Changsheng Wu

Presidential Young Professor/Assistant Professor
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Education

Georgia Institute of Technology, Atlanta, GA
Ph.D. in Materials Science and Engineering
Advisor: Zhong Lin Wang — Aug 2013 – Aug 2019
Thesis: *High Performance Triboelectric Nanogenerator and Its Applications*

National University of Singapore, Singapore
B.Eng. in Engineering Science — Aug 2009 – Jul 2013

University of British Columbia, Vancouver, Canada
Exchange Student in Applied Science — Jan 2012 – Apr 2012

Research Interests

My research interests are in the area of **sustainable digital health** at the interface between **wearable bioelectronics**, **renewable energy**, and **advanced manufacturing**. I am specifically interested in developing **smart materials capable of continuously and sustainably sensing body signals**. The platform involves two-fold efforts. One is to monitor and decode biosignals comfortably and accurately through **wireless wearable multimodal biosensors**. The second is to develop self-powered bioelectronic systems through **high-efficiency biomechanical energy harvesters**. My research will combine materials design, bioelectronics, biomechanical energy harvesting, wireless communication, and data analytics to study the associated fundamental and applied problems, including:

- Novel 3D metastructures for soft biosensors and energy harvesters
- Wireless wearable multimodal biosensors
- MEMS-based soft robotics for biosensing and drug delivery
- Closed-loop sensing & therapeutic systems
- Advanced signal processing and analysis of bio-signals
- Novel design of low-power electromechanical sensors
- Development of high-efficiency biomechanical energy harvesters

Research Experience

Rogers Research Group, Northwestern University Evanston, IL
Postdoctoral Research Fellow, Oct 2019 – Apr 2022
Advisor: John A. Rogers
Research: **Wireless flexible bioelectronics**

- Invented the first wireless, skin-interfaced multimodal biosensor capable of time-synced monitoring of hemodynamics, motion and temperature, and applied it to cases beyond the applicability of conventional systems, such as the study of muscle hemodynamics in athletes and cerebral hemodynamics in extreme environment (e.g. inflight pilots).
- Invented the first wireless, soft, flexible near-infrared spectroscopy (NIRS) sensor for long-term monitoring of tissue oxygenation in fasciocutaneous free flaps to improve flap salvage rate and reduce need for skilled personnel.

– Co-invented a wireless, soft, miniaturized NIRS sensor for cerebral hemodynamic monitoring in pediatric care.
– Invented the first wireless, skin-mounted, minaturized elastography system that incorporates a broadband dual-accelerometer sensor and an automated acoustic actuator.
– Demonstrated the unprecedented capability of the wireless elastography system for continuous, non-invasive, quantitative depth-sensitive evaluation of muscle elasticity.
– Applied advanced data processing techniques and machine learning algorithms to obtain vital signs (heart rate, respiratory rate, talking) and identify unconventional biomarkers (coughing, throat clearing, laughing) from mechano-acoustic signals at the suprasternal notch.
– Designed the fabrication workflow of and experimentally demonstrated the first hierarchical 3D assembly of mesostructures for soft tissue-electronics interface.

Wang Nanoscience Group, Georgia Institute of Technology, Atlanta, GA
Graduate Research Assistant, May 2015 – Aug 2019
Advisor: Zhong Lin Wang
Research: **Triboelectric nanogenerators**
– Designed novel electromechanical devices using the emerging technology called triboelectric nanogenerator (TENG) for energy harvesting and self-powered sensing.
– Investigated the fundamental relationship between TENG performance and ambient gas environments, and achieved a record-high triboelectric charge density through the optimiation of materials and operation environment with an enhancement in output power of 45 times.
– Introduced the methodology of spring-based resonance coupling into TENG design to hugely increase its performance in harvesting low-frequency vibration energy by up to 10 times.
– Invented a two-factor, keystroke-biometrics-based security system with a stretchable, self-powered triboelectric pressure sensing array, and the system achieved an authentication accuracy of 98.7% even with a leaked passcode.
– Co-invented the first self-powered, wireless optical communication system based on triboelectric pressure sensing.
– Invented the first self-powered iontophoretic transdermal drug delivery system that harnesses biomechanical energy to drive the electrically-assisted drug delivery process.

Panel Process and Optics Engineering Team, Apple Inc., Cupertino, CA
Summer Intern, May 2018 – Aug 2018
Advisor: Michael Vosgueritchian
– Characterized new materials for next-generation sensors and transducers.

