Kyushu University World Premier International Researcher Invitation Program: "Progress 100"

Special Short Seminar Series

Electrochemical Energy Conversion Research at Illinois

Part 1: High-Performance Ternary Oxide Electrocatalysts for Oxygen Evolution Reaction

Part 2: Understanding the Growth and Structural Control of Platinum-Based Oxygen Reduction Electrocatalysts through In Situ Techniques

Part 3: Bimetallic Nanostructures in Chemical Conversion for Sustainability Application

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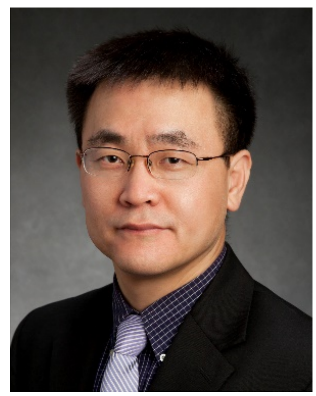

Bio-sketch: Prof. Hong Yang is the Richard C. Alkire Professor of Chemical Engineering at the University of Illinois at Urbana-Champaign (UIUC). He received his B.Sc. degree from Tsinghua University (1989), M.Sc. degree from University of Victoria (1994), and Ph.D. degree from University of Toronto (1998) and did his postdoctoral training at Harvard University. He worked at University of Rochester for the first ten years of his academic career and then joined the faculty of UIUC in 2012. Among his awards and honors, Dr. Yang received one of the two NSERC Canada Doctoral Prizes in Science (the highest graduate student award in Canada). He is an NSERC Postdoctoral Fellow, a US National Science Foundation CAREER Award winner, a Visiting Chair Professor with Shanghai Jiaotong University, and an elected Fellow of American Association for the Advancement of Science (AAAS). He is a Section Editor for *Current Opinion in Chemical Engineering*, and serves on the Editorial Boards of *Nano Today*, *ChemNanoMat*, *Frontiers in Energy* and a few other journals. He has given 160+ invited talks, including 26 plenary, keynote and name lectures. His publication has been cited for 16000+ times and an H-index of 62. His research interests include catalysis, and electrocatalysis, formation of nanocrystals, nanomaterials for energy applications.

Chair: Stephen M. Lyth

22nd March 2018, 3pm, I2CNER-1, 2nd Floor Conference Room

Talk 1: High-Performance Ternary Oxide Electrocatalysts for Oxygen Evolution Reaction

Improving the kinetics of oxygen evolution reaction (OER) is one of the challenging technical issues for energy generation and storage technology, especially the hydrogen production through water splitting. Ruthenium oxide and iridium oxide are the two best-known compounds that have reasonable catalytic activity along with good stability, especially in acid electrolyte. Recently several research groups have discovered ternary metal oxides of various types of perovskites and pyrochlores are excellent catalysts for OER, even in strong acid electrolytes in several materials. We found that several types of perovskites and pyrochlores show excellent performance in OER. Particularly, we showed $Y_2Ru_2O_7$ pyrochlore has not only improved OER activity but more importantly enhanced stability over RuO_2 catalysts. It was hypothesized that the introduction of yttrium in the pyrochlore structure could lower the energy state of Ru-O binding electrons thus structural stability based on the density functional theory (DFT) calculations, while affect the valency of Ru cation for high activity. I will present our recent study of such types of ternary oxide OER catalysts, and their structure-property relationship [1-4]. X-ray absorption spectroscopy (XAS), x-ray photoelectron spectroscopy (XPS), and DFT calculation are used to identify the effects of structure on the band position of d-electrons and the electrocatalytic properties. I will compare and discuss several models and contributing factors to the OER performance including, but not limited to, oxygen deficiency, mobile oxygen, cation valence state, and e_g orbital occupancy.

1. J. M. Kim,[#] P.-C. Shih,[#] K.-C. Tsao, Y.-T. Pan, X. Yin, C.-J. Sun, H. Yang, High-performance pyrochlore-type yttrium ruthenate electrocatalyst for oxygen evolution reaction in acidic media, *J. Am. Chem. Soc.*, **2017**, *139*, 12076-12083 (#: equal contribution).
2. J. M. Kim, X. X. Chen, P.-C. Shih, H. Yang, Porous perovskite-type lanthanum cobaltite as electrocatalysts towards oxygen evolution reaction, *ACS Sustainable Chem. Eng.*, **2017**, *5*, 10190-10917.
3. J. M. Kim, X. X. Chen, Y.-T. Pan, P.-C. Shih, H. Yang, W-doped $CaMnO_{2.5}$ and $CaMnO_3$ electrocatalysts for enhanced performance in oxygen evolution and reduction reactions, *J. Electrochem. Soc.*, **2017**, *164*, F1074-F1080.
4. J. M. Kim, X. Yin, K-C. Tsao, S. H. Fang, H Yang, $A_2B_2O_5$ as oxygen deficient perovskite electrocatalyst for oxygen evolution reaction, *J. Am. Chem. Soc.*, **2014**, *136*, 14646-14649.

