# YAN YAO

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## EDUCATION AND PROFESSIONAL TRAINING

- Postdoctoral Scholar, Stanford University, Stanford, USA, 2010-2012
- Ph.D. in Materials Science and Engineering, University of California, Los Angeles, USA, 2008
- M.S. in Materials Science, Fudan University, China, 2003
- B.S. in Materials Science, Fudan University, China, 2000

## RESEARCH INTERESTS

Advanced materials and nanostructures for applications in energy storage; Magnesium and sodium ion battery electrode and electrolyte; Design and synthesis of high-energy-density organic and polymeric materials for battery electrodes; Aqueous organic flow battery for grid scale energy storage; Solid state electrolyte and all-solid-state-sodium-ion battery.

## EMPOLYMENT HISTORY

- Assistant Professor (2012- Present). Department of Electrical & Computer Engineering and Materials Science Engineering Program, University of Houston, Houston, TX, USA
- Robert A. Welch Assistant Professor (2012-Present), Texas Center for Superconductivity, University of Houston, Houston, TX, USA
- Postdoctoral Scholar (2010-2012), Stanford University, Stanford, CA, USA
- Senior Research Scientist (2008-2010), Polyera Corporation, Skokie, IL, USA
- Research & Teaching Assistant (2003-2008), University of California, Los Angeles, Los Angeles, CA, USA
- Research & Teaching Assistant (2000-2003), Fudan University, Shanghai, China

## AWARDS AND ACADEMIC RECOGNITIONS

### Selected Research and Teaching Awards and Recognitions

- ARPA-E 2015 FOA Award, co-Principal Investigator, Washington DC, USA, 2015
- ARPA-E RANGE Award, Principal Investigator, Washington DC, USA, 2013
- US Office of Naval Research (ONR) Young Investigator Award, Arlington, USA, 2013
- Ralph E. Powe Junior Faculty Enhancement Award, Oak Ridge Ass. Univ., USA, 2013
- Robert A. Welch Endowed Professorship, TcSUH, 2012
- Excellence in Graduate Polymer Science Research, American Chemical Society, USA, 2008

- Chinese Government Award for Outstanding Students Abroad, China, 2007
- ICI Student Award Finalist in Applied Polymer Science, American Chemical Society, USA, 2007
- Dissertation Year Fellowship, UCLA, USA, 2007
- General Electric Scholarship, Fudan University, China, 2001
- Chun-Tsung Scholar, Chun-Tsung Endowment, 2000
- Outstanding Undergraduate Student Award, Shanghai Education Council, China, 2000

**HIGHLIGHTS OF PUBLICATION RECORD**

- I am an author of ~50 technical journal papers in top journals such as *Nature Materials, Nature Nanotechnology, Nature Communications, Nano Letters, JACS, Nano Energy*, etc. and 14 patent and patent applications.

- My Google Scholar ***h***-index **29**. The total number of citations of my publication is above **12,000**. 16 papers are cited more than 200 times.

**RESEARCH FUNDING**

- For the last three years my group's research budget was ~ $1M per year. The funding allows me to support **7 PhD** graduate students and **2 postdocs**.

  **Total external funding of ~$3.0 million since 2012:**

- ARPA-E (2016-2019): "Low Cost, Safe, and Efficient All Solid State Sodium Batteries for Grid-scale Energy Storage and Other Applications" co-PI: **$889,000** (total project: 2,949,872, PI: Steve Martin, ISU) (*41 projects were funded out of over 2400 proposals*)
- DOD ONR DURIP (2015-2017): "Physical Property Measurement System for Research on Advanced Materials for Energy and Electronic Applications" co-PI: **$121,500** (total project: $810,000, PI: Venkat Selvamanickam, UH)
- NSF (2015-2017): "SusChEM: Design and Manufacture of Electrodes for High Energy Density Rechargeable Sodium Batteries" single PI: **$353, 297**
- DOD ONR Young Investigator Program (2013-2017): "Developing Multivalent Ion Intercalation Batteries as High Energy and Safe Marine Distributed Power Sources" single PI: ~**$660,000** (*16 awardee out of 310 applications*)
- ARPA-E RANGE Plus-up (2015): "Aqueous Lithium-Ion Batteries with High-Energy Novel Organic Anodes for Safe and Robust Energy Storage" single PI: **$200, 000**
- ARPA-E RANGE (2013-2015): "Aqueous Lithium-Ion Batteries with High-Energy Novel Organic Anodes for Safe and Robust Energy Storage" PI: **$760, 000** (co-PI: Jeff Xu, Southwest Research Institute) - my share is **$560,000** (*the only RANGE project funded in Texas*)
- Ralph E. Powe Junior Faculty Award (2014): "Understanding the High Efficiency Origin of Two-Dimensional Conjugated Polymer Based Solar Cells" single PI: **$5,000**

**Total internal funding of $158,000 since 2012:**

- TcSUH Core Funding Award (2015-2016): "Achieving High Efficiency Perovskite Solar Cells through Understanding Intermediate Phase" single PI: **$25,000**.
- TcSUH Core Funding Award (2013-2015): "Novel High-Energy Polymer Anodes for Safe and Robust Aqueous Lithium-Ion Batteries" single PI: **$40,000**.
- TcSUH (2012-2015): "TcSUH Welch Foundation Professorship" single PI: **$90,000**.
- UH Small Grant (2013): "Inverse-Opal Nanostructured Cathodes for High Energy Density Lithium-Air Batteries" single PI: **$3,000**

## OVERVIEW OF RESEARCH DIRECTIONS AND ACHIEVEMENTS

The following paragraphs are brief summary of research directions and achievements.

- ***Multivalent Ion Intercalation Two-Dimensional Materials for High Energy Batteries:*** Multivalent ions like magnesium and aluminum are very-low-cost elements and can deliver ultra-high volumetric energy density in batteries. Mg rechargeable batteries represent a safe and high-energy battery technology but suffer from the lack of suitable cathode materials due to the slow solid-state diffusion of the highly polarizing divalent Mg ion. In 2012, I proposed interlayer expansion as a general and effective atomic-level lattice engineering approach to transform inactive intercalation hosts into efficient Mg storage. The proposal leads to ~$660,000 ONR YIP award. We demonstrated experimentally that by inserting a controlled amount of poly(ethylene oxide) into the lattice of $MoS_2$ to increase the interlayer distance from 0.62 nm to up to 1.45 nm. The expansion boosts Mg diffusivity by 2 orders of magnitude, effectively enabling the otherwise barely active $MoS_2$ to approach its theoretical storage capacity as well as to achieve one of the highest rate capabilities among Mg-intercalation materials. (Y. Liang, et al., *Nano Lett.* **2015**, *15*, 2194-2202). Our group also demonstrated a hybrid Mg-Li ion battery that showed no capacity loss for 100 cycles with Coulombic efficiency as high as 99.9% under high current density (2 mA $cm^{-2}$). (H.D. Yoo, et al. *ACS Appl. Mater. Interfaces* **2015**, *7*, 7001-7007).

- ***Advanced Aqueous Lithium-Ion Batteries using Low-Cost Organic Carbonyl Polymers (OCP):*** Lithium-ion batteries raise safety, environmental, and cost concerns, which mostly arise from their non-aqueous electrolytes. To address this challenge, I proposed to ARPA-E ROBUST AFFORDABLE NEXT GENERATION EV-STORAGE (RANGE) program to use a group of completely innovative electrochemical redox couples based on low-cost OCP materials that leverage "matured" rechargeable lithium battery cathode chemistry characteristics and develop a reliable and high capacity anode material. The proposed project will meet today's performance standards, while minimizing the potential impact of battery failure, thus offering manufacturers greater flexibility with regard to vehicle design. We have developed **4-electron transfer, high capacity (~ 400 mAh/g)** organic materials that are stable (1000 cycles) in neutral to mild alkaline electrolyte. We have also discovered an OCP that could replace metal hydride (MH) in Nickel-MH battery with **improved stability for 500 cycles** in 5M KOH. Remarkably, the low temperature performance greatly surpassed that of a Ni-MH cell. We have filed for three patent applications (US 2014/033652; US 14/825,802; US 62/165,377). Based on these work, a team of undergraduate business students from Wolff Center for Entrepreneurship developed business plan and won the first place in the UNL New Venture competition and the third place in the 4th Annual Richards Barrentine Values and Ventures Business Plan Competition with $15,000 prize.

