

课程大纲

COURSE SYLLABUS

1.	课程代码/名称 Course Code/Title	能源材料表征技术 Characterization techniques for energy materials
2.	课程性质 Compulsory/Elective	研究生课程
3.	课程学分/学时 Course Credit/Hours	3/64
4.	授课语言 Teaching Language	优先英文
5.	授课教师 Instructor(s)	曾国松, 助理教授, 机械与能源工程系 Email: zenggs@sustech.edu.cn Guosong Zeng, Assistant Professor, Department of Mechanical and Energy Engineering, Email: zenggs@sustech.edu.cn
6.	是否面向本科生开放 Open to undergraduates or not	否
7.	先修要求 Pre-requisites	(如面向本科生开放, 请注明区分内容。 If the course is open to undergraduates, please indicate the difference.)
8.	教学目标 Course Objectives	<p>(如面向本科生开放, 请注明区分内容。 If the course is open to undergraduates, please indicate the difference.)</p> <p>本课程旨在介绍在能源材料领域广泛应用的先进表征分析技术, 包括其工作原理, 适用范围, 技术优势, 以及当前局限。通过课程学习, 掌握仪器及分析对象特性, 了解各分析表征技术间在不同学科和研究领域中相互补充支撑的关系, 熟悉当前分析表征的发展方向, 使学生对多学科交叉产生一定认识, 理解不同技术使用范围和掌握对应表征技术的数据分析方法。同时, 通过课程设置的实践环节, 由学生操作仪器对具体样品材料进行表征分析, 使学生在亲自动手的过程中获得切身经历, 进一步加深对理论知识的理解, 使学生真正掌握理解课程所授知识。</p> <p>This course introduces the widely used state-of-the-art characterization techniques for energy material study, including their working principles, applicability, advantages, and their limits. From this course, students will manage different characterization techniques and the properties of the analyzed materials, understand the pros and cons of various techniques and how they complement each other, seeing the current progress and trend of developing state-of-the-art techniques for resolving remaining technical issues and bottlenecks. Thus, the students will obtain certain interdisciplinary knowledge, understand the feasibility of a technique under a certain condition, as well as the proper data processing method. Meanwhile, through the lab session, students will interrogate actual samples, thus obtain hands-on experience during the measurement, which will further consolidate the theoretical knowledge learned from the class.</p>
9.	教学方法 Teaching Methods	<p>(如面向本科生开放, 请注明区分内容。 If the course is open to undergraduates, please indicate the difference.)</p> <p>教室讲授, 使用多媒体授课, 进行案例解析, 并设置课程报告环节。实验部分借用分析测试中心平台, 部分内容由具体仪器相关负责人辅助讲解仪器工作原理及操作方法, 学生观摩实验操作过程。</p>
10.	教学内容 Course Contents	

(如面向本科生开放, 请注明区分内容。 If the course is open to undergraduates, please indicate the difference.)

Section 1 (4 hours)	能源材料基础 Introduction of energy materials
Section 2 (2 hours)	表征技术简介 Introduction of characterization techniques
Section 3 (6 hours)	半导体物理基础 Basics of semiconductor physics
Section 4 (4 hours)	光电子能谱 X-ray Photoemission Spectroscopy
Section 5 (4 hours)	X 射线吸收谱 X-ray Absorption Spectroscopy
Section 6 (4 hours)	电镜技术与应用 Introduction of electron microscopy and applications
Section 7 (4 hours)	先进光谱学技术 Advanced Spectroscopic Techniques
Section 8 (2 hours)	基于原子力显微镜的扩展技术 Atomic force microscopy based extended functions
Section 9 (2 hours)	其他表面/亚表面分析技术 Other Surface/Subsurface Analytical Techniques
Lab Section 1 (6 hours)	光电子能谱仪 X-ray Photoemission Spectroscopy
Lab Section 2 (8 hours)	电子显微镜 Electron Microscopy
Lab Section 3 (8 hours)	拉曼光谱仪与红外光谱仪 Raman Spectroscopy and Infrared Spectroscopy
Lab Section 4 (10 hours)	基于原子力显微镜的扩展功能 Atomic force microscopy based extended functions