Georgia Tech Manufacturing Institute, Georgia Institute of Technology, Atlanta, GA
Graduate Research Assistant, Oct 2013 – Apr 2015
Advisors: Ben Wang, Chuck Zhang
Research: **Additive manufacturing for novel biomedical devices**
– Designed 3D printable, dual-material-based metamaterials with tunable mechanical properties for patient-specific tissue-mimicking phantoms.
– Co-developed a novel procedure simulation platform for in vitro transcatheter aortic valve replacement (TAVR) using patient-specific 3D printed tissue-mimicking phantoms to quantitatively predict the occurrence, severity, and location of post-TAVR paravalvular leaks.

Solar Energy Research Institute of Singapore, Singapore
Final Year Research Student, Sep 2012 – May 2013
Advisors: Armin Aberle, Ian Marius Peters
– Developed a modelling tool that uses local meteorological data to predict the design requirement of solar panels and battery capacity for long-term, uninterrupted operation of standalone solar-powered systems.

Singapore-MIT Alliance for Research and Technology, Singapore

Research Assistant, Dec 2012 – Jun 2013
Advisors: Fuu Ming Kai, Charles Harvey
– Maintained a standalone solar-powered meteorological station in Kranji, Singapore.

Odom Research Group, Northwestern University, Evanston, IL
Summer Research Intern, Jun 2012 – Aug 2012
Advisor: Teri W. Odom
– Fabricated and simulated nanopatterned plasmonic organic solar cells.

Honors and Awards

Chinese Government Award for Outstanding Self-Financed Students Abroad, 2019
TechConnect Innovation Award, 2018
The 56th R&D 100 Awards, 2018
1st Place Poster Award, Georgia Tech MSE, 2018
Georgia Tech IEN Seed Grant Award, 2015
NUS First Class Honors Bachelor's Degree, 2013
The Ministry of Education of Singapore PRC Scholarship, 2009-2013

Journal Publications

Equal Contribution†, Corresponding Author∗

Manuscripts in Preparation

1. **Changsheng Wu**†, Chenhang Li†, Heling Wang, Ziwu Song, Allison Wang, Jiahong Li, Haixu Shen, Louie Shapiro, Hyoyoung Jeong, Wenbo Ding, Sabrina S.M. Lee, Yonggang Huang, John A. Rogers*, Xiaoyue Ni*, "On-body seismology for continuous monitoring of tissue mechanics." (Manuscript in preparation)
2. **Changsheng Wu**, Jong Yoon Lee, Jacob Trueb, Alina Y. Rwei, Mitchell A. Pet, Matthew R. MacEwan, John A. Rogers*, "Wireless, soft, skin-interfaced multimodal biosensor for concurrent monitoring of hemodynamics, temperature and motion." (Manuscript in preparation)

First/Co-First Authorship

3. Hangbo Zhao†, Xu Cheng†, **Changsheng Wu**†, Tzu-Li Liu, Shuo Li, Xinchen Ni, Yihui Zhang*, Yonggang Huang*, John A. Rogers*, "Mechanically guided hierarchical assembly of 3D mesostructures." *Advanced Materials* 34 (12), 2109416 (2022) [pdf]
4. **Changsheng Wu**†, Alina Y. Rwei†, Jong Yoon Lee, Wei Ouyang, Lauren Jacobsen, Haixu Shen, Haiwen Luan, Yameng Xu, Jun Bin Park, Sung Soo Kwak, Xiaoyue Ni, Wubin Bai, Daniel Franklin, Shuo Li, Yiming Liu, Xinchen Ni, Matthew R. MacEwan, John A. Rogers, Mitchell A. Pet*, "A wireless near infrared spectroscopy device for flap monitoring: proof of concept in a porcine musculocutaneous flap model." *Journal of Reconstructive Microsurgery* 38 (02), 096-105 (2022) [pdf].
5. Alina Y. Rwei†*, Wei Lu†, **Changsheng Wu**†, Kelia Human, Emily Suen, Daniel Franklin, Monica Fabiani, Gabriele Gratton, Zhaoqian Xie, Yujun Deng, Sung Soo Kwak, Lizhu Li, Carol Gu, Alanna Liu, Casey M Rand, Tracey M Stewart, Yonggang Huang, Debra E Weese-Mayer*, John A Rogers*, "A wireless, skin-interfaced biosensor for cerebral hemodynamic monitoring in pediatric care." *Proceedings of the National Academy of Sciences* 117 (50), 31674-31684 (2020) [pdf]
6. **Changsheng Wu**†, Peng Jiang†, Wei Li, Hengyu Guo, Jie Wang, Jie Chen, Mark R Prausnitz, Zhong Lin Wang*, "Self-powered iontophoretic transdermal drug delivery system driven and regulated by biomechanical motions." *Advanced Functional Materials* 30 (3), 1907378 (2020) [pdf]

