

**International Workshop & Summer School  
on the Frontiers of  
Advanced Functional Materials**

**July 20-23, 2016**

**Hangzhou, China**



## **2016 International Workshop & Summer School on the Frontiers of Advanced Functional Materials**

### **Introduction**

We are going to have the 2016 International Workshop on the Frontiers of Advanced Functional Materials this July in Hangzhou. An International Summer School for graduate students is also scheduled during the workshop. Faculty members mainly from Nanyang Technological University, National University of Singapore and Zhejiang University will give lectures in the workshop and summer school. All the faculty members and students will actively participate in discussion on the most recent progress on the research of advanced functional materials. Students will present posters on their own research. They will also visit research laboratories in the School of Materials Science and Engineering at Zhejiang University. Social activities will be organized to encourage the communication among students and faculty members.

### **Venue**

Room 211, Run Run Shaw Science Hall, Yuquan Campus, Zhejiang University

(浙大玉泉邵科馆 211)

### **Date**

July 20 - 23, 2016

### **Organizer**

School of Materials Science and Engineering, Zhejiang University

### **Co-Organizers**

Department of Materials Science and Engineering, National University of Singapore

School of Materials Science and Engineering, Nanyang Technological University

### **Organizing Committee**

Gaorong Han, Zhejiang University

John Wang, National University of Singapore

Hua Zhang, Nanyang Technological University

Lixin Chen, Zhejiang University

### **Secretariat**

Xiaodong Pi, Zhejiang University

Xuxia Yao, Zhejiang University

Jie Chen, Zhejiang University

### **Contact**

Dr. Xuxiao Yao (xuxia\_yao@zju.edu.cn)

## Program

July 20	July 21		July 22	July 23
	09:00-09:25	Opening Remark & Welcome Speech	Lecture 14	Visiting the Center of Electron Microscopy  & the State Key Laboratory of Silicon Materials (09:30-11:30)
	09:25-09:50	Lecture 1	Lecture 15	
	09:50-10:15	Lecture 2	Lecture 16	
	10:15-10:45	Group Photo & Coffee Break	Coffee Break	
	10:45-11:10	Lecture 3	Lecture 17	
	11:10-11:35	Lecture 4	Lecture 18	
	11:35-12:00	Lecture 5	Lecture 19	
	12:00-13:30	Lunch Break	Lunch Break	Lunch Break
	13:30-13:55	Lecture 6	Lecture 20	Excursion
	13:55-14:20	Lecture 7	Lecture 21	
	14:20-14:45	Lecture 8	Lecture 22	
	14:45-15:10	Lecture 9	Lecture 23	
	15:10-15:40	Coffee Break	Coffee Break	
	15:40-16:05	Lecture 10	Lecture 24	
16:00-18:00	16:05-16:30	Lecture 11	Lecture 25	
Registration	16:30-16:55	Lecture 12	Poster Award	
	16:55-17:20	Lecture 13	(16:30-16:45)	
18:00-20:00	17:30-19:00	Dinner	Dinner	
Welcome Reception	19:00-21:00	Poster Session	Evening Tour	

**Thursday, July 21, 2016, #211 Run Run Shaw Science Hall**

**SESSION 1**

**Chair: John Wang**

9:00-9:10

**Opening Remark**

*Ze Zhang*

School of Materials Science and Engineering, Zhejiang University

9:10-9:25

**Welcome Speech**

*Gaorong Han*

School of Materials Science and Engineering, Zhejiang University

*John Wang*

Department of Materials Science and Engineering, National University of Singapore

*Hua Zhang*

School of Materials Science and Engineering, Nanyang Technological University

9:25-9:50

**Innovating New Materials through Aberration-Corrected Microscopy**

*Stephen Pennycook*

Department of Materials Science and Engineering, National University of Singapore

9:50-10:15

**Valance and Coordination Mapping using Monochromated STEM EELS**

*He Tian*

School of Materials Science and Engineering, Zhejiang University

**Group Photo & Coffee Break**

10:15-10:45

**SESSION 2**

**Chair : Thirumany Sritharan**

10:45-11:10

**Microscopic Study of Two-Dimensional Molybdenum Disulfide from an Electron Microscopy's Point of View**

*Chuanhong Jin*

School of Materials Science and Engineering, Zhejiang University

11:10-11:35

**Synthesis and Applications of Novel Two-Dimensional Nanomaterials**

*Hua Zhang*

School of Materials Science and Engineering, Nanyang Technological University

11:35-12:00

**Landscape of Two-dimensional Materials: Synthesis, Characterization and Applications**

*Zheng Liu*

School of Materials Science and Engineering, Nanyang Technological University

**Lunch Break**

12:00-13:30

**SESSION 3**

**Chair : Hua Zhang**

13:30-13:55

**Carbon and Dielectric Compositeds Films for Spectrally Solar Absorbers**

*Yong Liu*

School of Materials Science and Engineering, Zhejiang University

13:55-14:20

**Large Scale Solar Assisted Water Splitting Using BiVO<sub>4</sub> Photoanode**

*Thirumany Sritharan*

School of Materials Science and Engineering, Nanyang Technological University

14:20-14:45

**Several Examples for Electrochemistry of Transition Metal Spinel Oxides**

*Zhichuan Xu*

School of Materials Science and Engineering, Nanyang Technological University

14:45-15:10

**Assembly of Layered Double Hydroxides as Potential Electrode Materials for Supercapacitors**

*Chuangdong Gu*

School of Materials Science and Engineering, Zhejiang University

**Coffee & Tea Break**

15:10-15:40

**SESSION 4**

**Chair : Chuanhong Jin**

15:40-16:05

**Designing High Energy Efficient, and High Performing Energy Storage Devices**

*Junmin Xue*

Department of Materials Science and Engineering, National University of Singapore

16:05-16:30

**Recent Advances in Electrode Materials for Lithium(Sodium) Ion Batteries**

*Yinzhu Jiang*

School of Materials Science and Engineering, Zhejiang University

16:30-16:55

**Magnetic Nanoparticles for In-vivo Hyperthermia Treatment**

*Jun Ding*

Department of Materials Science and Engineering, National University of Singapore

16:55-17:20

**Ultrasensitive SERS Detection in Common Fluids on Bioinspired Slippery Surfaces**

*Shikuan Yang*

School of Materials Science and Engineering, Zhejiang University

**Dinner**

17:30-19:00

**Poster Session**

19:00-21:00



**Friday, July 22, 2016, #211 Run Run Shaw Science Hall**

**SESSION 5**

**Chair : Stephen Pennycook**

9:00-9:25

**Nanocapsules for Multifunctional Applications Engineering**

*John Wang*

Department of Materials Science and Engineering, National University of Singapore

9:25-9:50

**Advanced Ceramics Processing Technologies**

*Richard Kwok*

ST Kinetics

9:50-10:15

**In Situ TEM Nanomechanics in Nanostructured Materials**

*Jiangwei Wang*

School of Materials Science and Engineering, Zhejiang University

**Coffee Break**

10:15-10:45

**SESSION 6**

**Chair : Yinzhu Jiang**

10:45-11:10

**Metal-Organic-Framework-Derived Functional Materials for Electrochemical Energy Storage and Conversion**

*Xiong Wen (David ) Lou*

School of Materials Science and Engineering, Nanyang Technological University

11:10-11:35

**Functional Metal-Organic Framework (MOFs) Membranes**

*Xinsheng Peng*

School of Materials Science and Engineering, Zhejiang University

11:35-12:00

**Computational Design of Magnetic Ordering@Oxide-interface Driven by Ferroelectric Polarization Discontinuity**

*Yunhao Lu*

School of Materials Science and Engineering, Zhejiang University

**Lunch Break**

12:00-13:30

**SESSION 7**

**Chair : Yunhao Lu**

13:30-13:55

**Polarization Screening and Thermal Expansion of Mesoporous Single-Crystal Ferroelectric Nanofibers**

*Zhaohui Ren*

School of Materials Science and Engineering, Zhejiang University

13:55-14:20

**Nanostructured Ferromagnetic and Ferroelectric Thin Films for the Application of Information Storage**

*Jingsheng Chen*

Department of Materials Science and Engineering, National University of Singapore

14:20-14:45

**Novel Properties from Ferromagnetic Composites**

*Tianyu Ma*

School of Materials Science and Engineering, Zhejiang University

14:45-15:10

**Silicon Quantum Dots for Optoelectronic Devices**

*Xiaodong Pi*

School of Materials Science and Engineering, Zhejiang University

**Coffee & Tea Break**

15:10-15:40

**SESSION 8**

**Chair : Xiaodong Pi**

15:40-16:05

**Ordered Si-based Hybrid Nanostructured Arrays**

*Yizhong Huang*

School of Materials Science and Engineering, Nanyang Technological University

16:05-16:30

**On the Luminescence Mechanism of Organo-Lead Perovskites**

*Haiping He*

School of Materials Science and Engineering, Zhejiang University

**Poster Award**

16:30-16:45

**Dinner**

17:30-19:00





## Poster Presentation

### 1. *Vincent Lee* (NUS)

Few Layers MoS<sub>2</sub> Graphene Aerogel Paper for Free-standing Electrode

### 2. *Xiangxia Wei* (NUS)

Additive Manufacturing of Electric Ceramics by Extrusion Free-forming

### 3. *Herng Yau Yoong* (NUS)

Tunneling Electroresistance (TER) Effect in Ultrathin BiFeO<sub>3</sub>-Based Ferroelectric Tunneling Junctions

### 4. *Haijun Wu* (NUS)

(K, Na)NbO<sub>3</sub>-Based Lead-Free Piezoelectric Materials: Giant Property, Structure and Physical Mechanism

