Professor Shao-Horn is the JR East Professor of Engineering and Professor of Materials Science and Engineering at Massachusetts Institute of Technology (M.I.T.). Professor Shao-Horn earned her B.S. degree from Beijing University of Technology and her Ph.D. degree from Michigan Technological University both in Metallurgical and Materials Engineering. She joined M.I.T. faculty in 2002.

Professor Shao-Horn’s research is centered on exploiting physical chemistry principles to understand and design charge transfer and dynamics at interfaces, critical to enable clean energy for decarbonization and mitigate climate change. Professor Shao-Horn and coworkers have pioneered the use of electronic/phononic structures to develop guiding principles of kinetics, ion mobility and dynamics to enhance functions across a number of applications spanning from making of sustainable fuels and chemicals from reduction of water, CO₂ or nitrogen, to rechargeable lithium-ion/air batteries. Research programs include experimental and computational components including synthesis, (electro)chemical measurements, synchrotron X-ray diffraction and spectroscopy, electron- and light-based imaging and spectroscopy, Density Functional Theory computation and machine learning. The research is highly interdisciplinary and involving close collaborations with other leading labs and private sectors in chemical, automotive, and energy industries. Select research results from the past few years are described in detail below.

Professor Shao-Horn and her coworkers have tuned the oxide electronic structure to develop active and non-precious-metal-containing catalysts to promote oxygen reduction and evolution kinetics (accounting for ~75% of total energy loss), which is central to achieve high efficiencies of water-splitting devices, fuel cells, and metal-air batteries. The oxide electronic structure features, more specifically the energy levels of metal d and O p density of states (DOS), dictate the filling of antibonding orbitals on metal and oxygen sites, metal-oxygen covalency, and the binding strength with reaction intermediates, which influences the reaction energetic barrier for the rate-limiting step and thus reaction kinetics. Shao-Horn and her collaborators have also shown that the antibonding orbital filling (“e₈” 3d electron) of surface transition-metal cations controls the catalytic activity of oxides for oxygen reduction (Suntivich et al. Nature Chemistry 2011) and oxygen evolution (Suntivich et al. Science 2011) in a volcano-shaped dependence over several orders of magnitude. Applying this principle to design new oxide chemistry has led to intrinsic oxygen evolution activity greater than state-of-the art IrO₂ (Suntivich et al. Science 2011) and record intrinsic oxygen reduction activity for non-precious-metal-based catalysts known to date (Stoerzinger et al. JPCL 2015). Shao-Horn and her coworkers have established criteria to obtain high stability and activity of most active catalysts for oxygen evolution, where increasing the metal-oxygen covalency (smaller energy gap between metal d and O 2p states) enhances activity but beyond an optimal value reduces oxide stability (May et al. JPCL 2012 and Grimaud et al. Nature Comm 2013). Exploiting this concept to examine a series of oxides not only sets record catalytic activity but also establishes a new reaction mechanism for the most active oxides, where both metal and oxygen sites can catalyze oxygen evolution (Grimaud et al. Nature Chemistry 2017) and deprotonation from oxide surface can be rate-limiting (Hong et al. EES 2017) – contrary to long-standing belief. Therefore, tuning metal-oxygen covalency and activating surface oxygen sites points to a new direction to increase oxide activity and stability.

Recently, tuning surface oxygen activity using electronic structure has been applied in the design of positive electrode materials to suppress the dehydrogenation of electrolytes to enhance the lifetime and safety of high-energy Li-ion batteries (Giordano et al. JPCL 2017, Yu et al., JPCC 2018 and Zhang et
Increasing metal-oxygen covalency enhances dissociative adsorption of carbonate molecules on surface oxygen sites, which generates protic species to de-fluorinate electrolyte salt, and produce dehydrogenated organic species (Zhang et al., EES 2019). New electrolyte solvents resistant to oxidative dehydrogenation were designed and used to show excellent cycling of nickel-rich positive electrodes as well as lithium (Xue et al. Nature Energy 2021).

Professor Shao-Horn and coworkers have made notable contributions to advance the development of fuel cells for consumer vehicles. Her work on the mechanism of Pt catalyst loss in fuel cells in collaboration with GM has contributed to prolonging the lifetime of fuel cells from hundreds to thousands of hours and to the first commercialization of fuel-cell-powered vehicle, Mirai, by Toyota in 2015. In addition, Shao-Horn and her coworkers have established the degradation mechanisms of Pt and Pt alloy nanoparticles in fuel cells (Ferreira et al. JES 2005 and Chen et al. JES 2010). Recent work has demonstrated record ORR activity for Pt alloy catalysts in fuel cells exceeding the target set by US Department of Energy for 2017 by teaming up with GM and Johnson Matthey (Han et al. EES 2015).