22nd March 2018, 4pm, I2CNER-1, 2nd Floor Conference Room

Talk 2: Understanding the Growth and Structural Control of Platinum-Based Oxygen Reduction Electrocatalysts through In Situ Techniques

Development of low-cost, active and durable oxygen reduction electrocatalysts is important for the hydrogen fuel cell and other alternative energy device applications. Low platinum group metal (PGM) catalysts by using faceted bimetallic have been actively studied in recent years. In this presentation, I will discuss our recent efforts towards addressing the challenges in the precision control of structural variables of metal catalysts through careful examination of quantitative models of growth kinetics through understanding the ligand chemistry. The *in situ* liquid cell transmission electron microscopy (TEM) is also proved to be quite powerful for quantifying the growth and dissolution kinetics of the faceted electrocatalysts, while environmental TEM (ETEM) is a useful tool for examining the reaction conditions that affect the dynamics of near surface structures in real time. Such information helps in the post-synthesis processing of Pt-Ni octahedral oxygen reduction reaction (ORR) catalyst for the high performance through the thermally driven composition redistribution [1-5].

1. Yung-Tin Pan, Jianbo Wu, Hong Yang, *In situ* ETEM study of composition redistribution in Pt-Ni octahedral catalysts for electrochemical reduction of oxygen, *AIChE J*, **2016**, *62*, 399-407.
2. Wenpei Gao, Jianbo Wu, Aram Yoon, Ping Lu, Liang Qi, Jianguo Wen, Dean Miller, James Mabon, William Wilson, Hong Yang, Jianmin Zuo, Dynamics of transformation from platinum icosahedral nanoparticles to larger FCC crystal at millisecond time resolution, *Sci. Rep*., **2017,** 7, 17243.
3. Thao Ngo, Hong Yang, Towards ending the guessing game: Study of the formation of nanostructures using in situ liquid transmission electron microscopy, *J. Phys. Chem. Lett*., **2015**, *6*, 5051-5061.
4. Jianbo Wu, Wenpei Gao, Jianguo Wen, Dean J. Miller, Ping Lu, Jian-Min Zuo, Hong Yang, Growth of Au on Pt icosahedral nanoparticles revealed by low-dose *in situ* TEM, *Nano Lett*., **2015**, *15*, 2711-2715.
5. Jianbo Wu, Wenpei Gao, Hong Yang, Jian-Min Zuo, Dissolution kinetics of oxidative etching of cubic and icosahedral platinum nanoparticles revealed by in situ liquid transmission electron microscope, *ACS Nano*, **2017**, *11*, 1696–1703.

23rd March 2018, 4pm, I2CNER-1, 2nd Floor Conference Room

Talk 3: Bimetallic Nanostructures in Chemical Conversion for Sustainability Application

Optimal design of nanostructure is essential to achieve the requirements of catalytic performance in activity and stability. In this context, catalysts produced through conventional impregnation method can be further treated to create the catalytic surface with controlled single atom position or sub-monolayer atoms. In this talk, I will discuss the design and post-synthesis treatment of bimetallic catalysts to address the processing challenges in size, facet, surface composition and structures (*e.g.*, site specific bimetallic catalysts). The focus of this presentation will be on the controlled synthesis of bimetallic structures in solution, *in situ* variable temperature environmental transmission electron microscopy (TEM) in studying the structural dynamics of bimetallic catalysts (such as, Ag-Pt and Rh-Pd), structure-property relationship, and density functional theory (DFT) calculation in understanding the new catalytic phenomena [1-5].

1. Yung-Tin Pan, Linqing Yan, Yu-Tsun Shao, Jian-Min Zuo, Hong Yang, Regioselective atomic rearrangement of Ag-Pt octahedral catalysts by chemical vapor-assisted treatment, *Nano Lett.*, **2016**, *16*, 7988-7992.
2. Yung-Tin Pan, Yuqi Yan, Yu-Tsun Shao, Jian-Min Zuo, Hong Yang, Ag-Pt Compositional intermetallics made from alloy nanoparticles, *Nano Lett.*, **2016**, *16*, 6599–6603.
3. Yung-Tin Pan, Lingqing Yan, Hong Yang, Chemically controlled surface compositions of Ag-Pt octahedral catalysts, *MRS Commun*., **2017**, *7*, 179-182.
4. Neil Wilson, Yung-Tin Pan, Yu-Tsun Shao, Jian-Min Zuo, Hong Yang, David Flaherty, Direct synthesis of H_2O_2 on AgPt octahedra: The Importance of Ag-Pt coordination for high H_2O_2 selectivity, *ACS Catalysis*, **2018**, *8*, 2880-2889.
5. Yung-Tin Pan, Hong Yang, Rhodium-on-palladium nanocatalysts for selective methanation of carbon dioxide, *ChemNanoMat*, **2017**, *3*, 639-645.