### 5. *Danping Wang* (NTU)

Solar Driven Water Splitting Using Modified BiVO<sub>4</sub>

### 6. *Le Yu* (NTU)

Complex Hollow Structures of Metal Sulfides for Energy-Related Applications

### 7. *Paul Wang* (NTU)

Metal Oxides for Energy Conversion and Storage: Applications and Fundamentals

### 8. *Bowei Zhang* (NTU)

Passivation at Nanoscale - the Cases of Copper, Nickel and Stainless Steels

### 9. *Ye Chen* (NTU)

Crystal Phase Engineering of Noble Metal Nanomaterials via Wet-chemical Synthesis

10.  **Jiadong Zhou (NTU)**

Large-Area and High-Quality 2D Transition Metal Telluride

11.  **You Li (ZJU)**

An Ultrasound-Assisted Wet-Chemistry Approach Towards Uniform  $\text{Mg}(\text{BH}_4)_2 \cdot 6\text{NH}_3$  Nanoparticles with Improved Dehydrogenation Properties

12.  **Yao Wang (ZJU)**

Strain-Induced Isostructural and Magnetic Phase Transitions in Monolayer  $\text{MoN}_2$

13.  **Shuang Xie (ZJU)**

A High-Quality Round-Shaped Monolayer  $\text{MoS}_2$  Domain and Its Transformation

14.  **Wenxin Lin (ZJU)**

A Porphyrin-Based Metal-Organic Framework PCN-221 as a PH-Responsive Drug Carrier and Photosensitizer

15.  **Donghuang Wang (ZJU)**

$\text{Li}_2\text{S}@C$  Composite Incorporated into 3D Reduced Graphene Oxide as a Cathode Material for Lithium-Sulfur Batteries

16.  **Shanshan Chen (ZJU)**

Study of Band Alignments and Strains of  $\text{ZnO}$  and  $\text{ZnMgO}$  Films Epitaxially Grown on Silicon Substrates

17.  **Danhui Lü (ZJU)**

Preferential Occupation of Selenium Atoms In Grain Boundaries of Chemical Vapor Deposited Monolayer  $\text{MoS}_{2(1-x)}\text{Se}_{2x}$  Alloy

18. ***Min Li (ZJU)***

The Growth of Mn-Containing Layered Double Hydroxides on Reduced Graphene Oxide for Supercapacitor

19. ***Tao Song (ZJU)***

Dye Encapsulated Metal-Organic Framework for Warm-White LED with High Color-Rendering Index

20. ***Dikai Xu (ZJU)***

High-Performance Graphene/n-Silicon Heterojunction Solar Cells with Photo-Induced p-Type Doping

21. ***Jingyuan Pei (ZJU)***

Hydrothermal Synthesis of CaTiO<sub>3</sub> Nanowire Net Structures with PVA Assistant and Its Visible Photocatalytic Performance

22. ***Jinhua Hong (ZJU)***

Probing the Anisotropic Electronic Structure of Atomically-Thin Molybdenum Disulfide by Electron Energy Loss Spectroscopy

23. ***Jialei Zhang (ZJU)***

A Smart Superhydrophobic Coating on AZ31B Magnesium Alloy with Self-Healing Effect

24. ***Tiezheng Fu (ZJU)***

High Thermoelectric Performance in SnTe Heavily Doped with Sb

25. ***Yalin Xiong (ZJU)***

Tuning Surface Structure and Strain in Pd-Pt Core-Shell Nanocrystals for Enhanced Electrocatalytic Oxygen Reduction



26. ***Chuyang Liu (ZJU)***

Multi-susceptible Single-Phased Ceramics with Both Considerable Magnetic and Dielectric Properties by Selectively Doping

27. ***Salman Ali Khan (ZJU)***

Pressure-Induced Structure Evolution in Liquid Calcium

28. ***Azkar Saeed Ahmad (ZJU)***

Structural Memory in Reversible Devitrification in Amorphous As<sub>2</sub>Se<sub>3</sub> under Pressure

29. ***Mohammad Taghi Asadi Khanouki (ZJU)***

Correlation between Fracture Surface Morphology and Ductility in Metallic Glasses

30. ***Wei Gu (ZJU)***

Silicon-Quantum-Dot Light-Emitting Diodes with Interlayer-Improved Hole Injection

31. ***Muhammad Ali (ZJU)***

Electronic and Magnetic Properties of Graphene, Silicene and Germanene with Vacancies





## Innovating New Materials through Aberration-Corrected Microscopy

*Stephen Pennycook*

Department of Materials Science and Engineering, National University of Singapore

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### Abstract

The aberration-corrected scanning transmission electron microscope (STEM) can provide real space imaging and spectroscopy at atomic resolution with a new level of sensitivity to structure, bonding, elemental valence and even spin state<sup>[1,2]</sup>. Coupled with first-principles theory, this represents an unprecedented opportunity to probe the functionality of complex nanoscale systems, which in turn can lead to new materials innovations. Examples will be shown of the direct imaging of atomic diffusion within a solid<sup>[3]</sup>, the identification of the active site in a catalyst<sup>[4]</sup>, the role of interface termination on ferroelectricity in BiFeO<sub>3</sub> (BFO) films grown on La<sub>0.5</sub>Sr<sub>0.5</sub>MnO<sub>3-x</sub> (LSMO)<sup>[5]</sup>, the origin of white light emission in ultra-small CdSe nanocrystals<sup>[6]</sup> and some surprising insights into the role of defects in CdTe solar cells<sup>[7]</sup>. Finally, some thoughts on future directions for aberration-corrected microscopy will be presented<sup>[8]</sup>.

[1] W. Zhou, et al., "Direct determination of the chemical bonding of individual impurities in graphene," *Phys Rev Lett*, 109, 206803 (2012).

[2] J. Gazquez, et al., "Atomic-Resolution Imaging of Spin-State Superlattices in Nanopockets within Cobaltite Thin Films," *Nano Lett*, 11, 973–976 (2011).

[3] R. Ishikawa, et al., "Direct Observation of Dopant Atom Diffusion in a Bulk Semiconductor Crystal Enhanced by a Large Size Mismatch," *Phys Rev Lett*, 113, 155501 (2014).

[4] X. Zhang, et al., "Catalytically active single-atom niobium in graphitic layers," *Nature Communications*, 4, 1924–7 (2013).

[5] Y.-M. Kim, et al., "Interplay of Octahedral Tilts and Polar Order in BiFeO<sub>3</sub> Films," *Adv Mater*, 25, 2497–2504 (2013).

[6] T. J. Pennycook, et al., "Dynamic Fluctuations in Ultrasmall Nanocrystals Induce White Light Emission," *Nano Lett*, 12, 3038–3042 (2012).

[7] C. Li, et al., "Grain-Boundary-Enhanced Carrier Collection in CdTe Solar Cells," *Phys Rev Lett*, 112, 156103 (2014).

[8] S. J. Pennycook, "Fulfilling Feynman's dream: "Make the electron microscope 100 times better"—Are we there yet?" MRS Bull, 40, 71–78 (2015).

### **Biography**

Stephen J. Pennycook is a Professor in the Materials Science and Engineering Dept., National University of Singapore, an Adjunct Professor in the University of Tennessee and Adjoint Professor in Vanderbilt University, USA. Previously, he was Corporate Fellow in the Materials Science and Technology Division of Oak Ridge National Laboratory and leader of the Scanning Transmission Electron Microscopy Group. Pennycook is a Fellow of the American Physical Society, the American Association for the Advancement of Science, the Microscopy Society of America, the Institute of Physics and the Materials Research Society. He has received the Microbeam Analysis Society Heinrich Award, the Materials Research Society Medal, the Institute of Physics Thomas J. Young Medal and Award, the Hsun Lee Award of the Chinese Academy of Sciences and the Materials Research Society Innovation in Characterization Award. His latest book is "Scanning Transmission Electron Microscopy."

## Valance and Coordination Mapping using Monochromated STEM EELS

*He Tian*

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### Abstract

(i) Understanding the alteration processes of the pigments is of key importance both to optimize the conditions in which works of art are stored and to allow selection of appropriate restoration treatments. We will demonstrate how insights into the alteration mechanism of pigments can be gained at the nano-scale level. 100 years old paint was investigated using state of the art transmission electron microscopy and spectroscopy, revealing the mechanism why some bright yellow colors in Vincent Van Gogh's paintings (for example in *Les Alyscamps*, 1888) are turning brown over time<sup>[1]</sup>. (ii) By combining atomic resolution HAADF STEM, GPA, ABF STEM, and monochromated STEM EELS, the coordination and oxidation state of near interface cations has been determined in great detail. Here, we will demonstrate the feasibility of oxidation state control by strain modification and show direct evidence of how a local strain field change the atomic coordination and introduces atomic displacements leading to a ferroelectric like polarization near an interface<sup>[2]</sup>.

[1] H. Tan#, H. Tian#\*, J. Verbeeck, L. Monico, K. Janssens, and G. Van Tendeloo, *Angewandte Chemie International Edition*, 52 (43) (2013) 11360-11363

[2] H. Tian\*, J. Verbeeck, S. Brück, M. Paul, D. Kufer, M. Sing, R. Claessen, and G. Van Tendeloo, *Advanced Materials*, 26 (2014) 461–465

### Biography

He Tian received his Ph.D. from Institute of Physics and Center for Condensed Matter Physics (C. A. S. China) in 2006. Thereafter, he joined the Electron Microscopy for Materials Research (EMAT) group of the University of Antwerp (Belgium). Afterwards, he joined center of electron microscope in Zhejiang University (China) in 2014. His main research focusses on the application and further development of advanced electron microscopy for advanced materials. He is also interested in the application of electron energy loss spectra (EELS) and electron vortex beam techniques to magnetic state mapping inside materials.