11. 课程考核 Course Assessment

- ① 考核形式 Form of examination: 考核 Assessment;
- ② . 分数构成 grading policy: a. 出勤 Attendance 5%; b. 课堂表现 Class performance 10%; c. 课程项目 Projects 40%; d. 期末报告 Final report/presentation 45%.
- ③ 如面向本科生开放, 请注明区分内容。 If the course is open to undergraduates, please indicate the difference.)

12. 教材及其它参考资料 Textbook and Supplementary Readings

推荐教材:
新能源材料-基础与应用, 艾德生等, 化学工业出版社

The Physics of Semiconductors, Marius Grundmann, Springer
Introduction to Solid State Physics, Charles Kittel, Wiley
参考教材:
新能源材料, 雷永泉, 天津大学出版社
The Oxford Solid State Basics, Steven H. Simon, OUP Oxford

Guosong Zeng, Ph.D

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Professional Experiences

Southern University of Science and Technology

Oct 2021 – present

Assistant Professor

Department of Mechanical and Energy Engineering, College of Engineering

Lawrence Berkeley National Laboratory (Berkeley, CA, USA)

Apr 2018 – Sep 2021

Postdoctoral Research Fellow (Chemical Sciences Division)

Supervisor: **Dr. Francesca M. Toma**

Lehigh University (Bethlehem, Pennsylvania, USA)

Jun 2017 – Mar 2018

Postdoctoral Research Associate (Surface Interfaces and Materials Tribology Laboratory)

Supervisor: **Dr. Brandon A. Krick**

Lehigh University (Bethlehem, Pennsylvania, USA)

Jan 2014 - May 2017

Research Assistant

Surface Interfaces and Materials Tribology Laboratory

Department of Mechanical Engineering and Mechanics, Lehigh University

Supervisor: **Dr. Brandon A. Krick**

Lehigh University (Bethlehem, Pennsylvania, USA)

Jun 2014 - May 2017

Research Assistant

Center for Photonics and Nanoelectronics

Department of Electrical and Computer Engineering, Lehigh University

Co-Supervisor: **Dr. Nelson Tansu**

Lehigh University (Bethlehem, Pennsylvania, USA)

Jun 2017

Teaching Assistant

Lehigh Microscopy School, Material Science and Engineering, Lehigh University

MNMT, Tianjin University (Tianjin, China)

Mar 2009 - Jul 2010

Research Assistant

Focused Ion Beam Research Group in the Center for Micro/Nano Manufacturing Technology (MNMT), Tianjin University

Education

Lehigh University (Bethlehem, Pennsylvania, USA)

Jan 2013 – May 2017

Ph.D. in Mechanical Engineering, Department of Mechanical Engineering and Mechanics

- Ph.D. advisor: Prof. Brandon A. Krick (ME, Lehigh)
- Ph.D. co-advisor: Prof. Nelson Tansu (ECE, Lehigh)

Lehigh University (Bethlehem, Pennsylvania, USA)

Sep 2010 – May 2012

Master of Science (M.S.) in Mechanical Engineering, Department of Mechanical Engineering and Mechanics

Research Interests

My postdoctoral research focuses on fabrication, characterization and optimization of (photo)electrochemical assemblies based on organic and inorganic materials, to produce stable and efficient devices for H₂ production and CO₂ reduction. This includes (1) Execution of materials characterization using techniques such as but not limited to: atomic force microscopy based advanced operando characterization techniques (e.g., SECM, SPCM, EC-AFM, etc.), synchrotron based ambient pressure X-ray photoemission spectroscopy (AP-XPS), X-ray absorption spectroscopy (EXAFS and NEXAFS), and transmission electron microscopy and electron energy loss spectroscopy (TEM/EELS); (2) Study of electrochemically and photoelectrochemically driven processes of III-Nitrides and Ta₃N₅; (3) Integration of protective coatings and catalyst for proton exchange membrane; (4) Developing understanding of integration issues and emergent degradation mechanisms of PECs at relevant scale; (5) Developing stable co-catalysts and surface protection schemes on halide perovskite thin films for solar water splitting application.