Professor Shao-Horn and collaborators have shown that lattice dynamics can be used to control ion mobility in solid state electrolytes, where lowering the phonon DOS of mobile ions such as lithium and sodium reduces activation energy and promote ion mobility (Muy et al. Chem Review 2016, EES 2018 and JACS 2018). Such school of thoughts are being used to search and discover new solid state electrolytes (Muy et al. iScience 2019). Ongoing efforts are centered on developing a unified framework and descriptor on liquid, polymer and solid-state ceramic electrolytes (Qiao et al., ACS Central Science 2020 and Bradford et al., ACS Central Science 2023).

More recently, Professor Shao-Horn and collaborators have shown that tuning non-convalent interactions and solvation environments at the electrified interface can significantly the kinetic barriers for electron transfer and proton transfer and alter the rates of electron transfer (Huang et al, JPCC 2021) and proton-concerted electron transfer reactions including hydrogen evolution/oxidation (Huang et al. JACS Au 2021) and oxygen reduction (Tao et al., Nature Catalysis 2021). Such concepts are being used to control the selectivity of N2 and CO2 reduction to make fuels from electricity from Solar/Wind.

Professor Shao-Horn is a member of National Academy of Engineering, and is among top five most cited female researchers in chemistry in the world, and Highly Cited Researchers (Thomson Reuters) based on ~420 archival journal papers (~77,500 citations and h-index of 133 on Google Scholar) and ~350 invited, keynote and plenary lectures in academia (e.g. Marvel Lecture 2017 and Cardona Lecture 2019), at industrial events (e.g., BASF 150 Symposium in 2015) and high-level strategic meetings (e.g., Ideaslab of World Economic Forum in Davos 2017). She has advised ~100 students and postdoctoral associates at MIT, who are now pursuing successful careers in industry, national research laboratories, and in academia (~40) including faculty positions at Northwestern, University of Michigan, MIT, and Cornell and academic positions in Europe and Asia.

Professor Shao-Horn’s leadership and service contributions include: MIT Climate Grand Challenges program, MIT Energy Council, Co-Director for Center for Energy Storage at MIT; Energy Area Head of MIT Mechanical Engineering. In addition, she is serving on the Board of Directors and advisory boards of private/public organizations including SLAC/SUNCAT, ENSUS research chair at Mohammed VI Polytechnic University (Morocco), Fritz Haber Institute of Max Planck Society (Germany) and Wallenberg Initiative Materials Science for Sustainability (Sweden). Moreover, Professor Shao-Horn serves on advisory boards of leading journals including the Journal of Physical Chemistry in ACS, and Advanced Energy Materials from Wiley and Cell Press Chem and Joule.
YANG SHAO-HORN

EDUCATION
Ph.D. in Metallurgical & Materials Engineering (May 1998)
Michigan Technological University, Houghton, MI 49931
Dissertation: The structural stability of transition metal oxides for lithium rechargeable cells.
Research Advisor: Professor Stephen A. Hackney
B.S. in Metallurgical & Materials Engineering (July 1992)
Beijing University of Technology, Beijing, P.R. China

EMPLOYMENT
JR East Professor of Engineering 7/2021-present
Professor of Mechanical Engineering and Materials Science and Engineering 7/2020-present
W.M. Keck Professor of Energy, MIT 7/2015-6/2020
Gail E. Kendall Chair in Mechanical Engineering, MIT 7/2011-6/2015
Associate Professor, Department of Mechanical Engineering, MIT 7/2007-6/2011
Assistant Professor, Department of Mechanical Engineering, MIT 8/2002-7/2007

PROFESSIONAL SOCIETIES
Materials Research Society (1998-present)
American Chemical Society (2002-present)

HONORS and AWARDS
Otto Warburg Prize of the University of Bayreuth (2024); International Award for Lithium Batteries (IALB-2023); Best Female Scientists (https://research.com/scientists-rankings/best-female-scientists);
Adjunct Senior Scientist at Columbia University (2023-2024); Hans Fischer Senior Fellow of the Technical University of Munich (2022-2026); J.R. East Professor of Engineering (2021-present);
Humboldt Research Prize in Chemistry (2020); Fellow of the National Academy of Inventors (2020);
Dr. Karl Wamsler Innovation Award of the Technical University of Munich (2020); Highly Cited Researcher (2015-present);
Faraday Medal from Royal Society of Chemistry (2018); National Academy of Engineering (2018); Fellow of the International Society of Electrochemistry (2018);
Fellow of the Electrochemical Society (2017); Battery Research Award of the Electrochemistry Society (2016); Singapore Research Professorship (2015); Fellow of Royal Society of Chemistry (2014);
Fellow of American Association for the Advancement of Science 2014; International Battery Association Research Award (2013); Charles W. Tobias Young Investigator Award of the Electrochemical Society (2008);
Tajima Prize of the International Society of Electrochemistry (2008); Invited Professorship at the Université de Nantes (2008-2009), 3M Innovation Award Fund (2007), Air Products Faculty Excellence Award (2006); Dupont Young Faculty Award (2006); MIT Presidential Energy Research Council (2005); Office of Naval Research Young Investigator Award (2003);
Atlantic Richfield Career Development Professorship (2002); NSF International Research Fellow Award (2000); Norman Hackerman Young Author Award of The Electrochemical Society (1999); Battery Division Student Research Award of The Electrochemical Society (1997).
Representative Publications of Yang Shao-Horn


