

## Bocong Zheng

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### RESEARCH INTERESTS

- **Plasma simulation:** develop plasma simulation software; particle-in-cell/Monte Carlo collision; plasma fluid model; plasma global model.
- **Gas discharge physics:** electron kinetics; electron energization; moment analysis of Boltzmann equation;  $E \times B$  plasmas; plasma instability; gas discharge similarity laws.
- **Plasma engineering and applications:** radio frequency discharges (e.g., capacitively coupled plasmas, inductively coupled plasmas); physical vapor deposition (e.g., magnetron sputtering, ion sources, ion implantation); hollow cathode discharges; atmospheric pressure plasmas (e.g., microdischarges); plasma-liquid interaction (e.g., plasma electrolysis).

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### APPOINTMENT

Jan. 2018-Present	<b>Fraunhofer USA Center Midwest</b>	<b>Scientist</b>
Jan. 2017-Dec. 2017	<b>Michigan State University</b>	<b>Postdoctoral Fellow</b>
	Department of Electrical and Computer Engineering	

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### EDUCATION

Sep. 2009-May 2016	<b>Dalian University of Technology</b>	<b>Surface Engineering</b>	<b>Ph.D.</b>
	Dissertation: "Numerical study on the plasma-surface interaction in pulsed plasma processings"		
Sep. 2005-Jul. 2009	<b>Dalian Maritime University</b>	<b>Material Sci. &amp; Eng.</b>	<b>B.Eng.</b>
	(Rank: 2 <sup>nd</sup> /56)		

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### CURRENT RESEARCH

2019-2021	Research Project: <b>Developing an Efficient Computation Scheme for Modeling Low-Pressure Plasmas.</b>
	Funded by National Science Foundation (NSF), \$250,000, in collaboration with MSU.
2019-2020	Research Project: <b>Single Beam Ion Sources for Advanced Materials Processing.</b>
	Funded by National Science Foundation (NSF) Small Business Innovation Research (SBIR) Program, \$225,000, with Fraunhofer subawards from MSU.

- 2019-2020      Research Project: **Plasma Sources with Broad Range of Ion Energies for Thin Film Processing.**  
Funded by Michigan Translational Research and Commercialization (MTRAC), \$100,000, with Fraunhofer subawards from MSU.
- 2017-2020      Research Project: **Resolving Abnormal Target Erosion in High Frequency Magnetron Discharge.**  
Funded by National Science Foundation (NSF), \$300,000, in collaboration with MSU.

## RESEARCH EXPERIENCE

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- 2018-2019      Research Project: **Development of Scalable Linear Ion Sources for Thin Film Processing.**  
Funded by Michigan Economic Development Corporation (MEDC) / Michigan State University (MSU) Advanced Grant, \$80,000, with Fraunhofer subawards from MSU.
- 2018-2019      Research Project: **High-Density Plasma Technologies for Efficient Manufacturing of Activated Carbon.**  
Funded by Michigan Translational Research and Commercialization (MTRAC), \$100,000, with Fraunhofer subawards from MSU.
- 2016-2019      Research Project: **Using Plasma Electrolysis for Efficient Manufacturing of Nanoparticles.**  
Funded by National Science Foundation (NSF), \$315,597, in collaboration with MSU.
- 2016-2019      Research Project: **High-density Plasma for Efficient Manufacturing of Electronic Devices.**  
Funded by National Science Foundation (NSF), \$243,726, in collaboration with MSU.
- 2009-2016      Doctoral Thesis: **Numerical study on the plasma-surface interaction in pulsed plasma processings**
- Develop fluid and global models for pulsed plasma processings.
  - Investigate the discharge characteristics of high-power impulse magnetron sputtering (HiPIMS) and plasma-based ion implantation (PBII) processings.