7. **Changsheng Wu**†, Jisu Jiang†, Hengyu Guo†, Xianjie Pu, Lisha Liu, Wenbo Ding, Paul A Kohl, Zhong Lin Wang*, "Sunlight-triggerable transient energy harvester and sensors based on triboelectric nanogenerator using acid-sensitive poly(phthalaldehyde)." *Advanced Electronic Materials* 5 (12), 1900725 (2019) [pdf]
8. Yejing Dai†, **Changsheng Wu**†, Zhiyi Wu†, Zhihao Zhao, Li Li, Yang Lu, Zhong Lin Wang*, "Ferroelectricity-enhanced piezo-phototronic effect in 2D V-doped ZnO nanosheets." *Advanced Science* 6 (16), 1900314 (2019) [pdf]
9. **Changsheng Wu**†, Halil Tetik†, Jia Cheng†, Wenbo Ding, Hengyu Guo, Xingtian Tao, Nanjia Zhou, Yunlong Zi, Zhiyi Wu, Huixuan Wu, Dong Lin*, Zhong Lin Wang*, "Electrohydrodynamic jet printing driven by a triboelectric nanogenerator." *Advanced Functional Materials* 29 (22), 1901102 (2019) [pdf]
10. **Changsheng Wu**, Aurelia C Wang, Wenbo Ding, Hengyu Guo, Zhong Lin Wang*, "Triboelectric nanogenerator: a foundation of the energy for the new era." *Advanced Energy Materials* 9 (1), 1802906 (2019) [pdf]
11. Wenbo Ding†, **Changsheng Wu**†, Yunlong Zi†, Haiyang Zou, Jiyu Wang, Jia Cheng, Aurelia C Wang, Zhong Lin Wang*, "Self-powered wireless optical transmission of mechanical agitation signals." *Nano Energy* 47, 566-572 (2018) [pdf]
12. Yunlong Zi†, **Changsheng Wu**†, Wenbo Ding†, Xingfu Wang, Yejing Dai, Jia Cheng, Jiyu Wang, Zhengjun Wang, Zhong Lin Wang*, "Field Emission of electrons powered by a triboelectric nanogenerator." *Advanced Functional Materials* 28 (21), 1800610 (2018) [pdf]
13. **Changsheng Wu**†, Wenbo Ding†, Ruiyuan Liu†, Jiyu Wang, Aurelia C Wang, Jie Wang, Shengming Li, Yunlong Zi, Zhong Lin Wang*, "Keystroke dynamics enabled authentication and identification using triboelectric nanogenerator array." *Materials Today* 21 (3), 216-222 (2018) [pdf]
14. Qiu Jiang†, **Changsheng Wu**†, Zhengjun Wang, Aurelia Chi Wang, Jr-Hau He, Zhong Lin Wang*, Husam N Alshareef*, "MXene electrochemical microsupercapacitor integrated with triboelectric nanogenerator as a wearable self-charging power unit." *Nano Energy* 45, 266-272 (2018) [pdf]
15. Jie Wang†, **Changsheng Wu**†, Yejing Dai†, Zhihao Zhao, Aurelia Wang, Tiejun Zhang, Zhong Lin Wang*, "Achieving ultrahigh triboelectric charge density for efficient energy harvesting." *Nature Communications* 8, 88 (2017) [pdf]
16. Yunlong Zi†, **Changsheng Wu**†, Wenbo Ding, Zhong Lin Wang*, "Maximized effective energy output of contact-separation-triggered triboelectric nanogenerators as limited by air breakdown." *Advanced Functional Materials* 27 (24), 1700049 (2017) [pdf]
17. **Changsheng Wu**, Ben Wang, Chuck Zhang*, Richard A Wysk, Yi-Wen Chen, "Bioprinting: an assessment based on manufacturing readiness levels." *Critical Reviews in Biotechnology* 37 (3), 333-354 (2017) [pdf]
18. **Changsheng Wu**†, Ruiyuan Liu†, Jie Wang, Yunlong Zi, Long Lin, Zhong Lin Wang*, "A spring-based resonance coupling for hugely enhancing the performance of triboelectric nanogenerators for harvesting low-frequency vibration energy." *Nano Energy* 32, 287-293 (2017) [pdf]
19. Kan Wang†*, **Changsheng Wu**†, Zhen Qian, Chuck Zhang, Ben Wang, Mani A Vannan, "Dual-material 3D printed metamaterials with tunable mechanical properties for patient-specific tissue-mimicking phantoms." *Additive Manufacturing* 12, 31-37 (2016) [pdf]
20. **Changsheng Wu**†, Xin Wang†, Long Lin, Hengyu Guo, Zhong Lin Wang*, "Paper-based triboelectric nanogenerators made of stretchable interlocking kirigami patterns." *ACS Nano* 10 (4), 4652-4659 (2016) [pdf]