- ***Heavily n-Dopable π-Conjugated Redox Polymers for Energy-Related Applications:*** Organic π-conjugated polymers are emerging as a materials class for energy-related applications, enabling a path to a more sustainable energy landscape without the need of energy-intensive, expensive, and sometimes toxic metal-based compounds. Hole-transporting (semi)conducting polymers with substantial redox activity and electronic conductivity have been long recognized as electrode materials for batteries, supercapacitors, and thermoelectrics. However, all-polymer devices of this type have been difficult to realize due to the limitations of electron-transporting polymers. We proposed a "π-conjugated redox polymer" simultaneously featuring a π-conjugated backbone and integrated redox sites, which can be stably and reversibly n-doped to a high doping level of 2.0 using Li ion with significantly enhanced electronic conductivity. When evaluated as a charge storage material for rechargeable Li batteries, the polymer delivers 95% of its theoretical capacity at a high rate of 100C (72 s per charge−discharge cycle) as well as 96% capacity retention after 3000 cycles of deep discharge−charge. (Liang et al. *J. Am. Chem. Soc.* **2015**, *137*, 4956-4959). This work was selected as Editor's Choice and JACS Spotlight and was also highlighted in *ScienceDaily, EurekaAlert, Phys.org, EnergyHarvest, Nanotech-now.com, etc.*

- ***All-Solid-State Sodium Batteries for Grid-Scale Energy Storage***: A robust, low-cost, safe, scalable, long-lifetime, and high-energy-density electrical energy storage system is critically needed to help enable the shift from mining carbon- based subsurface energy stores to harvesting near surface carbon-free energy flows such as solar and wind. In the most recent ARPA-E award team project (PI: Prof. Steven Martin, Iowa State University), we will advance what is believed to be the most promising of all of these by demonstrating an entirely new low-cost all-solid-state sodium battery (ASSSB). My role in this project is to develop a new class of sustainable organic carbonyl-based materials for the cathode where the electroactivity of non-toxic, non-hazardous organic carbonyl polymers will be optimized for reversible and fast redox electron-transfer reactions. This will accentuate the known ability of carbonyl oxygen atoms to coordinate sodium ions. A small-business entity specializing in all-solid-state batteries, Solid Power, will provide rapid prototype testing and technology-to-market transition for commercial deployment.

## PRSENTATIONS AND INVITED TALKS

- **Talks at International Conferences**

  1. Invited talk in symposium of "ACS Award for Creative Invention: Symposium in honor of Antonio Facchetti", Heavily n-Dopable π-Conjugated Redox Polymers for Ultrafast Energy Storage, ACS Meeting, San Diego, 3/2016 (programmed)
  2. Invited talk in symposium of "Interplay of Structure & Transport Properties in Materials for Energy Applications", Rational Nanostructure Design for High Performance Mg

Rechargeable Batteries, ACS Meeting, San Diego, 3/2016 (programmed)

3. Contributed talk, Heavily n-Dopable π-Conjugated Redox Polymers with Ultrafast Energy Storage Capability, MRS Meeting, Boston, MA, 12/2/2015
4. Invited talk, Rational Nanostructure Design for Efficient Mg Rechargeable Batteries, The 10th Sino-US Nano Forum, Wuhan University of Technology, China, 6/26/2015.
5. Invited talk, Modification of Magnesium Ion Cathode and Electrolyte for Mg Rechargeable Batteries, TMS Meeting, Orlando, FL, USA, 3/16/2015.
6. Contributed talk: Tailoring Lithium-intercalation Host Structure for Rechargeable Magnesium Ion Cathodes, ACS Meeting, San Francisco, CA, USA, 8/12/2014.
7. Invited Talk, Modification of Magnesium Ion Cathode and Electrolyte for Mg Rechargeable Batteries, ECS Meeting, Orlando, FL, USA 5/15/2014.
8. Invited Talk, Atomic-Level Manipulation of Magnesium Ion Intercalation Materials for High-Density Energy Storage, 2014 Electrochemical Conference on Energy & the Environment, Shanghai, China, 3/13/2014.
9. Invited Talk, Nanostructure Engineering of Layered Metal Chalcogenides for Magnesium Battery Cathode, TMS Meeting, San Diego, CA, USA, 2/20/2014.
10. Invited Talk, High Energy Density Silicon Anodes for Lithium-ion Batteries: Combining Hollow Nanospheres with Conductive Polymer Binder, 245th ACS National Meeting, Division of Energy and Fuels, New Orleans, LA, 4/7-11/2013.
11. Invited Talk, Nanostructure Design for Efficient Energy Devices, Workshop on Materials Science and Materials Chemistry for Energy, Beijing, China, 9/16-18/2012.
12. Invited Talk, Nanostructured Materials and Devices for Energy Harvesting and Storage, Master Class Lecture, Printed Electronics USA, San Jose, CA, 12/2011.
13. Contributed talk, Resonating Mode Enhanced Optical Absorption in Si Hollow Nanospheres Solar Cells", MRS Spring meeting, San Francisco, CA, 4/2011.
14. Contributed talk, Hollow Silicon Nanospheres for Highly Reversible and Long Cycle Life Lithium Ion Battery Anodes", MRS spring meeting, San Francisco, CA, 4/2011.
15. Contributed talk, Self-Organization of Polymer Chains in Efficient Polymer Solar Cells, Excellence in Polymer Graduate Research Symposium, ACS, New Orleans, LA, 4/2008.
16. Invited talk, Plastic Bulk-Heterojunction Solar Cells and Near-Infrared Photodetectors", AVS, Seattle, WA, 10/2007.
17. Contributed talk, Plastic Near-Infrared Photodetectors Utilizing Low Band Gap Polymer, ICI student award symposium, ACS meeting, Boston, MA, 8/2007.

**Invited Talks at University Colloquia and Seminars**

1. Invited Colloquium Speaker, Interlayer-Expanded Molybdenum Disulfide Nanocomposites for Electrochemical Magnesium Storage, Florida International University, Miami, FL, USA, 3/21/2015
2. TcSUH PI meeting, Energy Materials and Devices Research in Yao Group, Houston, TX, USA, 12/18/2014
3. Materials and Nanostructure Design for Efficient and Low-cost Energy Conversion and Storage, MIT, Dr. Ju Li Group, Boston, MA, USA, 10/24/2014.
4. Invited speaker, Recent Development for Silicon Based Li-Ion Battery Anodes and Mg-ion Battery Cathodes, Department Seminar in Wuhan Institute of Technology, Wuhan, China, 3/10/2014

5. Invited Speaker, Nanostructure Design for Efficient Energy Devices, South University of Science and Technology of China, Shenzhen, China, 12/13/2013.
6. Invited Speaker, Nanostructure Design for Efficient Energy Devices, Department of Electrical Engineering, Tsinghua University, Beijing, China, 9/17/2013.
7. Invited Speaker, Nanostructure Design for Efficient Energy Devices, University of Shanghai for Science and Technology, Environmental Engineering, Shanghai, China, 9/10/2013.
8. Invited Speaker, Nanostructure Design for Efficient Energy Devices, Baylor College of Medicine, TX, USA, 3/4/2013.
9. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Mechanical Engineering Colloquium, University of Houston, Houston, TX, USA, 1/17/2013.
10. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, School of Materials Science and Engineering, Beijing University of Technology, 9/19/2012.
11. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Mechanical Engineering, Yale University, 5/2/2012.
12. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Materials Science and Engineering, University of Virginia, 4/30/2012.
13. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, College of Engineering, Dartmouth College, 4/26/2012.
14. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Mechanical Engineering, University of Washington, 4/16/2012.
15. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Materials Science and Engineering, University of Wisconsin Madison, 4/5/2012.
16. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Electrical and Computer Engineering, University of Houston, 4/2/2012.
17. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Mechanical Engineering, Chinese University of Hong Kong, 3/27/2012.
18. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Mechanical Engineering, Suzhou Institute of Nanotechnology, 3/23/2012.
19. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Department of Physics, Nanjing University, 3/21/2012.
20. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, FIST, Xi'an Jiaotong University, 3/19/2012.
21. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Mechanical Engineering, EPFL, 3/8/2012.
22. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Mechanical Engineering, John Hopkins University, 2/16/2012.
23. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, IMRE, Singapore, 2/3/2012.
24. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Nanyang Technology University, Singapore, 2/1/2012.
25. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, Mechanical Engineering, University of Texas San Antonio, 1/26/2012.
26. Invited Colloquium Speaker, Nanostructure Design for Efficient Energy Devices, MSE, Drexel University, 12/13/2011.
27. Invited Speaker, Nanostructured Energy Devices: Polymer Solar Cells and Lithium Ion

Batteries", Institute of Chemistry, Chinese Academy of Sciences, Beijing, China, 9/2011.

28. Invited Speaker, Nanostructured Energy Devices: Polymer Solar Cells and Lithium Ion Batteries", Materials Science, Fudan University, Shanghai, China, 9/2011.