## REFeree SERVICE

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Journal of Applied Physics	International Journal of Molecular Sciences
Journal of Physics D	Crystal Growth & Design
Physics of Plasmas	Plasma
Review of Scientific Instruments	Applied Sciences
Vacuum	Crystals

Coatings

Materials

Polymers

Energies

Electronics

Micromachines

Symmetry

## PUBLICATIONS

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### A. PATENT:

- [1] Qi Hua Fan, Thomas Schuelke, Michael Becker, and **Bocong Zheng**, “Magnetically enhanced and symmetrical radio frequency discharge apparatus for material processing”. (US Patent application number: 16/520,464).

### B. JOURNAL ARTICLES

† as corresponding author

- [1] **Bocong Zheng**, Yangyang Fu, Keliang Wang, Thomas Schuelke, Qi Hua Fan†, Kinetic investigation of HiPIMS: Discharge runaway, electron energization, and sputtering wind, *Plasma Sources Science and Technology* (2021). [In preparation]
- [2] **Bocong Zheng**, Yangyang Fu, Keliang Wang, Thomas Schuelke, Qi Hua Fan†, Breathing oscillation and electron energization in magnetron discharges, *Plasma Sources Science and Technology* (2021). [In preparation]
- [3] Yangyang Fu†, Huihui Wang, **Bocong Zheng**†, Peng Zhang, Qi Hua Fan, Xinxin Wang, John P Verboncoeur, Direct current microplasma formation around microstructure arrays, *Applied Physics Letters* (2021). [Under review]
- [4] Keliang Wang†, **Bocong Zheng**, Junwoo Lee, Madeline Mackinder, Hong Jin†, Thomas Schuelke, Qi Hua Fan†, Enhanced capacitance and desalination performance with plasma activated biochar electrodes, *Journal of Environmental Chemical Engineering* (2021). [Under review]
- [5] **Bocong Zheng**, Yangyang Fu, Keliang Wang, Thomas Schuelke, Qi Hua Fan†, Electron dynamics in radio frequency magnetron sputtering argon discharges with a dielectric target, *Plasma Sources Science and Technology* 30, 035019 (2021).
- [6] Jiawei Li, Zhao Kong, Xiaoxi Liu, **Bocong Zheng**, Elias Garratt, Qi Hua Fan, Thomas Schuelke, Keliang Wang, Hui Xu, Hong Jin, Strategies to anode protection in Lithium metal battery - A review, *InfoMat* (2021). [Accepted, in press]
- [7] **Bocong Zheng**, Yangyang Fu, Keliang Wang, Thanh Phuc Tran, Thomas Schuelke, Qi Hua Fan†, Comparison of 1D and 2D particle-in-cell simulations for DC magnetron sputtering discharges, *Physics of Plasmas* 28, 014504 (2021).
- [8] Yangyang Fu†, **Bocong Zheng**†, Peng Zhang, Qi Hua Fan, John P Verboncoeur, Transition characteristics and electron kinetics in microhollow cathode discharges, *Journal of Applied Physics* 129(2), 023302 (2021).