Co-Authorship

21. Di Lu, Shupeng Li, Quansan Yang, Hany M Arafa, Yameng Xu, Ying Yan, Diana Ostojich, Wubin Bai, Hexia Guo, **Changsheng Wu**, Shuo Li, Lauren Jacobson, Amanda M Westman, Matthew R MacEwan, Yonggang Huang, Mitchell Pet*, John A Rogers*, "Implantable, wireless, self-fixing thermal sensors for continuous measurements of microvascular blood flow in flaps and organ grafts." *Biosensors and Bioelectronics* 206, 114145 (2022) [pdf]

22. Xiaoyue Ni, Wei Ouyang, Hyoyoung Jeong, Jin-Tae Kim, Andreas Tzaveils, Ali Mirzazadeh, **Changsheng Wu**, Jong Yoon Lee, Matthew Keller, Chaithanya K Mummidisetty, Manish Patel, Nicholas Shawen, Joy Huang, Hope Chen, Sowmya Ravi, Jan-Kai Chang, KunHyuck Lee, Yixin Wu, Ferrona Lie, Youn J Kang, Jong Uk Kim, Leonardo P Chamorro, Anthony R Banks, Ankit Bharat, Arun Jayaraman, Shuai Xu*, John A Rogers*, "Automated, multiparametric monitoring of respiratory biomarkers and vital signs in clinical and home settings for COVID-19 patients." *Proceedings of the National Academy of Sciences* 118 (19), e2026610118 (2021) [pdf]
23. Haiwen Luan, Qihui Zhang, Tzu-Li Liu, Xueju Wang, Shiwei Zhao, Heling Wang, Shenglian Yao, Yeguang Xue, Jean Won Kwak, Wubin Bai, Yameng Xu, Mengdi Han, Kan Li, Zhengwei Li, Xinchen Ni, Jilong Ye, Dongwhi Choi, Quansan Yang, Jae-Hwan Kim, Shuo Li, Shulin Chen, **Changsheng Wu**, Di Lu, Jan-Kai Chang, Zhaoqian Xie, Yonggang Huang, John A Rogers*, "Complex 3D microfluidic architectures formed by mechanically guided compressive buckling." *Science Advances* 7 (43), eabj3686 (2021) [pdf]
24. Donghwi Cho, Rui Li, Hyoyoung Jeong, Shupeng Li, **Changsheng Wu**, Andreas Tzavelis, Seonggwang Yoo, Sung Soo Kwak, Yonggang Huang, John A Rogers*, "Bitter flavored, soft composites for wearables designed to reduce risks of choking in infants." *Advanced Materials* 33 (39), 2103857 (2021) [pdf]
25. Wubin Bai, Hexia Guo, Wei Ouyang, Yang Weng, **Changsheng Wu**, Yihan Liu, Hao Zang, Lauren Jacobson, Yameng Xu, Di Lu, Ziying Hu, Shuo Li, Hany M Arafa, Quansan Yang, Amanda M Westman, Matthew R MacEwan, John A Rogers, Mitchell A. Pet*, "A wireless near infrared spectroscopy device for flap monitoring: proof of concept in a porcine musculocutaneous flap model." *Journal of Reconstructive Microsurgery* (2021) [pdf].