28. S. W. Lee, N. Yabuuchi, G.M. Gallant, S. Chen, B.S. Kim, P.T. Hammond and Y. Shao-Horn,


Selected Lectures of Yang Shao-Horn

Professor Shao-Horn has given ~350 invited, keynote and plenary lectures at university seminars, national and international conferences and events.

1. April 2024, Electrochemistry Renaissance for Climate Action, Materials Science Seminar, Boston University, MA.
2. March 2024, Understanding Electrolytes to Enable Advanced Batteries, Opening Lecture, Munch Battery Discussion, Munich, Germany.
4. November 2023, Understanding Electrolytes to Enable Advanced Batteries, IALB-Award Address, ABAA-14, Ho Chi Minh City, Vietnam.
5. November 2023, Electrochemistry Renaissance for Climate Action, Chemistry Seminar, MIT Chemistry Department, Cambridge, MA.
6. August 2023, Energy Storage for Climate Action, Opening Lecture, SUNCAT Summer School, Stanford University, Stanford, CA.
7. September 2022, Oxygen evolution on Rutile Ruthenium and Iridium Dioxides, Plenary, German Physics Society, Regensburg, Germany.
9. May 2022, Towards Net Zero, Karl Wamsler Innovation Award Address, Technical University of Munich, Munich, Germany.
11. November 2021, Mitigating Climate Change, CHUK, 100th Anniversary Celebration Lecture, virtual.
12. October 2021, Addressing Scientific Challenges to Mitigate Climate Change, Colloquium at Fritz Haber Institute of the Max Planck Society, Berlin, Germany.
13. April 2021, Towards decarbonizing chemicals and fuels, Andlinger Center Seminar, Princeton University, virtual.
27. February 2013, Oxygen Electrolysis on Oxides for Clean Energy Applications, **Plenary**, Zing Conference on Electrochemistry, Canary Islands, Spain.
Full Publications of Yang Shao-Horn

Professor Shao-Horn and coworkers have published ~420 peer-reviewed archival journal publications.


67. P. Pascual-Sebastian, Y. Shao-Horn and M. Escudero-Escribano, Toward understanding the role of the electric double layer structure and electrolyte effects on well-defined interfaces for electrocatalysis, Current Opinion in Electrochemistry, 32, 1008918, December 2021.


72. S. Vijay, H. H. Kristoffersen, Y. Katayama, Y. Shao-Horn, I. Chorkendorff, B. Seger, and K. Chan, How to extract adsorption energies, adsorbate–adsorbate interaction parameters and
saturation coverages from temperature programmed desorption experiments, Physical Chemistry Chemical Physics, 23, 24396-24402, October 2021.


Regulating oxygen activity of perovskites to promote NOx oxidation, Nature Catalysis, 4, 663-673, July 2021.
99. Y. Tsuji, S. Sako, K. Nitta, K. Yamamoto, Y. Shao-Horn, Y. Uchimoto and Y. Orihasa, Surface analysis of lanthanum strontium cobalt oxides under cathodic polarization at high temperature through operando total-reflection X-ray absorption and X-ray fluorescence spectroscopy, Solid

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106. T.-H. Shen, L. Spillane, J. Vavra, T. H. M. Pham, Y. Shao-Horn, and V. Tileli, Oxygen Evolution Reaction in Ba_{0.5}Sr_{0.5}Co_{0.8}Fe_{0.2}O_3-δ Aided by Intrinsic Co/Fe Spinel-Like Surface, Journal of the American Chemical Society, 142, 15876-15883, August 2020.


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**Full Patents and Patent Applications of Yang Shao-Horn**

*Many of these have associated international patents*


11. Lee, Dongjoon; Johnson, Jeremiah A.; Huang, Mingjun; Feng, Shuting; Zhang, Wenxu; Kwon, Hyukjae; Kim, Mokwon; Kim, Taeyoung; Shao-Horn, Yang; Giordano, Livia. “Polymer Compound, Film Compromising the Same, and Lithium Air Battery Comprising the Film”, US


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