- [9] Keliang Wang†, **Bocong Zheng**, Madeline Mackinder, Nina Baule, Elias Garratt, Hong Jin†, Thomas Schuelke, Qi Hua Fan†, Efficient electrophoretic deposition of MXene/reduced graphene oxide flexible electrodes for all-solid-state supercapacitors, *Journal of Energy Storage* 33, 102070 (2021).
- [10] Yangyang Fu†, **Bocong Zheng**†, De-Qi Wen, Peng Zhang, Qi Hua Fan, John P Verboncoeur, Similarity law and frequency scaling in low-pressure capacitive radio frequency plasmas, *Applied Physics Letters* 117, 204101 (2020).
- [11] Yangyang Fu†, **Bocong Zheng**, Peng Zhang, Qi Hua Fan, John P Verboncoeur, Xinxin Wang, Similarity of capacitive radio-frequency discharges in nonlocal regimes, *Physics of Plasmas* 27, 113501 (2020).
- [12] Yangyang Fu†, **Bocong Zheng**, De-Qi Wen, Peng Zhang, Qi Hua Fan, John P Verboncoeur, High-energy ballistic electrons in low-pressure radio-frequency plasmas, *Plasma Sources Science and Technology* 29, 09LT01 (2020).
- [13] **Bocong Zheng**, Yangyang Fu, De-Qi Wen, Keliang Wang, Thomas Schuelke, Qi Hua Fan†, Influence of metastable atoms in low pressure magnetized radio-frequency argon discharges, *Journal of Physics D: Applied Physics* 53, 435201 (2020).
- [14] Suihan Cui, Zhongzhen Wu†, Shu Xiao, **Bocong Zheng**, Lei Chen, Tijun Li, Ricky K. Y. Fu, Paul K. Chu, Xiubo Tian, Wenchang Tan, Daining Fang, Feng Pan†, Nano-second temporal particle behavior in high-power impulse magnetron sputtering discharge in a cylindrical cathode, *Journal of Applied Physics* 127, 023301 (2020).
- [15] Hui Chen, **Bocong Zheng**, Yixiang Ou, Mingkai Lei†, Microstructure and thermal conductivity of Ti-Al-Si-N nanocomposite coatings deposited by modulated pulsed power magnetron sputtering, *Thin Solid Films*, 693, 137680 (2019).
- [16] Madeline A. Mackinder, Keliang Wang, **Bocong Zheng**, Maheshwar Shrestha, Qi Hua Fan†, Magnetic field enhanced cold plasma sterilization, *Clinical Plasma Medicine*, 17-18, 100092 (2019).
- [17] **Bocong Zheng**, Maheshwar Shrestha, Keliang Wang, Thomas Schuelke, Evgeny Shun'ko, Veniamin Belkin, Qi Hua Fan†, Reduction of capacitive coupling in inductively coupled plasmas by solenoid coils on dielectric window, *Journal of Applied Physics* 126, 123302 (2019).
- [18] **Bocong Zheng**, Keliang Wang, Timothy Grotjohn, Thomas Schuelke, Qi Hua Fan†, Enhancement of Ohmic heating by Hall current in magnetized capacitively coupled discharges, *Plasma Sources Science and Technology* 28, 09LT03 (2019).
- [19] **Bocong Zheng**, Keliang Wang, Maheshwar Shrestha, Thomas Schuelke, Qi Hua Fan†, Understanding the chemical reactions in cathodic plasma electrolysis, *Plasma Sources Science and Technology* 28, 085016 (2019).
- [20] Keliang Wang†, **Bocong Zheng**, Madeline A. Mackinder, Nina Baule, Hui Qiao, Hong Jin, Thomas Schuelke, Qi Hua Fan†, Graphene wrapped MXene via plasma exfoliation for all-solid-state flexible supercapacitors, *Energy Storage Materials* 20, 299-306 (2019).
- [21] Suihan Cui, Zhongzhen Wu†, Hai Lin, Shu Xiao, **Bocong Zheng**, Liangliang Liu, Xiaokai An, Ricky K. Y. Fu, Xiubo Tian, Wenchang Tan, Paul K. Chu, Hollow cathode effect modified time-