26. Hyoyoung Jeong, Jong Yoon Lee, KunHyuck Lee, Youn J Kang, Jin-Tae Kim, Raudel Avila, Andreas Tzavelis, Joohee Kim, Hanjun Ryu, Sung Soo Kwak, Jong Uk Kim, Aaron Banks, Hokyung Jang, Jan-Kai Chang, Shupeng Li, Chaithanya K Mummidisetty, Yoonseok Park, Simone Nappi, Keum San Chun, Young Joong Lee, Kyeongha Kwon, Xiaoyue Ni, Ha Uk Chung, Haiwen Luan, Jae-Hwan Kim, **Changsheng Wu**, Shuai Xu, Anthony Banks, Arun Jayaraman, Yonggang Huang, John A Rogers*, "Differential cardiopulmonary monitoring system for artifact-canceled physiological tracking of athletes, workers, and COVID-19 patients." *Science Advances* 7 (20), eabg3092 (2021) [pdf]
27. Wubin Bai, Masahiro Irie, Zhonghe Liu, Haiwen Luan, Daniel Franklin, Khizar Nandoliya, Hexia Guo, Hao Zang, Yang Weng, Di Lu, Di Wu, Yixin Wu, Joseph Song, Mengdi Han, Enming Song, Yiyuan Yang, Xuexian Chen, Hangbo Zhao, Wei Lu, Giuditta Monti, Iwona Stepien, Irawati Kandela, Chad R Haney, **Changsheng Wu**, Sang Min Won, Hanjun Ryu, Alina Rwei, Haixu Shen, Jihye Kim, Hong-Joon Yoon, Wei Ouyang, Yihan Liu, Emily Suen, Huang-yu Chen, Jerry Okina, Jushen Liang, Yonggang Huang, Guillermo A Ameer, Weidong Zhou, John A Rogers*, "Bioresorbable multilayer photonic cavities as temporary implants for tether-free measurements of regional tissue temperatures." *BME Frontiers* 2021, 8653218 (2021) [pdf]
28. Jiarong Li, **Changsheng Wu**, Ishara Dharmasena, Xiaoyue Ni, Zihan Wang, Haixu Shen, Shao-Lun Huang, Wenbo Ding*, "Triboelectric nanogenerators enabled internet of things: a survey." *Intelligent and Converged Networks* 1 (2), 115-141 (2020) [pdf]
29. Yafeng Li, Marcos Bouza, **Changsheng Wu**, Hengyu Guo, Danning Huang, Gilad Doron, Johnna S Temenoff, Arlene A Stecenko, Zhong Lin Wang, Facundo M Fernández*, "Sub-nanoliter metabolomics via mass spectrometry to characterize volume-limited samples." *Nature Communications* 11, 5625 (2020) [pdf]
30. Jianguo Sun, Hengyu Guo, Javier Ribera, **Changsheng Wu**, Kunkun Tu, Marco Binelli, Guido Panzarasa, Francis WMR Schwarze, Zhong Lin Wang*, Ingo Burgert*, "Sustainable and biodegradable wood sponge piezoelectric nanogenerator for sensing and energy harvesting applications." *ACS Nano* 14 (11), 14665-14674 (2020) [pdf]
31. Marcos Bouza, Yafeng Li, **Changsheng Wu**, Hengyu Guo, Zhong L Wang, Facundo M Fernández*, "Large-area triboelectric nanogenerator mass spectrometry: expanded coverage, double-bond pinpointing, and supercharging." *Journal of the American Society for Mass Spectrometry* 31 (3), 727-734 (2020) [pdf]
32. Peng Jiang, Lei Zhang, Hengyu Guo, Chaoyu Chen, **Changsheng Wu**, Steven Zhang, Zhong Lin Wang*, "Signal output of triboelectric nanogenerator at oil–water–solid multiphase interfaces and its application for dual-signal chemical sensing." *Advanced Materials* 31 (39), 1902793 (2019) [pdf]