**Invited Talks at Government Organization and Industry**

1. Invited Speaker, Low-Cost and Safe Magnesium Batteries, Sichuan Tianqi Lithium Industries Inc, Shehong, Sichuan, China, 7/6/2015.
2. Invited Speaker, Advanced Aqueous Lithium Ion Batteries using Organic Materials, ARPA-E RANGE Program Review Meeting, Tempe, AZ, USA, 1/28/2015.
3. Invited Speaker, Modification of Magnesium Ion Cathode and Electrolyte for Mg Rechargeable Batteries, Sustainable Energy Technologies Department Seminar in Brookhaven National Laboratory, Upton, NY, USA, 6/13/2014.
4. Invited Speaker, Advanced Aqueous Lithium Ion Batteries using Organic Materials, ARPA-E RANGE Program Kick-off Meeting, Kennedy Space Center, Cape Canaveral, FL, USA, 1/28/2014.
5. Invited Speaker, Nanostructure Design for Efficient Energy Devices, Schlumberger Sugar Land Technology Center, Sugar Land, TX, USA, 5/9/2013.
6. Invited Speaker, Nanostructure Design for Efficient Energy Devices, Southwest Research Institute, San Antonio, TX, USA, 3/13/2013.

## TEACHING AND GRADUATE STUDENT SUPERVISION

### Course Development and Revision

- I revised "*Introduction to Nanotechnology (ECE5319/6306)"* with a focus on sustainable energy. The course is offered to both undergraduate and graduate students across four departments (Electrical, Mechanical, Materials, Chemical Engineering) and attracted more than ~50 students, doubling the enrollment before the revision.
- I also developed a new course "*Advanced Batteries (ECE5397/ECE6397)*" offering to graduate students in spring 2013 for the *first* time and become a permanent course in the Department of Electrical Engineering.

### Teaching Evaluation

- My teaching load was 2 courses per year. All my teaching evaluations were excellent and above the college average.

| sem/year | course | Yan Yao | College Average | Yao/College ratio |
|---|---|---|---|---|
| Spring/2013 | ECE5397 | 4.33 | 4.27 | 1.01 |
| Spring/2013 | ECE6397 | 4.91 | 4.37 | 1.12 |
| Fall/ 2013 | ECE5319 | 4.56 | 4.23 | 1.08 |
| Fall/ 2013 | ECE6306 | 5.00 | 4.35 | 1.15 |
| Fall/ 2013 | MTLS6319 | 4.67 | 4.35 | 1.07 |
| Fall/ 2013 | MECE5319 | 5.00 | 4.23 | 1.18 |
| Spring/2014 | ECE6397 | 4.85 | 4.38 | 1.11 |

| | | | | |
|---|---|---|---|---|
| Fall/2014 | ECE5319 | 4.29 | 4.28 | 1.00 |
| Fall/2014 | ECE6306 | 4.86 | 4.32 | 1.13 |
| Fall/2014 | MECE5319 | 4.33 | 4.28 | 1.01 |
| Spring/2015 | ECE 6397 | 4.75 | 4.37 | 1.09 |

**Awards Received by Students and Postdoctoral Researchers**

- PhD student Yifei Li received the "Urvish Medh" award for the best overall presentation at the UH ECE Graduate Research Conference.
- PhD student Yifei Li received the third place in the TcSUH's 47th Semiannual Student Symposium.
- Dr. Yanliang Liang received the Nano Research Poster Award (Silver) on the 10th Sino-US Nano Forum, Wuhan, China, 2015.
- David Pineda, an undergraduate student in my group, was featured in UH Engineering News for his undergraduate research experience of "Construction of a vanadium redox flow battery system".

**Current PhD Students (7)**

- Yifei Li (2012- Present); Dissertation: Atomic level engineering of two-dimensional layered materials as non-lithium ion intercalation battery electrodes.
- Jing Yan (2013- Present); Dissertation: Design and synthesis of carbonyl-based polymer materials for aqueous rechargeable batteries.
- Saman Gheytani (2013-Present); Dissertation: Developing high capacity and stable electrodes for aqueous battery application.
- Kuan Yi Lee (2014-Present); Dissertation: Aqueous organic flow batteries.
- Fang Hao (2015-Present); First-year graduate student
- Hui Dong (2015-Present); First-year graduate student
- Benjamine Emley (2015-Present); First-year graduate student

**Current Postdoc Researchers (2)**

- Dr. Yanliang Liang (Research Associate, 2012.11-Present)
- Dr. Swaminathan Venkatesan (Postdoctral, 2015.5-Present)

**Graduated Master Students (1)**

- Shiyang Zhao (MSEE, UH, Dec. 2015); Thesis: "Synthesis and characterization of organic materials for aqueous lithium-ion batteries".

**Supervised Postdoctoral Researchers and Current Positions (4)**

- Dr. Hyun Deog Yoo (Postdoctoral, 2013.11-2015.5); current job: Research Assistant Professor, University of Illinois, Chicago, USA

- Dr. Qingyou An (Postdoctoral, 2014.7-2015.7); current job: Associate Professor, Wuhan Institute of Technology, Wuhan, China
- Dr. Yaoguang Rong (Postdoctoral, 2014.9-2015.9); current job: Associate Professor, Huazhong University of Science and Technology, Wuhan, China
- Dr. Zelang Jian (Postdoctoral 2013.12-2014.8); current job: Research Associate, Oregon State University, Oregon, USA

**Supervised Undergraduate Researchers (8)**

- Kayshewa Chamupathi (2015.2-Present), Chemical Engineering, 2015 UH SURF
- Junyoung Kim (2015.8-Present), Chemical Engineering
- Lateefat Alabi (2015 summer), Rice University, 2015 NSF REU
- Sarah Siemann (2015 summer), Rice University, 2015 NSF REU
- Harrison Graham (2014 summer), Trinity College, 2014 NSF REU
- Matthew Patton (2014 summer), Chemical Engineering, 2014 UH SURF
- David Pineda (2013 summer), Mechanical Engineering, 2013 UH SURF
- Joseph Whitehouse (2013 summer), UT San Antonio, 2013 NSF REU

## PROFESSIONAL SERVICE

**Highlights of Services at Conferences**

- Symposium organizer (with J. Xiao, PNNL, J. Wu, NASA, P. Liu, UCSD), *Electrochemistry and Batteries for Safe and Low-cost Energy Storage, 229th ECS meeting*, San Diego, CA, 2016.
- Symposium organizer (with J. Xiao, PNNL, S. Harris, Berkeley, P. Liu, UCSD), *Materials and Architectures for Safe and Low-cost Electrochemical Energy Storage Technologies*, MRS, Boston, MA, 2015.
- Symposium organizer (with R. Shahbazian-Yassar, Michigan Tech. Univ. and D. Mitlin, Clarkson U.), *Nanostructured Materials for Rechargeable Batteries and for Supercapacitors III*, 144th Minerals, Metals and Materials Society (TMS) Annual Meeting, Orlando, FL, 2015.
- Symposium organizer (with S. Meng, UCSD, D. Ji, OSU, and C. Xiong, BSU), *Batteries and Fuel Cell Technologies: Challenges and Solutions*, 248th ACS Meeting, San Francisco, CA, 2014.
- Session chair, ECS Meeting, Orlando, FL, 2014
- Session chair, TMS Meeting, San Diego, CA, 2014
- Session chair, ECS Meeting, Honolulu, HI, 2012

**Professional Reviewer Service for Funding Agencies**
- US National Science Foundation (DMR, ECCS) three times (12/2012, 1/2013, 11/2013)
- Proposal reviewer for ACS Petroleum Research Fund twice (9/2014 and 4/2015)
- Proposal reviewer for NASA EPSCoR proposal (8/2015)
- Proposal reviewer for European Research Council proposal (7/2015)
- Proposal reviewer for AAAS Center proposal (12/2014)

**Highlights of the Reviewer Professional Service for Technical Journals**

Nature Communications, ACS Nano, Advance Materials, Angewandte Chemie, Advance Energy Materials, Advanced Functional Materials, Applied Physical Letter, Chemistry of Materials, Energy and Environmental Science, Nano Letters, Nano Energy, Nano Research, NPG Asia Materials, Optical Express, Scientific Reports, Small, Journal of Electrochemical Society, Journal of Physical Chemistry, Journal of Solid State Electrochemistry, RSC Advances.

**Invited Editorial Service for Technical Journals**

- Editorial Board Member, *Scientific Reports*, a journal from Nature Publishing Group (2014-present).

**Membership and Service in Professional Societies**

- Treasure, Institute of Electrical and Electronics Engineers Magnetic Society and Nanotechnology Council Houston Chapter (2015- present).
- Member, Materials Research Society (MRS)
- Member, Electrochemical Society (ECS)
- Member, American Chemical Society (ACS)

*Activities:* serve as symposium organizers and chairs for conferences sessions; gave several invited talks.