- dependent global model and high-power impulse magnetron sputtering discharge and transport in cylindrical cathode, *Journal of Applied Physics* 125, 063302 (2019).
- [22] Hui Chen, **Bocong Zheng**, Yuge Li, Zhili Wu Mingkai Lei†, Flexible hard Ti-Al-Si-N nanocomposite coatings deposited by modulated pulsed power magnetron sputtering with controllable peak power, *Thin Solid Films* 669, 377-386 (2019).
- [23] **Bocong Zheng**, Zhili Wu†, Suihan Cui, Shu Xiao, Liangliang Liu, Hai Lin, Ricky K. Y. Fu, Xiubo Tian, Feng Pan†, P. K. Chu, Discharge and deposition characteristics of high-power impulse magnetron sputtering using various target materials, *IEEE Transactions on Plasma Science* 47, 193-198 (2019).
- [24] Keliang Wang†, **Bocong Zheng**, Maheshwar Shrestha, Thomas Schuelke, Qi Hua Fan†, Magnetically enhanced plasma exfoliation of polyaniline-modified graphene for flexible solid-state supercapacitors, *Energy Storage Materials* 14, 230-237 (2018).
- [25] **Bocong Zheng**, Thomas Schuelke, Qi Hua Fan†, Acoustic standing wave modulation of capacitively coupled plasmas, *Journal of Physics D: Applied Physics* 51, 285201 (2018).
- [26] Maheshwar Shrestha, Keliang Wang, **Bocong Zheng**, Laura Mokrzycki, Qi Hua Fan†, Comparative study of furnace and flash lamp annealed silicon thin films grown by plasma enhanced chemical vapor deposition, *Coatings* 8, 97 (2018).
- [27] Maheshwar Shrestha, Ishop Amatya, Keliang Wang, **Bocong Zheng**, Zhengrong Gu, Qi Hua Fan†, Electrophoretic deposition of activated carbon YP-50 with ethyl cellulose binders for supercapacitor electrodes, *Journal of Energy Storage* 13, 206-210 (2017).
- [28] Nezam Uddin, Maheshwar Shrestha, **Bocong Zheng**, Hyeun-Joong Yoon, Xiuqing Wang, Qi Hua Fan†, Liquid sensors based on enhanced Fabry-Perot etalons, *IEEE Sensors Journal* 17, 22 (2017).
- [29] **Bocong Zheng**, Zhili Wu, Bi Wu, Yuge Li, Mingkai Lei†, A global plasma model for reactive deposition of compound films by modulated pulsed power magnetron sputtering discharges, *Journal of Applied Physics* 121, 171901 (2017).
- [30] Suihan Cui, Zhongzhen Wu†, Shu Xiao, Liangliang Liu, **Bocong Zheng**, Hai Lin, Ricky K. Y. Fu, Xiubo Tian, Paul K. Chu, Wenchang Tan, Feng Pan†, Electromagnetic control and optimization of high-power impulse magnetron sputtering discharges in cylindrical source, *Acta Physica Sinica* 66, 95203 (2017).
- [31] Shu Xiao, Zhongzhen Wu†, Suihan Cui, Liangliang Liu, **Bocong Zheng**, Hai Lin, Ricky K. Y. Fu, Xiubo Tian, Feng Pan†, Paul K. Chu, Cylindric high power impulse magnetron sputtering source and its discharge characteristics, *Acta Physica Sinica* 65, 185202 (2016).
- [32] **Bocong Zheng**, Di Meng, Honglong Che, Mingkai Lei†, On the pressure effect in energetic deposition of Cu thin films by modulated pulsed power magnetron sputtering: A global plasma model and experiments, *Journal of Applied Physics* 117, 203302 (2015).

- [33] **Bocong Zheng**, Kesheng Wang, Zhipeng Zhang, Honglong Che, Mingkai Lei†, Nitrogen mass transfer models for plasma-based low-energy ion implantation, *Journal of Vacuum Science & Technology A: Vacuum, Surfaces, and Films* 33, 021311 (2015).
- [34] **Bocong Zheng**, Mingkai Lei†, Nonuniform plasma diffusion and multi-pulse effect in plasma-based ion implantation, *Nuclear Instruments and Methods in Physics Research Section B: Beam Interactions with Materials and Atoms* 343, 83-88 (2015).
- [35] **Bocong Zheng**, Kesheng Wang, Mingkai Lei†, Modeling of inner surface modification of a cylindrical tube by plasma-based low-energy ion implantation, *Plasma Science and Technology* 17, 309-316 (2015).
- [36] Yi Li, **Bocong Zheng**, Mingkai Lei†, Plasma low-pressure nonsteady diffusion fluid model for pulsed plasma recovery, *IEEE Transactions on Plasma Science* 41, 43-48 (2013).
- [37] Yi Li, **Bocong Zheng**, Mingkai Lei†, Engineering the tube size for an inner surface modification by plasma-based ion implantation, *Vacuum* 86, 1278-1283 (2012).

