOCIETY 165 (16) A3648- A3655 10.1149/2.1391814jes (2018)
18. Xiang, K Yang, KQ; Carter, WC; Tang, M Chiang, YM, *Mesoscopic Phase Transition Kinetics in Secondary Particles of Electrode-Active Materials in Lithium-Ion Batteries*, CHEMISTRY OF MATERIALS, 30 (13), 4216—4225, 10.1021/acs.chemmater.7b05407 (2018)

19. Balakrishna, AR Carter, WC, *Combining phase-field crystal methods with a Cahn-Hilliard model for binary alloys*, PHYSICAL REVIEW E 97 (4) 10.1103/PhysRevE.97.043304 (2018)

20. Porz, L; Swamy, T; Sheldon, BW; Rettenwander, D; Fromling, T; Thaman, HL; Berendts, S; Uecker, R; Carter, WC; Chiang, YM , "*Mechanism of Lithium Metal Penetration through Inorganic Solid Electrolytes",* 7 (20) 10.1002/aenm.201701003 **(**2017)

21. Bucci, G; Swamy, T; Chiang, YM; Carter, WC, *"Modeling of internal mechanical failure of all-solidstate batteries during electrochemical cycling, and implications for battery design"*, JOURNAL OF MATERIALS CHEMISTRY A 5 **(**36) 19422-19430 10.1039/c7ta03199h (2017)

22. Bucci, G; Swamy, T; Chiang, YM; Carter, WC, "*Random Walk Analysis of the Effect of Mechanical Degradation on All-Solid-State Battery Power"*, JOURNAL OF THE ELECTROCHEMICAL SOCIETY 164 (12) A2660-A2664 10.1149/2.1581712jes **(**2017)

23. Bucci, G; Chiang, YM; Carter, WC; "*The Effect of Stress on Battery-Electrode Capacity*", JOURNAL OF THE ELECTROCHEMICAL SOCIETY 164 (4) A645-A654 10.1149/2.0371704jes **(**2017)

24. Chen, XW; Hopkins, BJ; Helal, A; Fan, FY; Smith, KC; Li, Z; Slocum, AH; McKinley, GH; Carter, WC; Chiang, YM, "*A low-dissipation, pumpless, gravity-induced flow battery*", ENERGY & ENVIRONMENTAL SCIENCE, 9 (5) 1760-1770, 10.1039/c6ee00874g (2016)

25. Matteini, F; Tutuncuoglu, G; Mikulik, D; Vukajlovic-Plestina, J; Potts, H; Leran, JB; Carter, WC; Morral, AFI "*Impact of the Ga Droplet Wetting, Morphology, and Pinholes on the Orientation of GaAs Nanowires",* CRYSTAL GROWTH & DESIGN, 16 (10) 5781-5786 10.1021/acs.cgd.6b00858 (2016)

26. Zucker, RV; Carter, WC; Thompson, CV, *"Power-law scaling regimes for solid-state dewetting of thin films"*, SCRIPTA MATERIALIA, *116* 143-146 10.1016/j.scriptamat.2016.01.039, (2016)

27. Bucci, G., Chiang, Y. –M., & Carter, W. C. "*Formulation of the coupled electrochemical-mechanical boundary-value problem, with applications to transport of multiple charged species"* Acta Materialia, 104, 33-51. doi:10.1016/j.actamat.2015.11.030 (2016).

28. Zucker, R. V., Carter, W. C., & Thompson, C. V. Power-law scaling regimes for solid-state dewetting of thin films. Scripta Materialia, 116, 143-146. doi:10.1016/j.scriptamat.2016.01.039 (2016).

29. Fan, Frank Y; Carter, W.Craig; Chiang, Yet-Ming, Mechanism and Kinetics of Li2S Precipitation in Lithium-Sulfur Batteries, ADVANCED MATERIALS, 27

(35) 5203-5209 (2015)

30. Li, Zheng, Xiang, Kai, Xing, Wenting., Carter, W. Craig , Chiang, Yet-Ming, Reversible "Aluminum-Ion Intercalation in Prussian Blue Analogs and Demonstration of a High-Power Aluminum-Ion Asymmetric Capacitor", ADVANCED ENERGY MATERIALS, *5* (5), art # 1401410, DOI: 10.1002/aenm.201401410, (2015)

31. Smith, Kyle C.; Brunini, Victor E.; Dong, Yajie; Chiang, Yet-Ming; Carter, W. Craig, "Electroactive-Zone Extension in Flow-Battery Stacks", *147*, 460-469, DOI: 10.1016/j.electacta.2014.09.108, (2015)