## UNIVERSITY SERVICES

- Member, UH ECE Faculty Search Committee, 2015 Fall
- Member, ECE Graduate Admission Committee, 2013-Preesent
- Guest speaker, College of Engineering's Future Faculty Program, 2014
- Judge, I-SWEEEP Energy Competition, 2014
- Discussion leader, UH SURF graduate and professional round-table discussion, 2013.
- Judge, Science and Engineering Fair of Houston for the 9th Grade Engineering Students, 2013.

## JOURNAL PUBLICATIONS IN REVERSE CHRONOLOGICAL ORDER

### 2015

[1] Yanliang Liang, Zhihua Chen, Yan Jing, Yaoguang Rong, Antonio Facchetti*, and Yan Yao*, Heavily n-dopable π-conjugated redox polymers with ultrafast energy storage capability *J. Am. Chem. Soc.* **2015**, *137*, 4956-4959.

[2] Yanliang Liang,† Hyun Deog Yoo,† Yifei Li, Jing Shuai, Hector A. Calderon, Francisco Carlos Robles Hernandez, Lars C. Grabow, and Yan Yao* Interlayer-expanded molybdenum disulfide nanocomposites for electrochemical magnesium storage, *Nano Lett.* **2015**, *15*, 2194-2202.

[3] Hyun Deog Yoo, Yanliang Liang, Yifei Li, and Yan Yao* High areal capacity hybrid magnesium−lithium-ion battery with 99.9% Coulombic efficiency for large-scale energy storage, *ACS Appl. Mater. Interfaces* **2015**, *7*, 7001-7007.

[4] Qinyou An, Fangyu Xiong, Qiulong Wei, Jinzhi Sheng, Liang He, Dongling Ma, Yan Yao,* and Liqiang Mai*, Nanoflake-assembled hierarchical Na3V2(PO4)3/C microflowers: superior Li storage performance and insertion/extraction mechanism, Adv. Energy. Mater. **2015**, 1401963.

[5] Qinyou An, Yifei Li, Hyun Deog Yoo, Shuo Chen, Qiang Ru, Liqiang Mai*, and Yan Yao*, Graphene decorated vanadium oxide nanowire aerogel for long-cycle-life magnesium battery cathodes, *Nano Energy* **2015**, *18*, 265-272.

[6] Saman Gheytani, Yanlaing Liang, Yan Jing, Jeff Xu, and Yan Yao*, Chromate conversion coated aluminium as light-weight and corrosion-resistant current collector for aqueous lithium-ion batteries, *Journal of Materials Chemistry A* **2015**, DOI: 10.1039/C5TA07366A.

[7] Mohammad M. Tavakoli, Kwong-Hoi Tsui, Siu-Fung Leung, Qianpeng Zhang, Jin He, Yan Yao, Dongdong Li, and Zhiyong Fan*, Fabrication of efficient planar perovskite solar cells using a one-step chemical vapor deposition method, *ACS Nano* **2015**, *9*, 10287-10295.

[8] Yaoguang Rong, Zhongjia Tang, Yufeng Zhao, Xin Zhong, Swaminathan Venkatesan, Harrison Graham, Matthew Patton, Yan Jing, Arnold M. Guloy* and Yan Yao*, Solvent engineering towards controlled grain growth in perovskite planar heterojunction solar cells *Nanoscale* **2015**, *7,* 10595-10599.

[9] Yifei Li, Yanliang Liang, Francisco C. Robles Hernandez, Hyun Deog Yoo, Qinyou An, Yan Yao*, Enhancing sodium-ion battery performance with interlayer-expanded MoS2–PEO nanocomposites *Nano Energy* **2015**, *15*, 453-461.

[10] Jingjing Fan, Yifei Li, Hang N. Nguyen, Yan Yao* and Debora F. Rodrigues*, Toxicity of exfoliated-MoS2 and annealed exfoliated-MoS2 towards planktonic cells, biofilms, and mammalian cells in the presence of electron donor, *Environmental Science: Nano* **2015**, *2*, 370-379.

[11] Mohammad M. Tavakoli, Leilei Gu, Yuan Gao, Claas Reckmeier, Jin He, Andrey L. Rogach, Yan Yao, Zhiyong Fan*, Fabrication of efficient planar perovskite solar cells using a one-step chemical vapor deposition method, *Scientific Reports* **2015**, *5*, 14083.

[12] Zelang Jian, Mingbo Zheng, Yanliang Liang, Xiaoxue Zhang, Saman Gheytani, Yucheng Lan, Yi Shi, Yan Yao* Li3VO4 Anchored Graphene Nanosheets for Long-Life and High-Rate Lithium-Ion Batteries, *Chem. Comm.*, **2015**, *51*, 229-231.

[13] Dan Sun, Yifan Jiang, Haiyan Wang*, Yan Yao, Guoqing Xu, Kejian He, Suqin Liu, Yougen Tang, Younian Liu, Xiaobing Huang, Advanced aqueous rechargeable lithium battery using nanoparticulate LiTi2(PO4)3/C as a superior anode, *Scientific Reports* **2015**, *5*, 10733.

**2014**

[1] Zelang Jian, Wenze Han, Yanliang Liang, Yucheng Lan, Zheng Fang, Yongsheng Hu, Yan Yao, * Carbon-Coated Rhombohedral$Li_3V_2(PO4)_3$ as Novel Electrode Materials for Lithium-Ion Batteries: Electrochemical Performance and Storage Mechanism, *Journal of Material Chemistry A*, **2014**, *2*, 20231-20236.

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[4] US Patent 8,748,739, Conjugated polymers and their use in optoelectronic devices, issued on 6/10/2014
[5] US Patent 8,598,450, Conjugated polymers and their use in optoelectronic devices, issued on 12/3/2013
[6] US Patent 8,598,449, Conjugated polymers and their use in optoelectronic devices, issued on 12/3/2013
[7] US Patent 8,598,448, Pyrrolo[3,2-b]pyrrole semiconducting compounds and devices incorporating same, issued on 12/3/2013.
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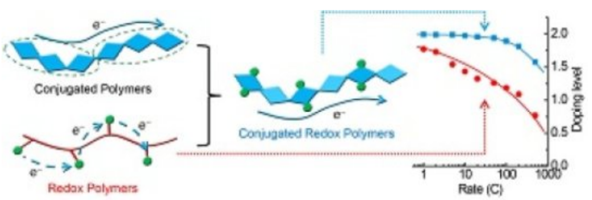
# Researchers discover N-type polymer for fast organic battery

*Date:* April 6, 2015

*Source:* University of Houston

*Summary:* Researchers have reported developing an efficient conductive electron-transporting polymer, a long-missing puzzle piece that will allow ultra-fast battery applications. The discovery relies upon a 'conjugated redox polymer' design with a naphthalene-bithiophene polymer, which has traditionally been used for applications including transistors and solar cells. With the use of lithium ions as dopant, researchers found it offered significant electronic conductivity and remained stable and reversible through thousands of cycles of charging and discharging energy.

**FULL STORY**




Rational combination of advantages of state-of-the-art polymers has resulted in highly electronically conducting polymers that could enable a battery to be 80 percent charged within 6 seconds, and fully charged in another 18 seconds.

*Credit: Image courtesy of University of Houston*

Researchers at the University of Houston have reported developing an efficient conductive electron-transporting polymer, a long-missing puzzle piece that will allow ultrafast battery applications.

The discovery relies upon a "conjugated redox polymer" design with a naphthalene-bithiophene polymer, which has traditionally been used for applications including transistors and solar cells. With the use of lithium ions as dopant, researchers found it offered significant electronic conductivity and remained stable and reversible through thousands of cycles of charging and discharging energy.

The breakthrough, described in the Journal of the American Chemical Society and featured as ACS Editors' Choice for open access, addresses a decades-long challenge for electron-transport conducting polymers, said Yan Yao, assistant professor of electrical and computer engineering at the UH Cullen College of Engineering and lead author of the paper.

Researchers have long recognized the promise of functional organic polymers, but until now have not been successful in developing an efficient electron-transport conducting polymer to pair with the established hole-transporting polymers. The lithium-doped naphthalene-bithiophene polymer proved both to exhibit significant electronic conductivity and to be stable through 3,000 cycles of charging and discharging energy, Yao said.

The discovery could lead to a cheaper alternative to traditional inorganic-based energy devices, including lithium batteries. Ultimately, Yao said, it could translate into less expensive consumer devices and even less expensive electric cars.

Yao's research group focuses on green and sustainable organic materials for energy generation and storage. He is also a principal investigator for the Texas Center for Superconductivity at UH.

Yanliang Liang, a research associate at UH and first author on the paper, said researchers aren't trying to compete directly with conventional lithium-ion batteries. "We are trying to demonstrate a new direction," he said.