## Microscopic Study of Two-Dimensional Molybdenum Disulfide from an Electron Microscopy's Point of View

*Chuanhong Jin*

School of Materials Science and Engineering, Zhejiang University

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### Abstract

Molybdenum disulfide (MoS<sub>2</sub>), as an emerging 2D semiconductor with atomically thin body, has attracted variety interests for its promising applications in optoelectronics and catalysis. In spite of currently achieved successes, there still exists a number of “barriers” among the community, i.e., low attainable carrier mobility, poor sample quality etc. In this talk, I will present the results from our recent studies on addressing the growth mechanism, atomic defects, alloying doping, and the associated mechanisms by employing the advanced electron microscopy and spectroscopy.

### References:

Q. H. Wang et al., Nat. Nanotechnology. 7, 699 (2012); H. Qiu et al., Nat. Commun. 4, 2642 (2013); H. P. Komsa et al., Phys. Rev. Lett. 109, 035503 (2012); W. Zhou et al., Nano Lett. 13, 2615 (2013); J. H. Hong et al., Nat. Commun. 6, 6293 (2015); J. H. Hong et al., under revisions; D. C. Zhu et al., submitted work (2016); D. H. Lv et al., to be submitted (2016); G. L. Yin et al., to be submitted (2016).

### Biography

Dr. Chuanhong Jin obtained his PhD degree in 2006 from the Institute of Physics, CAS under the supervision of Prof. Lianmao Peng. He joined the Nanotube Research Center in AIST, Japan, firstly was working as a JSPS postdoc fellow, and then as a staff scientist, before he joined the faculty of MSE School in Zhejiang University in 2011. His current research is focusing on studying the atomic and electronic structures of atomically thin 2D materials, and the associated growth mechanism by advanced electron microscopy and spectroscopy. Partial of his research interests will be devoted in the development of liquid-cell (scanning) transmission electron microscopy and its applications on revealing the fundamental behaviors of nanocrystals in solution environmental.

## Synthesis and Applications of Novel Two-Dimensional Nanomaterials

*Hua Zhang*

School of Materials Science and Engineering, Nanyang Technological University

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### Abstract

In this talk, I will summarize the recent research on synthesis, characterization and applications of two-dimensional nanomaterials in my group. I will introduce the synthesis and characterization of novel low-dimensional nanomaterials, such as graphene-based composites including the first-time synthesized hexagonal-close packed (hcp) Au nanosheets (AuSSs) on graphene oxide, surface-induced phase transformation of AuSSs from hcp to face-centered cubic (fcc) structures, the synthesis of ultrathin fcc Au@Pt and Au@Pd rhombic nanoplates through the epitaxial growth of Pt and Pd on the hcp AuSSs, respectively, the first-time synthesis of 4H hexagonal phase Au nanoribbons (NRBs) and their phase transformation to fcc Au RNBs as well as the epitaxial growth of Ag, Pt and Pd on 4H Au NRBs to form the 4H/fcc Au@Ag, Au@Pt and Au@Pd core-shell NRBs, and the epitaxial growth of metal and semiconductor nanostructures on solution-processable transition metal dichalcogenide (TMD) nanosheets at ambient conditions, single- or few-layer metal dichalcogenide nanosheets and hybrid nanomaterials, the large-amount, uniform, ultrathin metal sulfide and selenide nanocrystals, other 2D nanomaterials, nanodots prepared from 2D nanomaterials, and self-assembled 2D nanosheets and chiral nanofibers from ultrathin low-dimensional nanomaterials. Then I will demonstrate the applications of these novel nanomaterials in chemical and bio-sensors, solar cells, water splitting, hydrogen evolution reaction, electric devices, memory devices, conductive electrodes, other clean energy, etc.

Keywords: Two-dimensional nanomaterials; Graphene; Metal dichalcogenides; Nanodevices; Field-effect transistors; Sensors; Clean energy

### Biography

Dr. Hua Zhang obtained his B.S. and M.S. degrees at Nanjing University in China in 1992 and 1995, respectively, and completed his Ph.D. with Prof. Zhongfan Liu at Peking University in China in July 1998. He joined Prof. Frans C. De Schryver's group at Katholieke Universiteit Leuven (KULeuven) in Belgium as a Research Associate in January 1999. Then he moved to Prof.



Chad A. Mirkin's group at Northwestern University as a Postdoctoral Fellow in July 2001. He started to work at NanoInk Inc. (USA) as a Research Scientist/Chemist in August 2003. After that, he worked as a Senior Research Scientist at Institute of Bioengineering and Nanotechnology in Singapore from November 2005 to July 2006. Then he joined the School of Materials Science and Engineering in Nanyang Technological University (NTU) as an Assistant Professor. He was promoted to a tenured Associate Professor on March 1, 2011, and Full Professor on Sept. 1, 2013.

He has published **5** invited book chapters, **64** patent applications (including **8 granted US patents**), and over **360** papers, among which **330** papers were published in the journals with **IF>3** (including **140** papers published in **IF>10** journals and **66** papers published in **8<IF<10** journals). Some of his papers have been published in *Science* (1), *Nat. Chem.* (3), *Nat. Commun.* (6), *Sci. Adv.* (1), *Chem. Soc. Rev.* (8), *Acc. Chem. Res.* (1), *J. Am. Chem. Soc.* (12), *Angew. Chem. Int. Ed.* (22), *Adv. Mater.* (26), *Nano Lett.* (12), *ACS Nano* (24), *Energy Environ. Sci* (12), *Adv. Energy Mater.* (5), *Adv. Funct. Mater.* (3), etc. Based on *Web of Science* on June 2, 2016, the total citation times of his papers are over **26,400** with H-index of **79**. He has been invited to give more than **260** Plenary, Keynote or Invited Talks in international conferences, universities and institutes, and serve as the Session Chair. He has organized several tens of international conferences and served as the Symposium Chair or Conference Co-Chair. He is one of three Chairmen of the Editorial Board of *ChemNanoMat* (2015-) and an Associate Editor of *International Journal of Nanoscience* (2007-), sits on the Advisory Board of *Chem. Soc. Rev.* (2012-), *Nanoscale* (2012-) and *Nanoscale Horizons* (2015-), the Editorial Advisory Board of *ACS Nano* (2014-), *Chem. Mater.* (2014-), *ACS Appl. Mater. Interfaces* (2014-), *Small* (2012-) and *Nanofabrication* (2012-), the Editorial Board of *CHEM* (2016-), *Carbon* (2013-), *Applied Materials Today* (2015-), *Energy Storage Materials* (2015-), *NANO* (2007-), *Chinese Science Bulletin* (2014-), *Science China Materials* (2014-) and *Graphene Technology* (2016-), and the International Advisory Board of *Materials Research Express* (2014-) and *ChemPlusChem* (2012-). He is also one of the members of the Advisory Committee of *IOP Asia-Pacific* (2010-). In **2015**, he was elected as an *Academician* of the Asia Pacific Academy of Materials (APAM). In Nov. **2014**, he was elected as a *Fellow of the Royal Society of Chemistry (FRSC)*. Recently, he was listed in the "Highly Cited Researchers 2015" in *Chemistry and Materials Science*, and also listed as **one of 19** "Hottest Researchers of Today" in the world in the *World's Most Influential Scientific Minds 2015*

(Thomson Reuters, **2015**). In **2014**, he was listed in the "*Highly Cited Researchers 2014*" in *Materials Science*, and also listed as **one of 17** "*Hottest Researchers of Today*" and **No. 1** in *Materials and More* in the world in the *World's Most Influential Scientific Minds 2014* (Thomson Reuters, **2014**). Moreover, he got the *Young Investigator Award* (Young Giants of Nanoscience 2016, Hong Kong), *Vice-Chancellor's International Scholar Award* (University of Wollongong, Australia, **2016**), *ACS Nano Lectureship Award* (**2015**), *World Cultural Council (WCC) Special Recognition Award* (**2013**), the *ONASSIA Foundation Lectureship* (Greece, **2013**), *Asian Rising Stars* (15<sup>th</sup> Asian Chemical Congress, **2013**), *SMALL Young Innovator Award* (Wiley-VCH, **2012**) and *Nanyang Award for Research Excellence* (**2011**).

Dr. Zhang's research is highly interdisciplinary. His current research interests focus on synthesis of two-dimensional nanomaterials (graphene and transition metal dichalcogenides), carbon materials (graphene and CNTs) and their hybrid composites for various applications in nano- and biosensors, clean energy, water remediation, etc.; controlled synthesis, characterization and application of novel metallic and semiconducting nanomaterials; scanning probe microscopy; lithography-based fabrication of surface structures from micro- to nanometer scale; self-assembly and self-organization of nano- and biomaterials; self-assembled monolayers; etc.

# Landscape of Two-dimensional Materials: Synthesis, Characterization and Applications

*Zheng Liu*

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## Abstract

Recent times have seen a surge of activity in the exploration of two dimensional atomic layered structures with a range of properties. Here we will discuss our recent efforts in exploring various two-dimensional materials including graphene, hexagonal boron nitride (h-BN), various dichalcogenide systems and hybrid atomic layers consisting of multiple compositions. Scalable synthesis through vapour deposition of several of these structures will be discussed. Understanding of defects such as grain boundaries, edges and point defects in these structures is important for manipulating physical properties in these materials. Our efforts in manipulating these layers into creating vertically stacked hybrids as well as laterally engineered layers will be described. Overall, the talk will summarize our recent progress in synthesizing and characterizing atomically engineered layers of materials with a wide range of properties and their applications on active nano-systems and high performance energy components, e.g. resonators, photodetectors, high-density capacitors, ultrafast lithium storage etc.