32. Fan, Frank Y.; Woodford, William H.; Li, Zheng; Baram, Nir; Smith, Kyle C.; Helal, Ahmed; McKinley, Gareth H.; Carter, W. Craig; Chiang, Yet-Ming "Polysulfide Flow Batteries Enabled by Percolating Nanoscale Conductor Networks" NANO LETTERS (2014) *14* (4), 2210-2218

33. Neri Oxman, Daniel Dikovsky, Boris Belocon, W. Craig Carter, "Gemini: Engaging Experiential and Feature Scales Through Multimaterial Digital Design and Hybrid Additive–Subtractive Fabrication ", 3D Printing, *1* (3), DOI: 10.1089/3dp.2014.1505 (2014)

34. Frolov, Timofey; Carter, W. Craig; Asta, Mark "Capillary Instability in Nanowire Geometries*"* NANO LETTERS (2014) *14* (6), 3577-3581

35. Smith, Kyle C.; Brunini, Victor E.; Dong, Yajie ; Chiang, Yet-Ming; Carter, W. Craig "Electroactive-Zone Extension in Flow-Battery Stacks" Electrochimica Acta, Volume 147, 20 November 2014, Pages 460-469, ISSN 0013-4686, http://dx.doi.org/10.1016/j.electacta.2014.09.108.

36. Smith, Kyle C.; Chiang, Yet-Ming; Carter, W. Craig "Maximizing Energetic Efficiency in Flow Batteries Utilizing Non-Newtonian Fluids." JOURNAL OF THE ELECTROCHEMICAL SOCIETY 161, no. 4 (2014): A486-A496.

37. Swallow, J. G.; Woodford, W. H.; Chen, Y.; Lu, Q.; Kim, J. J.; Chen, D.; Chiang, Y. -M.; Carter, W. C.; Yildiz, B. and Tuller, H. L.; Van Vliet, K. J., "Chemomechanics of ionically conductive ceramics for electrical energy conversion and storage," JOURNAL OF ELECTROCERAMICS, 32(1), 3-26, (2014,) 10.1007/s10832-013-9872-2

38. Woodford, William H.; Chiang, Yet-Ming; Carter, W. Craig; "Quantifying reliability statistics for electrochemical shock of brittle materials," JOURNAL OF THE MECHANICS AND PHYSICS OF SOLIDS, Volume 70, October 2014, Pages 71-83, ISSN 0022-5096, http://dx.doi.org/10.1016/j.jmps.2014.05.011. (http://www.sciencedirect.com/science/article/pii/S0022509614001021)

39. Woodford, William H.; Carter, W. Craig; Chiang, Yet-Ming; "Strategies to Avert Electrochemical Shock and Their Demonstration in Spinels." JOURNAL OF THE

ELECTROCHEMICAL SOCIETY 161, no. 11 (2014): F3005-F3009.

40. Zucker, Rachel V.; Kim, Gye Hyun; Carter, W. Craig; Thompson, Carl V., A model for solid-state dewetting of a fully-faceted thin film, COMPTES RENDUS PHYSIQUE, 14(7), 564-577 (2013) 10.1016/j.crhy.2013.06.005

41. Kaplan, Wayne D. Chatain, D; Wynblatt, P.; Carter, W. C, A review of wetting versus adsorption, complexions, and related phenomena: the rosetta stone of wetting, JOURNAL OF MATERIALS SCIENCE 48 17 5681-5717 **DOI:** 10.1007/s10853-013-7462-y 2013

42. Li, Z; Young, D; Xiang, K; Carter, WC; Chiang, Y-M, Towards High Power High Energy Aqueous Sodium-Ion Batteries: The NaTi2(PO4)3/Na0.44MnO2 System, ADVANCED ENERGY MATERIALS 3 3 290-294 **DOI:** 10.1002/aenm.201200598 2013

43. Li, Zheng; Smith, Kyle C.; Dong, Yajie; Baram, Nir; Fan, Frank Y.; Xie, Jing; Limthongkul, Pimpa; Carter, W. Craig; Chiang, Yet-Ming, Aqueous semi-solid flow cell: demonstration and analysis, PHYSICAL CHEMISTRY CHEMICAL PHYSICS, 15(38) 15833-15839. (2013) 10.1039/c3cp53428f