Liang said conventional inorganic metal-based batteries and energy storage devices are expensive partly because the materials used to make them, including cobalt and silicon-based compounds, require huge energy expenditures to process. Organic polymers can be processed at relatively low temperatures, lowering the cost.

They also produce less $CO_2$, he said, adding to their environmental advantage. And while conventional materials are finite, organic polymers could potentially be synthesized from biomass.

"Organic -conjugated polymers are emerging as a materials class for energy-related applications, enabling a path to a more sustainable energy landscape without the need of energy-intensive, expensive and sometimes toxic metal-based compounds," the researchers wrote, concluding that "a model polymer, P(NDI2OD-T2), was stably and reversibly n-doped to a high doping level of 2.0, a significant progress for electron-transporting π-conjugated polymers. … With rational molecular design, π-conjugated redox polymers will establish new design space in polymer chemistry and see wide-spread applications, especially in energy-related ones such as batteries, supercapacitors and thermoelectrics."

The basic polymer used in the work was discovered in 2009; Yao said it was provided by members of the research team from Polyera Corporation, a technology company based in Illinois. Although naphthalene-bithiophene has been used for transistors and other applications since its discovery, this is the first time it has been converted for use in energy storage.

That was done through the addition of lithium and raised the polymer's doping level from a previously reported 0.1 to 2.0.

The results are record-setting. The polymer exhibits the fastest charge-discharge performance for an organic material under practical measurement conditions, allowing a battery to be 80 percent charged within 6 seconds and fully charged in another 18 seconds, Liang said.

Conventional inorganic batteries still are capable of holding more energy than the organic battery, and Yao said work will continue to improve the storage capacity of the material. His group also will continue to do basic scientific research on the polymer to learn more about it, he said.

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**Story Source:**

The above post is reprinted from materials provided by **University of Houston**. The original item was written by Jeannie Kever. *Note: Materials may be edited for content and length.*

**Journal Reference**:

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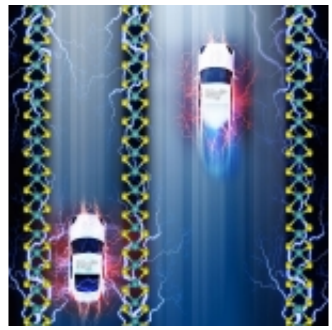
# MAGNESIUM-ION BATTERIES IN THE FAST LANE

Posted on March 26, 2015
By: Audrey Grayson



Yan Yao, assistant professor in the Cullen College's electrical and computer engineering department, is developing alternatives to popular lithium-ion batteries, which are used to power much of the modern world. Now, a recent breakthrough in this research has been published in the journals *Nano Letters* and *ACS Applied Materials and Interfaces*.

Yao's batteries use magnesium ions instead of the traditional lithium ions, which are expensive and fraught with safety concerns. Lithium-ion batteries have a tendency to catch fire and even explode under certain conditions, especially when the batteries are used to power electric vehicles.

Magnesium ions are much safer and potentially much cheaper than lithium-based batteries. Magnesium is a resource abundant material, and due to its dendrite-free deposition behavior and capacity to discharge energy twice as much as that of lithium, magnesium-based batteries have many benefits over their lithium-ion counterparts.

However, magnesium ions also have drawbacks. Magnesium ions move extremely slowly in traditional host materials due to the strong interaction between the magnesium ions and the negatively charged host lattices inside of the batteries.

"In the *Nano Letters* paper, we demonstrated for the first time an interlayer expansion approach to transform an inactive host into efficient magnesium storage materials," Yao said. The interlayer expansion was realized by inserting a thin layer of ionic conducting polymer into the layered materials' lattice, which boosts magnesium's diffusivity by two orders of magnitude.

The interlayer expansion approach could be leveraged to a wide range of host materials for the storage of various ions, leading to novel intercalation chemistry and new opportunities for the development of advanced materials for next-generation electric vehicles.

"In the paper published in *ACS Applied Materials and Interfaces*, we reported the other key advantage of magnesium-ion over lithium-ion batteries," Yao said. "The dendrite-free deposition behavior of the magnesium-metal anode at high current density condition ensures safe operation, which is considered the 'Holy Grail' for 'beyond lithium-ion' technologies."

Yanliang Liang and Hyun Deog Yoo, both postdoctoral research fellows in the electrical and computer engineering department, were first authors of the two papers. Graduate students Yifei Li and Jing Shuai were coauthors on the papers. The work published in *Nano Letters* was in collaboration with Lars Grabow, assistant professor of chemical and biomolecular engineering at the Cullen College, professor Hector Calderon of the School of Physics and Mathematics at the National Polytechnic Institute in Mexico City, Mexico, and associate professor Francisco Hernandez from the UH College of Technology.

The magnesium ion research was sponsored by the grant from the U.S. Navy's Office of Naval Research Young Investigator Program (YIP) to develop safer and longer-lasting batteries for everything from electric vehicles to Navy vessels. In addition to research on magnesium-ion batteries, Yao and his team also work on aqueous-based batteries and sodium-ion batteries funded by the Advanced Research Projects Agency – Energy (ARPA-E) and the National Science Foundation (NSF), respectively.

For more information on these two publications, please click on the paper titles below:

Interlayer-Expanded Molybdenum Disulfide Nanocomposites for Electrochemical Magnesium Storage, Nano Lett., 2015, 15 (3), pp 2194–2202

High Areal Capacity Hybrid Magnesium–Lithium-Ion Battery with 99.9% Coulombic Efficiency for Large-Scale Energy Storage, ACS Appl. Mater. Interfaces, Article ASAP, DOI: 10.1021/acsami.5b01206

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# ENGINEERING STUDENT EARNS SILVER NANO RESEARCH POSTER AWARD

Posted on October 23, 2015
By: Elena Watts


Yanliang (Leonard) Liang, electrical and computer engineering research associate at UH Cullen College, won the Silver Nano Research Poster Award at the 10th Sino-U.S. Symposium on Nanoscale Science and Technology in June.

Liang's poster titled, "Rational Nanostructure Design for Efficient Mg Rechargeable Batteries," was among more than 200 posters submitted and was one of only eight that earned awards. The symposium, sponsored by Tsinghua University Press, attracted more than 1,000 attendees.

"No one expects to win anything because the environment is pretty competitive with scientists from all over China and the United States," Liang said. "The work started long before this forum, so it's good to be recognized for our contribution to the field and to know that people are interested in our work."

Under the supervision of Yan Yao, assistant professor of electrical and computer engineering at UH Cullen College, Liang helped to develop an alternative to traditional lithium-ion batteries, and papers about their breakthrough published in the journals Nano Letters and ACS Applied Materials and Interfaces.

Instead of lithium ions, Liang and Yao opted for safer and more economical magnesium ions to produce their battery. Magnesium is an abundant material and discharges twice as much energy as its lithium counterpart. However, magnesium ions move slowly in host materials because of their interaction with the batteries' negatively charged lattices.

Liang and Yao created an interlayer expansion method to boost magnesium's diffusivity by two orders of magnitude, and researchers could potentially leverage this approach across a range of host materials that store various ions. Their discovery provides opportunities for the development of advanced materials for next-generation electric vehicles, among other sustainable development innovations.

The symposium provides a forum for researchers to share their work in the field of nanotechnology to optimize solutions for energy shortages, environmental contamination and life science challenges, according to the event's website.

"Yanliang joined my research group in Fall 2012 as a postdoc researcher, and he has undoubtedly shown a high level of excellence and distinction in materials and battery research," Yao said. "I am confident that he has great potential in making more significant achievements and becoming a young leader in the future. This award recognizes his past achievements and motivates him to achieve a higher level of success in his career."

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Home

# GRC Awards

**Urvish Medh Memorial** -- is awarded for the best overall presentation at the GRC. The winner will receive an award of $500 and a plaque. This award was dedicated in memory of a former graduate student.

**Best oral presentation** -- is awarded for the best oral presentation at the GRC (not including the Urvish Medh Memorial winner). The winner will receive a gift certificate in the amount of $50 and a plaque.

**Best poster presentation** **--** is awarded for the best Poster presentation at the GRC (not including the Urvish Medh Memorial winner). The winner will receive a gift certificate in the amount of $50 and a plaque.

## GRC Award Recipients

**2014**

**1. The Urvish Medh award for best overall presentation:**

Yifei Li

**2. The SEL award for best oral presentation:**

Chih-Hao Liu

**3. The ECE award for outsatanding poster presentation:**

Ji Qi

## CDC Awards

Three Capstone Design Awards were established to recognize outstanding overall performance of students in completing Senior Design Projects and their presentations at the Capstone Design Conference both in Oral and Poster Sessions.