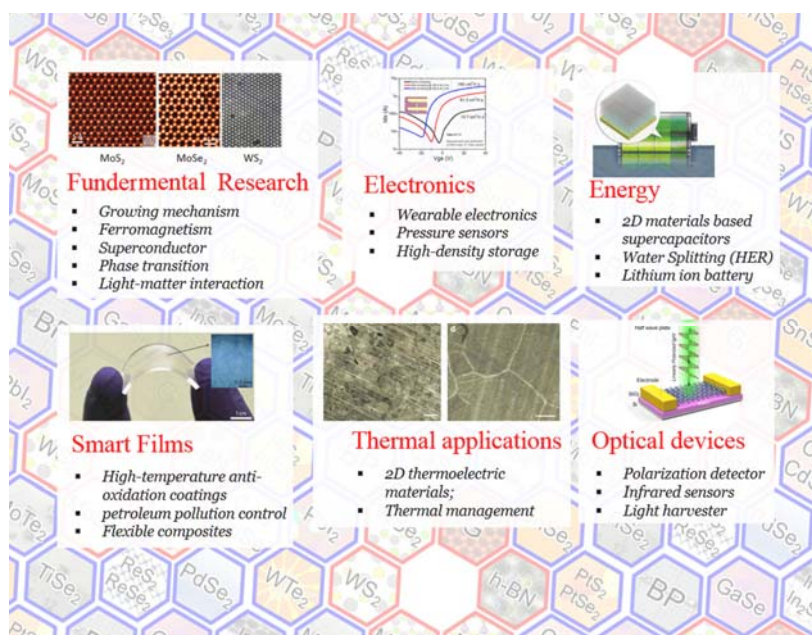


Figure 1 Families of two-dimensional materials and their potential applications

## References:

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## Biography

Dr. Zheng Liu received his B.S. degrees (2005) at Nankai University (China), and completed his Ph.D at National Center for Nanoscience and Technology (NCNST, China), working on the synthesis and energy harvest of carbon nanotubes. He then worked in Prof. Pulickel M. Ajayan and Prof. Jun Lou's groups as a joint postdoc research fellow (2010~2012) and research scientist (2012~2013) at Rice University (USA), focusing on the synthesis and applications of two-dimensional (2D) crystals, including graphene, hexagonal boron nitride, oxides and transition metal dichalcogenides (TMD: MoS<sub>2</sub>, MoSe<sub>2</sub> etc). He has made contributions not only to the synthesis of 2D heterostructures such as vertical and lateral graphene/h-BN, but also the 2D materials based nanoelectronics, active nano-systems and high performance energy components, e.g. resonators, graphene photodetectors.

He has published more than 90 peer-reviewed papers in top journals including 10 papers in Nature and Science serial journal (Nat Mater, Nat Nanotech, Nat Comm and Sci Adv); 17 in Nano Lett; 7 in Adv Mater; 7 in ACS Nano, with total citations more than 7000 and h-index of 41. These works have also been reported by Science daily, IEEE spectrum, etc., and highlighted by the top journals such as Nature Physics, Nature Nanotechnology, Chem Int Ed, etc. He was also a recipient of the World Technology Award in Energy category in 2012. This award has been presented as a way to honor those in doing "the innovative work of the greatest likely long-term significance." He was awarded the prestigious Singapore NRF Fellowship and Nanyang Assistant Professorship in 2013.

## Carbon and dielectric composited films for spectrally solar absorbers

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### **Abstract**

Solar selective absorber film is a functional material that could realize the high efficient photo-thermal conversion, regard as a kind of new energy materials. It could help mankind to utilize the solar energy in a highly efficient way, so that there is an urgent need for the research of solar selective absorbers due to today's increasingly serious energy crisis. Nano metal ceramic composite film is currently the most widely used solar selective absorber film, mainly owing to its advantages on the spectrum performance, film quality, substrate adhesion, etc, but its poor thermal stability has been widely criticized, hindering its application on high temperature photo-thermal fields. In this presentation we focus on a C-Cu-TiO<sub>2</sub> composite porous film prepared by using the sol-gel method, combined with the ligand exchange, sol network crosslinking, induced phase separation, Marangoni effect and vacuum annealing process. In this ternary composite film, TiO<sub>2</sub> performs as particle-like skeleton material, covered by carbon material, while Cu particles are embedded in the base material to form nano composite reinforced structure. Furthermore, hierarchical porous structure is formed on the surface of film, improving the optical selectivity of this ternary composite film. The sol precursor wet chemical process, annealing process, micro-nano structure tuning, and relationships between film structure and its optical selectivity performance and thermal stability are discussed. Also, a theoretical model has been established, helping us fully understand the mechanisms and the insights into the optical selectivity of this ternary composite porous film.

### **Biography**

Dr. Yong Liu obtained his B. Eng. (2001) and Ph.D degrees (2006) in Materials Science from Zhejiang University. After three years' postdoc experience (Department of Computer Science and Engineering, Zhejiang University (2006~2008) and Department of Materials Science and Engineering, KTH (2009~2010)), he joined the School of Materials Science and Engineering, Zhejiang University as an Assistant Professor. His research interests include optical-electronic

functional films, theoretical simulation method and applied materials physics. He has published more than 50 papers and has been granted 6 patents. He has received Second Prize of National Science and Technology Progress Award (2008, 10/10) and First Prized of Zhejiang Province Science and Technology Award (2013, 2/13). More recently, he focuses on the new multiscale structured solar selective absorbers and numerical simulation of float glass processing.

## Large Scale Solar Assisted Water Splitting Using BiVO<sub>4</sub> Photoanode

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### **Abstract**

A photoelectrochemical (PEC) cell was designed and fabricated to take anodes of areas of 5x5 cm<sup>2</sup>. This could be used as a testbed to evaluate different anode and cathode materials for water splitting. Candidate materials for photo active anodes were synthesized and evaluated for water splitting with platinum as the cathode material. Hematite (Fe<sub>2</sub>O<sub>3</sub>) has already been shown to act as a good photoactive anode for water splitting by other workers but in relatively small effective areas of the order of 5 cm<sup>2</sup>, but it needs to operate at high pH of above 13. In this paper we will examine BiVO<sub>4</sub> as a potential anode in this cell. It was initially studied in small area anodes to optimize synthesis conditions, film thickness and dopants. The optimized anodes were made in the large area of 25 cm<sup>2</sup> and evaluated in this PEC cell. Hematite anodes were also examined for comparison. The results will be discussed, and it will be shown that Mo-doped BiVO<sub>4</sub> performed excellently generating photocurrents of the order of 2 mA/cm<sup>2</sup> when the film thickness was about 300 nm. A WO<sub>3</sub> underlayer improved the performance of Mo-doped BiVO<sub>4</sub> anode to enhance the photocurrent. This is a good alternative to the commonly reported Fe<sub>2</sub>O<sub>3</sub> but studies on its stability are underway. We obtained benchmark efficiency values in terms of hydrogen generated per input photon energy, in addition to the commonly reported IPCE efficiencies.

### **Biography**

Prof Sritharan obtained his PhD from The University of Sheffield, UK and did his postdoctoral research at The University of Melbourne. Then he worked at the Comalco Research Centre, Melbourne before moving to NTU, Singapore when the Materials Engineering program was established. His current research interests are in functional properties of oxides and sulphides. He leads a group of researchers from NTU in a multifaceted program with University of California, Berkeley funded by Singapore's NRF. This programme is on Solar Energy harvesting with the aim of reducing the cost of solar to electrical energy conversion and also to explore the solar to liquid fuel conversion.



## Several Examples for Electrochemistry of Transition Metal Spinel Oxides

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### **Abstract**

Transition metal oxides have been found great potential to be next generation electrode materials for efficient and low cost energy conversion and storage. Various transition metal oxides with redox ability have been investigated under electrochemical conditions. They have been used as oxygen electrocatalysts for ORR and OER, which are critical reactions for developing renewable energy technologies like fuel cells, metal-air batteries, and water electrolyzers. This presentation will present a systematic study on spinel oxides' redox ability and oxygen electrocatalysis.<sup>[1,2]</sup> Starting with a model system of Mn-Co spinel, the presentation will introduce the correlation of oxygen catalytic activities of these oxides and their intrinsic chemical properties. The catalytic activity was measured by rotating disk technique and the intrinsic chemical properties were probed by synchrotron X-ray absorption techniques. It was found that molecular orbital theory is able to well-explain their activities.<sup>[3,4]</sup> The attention was further extended from cubic Mn-Co spinels to tetragonal Mn-Co spinels and it was found that the molecular theory is again dominant in determining the catalytic activities. This mechanistic principle is further applied to explain the ORR/OER activities of other spinels containing other transition metals (Fe, Ni, Zn, Li, and etc.).

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### **Biography**

Dr. Zhichuan Xu is currently an assistant professor in the School of Materials Science and Engineering at Nanyang Technological University. Dr. Xu received his PhD training from

Lanzhou University, Institute of Physics, CAS, and Brown University (2002-2008). His PhD study focused on nanomaterials synthesis and characterizations. He worked in State University of New York at Binghamton as a Research Associate (2007-2009) and then he worked in Massachusetts Institute of Technology as a Postdoctoral Researcher (2009-2012). Dr. Xu's research interests include electrochemistry, catalysis, energy storage, magnetic nanomaterials, and sensors.

## Assembly of Layered Double Hydroxides as Potential Electrode Materials for Supercapacitors

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### Abstract

Layered double hydroxides (LDHs) are lamellar crystals with positively charged brucite-like host layers and weakly bound anions to compensate the charge. As promising battery-type electrode materials, LDHs based hybrid supercapacitors exhibit larger operating voltages compared with those that are based on activated carbons and double-layer capacitance mechanisms. In this talk, I would like to introduce three solution-based methods to assemble LDHs nanostructures. An ionothermal strategy from a deep eutectic solvent was proposed to successfully fabricate layered single and double hydroxides with larger interplanar distances. These LDHs materials exhibit enhanced electrochemical performance as energy storage electrodes.[1] A novel and facile room-temperature method was also proposed to fabricate a-Ni(OH)<sub>2</sub> and a-Co(OH)<sub>2</sub> superstructures by using the double hydrolysis of Ni<sup>2+</sup> or Co<sup>2+</sup> and NCO<sup>-</sup> without the presence of any structure directing agent.[2] Lastly, a co-feeding method for preparing periodic stacking of 2D charged LDH and GO sheets was optimized. The novel superlattice structured Ni-Al LDH/rGO electrodes exhibit promising electrochemical activity.[3]

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## **Biography**

Changdong Gu (ResearcherID: B-3299-2008) received his Ph. D degree in Material Science from Jilin University in 2007. He worked at the Department of Mechanical Engineering, HKUST from 2007 to 2009 as a Research Associate. Then he joined School of Materials Science and Engineering, Zhejiang University as an Associate Professor. His research work focuses on energy storage materials, surface and coatings technology, and novel application of deep eutectic solvents in electrochemistry.