My PhD research interests are related to the investigation of mechanical properties and surface chemistry of MOCVD-grown III-Nitride semiconductor materials (e.g., GaN, InN, AlN and allied ternary alloys). My research covers the experimental and theoretical/computational studies of tribological performances of III-Nitride semiconductor materials under various environments. My other research interests include: tribological properties of ALD-grown thin films (e.g., alumina, SiC, TiVN), steel, silicon; ultraprecision machining; phase transformation of semiconductor materials. My previous studies include the investigation of thermal effects on RF-MEMS switches and the fabrication of SERS-based sensors by focused ion beam.

Awards & Honors

The Hydrogen and Fuel Cells Postdoctoral Recognition Award (Oct 2020), The U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) announced the recipients of EERE's Hydrogen and Fuel Cell Technologies Office's (HFTO's) inaugural Postdoctoral Recognition Award. The award recognized postdoctoral fellows from DOE National Laboratories for outstanding contributions in identifying research solutions to hydrogen and fuel cell research challenges.

Lehigh University Doctoral Fellowship (Sep 2016 – Jan 2017), Lehigh University

The E. Elmer Klaus Fellowship (May 2016), Society of Tribologists and Lubrication Engineers (STLE) most prestigious award for graduate students. Awarded annually to the top graduate students participating in tribology research.

Lehigh University Doctoral Fellowship (Jan 2015 – May. 2015), Lehigh University

Lehigh University Doctoral Fellowship (Jan 2014 – May. 2014), Lehigh University

Lehigh University Research Assistantship (Jun 2014 – present), Lehigh University

Distinguished undergraduate dissertation, (Jul 2010) Tianjin University

Tianjin University Merit Student Scholarship, (Feb 2008 – Jul 2008) Tianjin University

Publications

First Authorship

1. **G. Zeng**, T. A. Pham, S. Vanka, G. Liu, C. Song, J. K. Cooper, T. Ogitsu, Z. Mi, F. M. Toma, Sustained Hydrogen Production on Self-Improving GaN/Si Photocathode, *Nature Materials*, 20, 2021, 1130-1135
2. T, Kristle*, **G. Zeng*** (co-first), J. Young, F. M. Toma, F. Houle, T. Geutsch, N. Danilovic, Emergent Degradation Mechanisms with Integration and Scale Up of PEC Devices, *Advanced Energy Materials*, 2020, 2002706

3. **G. Zeng**, X. Yang, C. K. Tan, C. Marvel, B. E. Koel, N. Tansu, B. A. Krick, Shear-induced band bending in GaN, *ACS Applied Materials and Interfaces*, 10 (34), 2018, 29048-29057
4. **G. Zeng**, W. Sun, R. Song, N. Tansu, B. A. Krick, Crystallographic Orientation Effect on GaN Wear, *Scientific Reports*, 7, 2017, 14126
5. **G. Zeng**, N. Tansu and B. A. Krick, Moisture Dependent Wear Mechanisms of Gallium Nitride, *Tribology International*, 118, 2017, 120-127
6. **G. Zeng**, X. Yang, C. H. Skinner, B. E. Bruce, N. Tansu, B. A. Krick, Controlling Factors of GaN Wear, *Tribology and Lubrication Technology*, 73(3), 22-28, 2017
7. **G. Zeng**, C. K. Tan, N. Tansu, B. A. Krick, Ultralow of Gallium Nitride, *Applied Physics Letters*, 109, 2016, 105602