33. Wenbo Ding, Jianfeng Zhou, Jia Cheng, Zhaozheng Wang, Hengyu Guo, **Changsheng Wu**, Sixing Xu, Zhiyi Wu, Xing Xie*, Zhong Lin Wang*, "TriboPump: a low-cost, hand-powered water disinfection system." *Advanced Energy Materials* 9 (27), 1901320 (2019) [pdf]
34. Cheng Xu, Binbin Zhang, Aurelia Chi Wang, Haiyang Zou, Guanlin Liu, Wenbo Ding, **Changsheng Wu**, Ming Ma, Peizhong Feng, Zhiqun Lin, Zhong Lin Wang*, "Contact-electrification between two identical materials: curvature effect." *ACS Nano* 13 (2), 2034-2041 (2019) [pdf]
35. Jiyu Wang, Lun Pan, Hengyu Guo, Binbin Zhang, Rongrong Zhang, Zhiyi Wu, **Changsheng Wu**, Lijun Yang, Ruijin Liao, Zhong Lin Wang*, "Rational structure optimized hybrid nanogenerator for highly efficient water wave energy harvesting." *Advanced Energy Materials* 9 (8), 1802892 (2019) [pdf]
36. Wenbo Ding, Aurelia C Wang, **Changsheng Wu**, Hengyu Guo, Zhong Lin Wang*, "Human–machine interfacing enabled by triboelectric nanogenerators and tribotronics." *Advanced Materials Technologies* 4 (1), 1800487 (2019) [pdf]
37. Jia Cheng, Wenbo Ding, Yunlong Zi, Yijia Lu, Linhong Ji, Fan Liu, **Changsheng Wu**, Zhong Lin Wang*, "Triboelectric microplasma powered by mechanical stimuli." *Nature Communications* 9, 3733 (2018) [pdf]
38. Ruilong Ma, **Changsheng Wu**, Zhong Lin Wang, Vladimir V Tsukruk*, "Pop-up conducting large-area biographene kirigami." *ACS Nano* 12 (10), 9714-9720 (2018) [pdf]
39. Hengyu Guo, Xianjie Pu, Jie Chen, Yan Meng, Min-Hsin Yeh, Guanlin Liu, Qian Tang, Baodong Chen, Di Liu, Song Qi, **Changsheng Wu**, Chenguo Hu*, Jie Wang*, Zhong Lin Wang*, "A highly sensitive, self-powered triboelectric auditory sensor for social robotics and hearing aids." *Science Robotics* 3 (20), eaat2516 (2018) [pdf]
40. Aurelia Chi Wang, **Changsheng Wu**, Dario Pisignano, Zhong Lin Wang, Luana Persano*, "Polymer nanogenerators: opportunities and challenges for large-scale applications." *Journal of Applied Polymer Science* 135 (24), 45674 (2018) [pdf]
41. Zhiyi Wu, Wenbo Ding, Yejing Dai, Kai Dong, **Changsheng Wu**, Lei Zhang, Zhiming Lin, Jia Cheng, Zhong Lin Wang*, "Self-powered multifunctional motion sensor enabled by magnetic-regulated triboelectric nanogenerator." *ACS Nano* 12 (6), 5726-5733 (2018) [pdf]
42. Haiwu Zheng, Yunlong Zi, Xu He, Hengyu Guo, Ying-Chih Lai, Jie Wang, Steven L Zhang, **Changsheng Wu**, Gang Cheng, Zhong Lin Wang*, "Concurrent harvesting of ambient energy by hybrid nanogenerators for wearable self-powered systems and active remote sensing." *ACS Applied Materials & Interfaces* 10 (17), 14708-14715 (2018) [pdf]
43. Jiyu Wang, Wenbo Ding, Lun Pan, **Changsheng Wu**, Hua Yu, Lijun Yang, Ruijin Liao, Zhong Lin Wang*, "Self-powered wind sensor system for detecting wind speed and direction based on a triboelectric nanogenerator." *ACS Nano* 12 (4), 3954-3963 (2018) [pdf]
44. Yejing Dai, Xingfu Wang, Wenbo Peng, Cheng Xu, **Changsheng Wu**, Kai Dong, Ruiyuan Liu, Zhong Lin Wang*, "Self-powered Si/CdS flexible photodetector with broadband response from 325 to 1550 nm based on pyro-phototronic effect: an approach for photosensing below bandgap energy." *Advanced Materials* 30 (9), 1705893 (2018) [pdf]
45. Yejing Dai, Xingfu Wang, Wenbo Peng, **Changsheng Wu**, Yong Ding, Kai Dong, Zhong Lin Wang*, "Enhanced performances of Si/CdS heterojunction near-infrared photodetector by the piezo-phototronic effect." *Nano Energy* 44, 311-318 (2018) [pdf]
46. Hua Yu, Xu He, Wenbo Ding, Yongshan Hu, Dongchen Yang, Shan Lu, **Changsheng Wu**, Haiyang Zou, Ruiyuan Liu, Canhui Lu, Zhong Lin Wang*, "A self-powered dynamic displacement monitoring system based on triboelectric accelerometer." *Advanced Energy Materials* 7 (19), 1700565 (2017) [pdf]
47. Haiyang Zou, Xiaogan Li, Wenbo Peng, Wenzhuo Wu, Ruomeng Yu, **Changsheng Wu**, Wenbo Ding, Fei Hu, Ruiyuan Liu, Yunlong Zi, Zhong Lin Wang*, "Piezo-phototronic effect on selective electron or hole transport through depletion region of Vis–NIR broadband photodiode." *Advanced Materials* 29 (29), 1701412 (2017) [pdf]