## CDC Award Recipients

**2014**

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Home > Business Students Win Big With Yao's Technology

# BUSINESS STUDENTS WIN BIG WITH YAO'S TECHNOLOGY

Posted on April 1, 2014
By: Melanie Ziems

In a continuing trend of collaboration between University of Houston colleges, the Cullen College of Engineering and C.T. Bauer College of Business joined forces to create an award-winning team which competed at the University of Nebraska-Lincoln New Venture Competition.

The New Venture Competition, one of the oldest business plan competitions in the nation, pits student teams against one another in a battle of business savvy. Teams present manufacturing and business plans surrounding new technologies to industry heavy-hitters and the most successful plan wins. The UH team – named "Energetik" and composed of Jonathan Brown, Jonathan Cohen-Kurzrock, Rowbin Hickman and Noy Shemer – teamed up with Yan Yao, assistant professor of electrical and computer engineering, to created their award-winning business plan based on Yao's research into developing better and safer batteries for energy storage.

"Dr. Yao's successful research and development of this technology will create a battery that is safe, significantly lighter and smaller than any other batteries on the market, allowing for a competitive energy density and most importantly, a longer lifetime," Cohen-Kurzrock said. "This battery's application can range from power storage for telecommunications to submarines, but we are focusing on the solar power industry."

The team's business plan involved outsourcing the battery manufacturing and using a third party logistics company to handle warehouse and distributions. The team would then sell the battery to solar installers. Yao worked with the team for three months leading up to the competition.

"It is a great idea to have students from the business college developing business plans for technologies developed at [Cullen] College of Engineering," Yao said. "I am extremely impressed at the quality of the undergraduate students from the Wolff Center. They are smart and fast learners. I am thrilled to be working together with them to bring this technology to market."

After their presentation at the New Venture Competition, the team was approached by several individuals interested in bringing the conceptual business plan to fruition with Yao's technology.

Main Content

# Undergraduates Win $30,000 in Awards at Rice, TCU Business Plan Competitions

Published on April 16, 2014

## Wolff Center for Entrepreneurship Students Compete Against Top MBA Teams at Business Plan Competitions

Two teams of undergraduate students from the Wolff Center for Entrepreneurship at the C. T. Bauer College of Business at the University of Houston brought home $30,000 in awards at two different Texas business plan competitions this past week.

## Energetik team at 4th Annual Richards Barrentine Values and Ventures Business Plan Competition

Bauer student team Energetik, including (from left) Rowbin Hickman, Jonathan Cohen-Kurzrock, Noy Shemer, Jonathan Brown and Brenda Rojo from the college's Wolff Center for Entrepreneurship, placed third at the 4th Annual Richards Barrentine Values and Ventures Business Plan Competition at TCU.

Energetik, who placed third and received the Quicksilver Energy Independence Award at the 4th Annual Richards Barrentine Values and Ventures Business Plan Competition on April 12 at Texas Christian University's Neeley School of Business, includes undergraduates Jonathan Brown, Jonathan Cohen-Kurzrock, Rowbin Hickman, Brenda Rojo and Noy Shemer. Their business plan focuses on a technology pioneered by UH Cullen College of Engineering Assistant Professor Yan Yao that replaces the anode of a battery with 100 percent organic materials, resulting in a longer-lasting solution.

"Opening our doors and partnering with other departments within the university is possibly one of the most powerful actions our university has ever taken," entrepreneurship senior Shemer said. "This is definitely something that no other college or university is doing, and if they are doing it, it is only at the graduate level."

The third place win for the team came with a $10,000 prize and an additional $5,000 prize for the Quicksilver Energy Independence Award.

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Home > Experiential Learning: Undergrad Research in Energy Storage

# EXPERIENTIAL LEARNING: UNDERGRAD RESEARCH IN ENERGY STORAGE

Posted on July 30, 2013
By: Esmeralda Fisher

The summer semester offers a perfect opportunity for undergraduates to conduct engineering research under the mentorship of a faculty member. Cullen College of Engineering undergraduates selected for the Summer Undergraduate Research Fellowship (SURF) gained practical experience in research methods and a newfound interest in the science of innovation.

David Pineda, a mechanical engineering junior, has been working in assistant professor Yan Yao's newly-created Laboratory of Energy Materials and Devices. His project is the construction of a vanadium redox flow battery system.

Similar to a fuel cell, the vanadium redox (reduction-oxidation) battery comprises a power cell in which electrolytes flow from external tanks into the central stack where reactions take place and electrons are created. The focus of Pineda's project is to create a platform, or small scale vanadium redox battery for the development of inexpensive, novel materials used to replace electrolyte solutions and membrane.

While vanadium redox battery systems are rare or not widely used, they hold potential for large-scale applications, including emergency power backup.
"One of the problems with the current energy grid is that it isn't able to adjust to fluctuations between main supply and consumer demand in the main supply," Pineda said. "During the day, when we need a lot of electricity the power plant can only supply a constant maximum amount - it cannot downgrade or upgrade very efficiently. So at night, when less electricity is used, the day's collection of electricity is wasted. Energy storage is needed to bridge this gap, such that nighttime excess electricity can be used during the day when demand is at its highest."

The vanadium redox flow battery hasn't been widely applied due to its expense. The cost of the active material, vanadium, rises with high demand in the steel industry. Additionally, the cost of the proton exchange membrane (the component inside the central stack where positive ions flow to the negative side, creating a complete circuit) accounts for about 40 percent of the overall cost. The goal is to produce cost-effective materials that allow more efficient permeation of ions.

Pineda's research is self-managed – he scouts new materials and creates the best ways of putting them together. The ability to direct the research is something that motivates Pineda.

"The main reason I decided to come into the SURF program was to find out what research is all about," Pineda said, who feels confident in his choice to pursue graduate studies and after that, research and analysis in industry.

Pineda emphasizes that research is a very open, non-linear, improvisational process. “A lot of the things you do in research haven’t been done before,” he said. For engineering students wishing to explore research areas, the most important characteristics to have are curiosity and ambition. “You’re on your own; you can’t go to a textbook and find a solution. It’s not easy but it’s rewarding if you put in the time and effort. Get a clear picture of how your field applies to real life. Start reading about research that’s going on here, and other places. Be knowledge-hungry. The best way to learn is by experience itself.”

*The Summer Undergraduate Research Fellowship program at the University of Houston seeks to provide funding for rising UH sophomores, juniors, and seniors to participate in a focused, full-time, 10-week research experience under the direction of UH faculty. For more information on this and other undergraduate research opportunities, visit the Office of Undergraduate Research.*

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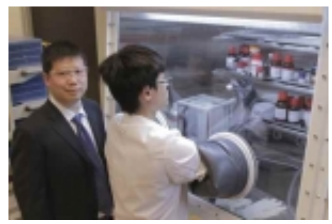
Home > Professor Wins ARPA-E Funding to Build New Type of Electric Vehicle Battery

# PROFESSOR WINS ARPA-E FUNDING TO BUILD NEW TYPE OF ELECTRIC VEHICLE BATTERY

Posted on August 28, 2013
By: Toby Weber



For all their virtues, electric vehicles have two major drawbacks: their cost – usually tens of thousands of dollars more than comparable gasoline-powered cars – and how far they can travel on a single charge.

Yan Yao, assistant professor of electrical and computer engineering at the University of Houston Cullen College of Engineering and Robert A. Welch Professor with UH's Texas Center for Superconductivity, will work to solve both of these problems thanks to a major grant from the Advanced Research Project Agency – Energy (ARPA-E).

Part of the U.S. Department of Energy, ARPA-E invests in high-potential, high-impact technologies that need further development to win private sector funding. This grant comes through its new RANGE program (Robust Affordable Next Generation EV-Storage), a $36 million initiative to radically improve energy storage systems for electric vehicles (EVs). Though the final amount of the award is still being negotiated, the application sought $760,000 for just one year of work.

Yao and his collaborator, Jeff Xu, a principal scientist with the Southwest Research Institute (SwRI), will use the funding to develop an entirely new type of battery for electric vehicles.

"Yao's work is an example of the ways in which the university's energy research is expanding beyond the traditional boundaries of hydrocarbons, wind and solar energy," said Ramanan Krishnamoorti, Chief Energy Officer at UH and professor of chemical and biomolecular engineering. "Battery technology is a critical enabler for the monetization and commercialization of electrical vehicles and for the integration of intermittent sources such as wind and solar energy. New-generation safe batteries, and less expensive batteries, will be the key to making electric vehicles affordable and practical."

According to Yao, this is because existing EV batteries not only determine how far these vehicles can travel, they also drive up their price. "It's a linear relationship. The longer you want to drive the more expensive the vehicle. The battery is a big driver of cost."

First, a quick primer on how these batteries work. All EV batteries generate electricity through a pair of chemical reactions. These reactions occur on different sides of the device, the anode and the cathode. Separating the two sides is an electrolyte, which allows molecules involved in the chemical reactions to travel back and forth between the sides.