Co-authorship

1. G. Liu, F. Zhang, J. Li, **G. Zeng**, D. M. Larson, J. W. Ager, L. Wang, F. M. Toma, Rational Design of Protection Schemes by Unraveling the Mechanism of Photoelectrochemical Transformations in Cu₂O Photoelectrodes, *Nature Energy* (**in press**)
2. H. Li, P. Yu, R. Lei, F. Yang, P. Wen, X. Ma, **G. Zeng**, J. Guo, F. M. Toma, Y. Qiu, S. M. Geyer, X. Wang, T. Cheng, W. Drisdell, *Angewandte Chemie* (**in press**)
3. S. Chatterjee, X. Peng, S. Intikhab, **G. Zeng**, N. N. Kariuki, D. J. Myers, N. Danilovic, J. Snyder, Nanoporous Iridium Nanosheets for Polymer Electrolyte Membrane Electrolysis, *Advanced Energy Materials*, 2021, 11, 2101438
4. G. Liu, M. Lee, S. Kwon, **G. Zeng**, K. Jiang, J. Eichhorn, A. K. Buckley, A. T. Bell, W. A. Goddard, F. M. Toma, Pure Cu Electrocatalysts produce only H₂ in Electrocatalytic CO₂ Reduction at -1V RHE, *PNAS*, 2021, 118, 23
5. Y. N. Regmi, E. Tzanetopoulos, **G. Zeng**, X. Peng, D. Kushner, T. A. Kistler, P. Agbo, L. A. King, A. Z. Weber, N. Danilovic, Supported Oxygen Evolution Catalysts by Design: Towards Lower Precious Metal Loading and Improved Conductivity in Proton Exchange Membrane Water Electrolyzers, *ACS Catalysis*, 2020, 10, 13125-13135
6. X. Liu, C. Sammarco, **G. Zeng**, D. Guo, W. Tang, C. Tan, Investigations of Monoclinic- and Orthorhombic-based (B_xGa_{1-x})₂O₃ Alloys, *Applied Physics Letters*, 2020, 117, 012104
7. K. Jiang, Z. Zhang, **G. Zeng**, G. Liu, F. M. Toma, J. K. Cooper, A. T. Bell, Effects of Surface Roughness on the Electrochemical Reduction of CO₂ over Cu, *ACS Energy Letters*, 2020, 5, 4, 1206-1214
8. A. De Riccardis, M. Lee, R. V. Kazantsev, A. J. Garza, **G. Zeng**, D. M. Larson, E. L. Clark, P. Lobaccaro, P. W. W. Burroughs, E. Bloise, J. W. Ager, A. T. Bell, M. Head-Gordon, G. Mele, F. M. Toma, Heterogenized pyridine-substituted cobalt(II) phthalocyanine yields reduction of CO₂ by tuning the electron affinity of the Co center, *ACS Applied Materials and Interfaces*, 2020, 12, 5, 5251-5258
9. S. Vanka, K. Sun, **G. Zeng**, A. Pham, F. Toma, T. Ogitsu and Z. Mi, Long-Term Stability Studies of a Semiconductor Photoelectrode Protected by Gallium Nitride Nanostructures, *Journal of Materials Chemistry A*, 7, 2019, 27612-27619
10. W. Ji, T. Allen, X. Yang, **G. Zeng**, S. D. Wolf, A. Javey, Polymeric electron-selective contact for crystalline silicon solar cells with an efficiency exceeding 19%, *ACS Energy Letters*, 2020, 5, 3, 897-902
11. A. C. Kozen, M. J. Sowa, L. Ju, N. C. Strandwitz, **G. Zeng**, T. Babuska, Z. Hsain, B. A. Krick, Plasma-Enhanced Atomic Layer Deposition of Vanadium Nitride, *Journal of Vacuum Science and Technology A*, 37, 2019, 061505
12. M. J. Sowa, L. Ju, A. C. Kozen, N. C. Strandwitz, **G. Zeng**, T. Babuska, Z. Hsain, B. A. Krick, Plasma-enhanced atomic layer deposition of titanium vanadium nitride, *Journal of Vacuum Science and Technology A*, 36, 2018, 06A103