## Designing High Energy Efficient, and High Performing Energy Storage Devices

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### **Abstract**

High performing energy storage devices (ESD) have long been considered to be a key technological barrier for emerging renewable technologies such as solar energy, and for the development of miniaturizing ultra-performing electronic devices. Despite the significant advancement in ESD research whereby impressive electrochemical performance (in terms of energy and power density) have been continuously reported, it is peculiar as to the lack of attention in the practical aspect, that is the energy efficiency of the reported device. Lithium-ion capacitor (LIC) has shown promising theoretical electrochemical performance in the recent years, but its lower energy efficiency of 55 – 75 % at high cell potential ( $\geq 3.5$  V) ultimately lowers its practicality value. In contrast, lowering the cell potential (2 - 3 V) can improve the attainable energy efficiency (to above 80 %), but at the expense of energy density. This creates a strong paradox between energy density and energy efficiency which researchers have to carefully tackle. In order to maximize the energy efficiency of LIC, it would require a combined effort from both the material scientist and cell engineer, however this work will at the moment present the material design considerations for developing high energy efficient LIC. Thus, in order to resolve this paradox, LIC electrode materials have to be meticulously designed with heightened attention on improving voltage efficiency and coulombic efficiency of the system. Herein, an all-amorphous LIC with high energy efficiency and good electrochemical performance is designed in this work by employing amorphous with slight graphitic character carbon negative and amorphous carbon positive electrodes. Such designed system was able to operate with a high energy efficiency of 84.3 % ( $1 \text{ A g}^{-1}$ ) at a cell potential of 3.5 V, while delivering a high energy density of  $133 \text{ Wh kg}^{-1}$  at a power density of  $210 \text{ W kg}^{-1}$ . A good cyclic stability of 81.8 % was attained after cycling at  $5 \text{ A g}^{-1}$  for 5000 cycles. Thus, this work serves as a guideline for developing high performing yet practical LIC by considering material design with respect to voltage and coulombic efficiency.

## **Biography**

Dr Xue Jun Min received his BSc degree from the University of Chemical Technology of East China and Ph.D degree from the Shanghai Institute of Ceramics, Chinese Academy of Science. He is currently an Associate Professor of Department of Materials Science and Engineering at NUS. His research interests mainly focused on functional nanomaterials for various applications such as energy storage and biomedical. He has done significant research work in his research areas and published over 160 international journal papers.

## Recent Advances in Electrode Materials for Lithium(Sodium) Ion Batteries

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### **Abstract**

Rechargeable batteries represented by lithium (sodium) ion batteries have been the most important approach for the emerging applications in electric vehicle and energy storage systems. Advance of electrode material is vital to extend such practical applications in large scale. In the present presentation, our recent advances on electrode materials will be introduced: 1) In the view of atom migration and structural integrity upon lithiation/delithiation, we realized spatially-confined electrochemical reactions through the special design of highly dense multi-oxide nanocomposite anode, achieving large reversible capacity (volumetric & gravimetric), high rate capability and superior cycling stability simultaneously for high performance lithium ion batteries; 2) We demonstrated ultrahigh-rate lithium storage in a novel RGO-MnO-RGO sandwich nanostructure, in which dynamic equilibrium between surface pseudocapacitance and diffusion-controlled lithium storage is achieved after a novel cycle-induced microstructure evolution, opening up possibilities for designing high-power lithium ion batteries; 3) In the light of understanding on vacancy-impacted sodium storage and Na-inserted reaction kinetics, we report in-situ synthesized PB@C composite as a high-performance SIB cathode. The superior reaction kinetics is demonstrated for the redox reactions of the FeHS(N) couple, which relies on the partial insertion of Na ions to enhance the electron conduction. With the synergistic effect in structure and morphology, the PB@C composite achieves unprecedented rate capability and outstanding cycling stability (77.5 mAh g<sup>-1</sup> at 90 C, 90 mAh g<sup>-1</sup> after 2000 cycles at 20°C with 90% capacity retention).

On one hand, through the in-situ synthesis, PB cubes were grown directly on carbon chains, assuring fast charge transfer and Na-ion diffusion. On the other hand, as-prepared material has much lower content of coordinated water and vacancy, thus the capacity of high voltage plateau was activated. The influence of vacancy and sodium storage behavior to capacity and rate performance were illustrated systematically combined with theoretically calculation. Thus sodium ion battery cathode material with long cycle life and ultrahigh rate performance was obtained.

## **Biography**

Dr. Yinzhu Jiang is currently an Associate Professor of Materials Science and Engineering at Zhejiang University. He earned his B. Sc (2002) and Ph. D (2007) in MSE from University of Science and Technology of China (USTC). He also holds B. Eng at Computer applications (2002) from USTC. He was a project leader (2007) at Accelergy R&D center in China, a research associate (2007-2008) at Heriot-Watt University in UK, and a research fellow (AvH Fellowship, 2008-2010) at Bielefeld University in Germany. He joined School of Materials Science and Engineering at Zhejiang University as an Associate Professor in 2010, where he leads the group of Electrode Materials for Rechargeable Batteries. His research portfolio currently includes: (1) Oxides and sulfides for lithium ion batteries; (2) Novel cathodes and anodes for sodium ion batteries; (3) Electrode design and preparation; (4) Electrochemical processes and mechanisms. Dr. Jiang has published over 50 journal articles in Energy Environ. Sci., Adv. Funct. Mater., Nano Energy and other respected journals. He has also applied for 16 National Patents for Inventions, in which 6 items have been authorized.



## Magnetic Nanoparticles for in-vivo Hyperthermia Treatment

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### **Abstract**

Magnetic nanoparticles can generate a considerable heat under AC field. The behavior is used for cancer treatment – magnetic hyperthermia, as cancer cells can be killed if the local temperature raises over 42°C. Many works have demonstrated the good hyperthermia performance against cancer after intratumoral injection. However, the more ideal delivery path is the intravenous injection. But, there are still technical challenges for practical applications, such as effective delivery with a substantial quantity in tumor and accurate in-vivo estimation of its concentration. In this work, we have prepared ultrafine Gd-doped Fe<sub>3</sub>O<sub>4</sub> nanoparticles with a particle size of 4-5 nm. After suitable surface functionalization, these nanoparticles have excellent colloidal stability. The presence of Gd enables us to estimate the distribution of these Gd-doped nanoparticles accurately after intravenous injection. Long blood circulation time has been obtained. Considerable amount of nanoparticles was found in the implanted tumor. Using MRI technique, T1-weighted image can be used for monitoring of distribution of magnetic nanoparticles. The MRI parameter R1 can be used for an accurate in-vivo estimation of nanoparticle concentration in tumor. This work has shown the potential of Gd-doped iron oxide nanoparticles for hyperthermia cancer treatment after intravenous injection.

### **Biography**

Dr Jun Ding is currently working as Professor at Department of Materials Science & Engineering, National University of Singapore. His current research focuses on 3D printing of different functional devices (metal, ceramics and polymer) for advanced engineering applications (aerospace, biomedicine, energy/environment and electronics).

## Ultrasensitive SERS Detection in Common Fluids on Bioinspired Slippery Surfaces

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### **Abstract**

Detecting target analytes with high specificity and sensitivity in any fluid is of fundamental importance to analytical science and technology. Surface-enhanced Raman scattering (SERS) has proven to be capable of detecting single molecules with high specificity but achieving single molecule sensitivity in any highly diluted solutions remains a challenge. Here we demonstrate a universal platform that allows for the enrichment and delivery of analytes into the SERS-sensitive sites in both aqueous and non-aqueous fluids, and its subsequent SERS detection down to the attomolar level ( $10^{-18}$  mol<sup>-1</sup>). These levels of detection represent at least five orders of magnitude improvement in non-aqueous solutions and an order of magnitude improvement in aqueous solutions compared to those of state-of-the-art SERS detection methods. The platform is based on a pinning-free, bio-inspired omniphobic slippery substrate, which enables the complete concentration of analytes and SERS substrates (e.g., Au nanoparticles) within an evaporating liquid droplet. Our method allows for ultra-sensitive airborne and molecular detections in a broad range of common fluids for applications related to analytical chemistry, molecular diagnostics, environmental monitoring, and national security.

### **Biography**

Dr. Shikuan Yang obtained his Ph.D. in the Institute of Solid State Physics, Chinese Academy of Sciences in 2009. Then he moved to Muenster University (Germany) as a postdoctoral scholar. In 2011, he joined the Pennsylvania State University (USA) as a postdoctoral scholar. In 2015, he was selected into the Thousand Youth Talents Plan. He started his professorship at the School of Materials Science and Engineering in Zhejiang University in 2016. His research areas cover fabrication and device application of surface micro/nanopatterns, SERS sensing, photonics and plasmonics, quantum dots and related optical devices, biomimicry, etc. Dr. Yang has published more than 50 peer-reviewed papers with about 30 as the first/corresponding author, including

PNAS, Advanced Materials, Advanced Functional Materials, ACS Nano, etc. His research has been featured in a number of news outlet including Science Daily, Phys.Org, Nanowerk, R&D Magazine, Futurism, Kurzweil, NSF, etc. These publications have attracted more than 2500 citations with an H-index of 25 according to Google Scholar.