48. Yejing Dai, Xingfu Wang, Wenbo Peng, Haiyang Zou, Ruomeng Yu, Yong Ding, **Changsheng Wu**, Zhong Lin Wang*, "Largely improved near-infrared silicon-photosensing by the piezo-phototronic effect." *ACS Nano* 11 (7), 7118-7125 (2017) [pdf]
49. Ruiyuan Liu, Jie Wang, Teng Sun, Mingjun Wang, **Changsheng Wu**, Haiyang Zou, Tao Song, Xiaohong Zhang, Shuit-Tong Lee, Zhong Lin Wang*, Baoquan Sun*, "Largely improved near-infrared silicon-photosensing by the piezo-phototronic effect." *Nano Letters* 17 (7), 4240-4247 (2017) [pdf]
50. Zhen Qian*, Kan Wang, Shizhen Liu, Xiao Zhou, Vivek Rajagopal, Christopher Meduri, James R Kauten, Yung-Hang Chang, **Changsheng Wu**, Chuck Zhang, Ben Wang, Mani A Vannan, "Quantitative prediction of paravalvular leak in transcatheter aortic valve replacement based on tissue-mimicking 3D printing." *JACC: Cardiovascular Imaging* 10 (7), 719-731 (2017) [pdf]
51. Xingfu Wang, Wenbo Peng, Ruomeng Yu, Haiyang Zou, Yejing Dai, Yunlong Zi, **Changsheng Wu**, Shuti Li, Zhong Lin Wang*, "Simultaneously enhancing light emission and suppressing efficiency droop in GaN microwire-based ultraviolet light-emitting diode by the piezo-phototronic effect." *Nano Letters* 17 (6), 3718-3724 (2017) [pdf]
52. Wei Li, David Torres, Ramón Díaz, Zhengjun Wang, **Changsheng Wu**, Chuan Wang, Zhong Lin Wang, Nelson Sepúlveda*, "Nanogenerator-based dual-functional and self-powered thin patch loudspeaker or microphone for flexible electronics." *Nature Communications* 8, 15310 (2017) [pdf]
53. Xu He, Yunlong Zi, Hengyu Guo, Haiwu Zheng, Yi Xi, **Changsheng Wu**, Jie Wang, Wei Zhang, Canhui Lu, Zhong Lin Wang*, "A highly stretchable fiber-based triboelectric nanogenerator for self-powered wearable electronics." *Advanced Functional Materials* 27 (4), 1604378 (2017) [pdf]
54. Xin Wang, Zhen Wen, Hengyu Guo, **Changsheng Wu**, Xu He, Long Lin, Xia Cao, Zhong Lin Wang*, "Fully packaged blue energy harvester by hybridizing a rolling triboelectric nanogenerator and an electromagnetic generator." *ACS Nano* 10 (12), 11369-11376 (2016) [pdf]
55. Ying-Chih Lai, Jianan Deng, Simiao Niu, Wenbo Peng, **Changsheng Wu**, Ruiyuan Liu, Zhen Wen, Zhong Lin Wang*, "Electric eel-skin-inspired mechanically durable and super-stretchable nanogenerator for deformable power source and fully autonomous conformable electronic-skin applications." *Advanced Materials* 28 (45), 10024-10032 (2016) [pdf]
56. Hengyu Guo, Min-Hsin Yeh, Ying-Chih Lai, Yunlong Zi, **Changsheng Wu**, Zhen Wen, Chenguo Hu, Zhong Lin Wang*, "All-in-one shape-adaptive self-charging power package for wearable electronics." *ACS Nano* 10 (11), 10580-10588 (2016) [pdf]
57. Jie Wang, Zhen Wen, Yunlong Zi, Long Lin, **Changsheng Wu**, Hengyu Guo, Yi Xi, Youlong Xu, Zhong Lin Wang*, "Self-powered electrochemical synthesis of polypyrrole from the pulsed output of a triboelectric nanogenerator as a sustainable energy system." *Advanced Functional Materials* 26 (20), 3542-3548 (2016) [pdf]
58. Yung-Hang Chang, Kan Wang*, **Changsheng Wu**, Yiwen Chen, Chuck Zhang, Ben Wang, "A facile method for integrating direct-write devices into three-dimensional printed parts." *Smart Materials and Structures* 24 (6), 065008 (2015) [pdf]