13. C. V. Hadena, G. Zeng, F. M. Carter III, C. Ruhla, B. A. Krick, D. G. Harlow, Wire and Arc Additive Manufactured Steel: Tensile and Wear Properties, Additive Manufacturing, 16, 2017, 115-123
14. Z. Hsain, G. Zeng, N. C. Strandwitz, B. A. Krick, Wear behavior of annealed atomic layer deposited alumina, Wear, 372-373, 2017, 1-6

i. Conference Paper, Book Chapters and Other Archival Publications

1. G. Zeng, A. T. Pham, S. Vanka, G. Liu, J. K. Cooper, Z. Mi, T. Ogitsu, F. M. Toma, Self-improving GaN/Si Photocathode in PEC Water Splitting, ACS Fall 2020 Virtual Meeting and Expo, 2020
2. G. Zeng, S. Vanka, G. Liu, J. K. Cooper, Z. Mi, F. M. Toma, Si-based Photocathode with GaN Protection Layer for Photoelectrochemical Water Splitting, 236th ECS Meeting, Atlanta, GA, USA, 2019
3. G. Zeng, X. Yang, B. E. Koel, F. M. Toma, N. Tansu, B. A. Krick, Shear-induced electronic property modification of GaN characterized by XPS, Poster session, Molecular Foundry Annual User Meeting, Berkeley, CA, 2018
4. **(Invited Conference Paper)** B. A. Krick, G. Zeng, X. Yang, C. K. Tan, B. E. Koel, N. Tansu, Tribology of GaN, Beyond Ultra Low Wear, Gordon Research Conference, Progress in Tribology at the Interface Between Disciplines (GRC), Lewiston, ME, 2018
5. G. Zeng, X. Yang, W. Sun, B. E. Koel, N. Tansu, and B. A. Krick, Tribodoping on III-Nitrides; New Way to Investigate Shear-induced Electronic Property Modification of Semiconductor Materials, Proc. of the Society of Tribologists and Lubrication Engineers Annual Meeting (STLE) 2018, Minneapolis, MN, USA, 2018
6. **(Invited Conference Paper)**, G. Zeng, X. Yang, B. E. Koel, N. Tansu, B. A. Krick, Crystal Orientation Effect on Mechanical and Electronic Properties of GaN, BIT's 6th Annual Conference of AnalytiX, Miami, 2018
7. **(Invited Conference Paper)**, G. Zeng, X. Yang, Chee-Keong Tan, B. E. Koel, N. Tansu, B. A. Krick, GaN: Beyond ultralow wear, Forum of Young Tribologists, 6th World Tribology Congress, Beijing, China, 2017
8. W. Sun, G. Zeng, R. Song, J. J. Wierer, Jr., N. Tansu, Strain Relaxation Properties of OMVPE-Grown AlInN Semiconductors, Proc. of the 21st American Conference on Crystal Growth and Epitaxy, Santa Fe, NM, July 2017.
9. M. J. Sowa, N. C. Strandwitz, L. Ju, A. C. Kozen, T. F. Babuska, G. Zeng, B. A. Krick, Mechanical, physical, and electrical properties of PEALD VN using TDMAV and N₂ plasma, AVS 64th international Symposium and Exhibition, Tampa, FL, 2017
10. Z. Hsain, G. Zeng, N. C. Strandwitz, B. A. Krick, Wear Mechanisms of Annealed Atomic Layer Deposited Alumina Thin Films, Poster session, AVS 64th international Symposium and Exhibition, Tampa, FL, 2017
11. M. J. Sowa, N. C. Strandwitz, L. Ju, A. C. Kozen, B. A. Krick, G. Zeng, Mechanical, physical, and electrical properties of plasma-enhanced atomic layer deposition of TiVN, 17th International Conference on Atomic Layer Deposition, Denver, CO, 2017
12. G. Zeng, X. Yang, B. E. Koel, D. Borovac, C. K. Tan, N. Tansu, B. A. Krick, Tribochemistry of GaN, Proc. of the Society of Tribologists and Lubrication Engineers Annual Meeting (STLE) 2017, Atlanta, GA, USA, 2017
13. Z. Hsain, G. Zeng, N. C. Strandwitz, B. A. Krick, Wear mechanisms in annealed atomic layer deposited alumina thin films, Proc. of the Society of Tribologists and Lubrication Engineers Annual Meeting (STLE) 2017, Atlanta, GA, USA, 2017
14. G. Zeng, X. Yang, B. E. Koel, D. Borovac, C. K. Tan, N. Tansu, B. A. Krick, Tribochemistry of GaN, a surprisingly wear resistant semiconductor, 253rd American Chemical Society National Meeting & Exposition, San Francisco, CA, USA, 2017
15. G. M. Erickson, S. M. Kuhn-Hendricks, M. A. Sidebottom, J. F. Curry, G. Zeng, M. A. Norell, B. A. Krick, Wavy Enamel in Hadrosaurid Dinosaurs with Grinding Dentitions Functioned to Limit