### C. CONFERENCE AND SYMPOSIUM PROCEEDINGS

† as presenter or speaker

- [1] **Bocong Zheng**†, Yangyang Fu, Keliang Wang, Thomas Schuelke, Qi Hua Fan, One-dimensional PIC/MCC simulation of HiPIMS discharges, 64th Annual SVC Technical Conference (SVC, Online Virtual), 2021. (Oral)
- [2] **Bocong Zheng**†, Yangyang Fu, Keliang Wang, Thomas Schuelke, Qi Hua Fan, Kinetic investigation of electron energization in magnetron discharges RFMS, DCMS, and HiPIMS, Plasma Processing and Technology International Conference (Plasma Tech 2021, Online Virtual), April 7-9, 2021. (Oral)
- [3] **Bocong Zheng**†, Yangyang Fu, Keliang Wang, Thomas Schuelke, Qi Hua Fan, Electron dynamics in magnetron sputtering discharges, The 8<sup>th</sup> International Conference on Microelectronics and Plasma Technology (ICMAP, Online Virtual), January 17-20, 2021. (Oral)
- [4] Yangyang Fu†, **Bocong Zheng**, Peng Zhang, Qi Hua Fan, and John P. Verboncoeur, Similarity Laws for Low-Temperature Plasmas from Continuum to Kinetic Regimes, The 8<sup>th</sup> International Conference on Microelectronics and Plasma Technology (ICMAP, Online Virtual), January 17-20, 2021. (Oral)
- [5] Yangyang Fu†, **Bocong Zheng**, De-Qi Wen, Peng Zhang, Qi Hua Fan, John P Verboncoeur, High-energy ballistic electrons in low-pressure radio-frequency plasmas, The 73<sup>rd</sup> Annual Gaseous Electronics Conference (GEC, Online Virtual), San Diego, California, USA, October 5-9, 2020. (Oral)