Patents

1. US Patent 11025176B2, "Self-powered wireless optical communication systems and methods", Jun 1, 2021
2. CN Patent 109815655A, "An identification and authentication system based on triboelectric keyboard", Apr 02, 2021 (WO Patent 2019101016A1 filed on Nov 16, 2018)
3. US Patent 10726742B2, "3D printed metamaterial tissue-mimicking phantoms", Jul 28, 2020
4. CN Patent 109149992B, "A Triboelectric nanogenerator enhanced by polarization coupling", Mar 10, 2020
5. CN Patent 106655878B, "A spring-assisted triboelectric nanogenerator", Sep 28, 2018

Teaching and Mentoring Experience

Northwestern University, Evanston, IL
Research mentor
Supervised three master's students
– Wenyuan Yan, Materials Science and Engineering, Northwestern University, Sep 2021 – Present
– Chenhang Li, Civil Engineering, Northwestern & Duke University, Oct 2020 – Present
– Maria Ali, Electrical Engineering, Northwestern University, Sep 2020 – Jun 2021
– Haixu Shen, Materials Science and Engineering, Northwestern University, Jan 2020 – Aug 2020
Supervised 4 undergraduate research assistants
– Katelynn Nguyen, Biomedical Engineering, Northwestern University, Jul 2021 – Present
– Alanna Liu, Biomedical Engineering, Northwestern University, Jul 2021 – Present
– Peter Podobinski, Biomedical Engineering, Northwestern University, Jul 2021 – Aug 2021
– Louie Shapiro, Mechanical Engineering, Northwestern University, Apr 2021 – Jun 2021

Georgia Institute of Technology, Atlanta, GA
Guest Lecturer
Delivered a guest lecture on triboelectric nanogenerator to 30 undergraduates.
– *Statics*, Aug 2018 – Dec 2018. Instructor: Prof. Hailong Chen

Teaching assistant
Responsibilities included holding office hours, assisting lecturers, and grading homework and exams.
– *Principles and Applications of Engineering Materials*, Aug 2015 – Dec 2015. Instructor: Prof. Dong Qin
– *Statistics and Numerical Methods*, Jan 2014 – Apr 2014. Instructor: Prof. Seung Soon Jang

National University of Singapore, Singapore
Teaching assistant
Responsibilities included holding office hours and giving tutorials.
– *Thermodynamics and Statistical Mechanics*, Aug 2012 - Dec 2012. Instructor: Prof. Lim Hock Siah

Invited Talks

1. "Smart materials for wearable Biosensors and biomechanical energy towards digital health," ARTIC Monthly Seminar, National University of Singapore, Singapore, Nov 2021
2. "Smart materials for flexible electronics and biomechanical energy harvesting towards digital health," Special Research Seminar, Materials Science and Engineering, National University of Singapore, Singapore, Jul 2021
3. "High performance triboelectric nanogenerator and its applications," Graduate Seminar, Industrial and Manufacturing Systems Engineering, Kansas State University, Manhattan, KS, Feb 2018
4. "Towards high performance triboelectric nanogenerators," Graduate Seminar, Beijing Institute of Nanoenergy and Nanosystems, CAS, Beijing, Mar 2017

Conference Presentations

1. "Achieving ultrahigh triboelectric charge density for efficient mechanical energy harvesting" MRS Spring Meeting, Phoenix, AZ, 2018
2. "Keystroke dynamics enabled authentication and identification using triboelectric nanogenerator array" MRS Spring Meeting, Phoenix, AZ, 2018
3. "Patient-specific 3D printed tissue-mimicking phantoms for transcatheter aortic valve replacement planning" MRS Spring Meeting, Phoenix, AZ, 2018

4. "Thin-film-based triboelectric nanogenerators made of stretchable interlocking kirigami patterns" MRS Spring Meeting, Boston, MA, 2016

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