- Fracture Damage through Energy-Robbing Crack Deflection and Channeling, Society of Vertebrate Paleontology 76th Annual Meeting, Salt Lake City, UT, USA, 2016
16. **G. Zeng**, X. Yang, C. K. Tan, B. E. Koel, N. Tansu, B. A. Krick, Investigation of Ultralow Wear of III-Nitride Materials, International Workshop on Nitride Semiconductors 2016, Orlando, FL, USA, 2016
 17. **G. Zeng**, X. Yang, C. K. Tan, B. E. Koel, N. Tansu, B. A. Krick, Ultralow Wear of Gallium Nitride, 58th Electronic Materials Conference (EMC) 2016 **LATE NEWS**, Newark, DE, USA, 2016
 18. Z. Hsain, **G. Zeng**, N. C. Strandwitz, B. A. Krick, Effect of Annealing on the wear behavior of atomic layer deposited of alumina, Poster session, Proc. of the Society of Tribologists and Lubrication Engineers Annual Meeting (STLE) 2016, Las Vegas, NV, USA, 2016
 19. **G. Zeng**, X. Yang, C. K. Tan, B. E. Koel, N. Tansu, B. A. Krick, Humidity effect on wear performance of gallium nitride, Poster session, Proc. of the Society of Tribologists and Lubrication Engineers Annual Meeting (STLE) 2016, Las Vegas, NV, USA, 2016
 20. **G. Zeng**, N. Tansu, B. A. Krick, *Wear Mechanism of III-Nitride Semiconductor Materials*, Proc. of the Society of Tribologists and Lubrication Engineers Annual Meeting (STLE) 2016, Las Vegas, NV, USA, 2016
 21. **G. Zeng**, B. A. Krick, N. Tansu, Ultralow Wear of GaN, SPIE Photonics West 2016, San Francisco, CA, USA, Feb 2016
 22. B. A. Krick, **G. Zeng**, C. K. Tan, N. Tansu, Surprisingly Low Wear Behavior of Gallium Nitride Coatings, STLE Frontiers Conference 2015, Denver, CO, USA, Oct 2015
 23. **G. Zeng**, B. A. Krick, N. Tansu, J. F. Curry, M. A. Sidebottom, Nanoscale Mechanisms in Ductile Wear of Brittle Material, Proc. of the Society of Tribologists and Lubrication Engineers Annual Meeting (STLE) 2015, Dallas, TX, USA, May 2015.
 24. **G. Zeng**, B. A. Krick, N. Tansu, Shear-Induced Phase Transformation: From Single-Crystal Silicon to Si-IV, Proc. of the American Physical Society (APS) Annual March Meeting 2015, San Antonio, Texas, USA, March 2015
 25. Z. W. Xu, F. Z. Fang, **G. Zeng**, Focused ion beam nanofabrication technology, Handbook of manufacturing engineering and technology, 2012, Springer