The only existing batteries strong enough to power a full day's worth of driving use electrolytes that are both expensive and extremely flammable. This is a major problem in EV design, said Yao.

"Because these batteries are so flammable and fragile you have to put a lot of protection around them. This protection is inactive. You cannot store energy with it. It's basically dead weight that reduces the effective energy density and drives up the price of the vehicle."

Yao's solution: develop a lithium-ion battery that uses a water-based electrolyte. Dubbed aqueous lithium-ion batteries, they should be cheaper and safer than existing EV batteries. Even better, they won't need to be surrounded by dead weight to shield them in an accident. That would leave more room for the battery itself, resulting in longer driving ranges per charge.

While aqueous lithium-ion batteries have been built in laboratories, their performance has not been good enough to draw industry investment. This is due to the chemicals on both sides of the aqueous batteries. Put simply, there are no materials that can generate a commercially acceptable amount of energy in a functioning aqueous environment.

Yao, though, has struck upon an entirely new class of material that can be used for these devices' anode side, the most problematic part of an aqueous lithium-ion battery. Though he can't reveal the exact compounds he's experimenting with, he can say that they are organic compounds, meaning they contain at least one of the four organic elements: carbon, hydrogen, oxygen and nitrogen.

Few battery researchers, Yao said, have even considered using organic materials simply because their training focuses on inorganics. Yao himself is unusual in that he has worked extensively with both types of compounds.

One of the main advantages of organics in battery research, he said, is their design flexibility. It is easy to tune these compounds to meet different goals, such as redox potential, surface energy, or faster battery charging and discharging. Added Xu: "This joint research effort will leverage SwRI's expertise in battery chemistry, cell fabrication, and vehicle-level development to provide value to the overall project and to the area of EV safety."

The great potential of this new type of battery has set a high bar for Yao and his team. He will use the funding to bring on board multiple post-doctoral researchers and students. At the end of the one-year project the team is expected to produce not just a few academic papers but an actual working prototype battery that has been fully characterized for safety, energy density, charge and discharge rates and more.

"We've got a lot of work to do in one year," said Yao. "In the end we want to have a prototype and a patented technology that someone can build a business around."

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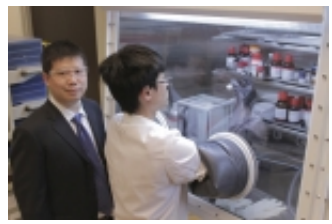
Home > Professor Wins Naval Young Investigator Award for Battery Development

# PROFESSOR WINS NAVAL YOUNG INVESTIGATOR AWARD FOR BATTERY DEVELOPMENT

Posted on August 2, 2013
By: Toby Weber



A professor with the University of Houston Cullen College of Engineering is working to make safer and longer-lasting batteries for everything from electric vehicles to Navy vessels.

Yan Yao, assistant professor in the Cullen College's electrical and computer engineering department and Robert A. Welch Professor at the Texas Center for Superconductivity at the University of Houston (TcSUH), is developing alternatives to popular lithium-ion batteries, which are used to power much of the modern world. To carry out this work, he recently received grant worth nearly $660,000 from the U.S. Navy's Office of Naval Research Young Investigator Program (YIP), which is interested in new batteries as a distributed power source for marine vessels.

The Young Investigator Program seeks to identify and support academic scientists and engineers who are in their first or second full-time tenure-track (or tenure-track-equivalent) academic appointment and who show exceptional promise for conducting creative research. The program seeks to attract outstanding faculty to the Navy's research program, to support their research, and to encourage their teaching and research careers.

In a letter to University of Houston President and UH System Chancellor Renu Khator, Rear Admiral Matthew Klunder, the Chief of Naval Research, outlined how difficult this grant competition was. “Dr. Yao is one of 16 investigators selected for award from an outstanding group of 310 applicants…He emerged successfully from a very competitive pool because of his academic achievements, his ability to contribute to the strength of the Nation's research and development, and the commitment to him expressed by university administrators.”

“I am extremely honored to be selected as an ONR YIP recipient since I started my independent career at UH less than a year ago,” Yao said. “I am grateful to ONR for their invaluable support on developing safer and more powerful battery technology, which is critical to energy security and independence,” " I am also proud of being part of the UH Energy research. I am indebted to the strong support from Cullen College, the ECE department, and TcSUH.”

Lithium ions are commonly used in batteries because they are light and have a high energy density, which allows them to hold large amounts of energy in a small space, said Yao. Lithium, though, is expensive. Even worse, lithium-ion batteries often develop dendrite growth problems – essentially breaches in their internal structural integrity – that cause them to catch fire and even explode under certain conditions.

Yao, then, is developing batteries that use with magnesium ions and aluminum ions, which are safer and potentially cheaper than lithium-based batteries. In addition, these two ions are also both multivalent, meaning they have multiple extra electrons and thus greater potential energy density than lithium ions.

The problem lies in how these ions actually behave in batteries, where they must move through dense crystal structures in order to reach the devices they power. Due to Coulomb's Law, which governs how electrically charged particles interact, magnesium ions and aluminum ions move much more slowly through these crystals than lithium ions.  As a result, real-world batteries that use these ions are larger, heavier and store less energy than their lithium ion counterparts.

Yao's solution for this problem is a novel one. "We want to modify the existing battery materials to increase the mobility of the magnesium or aluminum ions so they can diffuse [either during charging or discharging] faster than they did before modification," he said.

This work, said Yao, has both basic and applied science aspects. He and his research team will collaborate with experts in conducting atomic-scale simulations to predict how the multivalent ions move inside different crystal structures. They will verify their findings using in situ transmission electron microscopy experiments, where they will be able to view actual ion movement. They will then turn their attention to the practical applications of their research, building, testing and optimizing new batteries.

While it will probably take years for shoppers to find devices that use Yao's research on store shelves, the potential for such multivalent ion batteries is undeniable. "The energy density of these batteries is potentially four times higher than state-of-the-art lithium ion batteries," said Yao. "This would mean cell phones that hold a charge for days and electric vehicles that cost less and can go much farther on a single charge. There's great potential here."

As one of the college's newer professors, Yao added that he is currently looking to add to his research team, including students at all levels. In fact, this summer Yao mentored a student through a National Science Foundation Research Experience for Undergraduates grant; a UH student through the university's Summer Undergraduate Research Fellowship program, and three high school students.

"I am looking for bright UH students motivated in energy research to join my group," said Yao, "It doesn't matter if he or she has a background chemistry, physics, or engineering, or if he or she is a graduate or an undergraduate. All are invited to join my team to address the grand energy challenge together."

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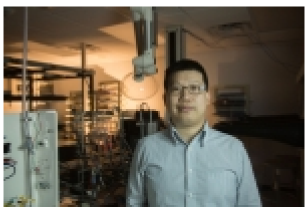
Home > UH Engineer Joins Project to Transform Energy Storage

# UH ENGINEER JOINS PROJECT TO TRANSFORM ENERGY STORAGE

Posted on December 15, 2015
By:
Jeannie Kever



An engineer from the UH Cullen College of Engineering will lead development of a key component for a new, all solid-state sodium battery with the potential to revolutionize the nation?s electric grid.

Yan Yao, assistant professor of electrical and computer engineering at UH, will work with a team of researchers and battery company Solid Power to produce a low-cost, safe and efficient sodium battery for grid-scale energy storage and other applications. The project is supported by $2.9 million in funding from the Department of Energy?s Advanced Research Projects Agency-Energy (ARPA-E).

Yao, who also is a principal investigator for the Texas Center for Superconductivity at UH, said there are three reasons for the work.

While conventional lithium-ion batteries have proven effective at storing energy on a limited scale, the liquid electrolyte in the batteries is flammable; a solid-state sodium battery would be much safer, he said, as well as less expensive and able to store greater amounts of energy.

Yao, whose research group focuses on green and sustainable organic materials for energy generation and storage, will create a new battery cathode, the terminal from which electrical current leaves the battery.

Other researchers include principal investigator Steve W. Martin at Iowa State University; Sehee Lee at the University of Colorado-Boulder; Scott Beckman and Soumik Banerjee at Washington State University, and Josh Buettner-Garrett at Solid Power.

Existing sodium-sulfur batteries for grid energy storage operate at temperatures between 300 and 350 degrees Celsius, using molten sodium and sulfur separated by a solid electrolyte membrane; Yao said those have safety and durability concerns, as well as high production costs. The battery proposed by the researchers would operate near room temperature and, with an all solid-state design, would be more robust, scalable to manufacture and composed entirely of recyclable and renewable materials.

The project is one of 41 cutting-edge energy technologies funded in a $125 million ARPA-E initiative, OPEN

2015. ARPA-E funds innovative technologies that display promise for both technical and commercial impact, but are too early for private-sector investment.