## Nanocapsules for Multifunctional Applications Engineering

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### **Abstract**

For targeted bioimaging and theranostic applications, we have successfully developed a class of PEOlated polymeric micelle/silica as multifunctional nanocapsules for targeted bioimaging and controlled delivery. Bioimaging contrast agents, such as fluorescent conjugated polymers, CdSe/CdS/ZnS quantum dots (QDs), MnO and Fe<sub>3</sub>O<sub>4</sub> nanocrystals have been successfully encapsulated into poly(ethylene oxide) (PEO)-based polymeric micelle/silica dual layers via interfacial templating condensation. The encapsulation follows a green and straightforward microemulsion mechanism that directly proceeds in a near neutral pH aqueous environment. No detriment effects to the optical and magnetic properties of fluorescent conjugated polymers, QDs, MnO, and Fe<sub>3</sub>O<sub>4</sub> nanocrystals are observed during encapsulation. The core-shell nanocapsules thus generated possess a polymeric micelle framework with a single QD/Fe<sub>3</sub>O<sub>4</sub> nanocrystal encapsulated in the hydrophobic micellar core, an ultrathin (<5 nm in thickness) yet robust silica shell confined to the micellar core/corona interface and free PEO chains dangling on the surface. The free PEO chains effectively prevent nonspecific adsorption of biomolecules to the nanoparticles. Double shielding of polymeric micelle/silica shell remarkably improves the fluorescence resistance of conjugated polymers and QDs to strong acids and highly salted buffers. In vitro testing using MDA-MB-231 breast cancer cells demonstrates that these organic/inorganic dual layer-protected nanocapsules conjugated with folate show noncytotoxicity, bright fluorescence cellular imaging with high target specificity and improved performance in controlled delivery. In this talk, the latest development for the multifunctional nanocapsules is presented. The processing parameters involved in developing the multifunctional nanocapsules and their performance in bioimaging, both for T<sub>1</sub> and T<sub>2</sub>, and theranostic applications are presented and discussed.

## Advanced Ceramics Processing Technologies

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### **Abstract**

Industrial interest towards the use of modern advanced ceramics has grown exponentially over the years amidst a greater push towards the search for materials that are able to extend the mechanical, chemical, and functional limits of current day technologies.

At ST Kinetics, research has been dedicated towards producing and exploiting the various benefits of advanced ceramics to deliver customised or niche application and products or components that provide superior performance with saving in cost and weight.

System weight is a premium in the transport industry, and the saving of which is a dominant imperative for various platform developers as this translates to greater payloads.

For ST Kinetics, ceramics research involves the use of various advanced processing techniques. Some of the notable technologies currently in use include spray atomisation, hot press and spark plasma sintering, as well as cold gas dynamic spray (cold spray).

As atomiser has the ability to produce both fine and ultrafine powders with narrow powder size distributions to develop functional material. Spark plasma sintering (SPS) is capable of deliver highspeed powder consolidation/ sintering technology to process conductive and non-conductive materials.

The combination of using state of art equipment and processing technique open up new possibilities and challenges in producing advanced Ceramic.

### **Biography**

Dr Richard Kwok is the Executive Vice President and Chief Technology Officer, Singapore Technologies Kinetics Ltd (ST Kinetics) and with ST Engineering since 1978. ST Kinetics is the land systems and specialty vehicles arm of Singapore Technologies Engineering, a company listed on the Singapore Exchange.

Dr Kwok has more than 40 years of diverse working experience. He has a concurrent appointment as Chief Executive Officer with Advanced Technology Research Centre (ATREC, a

JV between Defence Science Organisation and Singapore Technologies since April 2006). Dr Kwok is a product designer, an engineer, a technologist, an academia and a researcher. His areas of interest and research include robotic technologies, survivability & protective technologies, nano & novel materials, power transmission, railway and transportation, renewable energy, manned and unmanned system, Intellectual property and business management. Dr Kwok is also the chairman of Intellectual Property Right Committee in Singapore Technologies Engineering since 2000. He was appointed as Adjunct Professor with Southern Cross University in 2000 to 2007 and also served as Adjunct Associate Professors with the Nanyang Technological University and the National University of Singapore in 1999 and 2005 respectively. He is also an Adjunct Professor, School of Science & Technology at SIM University (UniSIM) since March 2011. Dr Kwok has a Master of Science in Automotive Engineering (1987), from Cranfield University in the United Kingdom. During his course of study at Cranfield University, he received the Rootes Prize award. He was also conferred a Ph.D. in Technology Management in 2000 from University of Southern Australia. Dr Kwok was the recipient of the prestigious Defence Technology Prize 2002 (Individual Engineering Award), in recognition of his outstanding contributions to the Defence Industry. He was also awarded the Defence Technology Prize (Team) Award by the Ministry of Defence Singapore, for the development of the Bionix Infantry (1999) and the Cheng Fook Choon Gold Award in Engineering Process Innovation & Improvement by Singapore Technologies, for developing a collaborative engineering process used in the development of weapon systems in Singapore Technologies Kinetics Ltd (1997). In December 2006, he also won the Lifelong Learner Award.

Since 1995, Dr Kwok serves in the following Boards:

1. Member of the Advisory Committee of Mechanical Engineering, Ngee Ann Polytechnic from April 1995 to 2007
2. Advisory member of the Nanyang Technological University at the School of Material Engineering in 2005 to 2008
3. Member of the Board of Governor of Intellectual Property Academy since January 2007 to March 2012
4. Member of the Advisory Board of Temasek Polytechnic since April 2007
5. Supervisory Board member of Solar Energy Research Institute of Singapore (SERIS) since

March 2008

6. Member of Local Evaluation Panel of National Research Foundation (NRF) Competitive Research Programme between June 2008 to Dec 2013
7. Member of the Consultative Committee in NUS with the Department of Technology Management since September 2008
8. Co-Chairman of Solar Energy Test-Bedding and Application Centre (SETAC) @ Singapore Polytechnic from October 2008 to Sept 2010
9. Chairman of Advanced Composites Engineering Laboratory (ACEL) @ Republic Polytechnic since July 2010
10. Co-Chairman of Applied Material Engineering Centre (AMEC) @ Singapore Polytechnic since September 2010
11. Adjunct Professor, School of Science & Technology at SIM University (UniSIM) since March 2011
12. Council member of Institute of engineers Singapore since 2011
13. Vice President of Institute of Engineers Singapore (Research, Technology & Standard) since 2012
14. Fellow member of Institute of Engineers Singapore since 2012
15. Chairman of IES, NCEO Committee since 2012
16. Chairman of IES NED 2012 Organising Committee since 2012 to 2015
17. Chairman of IES, Research, Technology and Standards Group since 2012 to 2014
18. Member of the School Advisory Committee of the School of Materials Science and Engineering (MSE) NTU since 1 July 2013
19. Member of Advisory Board of Newcastle University International Singapore since Oct 2014  
“Advancing Smart Engineering” 11/07/16 23:33
20. Chairman of Emerging Pilot Processes Integration Centre (EP2IC) @ since Mar 2014
21. Chairman of IPOS-IES IP Advisory Board cum Steering Committee since Nov 2014
22. Chairman of IES Chartered Engineer, Railway and Transportation Engineering since April 2015
23. Chairman of Doctor of UniSIM, Philosophy and Master of Engineering Programme Advisory Committee since May 2015

24. Fellow members of Intellectual Property Technology Consultant (IPTC) since August 2015
25. Co-Chairman of Advanced Material and Additive Processes Engineering Centre (AMAPEC)  
@ NUS since Dec 2015
26. Chairman of University of Glasgow Singapore (UGS) advisory Board since January 2016
27. Member of Singapore Rail Academy (SGRA) Board since June 2016



## **In Situ TEM Nanomechanics in Nanostructured Materials**

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### **Abstract**

A fundamental understanding of the mechanical deformation and degradation in nanostructured materials is critical for designing the damage-tolerant nanostructures and devices. In situ transmission electron microscopy technique provides an unprecedented approach to uncover the atomic-scale dynamic deformation and degradation mechanisms in nanostructured materials under various loading conditions. In this talk, I will present our recent progresses on the in situ TEM study on the electrochemical degradations of anodes in batteries and the nanomechanical behavior of metallic nanostructures, including the degradations of Si-based nanostructure anodes in batteries, size-dependent pulverization in Sn nanoparticle anodes, structure-property relationship in nanotwinned Au nanowires, twinning-dominated deformation in BCC nanowires etc. The in situ TEM studies provide new insights that cannot be offered by the traditional mechanics studies, and will ultimately revolutionize the design of novel materials and devices from the smallest bottom.

### **Biography**

Dr. Jiangwei Wang is a faculty in the Center of Electron Microscopy, School of Materials Science and Engineering at Zhejiang University. He received his PhD degree from University of Pittsburgh in 2014 and joined Zhejiang University in 2016. His research interests are in the nanomechanics of materials, in situ characterization of energy-storage materials and in situ TEM technique. He has received the MRS Graduate Student Silver Award in 2014 MRS spring meeting and co-organized the seminar “Mechanical Behavior at the Nanoscale III” in 2016 TMS Annual Meeting & Exhibition.

## **Metal-Organic-Framework-Derived Functional Materials for Electrochemical Energy Storage and Conversion**

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### **Abstract**

We use metal-organic frameworks (MOFs) as a unique platform to synthesize nanostructured functional materials with both optimized composition and structure. Due to the atomically arranged metal ions and organic ligands, as well as the wide variety of compositions and porous structures, MOFs provide unique precursors for easy preparation of metal-based materials, carbonaceous materials and nanocomposites with high porosity and tunable composition/structure. In this talk, I will briefly discuss some progress we have achieved in this area. Specifically I will mention some examples of designed synthesis of nanostructured metal oxides, sulfide, nitride, and carbide using MOFs precursors. These MOFs derived nanomaterials exhibit interesting electrochemical properties.