44. Zucker, RV; Chatain, D; Dahmen, U; Hagege, S; Carter, WC; New software tools for the calculation and display of isolated and attached interfacial-energy minimizing particle shapes JOURNAL OF MATERIALS SCIENCE 47 24 8290-8302 **DOI:** 10.1007/s10853-012-6739-x 2012

45. Woodford, William H.; Chiang, Yet-Ming; Carter, W. Craig, Electrochemical Shock in Ion-Intercalation Materials with Limited Solid-Solubility, JOURNAL OF THE ELECTROCHEMICAL SOCIETY, 160(8), A1286-1292, (2013) 10.1149/2.104308jes

46. Tang, M; Carter, WC, Branching Mechanisms in Surfactant Micellar Growth, JOURNAL OF PHYSICAL CHEMISTRY B 117 **(**10)0 2898-2905 **DOI:** 10.1021/jp309204t MAR 14 2013

47. Kim, GH (Kim, Gye Hyun); Zucker, RV (Zucker, Rachel V.); Ye, J (Ye, Jongpil); Carter, WC (Carter, W. Craig); Thompson, CV (Thompson, Carl V.) Quantitative analysis of anisotropic edge retraction by solid-state dewetting of thin single crystal films, JOURNAL OF APPLIED PHYSICS 113 (4) #043512 **DOI:** 10.1063/1.4788822 JAN 28 2013

48. Qu, M; Woodford, WH; Maloney, JM; Carter, WC; Chiang, YM; Van Vliet, KJ,Nanomechanical Quantification of Elastic, Plastic, and Fracture Properties of LiCoO2 ADVANCED ENERGY MATERIALS Volume: 2 Issue: 8 Pages: 940 Published: AUG 2012

49. Woodford, William H.; Carter, W. Craig; Chiang, Yet-Ming, Design criteria for electrochemical shock resistant battery electrodes ENERGY & ENVIRONMENTAL SCIENCE 5 I7 Pages: 8014-8024, Published: JUL 2012

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53. V. E. Brunini, C. A. Schuh, W. C. Carter, Percolation of diffusionally evolved two-phase systems. *Physical Review E* **83**, (Feb, 2011).

54. V. Sharma, D. Y. Xia, C. C. Wong, W. C. Carter, Y. M. Chiang, Templated self-assembly of non-close-packed colloidal crystals: Toward diamond cubic and novel heterostructures. *Journal of Materials Research* **26**, 247 (Jan, 2011).

55. M. Drozdov, Y. Kauffmann, W. C. Carter, W. D. Kaplan, Shape-controlled nanopores in single crystals. *Nanotechnology* **21**, (Nov, 2010).

56. Y. H. Kao *et al.*, Overpotential-Dependent Phase Transformation Pathways in Lithium Iron Phosphate Battery Electrodes. *Chemistry of Materials* **22**, 5845 (Nov, 2010).

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58. W. C. Carter, STRUCTURE PREDICTIONS The genetics of grain boundaries. *Nature Materials* **9**, 383 (May, 2010).

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61. W. H. Woodford, Y. M. Chiang, W. C. Carter, "Electrochemical Shock" of Intercalation Electrodes: A Fracture Mechanics Analysis. *Journal of the Electrochemical Society* **157**, A1052 (2010).

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63. Vyom Sharma, Qingfeng Yan, C.C. Wong, W. Craig Carter, Yet-Ming

Chiang,Controlled and rapid ordering of oppositely charged colloidal particles, Journal of Colloid and Interface Science,Volume 333, Issue 1, 2009, Pages 230-236, ISSN 0021-9797, https://doi.org/10.1016/j.jcis.2009.01.047.

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66. M. Tang *et al.*, Nanometer-scale wetting of the silicon surface by its equilibrium oxide. *Langmuir* **24**, 1891 (Mar, 2008).

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69. R. F. Rajter, R. H. French, W. Y. Ching, W. C. Carter, Y. M. Chiang, Calculating van der Waals-London dispersion spectra and Hamaker coefficients of carbon nanotubes in water from ab initio optical properties. *Journal of Applied Physics* **101**, (Mar, 2007).

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Contributions to Scientific Community

1. Publication of publicly available OpenCourseWare for Mathematics in Materials Science and Engineering, Materials Thermodynamics
2. Public Domain Software “Wulffman,” “OOF,”
3. Past Chair, Basic Science for American Ceramic Society, Editorial Board for Journal of Materials Science, Gordon Conference Organizer
4. Ceramics Gordon Conference Chair
5. Advisor, Doctoral Training Center for Materials Modeling, Imperial College