The ARPA-E announcement noted the climate change talks in Paris and global efforts to lower carbon emissions. Large-scale energy storage is considered key to broader adoption of both solar and wind energy, allowing energy generated during sunny and windy periods to be stored for use at a future time.

But Yao said any storage system will have to avoid several hurdles: It must be inexpensive to produce, have high energy density and avoid the flammability and other safety issues inherent in many batteries. Sodium is a soft, highly reactive metal, widely available across the world, he said.

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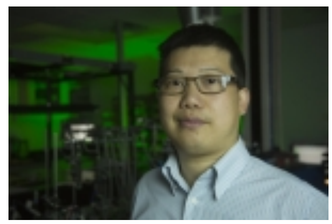
Home > ECE Professor Developing Sodium-Ion Batteries With NSF Award

# ECE PROFESSOR DEVELOPING SODIUM-ION BATTERIES WITH NSF AWARD

Posted on August 13, 2014
By: Audrey Grayson



Last June, Texas Gov. Rick Perry drove an electric car made by Tesla Motors in front of the Texas State Capitol Building in Austin – a symbolic gesture meant to signify his intention of convincing Tesla executives to build their more than $4 billion battery factory right here in the Lone Star State.

“The timing of all of this couldn’t be better for battery research,” said Yan Yao, assistant professor of electrical and computer engineering at the UH Cullen College of Engineering. Yao recently won a three-year award from the National Science Foundation (NSF) totaling more than $340,000 to study sodium-ion batteries.

This research is particularly important to the state of Texas, which represents one of only four states in the U.S. with an independent electricity grid. Because Texas’ electricity grid operates independently from the national grid, the state has the benefit of making modifications to its grid without seeking federal approval to do so. “Now, the state is looking into adding an energy storage function to the existing grid,” Yao explained. “This is the motivation for my research group.”

Yao’s main research expertise is developing suitable alternatives to traditional lithium-ion batteries, which are used to power much of the modern world. Lithium ions are commonly used in batteries because they are light and have a high energy density, which allows them to hold large amounts of energy in a small space, said Yao.

Lithium, though, is an expensive metal. When building batteries to power a cell phone, for example, the cost of lithium ions may seem somewhat reasonable, but as we move toward building batteries that can power an electric car or store energy from an electricity grid, the need for far cheaper materials becomes increasingly urgent.

That’s why Yao first proposed to study the underlying kinetics and mechanisms of sodium-ion batteries, an earth abundant material that’s much cheaper than lithium-ion. However, Yao explained that sodium-ion batteries are extremely difficult to make. Because the size of sodium ions is much larger than lithium ions, they charge and discharge energy much slower than their lithium counterparts.

Yao said he hopes that by understanding the fundamental limitations of sodium-ion intercalation kinetics in existing host materials used for batteries, his team will be able to develop better sodium-ion batteries which can store and discharge energy as efficiently as lithium-ion batteries.

This research falls under the NSF's "SusChem" (or sustainable chemistry) initiative, which addresses the interrelated challenges of sustainable supply, engineering, production, and use of chemicals and materials. Yao said much of the research within his lab is devoted to finding low-cost, earth-abundant and sustainable energy storage solutions. All of this work would have an enormous impact in Texas, especially if the state's bid for Tesla's so-called gigafactory is successful.

Tesla's battery factory, which would employ 6,500 workers, will be devoted to research and development for long-range electric batteries. Yao said that many of the non-lithium-ion batteries his lab is developing would work well for electric vehicles and hopefully even for power grid energy storage.

"This is very exciting time," Yao said. "But to make gigawatt batteries, we first need to figure out how to make batteries as good or better than lithium-ion batteries using earth abundant metals and materials."

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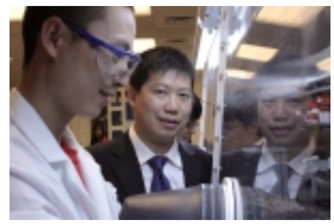
Home > ECE Professor Wins Ralph E. Powe Junior Faculty Enhancement Award

# ECE PROFESSOR WINS RALPH E. POWE JUNIOR FACULTY ENHANCEMENT AWARD [1]

Posted on May 22, 2013
By: Audrey Grayson

[2]



Dr. Yan Yao [3], an assistant professor in the department of electrical and computer engineering [4] and Robert A. Welch Professor at the Texas Center for Superconductivity [5] at the University of Houston (TcSUH), was awarded the 2013 Ralph E. Powe Junior Faculty Enhancement Award [6] from the Oak Ridge Associated Universities [7].

The Ralph E. Powe Junior Faculty Enhancement Awards provide seed money for research by junior faculty at Oak Ridge Associated Universities (ORAU) member institutions [8]. These awards are intended to enrich the research and professional growth of young faculty and result in new funding opportunities. Out of 147 applicants, Yao was among the thirty chosen to receive the prestigious award.

The $5,000 award from ORAU -- which will be matched by the University of Houston -- will help to support Yao's ongoing research into understanding the high efficiency origin of two-dimensional conjugated polymer based solar cells.

View photos of professor Yan Yao receiving this award! [9]



**Links:**

[1] https://www.egr.uh.edu/news/201305/ece-professor-wins-ralph-e-powe-junior-faculty-enhancement-award

[2] https://www.egr.uh.edu/sites/ccoe.egr.uh.edu/files/styles/large/public/images/news/2013/img_8773-v-2-color-correct-web.jpg?itok=d1XWOZQV

[3] http://www.ee.uh.edu/faculty/yao

[4] http://www.ee.uh.edu

[5] http://www.tcsuh.com/

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Home > New ECE Faculty Appointed Welch Professor

# NEW ECE FACULTY APPOINTED WELCH PROFESSOR [1]

Posted on September 5, 2012
By: Toby Weber

[2]

The newest faculty member of the Department of Electrical and Computer Engineering [3] at the University of Houston Cullen College of Engineering has joined UH with a prestigious endowed professorship.

Assistant Professor Yan Yao [4] has been awarded a Robert A. Welch Professorship by UH's Texas Center for Superconductivity (TcSUH) [5], effective Sept. 1, 2012. The endowed Robert A. Welch Professorships in High Temperature Superconducting and Chemical Materials were created at TcSUH by the Robert A. Welch Foundation [6] to assist in the recruitment and/or retention of outstanding faculty, research faculty, and visiting scientists. The appointments are typically for two years.

"I'm honored to be selected for such a prestigious professorship," said Yao. "The funding provided by the Welch Foundation will help me to quickly establish my research program and begin making contributions toward solving real-world energy problems."

Yao specializes in the development of nano-scale materials and devices for energy applications. He will use the funds provided by the professorship to develop next-generation electrodes for rechargeable magnesium batteries, which are particularly attractive for the central material's abundance, environmental friendliness, operational safety, and high energy density.

"Professor Yao will make an important contribution to TcSUH's developing portfolio of energy materials programs," said Allan Jacobson [7], Robert A. Welch Chair of Science in the UH chemistry department and director of TcSUH.

Among the applications of this technology are large-scale energy storage systems for use in conjunction with solar power and wind power generators, and more affordable electric vehicles. These systems, he said, will ideally rely heavily on green and earth-abundant materials, making them safer and more environmentally friendly than many existing energy storage systems, which often rely on toxic materials and are hard to recycle.

Yao joins UH from Stanford University [8], where he had served as a postdoctoral fellow since 2010. Prior to Stanford, he worked as the lead scientist overseeing solar power-related research at Polyera Corporation [9], a start-up focused on developing polymers and polymer technologies for several different applications. In this post, he and his team set multiple records for energy conversion using polymer-based solar cells.

Yao left industry because of the greater freedom offered by academia and what that freedom will allow him to accomplish. "I wanted to do more fundamental research and what I think will have a real impact on society," he said. "My three years of industrial experience helps me better understand what industry needs. I plan to work closely with industry partners to identify key challenges, address them, solve them, and transfer the knowledge back to make better products for our society."

Yao is currently recruiting members for his research group. Undergraduates, graduate students, postdoctoral researchers, and visiting scholars from a variety of disciplines are invited to learn more by visiting his homepage [4].



**Links:**

[1] https://www.egr.uh.edu/news/201209/new-ece-faculty-appointed-welch-professor

[2] https://www.egr.uh.edu/sites/ccoe.egr.uh.edu/files/styles/large/public/images/faculty/ee/yao.jpg?itok=D4a7rQjQ

[3] http://www.ee.uh.edu/

[4] http://www.ee.uh.edu/faculty/yao

[5] http://www.tcsuh.com/

[6] http://www.welch1.org/

[7] http://www.chem.uh.edu/people/faculty/jacobson/

[8] http://www.stanford.edu/

[9] http://www.polyera.com/index.php