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### **Biography**

Dr. David Lou received his B.Eng. (1st class honors) (2002) and M.Eng. (2004) degrees from the National University of Singapore. He obtained his Ph.D. degree in chemical engineering from Cornell University in 2008. Right after graduation, he joined Nanyang Technological University

(NTU) as an Assistant Professor. He was promoted to Associate Professor since September 2013. and to Full Professor since September 2015. He has published about 230 papers with a total ISI citation of ~28,000, and an h-index of ~98 as of July 2016. His main research interest is on designed synthesis of nanostructured materials for energy and environmental applications. In particular, he has strong interest on synthesis of hollow nanostructures for different applications, such as, lithium-ion batteries and supercapacitors. He also explores the applications of novel nanostructured materials for electrocatalysis and photocatalysis. He has received several important awards including the Young Scientist Award 2012 by National Academy of Science of Singapore. He also received the Nanyang Research Award 2012 by Nanyang Technological University. He was listed as a Highly Cited Researcher by Thomson Reuters in 2014 (in Materials Science) and 2015 (in both Materials Science & Chemistry). He is currently an Associate Editor for Journal of Materials Chemistry A.

## Functional Metal-Organic Framework (MOFs) Membranes

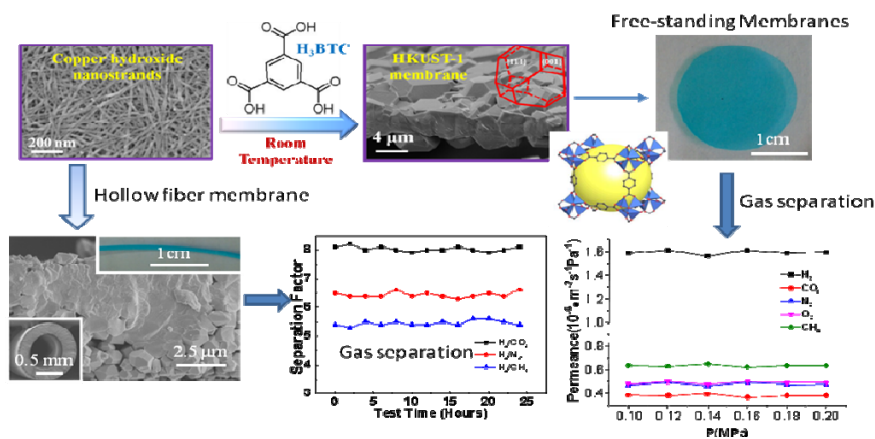
Xinsheng Peng

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### Abstract

Metal-organic frameworks (MOFs) demonstrate great potential for wide applications. However, most of them were prepared by relative high temperature and toxic organic solvent as well as toxic metal salts. Here, we present a general method that by using active nanostructured metal oxide or hydroxide as metal precursors, free-standing MOFs films<sup>1</sup>, MOFs/polymer hollow fiber membranes<sup>2</sup>, facet-oriented membranes<sup>3</sup> and thin films composite membrane<sup>4-5</sup> were prepared and show nice gas separation performance. In addition, diverse functional components, including small ions, micrometer-sized particles, inorganic nanoparticles and bioactive proteins, were rapidly encapsulated in MOF thin films at room temperature via a confinement technique.<sup>6</sup> These functional component-encapsulated MOF composite thin films exhibit synergistic and size-selective catalytic, bio-electrochemical, conductive and flexible functionalities that are desirable for thin film devices, including catalytic membrane reactors, biosensors, and flexible electronic devices.



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## **Biography**

Xinsheng Peng received his PhD from Chinese Academy of Sciences in 2003. Then, from 2003 to 2010, he worked at the Department of Chemistry of Lakehead University, Canada and National Institute for Materials Science (NIMS), Japan, as a postdoctor, research scientist and NIMS researcher, respectively. After that, he joined Zhejiang University, as a full professor. His current research focuses on functional thin films for novel separation membranes and energy storage.

## Computational Design of Magnetic Ordering@Oxide-interface Driven by Ferroelectric Polarization Discontinuity

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### **Abstract**

Electronic and magnetism properties of ferroelectric  $\text{TiO}_2/\text{PbTiO}_3$  (001) heterostructure are investigated via density functional theory calculations as well as TEM and EELS. Both the DFT calculation and experimental measurement results indicate that a metal-insulator phase transition and spin polarization at the interface of these non-magnetic insulator. Ferroelectric polarization induces half-metallic 2D electrons at positive interface. For the negative interface, 2D hole gas induced by the interface O-2p orbitals is also spin-polarized. The electronic and magnetism properties are sensitive to the charge distribution around the interface, which is determined by ferroelectric polarization. The strain and electric field effect on the ferroelectric polarization are discussed. The controllable magnetic interface properties are useful for the next generation electronic device in future.

### **Biography**

Yunhao Lu received his Bachelor of Science degree and PhD from Zhejiang University, China, in 2003 and 2008, respectively. Subsequently, he worked as a research fellow in the Computational Physics Group of National University of Singapore, where he focused on computational materials science. He joined Zhejiang University, China, in 2010 and has been a faculty member since. He studies the physical and chemical properties of materials by first principles calculations. His current research interests include: electronic, optical, and transport properties of 2D materials, nano-semiconductor interface structures, the transition metal surface atoms and organic molecules adsorption, conductive oxide interface, etc.

## **Polarization Screening and Thermal Expansion of Mesoporous Single-Crystal Ferroelectric Nanofibers**

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### **Abstract:**

In the past decade, one-dimensional (1D) perovskite ferroelectric oxide nanostructures have been the focus of numerous studies because of their intriguing piezoelectric and ferroelectric properties as well as potential applications in high-density storage, sensor and energy field <sup>[1]</sup>. We will firstly introduce recent progress in a new pre-perovskite and perovskite PbTiO<sub>3</sub> nanofiber <sup>[2-6]</sup>. A solid state phase transformation from pre-perovskite and perovskite one has led to the formation of mesoporous single-crystal ferroelectric PbTiO<sub>3</sub> nanofibers, where the negative-pressure-induced enhancement in ferroelectricity was argued <sup>[7]</sup>. By using in-situ XRD and TEM techniques, however, we find that ferroelectricity in such nanofibers was undermined due to the polarization screening within the mesoporous structure. In particular, the polarization screening gives rise to a specific thermal expansion of the nanofibers.

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### **Biography**

Dr. Zhaohui Ren is an associate professor in School of Materials Science & Engineering at Zhejiang university. He got his Ph.D degree in Materials Science and Engineering from Zhejiang University in June, 2008. From July, 2008 to October, 2010, he continued his postdoctoral research at Zhejiang University and subsequently joined the faculty of Zhejiang University. He has

been a visiting scholar in MMK at Stockholm University in 2012. Dr. Ren focuses his research in single-crystal nanostructures of functional ferroelectric oxides and their potential application in sensors, catalysis and energy etc. The work was financially supported by National Natural Science Foundation of China (NSFC) and Cyrus Tang Center for Sensor Materials and Application of Zhejiang University, China.



## **Nanostructured Ferromagnetic and Ferroelectric Thin Films for the Application of Information Storage**

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### **Abstract**

With the advance of the information technology data has become a new asset class- the new oil of the internet. The media of storing the data becomes more and more important. In the information storage devices, the data are stored in term of the electron spin and electron charge. In the present talk, I will discuss the researches in my group on the nanostructured materials used for the ultra-high density magnetic recording media, magnetic random access memory and electric field controlled energy efficient resistance memory. For the application of high density magnetic recording media and magnetic random access memory, our research focused on the development of high anisotropy magnetic materials –  $L1_0$  FePt with magnetic anisotropy is as high as  $7 \times 10^7$  erg/cm<sup>3</sup>, which allows the storage density to be as high as 50 Tbits/in<sup>2</sup>. Through the material and structure design, nanostructured FePt films have been developed to meet all the requirements of the industry. For example, for application of FePt for next generation magnetic recording media- heating assisted magnetic media, FePt films with uniform small grain size (5 nm), (001) texture, and high anisotropy are developed. For the MRAM application, ultra-thin FePt film (1 nm) with (001) texture and high anisotropy were obtained. For energy efficient memory, voltage (electric field) rather current used in CMOS and hard disk drives are used to writing the data. In this part, I will discuss a new emerging information storage technology based on ferroelectric tunnel junction which combines electric field writing and resistance reading. The ferroelectric tunnel junction was successfully developed on silicon substrate and writing speed, endurance and fatigue will be discussed.

### **Biography**

Prof. Chen Jingsheng is now with Department of Materials Science and Engineering, National University of Singapore. Prof. Chen earned Ph.D degree in Lanzhou University in 1999. Before he joined NUS in 2008, he was senior research scientist and group leader in Data Storage Institute,

Singapore. Until now, Seagate technology – the largest Hard disk drive company in the world has sponsored him more than US\$800K. A few technologies developed by Prof. Chen has been used in the product by Seagate Technology. He has got more than S\$12 million research grant from MOE, NRF and A\*STAR. His research interests are magnetic materials and device, spintronics, strong correlated oxide films. He has published more than 200 papers and filed/granted more than 10 patents. He has delivered more than 30 invited presentation in the international conferences and workshops.

## Novel Properties from Ferromagnetic Composites

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### **Abstract**

The coupling between magnetization and strain order parameters in ferromagnets has led to wide applications in sensors, transducers and actuators. All single-phase ferromagnets suffer magnetization deterioration upon heating or under stress. In this talk, we shall we show ferromagnetic composites that have thermally-stable or stress-insensitive magnetism. The proof-of-principal reference is Fe-Ga alloy, which contains both BCC and FCC phases. Upon heating, a gradual structural-magnetic transition occurs between two magnetic phases so that the magnetism deterioration is compensated by the ferromagnetic phase with larger magnetization. Under stress, the competing domain switches between the two components also facility stress insensitive magnetic permeability via piezomagnetic compensation. These novel properties may provide new recipes for designing advanced magnets.