- [6] Yangyang Fu†, **Bocong Zheng**, Peng Zhang, Qi Hua Fan, John P Verboncoeur, Xinxin Wang, Similarity of radio-frequency discharges in nonlocal regimes, The 73<sup>rd</sup> Annual Gaseous Electronics Conference (GEC, Online Virtual), San Diego, California, USA, October 5-9, 2020. (Poster)
- [7] Yangyang Fu†, **Bocong Zheng**, Peng Zhang, John P Verboncoeur, Similarity of low-pressure radiofrequency discharges, The 47<sup>th</sup> IEEE International Conference on Plasma Science (ICOPS, Online Virtual), Singapore, May 24-28, 2020. (Oral)
- [8] **Bocong Zheng**†, Thomas Schuelke, Qi Hua Fan, Electron heating in magnetized capacitively coupled discharges, The 72<sup>nd</sup> Annual Gaseous Electronics Conference (GEC), College Station, Texas, October 28-November 1, 2019. (Oral)
- [9] Yangyang Fu, **Bocong Zheng**†, Janez Krek, Deqi Wen, Peng Zhang, John P Verboncoeur, On the similarities of high pressure microdischarges, 72<sup>nd</sup> Annual Gaseous Electronics Conference (GEC), College Station, Texas, October 28-November 1, 2019. (Poster)
- [10] **Bocong Zheng**†, Kelian Wang, Thomas Schuelke, Qi Hua Fan, Effect of surface charge accumulation on ion current distribution in radio-frequency magnetron discharges, AVS 66<sup>th</sup> International Symposium & Exhibition, Columbus (AVS), Ohio, US, October 21-25, 2019. (Poster)
- [11] **Bocong Zheng**†, Thomas Schuelke, Qi Hua Fan, Plasma modulation in a high-intensity acoustic standing wave field, The 71<sup>st</sup> Annual Gaseous Electronics Conference (GEC), Portland, Oregon, November 5-9, 2018. (Oral)
- [12] **Bocong Zheng**†, Maheshwar Shrestha, Kelian Wang, Thomas Schuelke, Qi Hua Fan, Modeling chemical reactions in contact glow discharge electrolysis, AVS 65<sup>th</sup> International Symposium & Exhibition (AVS), Long Beach, California, US, October 21-26, 2018. (Oral)
- [13] **Bocong Zheng**†, Maheshwar Shrestha, Qi Hua Fan, Magnetically enhanced inductive plasmas generated by symmetrical solenoid coils, AVS 64<sup>th</sup> International Symposium & Exhibition (AVS), Tampa, Florida, US, October 29-November 3, 2017. (Poster)
- [14] Honglong Che†, **Bocong Zheng**, Di Meng, Mingkai Lei, On the microstructure evolution of deposited Cu thin films by modulated pulsed power magnetron sputtering, The tenth session of the national assembly of surface engineering, Wuhan, China, October 28-31, 2014. (Oral)
- [15] **Bocong Zheng**†, Lei M K, Influence of plasma nonuniformity and recovery in plasma-based ion implantation, The 6<sup>th</sup> Joint Workshop between the School of Materials Science and Engineering of Dalian University of Technology and Department of Metallurgy of Tokyo Institute of Technology, Dalian, China, October 25, 2014. (Oral)
- [16] Honglong Che†, Di Meng, **Bocong Zheng**, Fei Ye, Hui Chen, Mingkai Lei, The effect of plasma state on microstructure of Cu films deposited by MPPMS, 2014 Sino-Russian Symposium on Advanced Materials and Processing Technology, Qingdao, China, June 3-5, 2014. (Oral)
- [17] **Bocong Zheng**†, Di Meng, Honglong Che, Mingkai Lei, A time-dependent global model for modulated pulsed power magnetron sputtering discharges, 2014 Sino-Russian Symposium on Advanced Materials and Processing Technology, Qingdao, China, June 3-5, 2014. (Oral)

- [18] **Bocong Zheng**<sup>†</sup>, Yi Li, Mingkai Lei, Effect of processing parameters on pulsed plasma recovery during magnetic field enhanced plasma immersion ion implantation, The 9<sup>th</sup> Asian-European International Conference on Plasma Surface Engineering, Jeju Island, Korea, August 25-30, 2013. (Oral)
- [19] **Bocong Zheng**<sup>†</sup>, Yi Li, Mingkai Lei, Numerical investigation for inner surface modification of a tube by plasma-based ion implantation, 13<sup>th</sup> Joint China-Russia Symposium on Advanced Materials and Processing Technology, Harbin, China, June 5-7, 2012. (Oral)
- [20] Yi Li, **Bocong Zheng**<sup>†</sup>, Mingkai Lei, Plasma recovery in plasma immersion ion implantation for a planar target modification by a fluid diffusion model, The 8<sup>th</sup> Asian-European International Conference on Plasma Surface Engineering, Dalian, China, September 19-22, 2011. (Poster)
- [21] Yi Li, **Bocong Zheng**<sup>†</sup>, Mingkai Lei, The tube critical radius for an inner surface modification by plasma-based ion implantation, The 15<sup>th</sup> National Conference on Plasma Science and Technology, Huangshan, China, August 8-10, 2011. (Oral)

## SOFTWARE DEVELOPED

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### ASTRA: Efficient Plasma Simulation Software

ASTRA combines multiple efficient algorithms to eliminate the spatial and temporal constraints in the state of the art particle-in-cell schemes. The computation is one to two orders of magnitude more efficient than the current commercial software.

- 1d3v/2d3v simulation
- Explicit/Implicit algorithm
- Momentum/Energy conserving scheme
- Moment analysis of Boltzmann equation
- Multi-species collision
- Customized sputtering and emission