### **Biography**

Tianyu Ma received the BS and Ph.D. degrees in Materials Science from Beijing University of Aeronautics and Astronautics in 2001 and 2006, respectively. After graduating, he became a research associate in 2006 and an associate professor in 2009 at the Department of Materials Science and Engineering, Zhejiang University. From 2011 and 2013, he worked in National Institute for Materials Science (NIMS), Japan as a JSPS Postdoctor Fellow. His current research interest is materials science in permanent magnets and magnetostrictive materials. He is also active in the solid phase transformation of functional materials.

## Silicon Quantum Dots for Optoelectronic Devices

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### Abstract

As one of the most important semiconductor nanostructures, silicon quantum dots (Si QDs) have important applications in optoelectronics. The remarkable electronic and optical properties of Si QDs are intimately related to their tunable size in the nanometer-sized regime. We have recently shown that surface states [1] and impurities [2-6] also matter for Si QDs. The manipulation of the surface states and impurities of Si QDs leads to added freedom for the tuning of the electronic and optical properties of Si QDs.

It is found that the radiative recombination of hydrosilylated Si QDs is sensitive to their surface states [1]. In most cases hydrosilylation leads to enhanced light emission from Si QDs. Optimum light emission efficiency exists as the QD size varies, resulting from the interplay between the quantum confinement effect and surface effect. The optimum light emission efficiency may change with the QD surface states.

We demonstrate that localized surface plasmon resonance (LSPR) occurs to both P- and B-doped Si QDs [2-5]. The LSPR frequency increases with the dopant concentration, highlighting the remarkable tunability of LSPR in doped QDs. It is also shown that B-doped Si QDs are better positioned for practical use than P-doped Si QDs.

Regarding the optoelectronic application of Si QDs, we have made progress on the use of Si QDs in the structures of solar cells [7], light-emitting diodes [8] and photodetectors [9].

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## Biography

Dr. Xiaodong Pi is a full professor in the State Key Laboratory of Silicon Materials and School of Materials Science and Engineering at Zhejiang University. He obtained his PhD degree in the department of physics at the University of Bath, UK with the Derek Chesterman medal for original research in 2004. He then carried out research in the Department of Engineering Physics at McMaster University, Canada and in the Department of Mechanical Engineering at the University of Minnesota, Twin Cities, USA. Dr. Pi was a research assistant professor at the University of Minnesota, Twin Cities before he joined Zhejiang University as an associated professor near the end of 2008. Dr. Pi was promoted to be a full professor in 2012. Dr. Pi's research has been supported by National Natural Science Foundation for Excellent Young Researchers. Dr. Pi has recently published papers in peer-reviewed journals such as *Physical Review Letters*, *Physical Review B*, *Advanced Materials*, *Advanced Optical Materials*, *ACS Nano* and *ACS Photonics*.

## Ordered Si-based Hybrid Nanostructured Arrays

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### **Abstract**

Hybrid nanostructures consist of two or more nanostructures that allow the significant property enhancement for individual nanocomponents. Due to the difficulty of control during their fabrication, most available hybrid nanostructures, at present, are generally arranged in a random order leading to significant degeneration of performance in comparison with perfectly-ordered hybrid nanostructures. Two special Si-based ordered hybrid nanostructured arrays have been successfully fabricated with their properties including gas sensing and photocurrent response that have been evaluated. One is a unique hybrid nanoneedle structure, consisting of a nanorod with a small nanodot sitting on the top. The sharp tip of the nanonipples with a small radius, for instance, is an ideal design of field ionizer for gas sensing. The measurements show that the nanoneedle gas sensor not only is capable of differentiating the type of gas but also has a high sensitivity of resolving the gas quantity with a small breakdown applied voltage. Ordered ZnO/Si nanoheterojunction is the other hybrid nanostructured array, where ZnO nanorods are grown on top of ordered Si (p-type) nano-needles. Each nano-heterojunction is examined to be a p-n junction and shows better diode characteristic after heat treatment. A number of such individual nano-heterojunctions that are perfectly arranged across the Si substrate surfaces can provide a building block to fabricate various types of optoelectronic nanodevices, such as photovoltaic solar cells and light emitting diodes with significantly enhanced properties.

Keywords: Silicon, ZnO, hybrid nanoneedle/junction array, gas sensing.

### **Biography**

Dr Yizhong Huang is currently an Associate Professor in School of Materials Science and Engineering at Nanyang Technological University Singapore. He is also a Director of a spin off company (coating concepts Pte Ltd) and has been working in University of Oxford as a postdoc and then research fellow (faculty member) and college fellow of Wolfson and now an academic visitor. He has published over a hundred fifty papers in journals such as Nature communications,

Nano Letters, Advanced Materials, ACS Nano and Small. He has strong expertise in transmission electron microscopy system with specific research interests in nanoelectrochemistry and hybrid nanostructured materials.

## On the Luminescence Mechanism of Organo-Lead Perovskites

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### **Abstract**

Organo-lead trihalide perovskites have attracted great attention due to the stunning advances in both photovoltaic and light-emitting devices. However, the photo-physical properties, especially the recombination dynamics of photo-generated carriers, of this class of materials are controversial. In this talk I will address this issue by comprehensive photoluminescence studies. We found that under an excitation level close to the working regime of solar cells, the recombination of photo-generated carriers in solution-processed perovskite films is dominated by excitons weakly localized in band tail states. The exciton localization effect is found to be general for several solution processed hybrid perovskite films prepared by different methods. Our results provide insights into the charge transport and recombination mechanism in perovskite films and help to unravel their potential for high-performance optoelectronic devices.

### **Biography**

Haiping He is an Associate Professor in the School of Materials Science and Engineering at Zhejiang University. He received his B. S. degree in Materials Physics and Ph.D degree in Condensed Matter Physics from University of Science and Technology of China (USTC). He joined the faculty at Zhejiang University in 2006. His research interests focus on semiconductor optics and novel luminescent materials.







## Travel Information in Hangzhou

### Friday, July 22 19:00-21:00

1. West Lake
2. Hefang Street
3. Wulin Square

### Saturday, July 23 13:00-17:00

1. West Lake
2. Hefang Street
3. Lingyin Temple
4. Xixi Wetland
5. Song Dynasty Town

### Brief Introductions of Some Places

#### West Lake



West Lake or Xi Hu is a famous fresh water lake located in the historic area of Hangzhou, the capital of Zhejiang province in eastern China. It evolved from a shallow bay through which the Qiantang River flowed into the East China Sea. In the ancient times it was called Wulin Waters, Golden Buffalo Lake, Qiantang Lake and Xizi Lake.

The name of West Lake was fixed as early as the Tang Dynasty (618-907). In the

Song Dynasty (960-1279), the Chinese renowned poet Su Dongpo wrote a poem to praise the West Lake and compared it to Xizi, a Chinese legendary beauty. Since then, the West Lake has another elegant name Xizi Lake. And as it lies in the west of Hangzhou, it is usually called the West Lake.

The lake is divided into 5 parts by the causeways of Su Di, Bai Di, and Yanggong Di. There are numerous temples, pagodas, gardens, and artificial islands within the lake. With ripples on the water's surface and thickly-wooded hills dotted by exquisite pavilions on its four sides, the West Lake is one of China's best known scenic spots.

## Hefang Street



Hefang Street is a well-designed old pedestrian street, which is the epitome of old Hangzhou. The original street has been ruined and it recently takes on a completely new look after large-scale of restoration. Shops selling art crafts, souvenirs, silk, teahouses, and restaurants line on both sides of the street. Many famous century-old shops including Hu Qing Yu Tang, Wang Xingji Fans can be found along the street. Hefang Street is otherwise known as the Snack Street for the diverse food it serves. The street clearly concentrates food from all around the country, while at some time highlighting the local flavors.

## Lingyin Temple



Situated at the foot of Lingyin Mountain, aside from the West Lake, Lingyin Temple (Temple of Inspired Seclusion) is one of the ten most famous ancient Buddhist temples in China. First built by an Indian monk Huili in 326 AD during the Eastern Jin dynasty (317-420 AD), the temple was named Lingyin Temple because its environment is very beautiful and serene and suitable for "gods rest in seclusion". In its prime, this temple, containing over 1300 rooms and 3000 monks, used to be a large monastery. Due to war and calamity, the temple has experienced about 1700 years of repeated circles of prosperity and decline until its last restoration in the Qing dynasty (1644-1911). There are three famous halls of Heavenly Kings, Daxiongbaodian Hall (Precious Hall of the Great Hero), Pharmaceutical Master Hall and Great Mercy Hall.

## Xixi Wetland



Xixi Wetland Park has an extensive history and is located on the southern tip of the longest and oldest canal in the world, the Hangzhou-Beijing Canal. Dragon boats take you around in the network of rivers and show you a new side of Hangzhou, also known as the paradise city of China.

Xixi Wetland Park is the nation's first and only collection of urban wetland,

farming wetland and cultural wetland in the integration of national wetland park. Water is the soul of xixi, about 70% of the area is river, pond, lake, and swamp. Meanwhile there are many branching stream and designed in fish ponds, forming a unique xixi wetland landscape.

## Song Dynasty Town



“Given me one day, I will give you back one thousand years”, so promises the marketing mastermind behind the largest scale Song Dynasty theme park in China. This slogan does indeed deliver on its promise; this is one of the places around Hangzhou to experience ancient China within the walls of the park.

The main drag inside the theme park was styled after “The Riverside Scene at Qingming Festival.” A famous painting noted by the Song artist Zhang Zheduan. The grounds of the park also include a bell tower, city tower, a temple and various gardens that feature the grotesquely shaped rocks that were the height of fashion at the time. Song City is a fun place to wander around perusing the colorful daily necessities in a traditional manner. On special occasions, the park also hosts elaborate parades with singing, dancing and acrobatics.









