

SUMMARY

Funded by **The National Institute of Health (NIH)**, **The National Science Foundation (NSF)**, **The Burroughs Wellcome Fund (BWF)**, **The Department of Energy (DOE)**, **The UNYTE Translational Research Network**, **Colgate Palmolive**, **L3Harris**, **SiPhox**, and **Biological Mimetics**, my lab at the Rochester Institute of Technology has an unstopping motivation to advance the research of mechanical/biomedical engineering and save lives. Current research activities include but not limited to: In vivo biosensing, in vitro diagnostic devices, CRISPR assays, optofluidics, mechanobiology, nanopore sequencing, scalable nanomanufacturing, functional nanomaterials, and artificial intelligence.

Since the establishment in 2018, my lab has secured over 2.4 million research funding in less than 3 years. Currently, I am supervising 1 postdoc researcher, 5 Ph.D. students (3 more joining soon), 3 M.S. students, and 8 undergraduate students. Research outcomes from my lab have been published in journals including **ACS Sensors** (complementary cover), **ACS Applied Materials and Interfaces** (complementary cover), **ACS Omega** (complementary cover), **Biosensors and Bioelectronics**, **Diagnostics**, **Electrophoresis** (front cover), **Optics Express**, and **Nanotechnology**. More information can be found on our website: www.3natrit.com

EDUCATION AND TRAINING

Postdoc in Chemistry/Bioengineering, University of California, Berkeley, 2015-2018

Advised by Professor Richard A. Mathies

Ph.D. in Mechanical Engineering, Stevens Institute of Technology, 2009-2015

Advised by Professor Chang-Hwan Choi

M.S. in Mechanical Engineering, University of South Florida, 2007-2009

B.S. in Materials Physics, 2007, University of Science and Technology, Beijing, 2003-2007

PROFESSIONAL EXPERIENCE

Assistant Professor, Mechanical Engineering, Rochester Institute of Technology, 2018-now

Assistant Professor, Microsystems Engineering, Rochester Institute of Technology, 2018-now

Program Faculty, School of Chemistry and Materials Science, Rochester Institute of Technology, 2019-now

Adjunct Faculty, Engineering, Diablo Valley College, 2016-2018

HONORS / AWARDS

- NIH Maximizing Investigators' Research Award (MIRA) (R35), 2021
- Colgate Innovation Award, 2021
- Rising star in sensing, *ACS Sensors*, 2020
- Finalist, Microsystems and Nanoengineering Young Scientist Awards, 2020
- Burroughs Wellcome Fund, 2019
- *Biosensors* Travel Award (only one awardee worldwide), 2017
- *Micromachines* Travel Award (two awardees worldwide), 2017
- James H. Potter Award for excellent academic performance, 2014
- NSF Graduate Student Fellowship, 2012

INDEPENDANT RESEARCH FEATURED BY UNIVERSITY NEWS

Stevens News: [His Quest to Diagnose COVID-19 and Contain Future Pandemics](#)

RIT News: [RIT professor develops device to better detect Ebola virus](#)

RIT News: [RIT researchers build micro-device to detect bacteria, viruses](#)

Rutgers Today: [New Device Quickly Detects Harmful Bacteria in Blood](#)

INDEPENDANT RESEARCH FEATURED BY POPULAR MEDIA

Yahoo Finance, EurekAlert!, Science Daily, Phys.org, Technology Networks, Medical Press, GEN, Business Standard, Photonics.com, R&D, The Medical News, Drug Discovery and Development, Ticker Tech, 2 News, Bio-Medicine.org, EE World, and Rochester Business Journal

INVITED TALKS

- Mammoth Biosciences (online presentation), Apr. 2021
- 1st Workshop on Next Generation of Sensors (online presentation), Mar. 2021
- Syracuse University (online presentation), Feb. 2021
- University of Buffalo (online presentation), Nov. 2020
- UIUC-ZJU (online presentation), Apr. 2020
- University of Rochester Medical Center, Mar. 2020
- Binghamton University, Feb. 2020
- Corning Inc., Feb. 2020
- Rutgers, The State University of New Jersey, Oct. 2019
- National Institute of Standards and Technology, Jun. 2019
- The 63rd EIPBN Conference, May. 2019
- Stevens Institute of Technology, Apr. 2019
- University of Rochester, Oct. 2018
- Lawrence Berkeley National Lab, Jul. 2018

PROFESSIONAL SERVICES

- Prize Reviewer, The U.S. Department of Health and Human Services, 2021
- Symposium Organizer, ACS Spring 2022 National Meeting & Exposition, 2021
- Faculty Search Committee, Department of Mechanical Engineering, RIT, 2021
- Editor Board Member, *Micromachines*, 2020 – now
- Reviewer Board Member, *Biosensors*, 2020 – now
- Symposium Organizer, ACS Northeast Regional Meeting, 2020
- Proposal Reviewer, Israel Science Foundation (ISF), 2020
- Proposal Reviewer, The Leverhulme Trust, 2020
- Proposal Reviewer, Chinese Society for Testing and Materials, 2020 - now
- Panelist, CMMI, The National Science Foundation, 2019
- Proposal Reviewer, The Innovation and Technology Commission (ITC) of Hong Kong, 2019
- Proposal Panelist, Center of Functional Nanomaterials (CFN), Brookhaven National Laboratory, 2019
- Session Chair, The 63rd International Conference on Electron, Ion, and Photon Beam Technology and Nanofabrication (EIPBN), 2019
- Session Chair, ASME International Mechanical Engineering Congress & Exposition, 2019
- Guest Editor, *Micromachines*, special issue of "Scalable Micro/Nano Patterning", 2016
- Member of the program committee for the EIPBN conference, 2011-2014
- Member of the organizing committee for the 2012 BNL Young Research Symposium
- Invited reviewer for over 40 peer-reviewed journals, including *Nature Biomedical Engineering*, *ACS Applied Materials & Interfaces*, *ACS Applied Polymer Materials*, *ACS Biomaterials Science & Engineering*, *Advanced Biology*, *Analytical Chemistry*, *Analytica Chimica Acta*, *Advanced Functional Materials*, *Advanced Materials*, *Advanced Materials Technologies*, *Advanced Optical Technologies*, *ACS Sensors*, *ACS Synthetic Biology*, *Biotechnology Advances*, *Biosensors and Bioelectronics*, *Biotechnology and Bioengineering*, *BioEssays*, *Biotechnology Journal*, *Diagnostics*, *Drug Discovery Today*, *European Journal of Oral Sciences*, *Frontiers of Chemistry*, *Journal of Micromechanics and Microengineering*, *Journal of Manufacturing Processes*, *Journal of Vacuum Science and Technology A*, *Journal of Vacuum Science and Technology B*, *Langmuir*, *Lab Chip*, *Micromachines*, *Microsystems and Nanoengineering*, *Microfluidics and Nanofluidics*, *Optics Letters*, *Pathogens*, *Plasmonics*, *Small*, *Sensors and Actuators A*, *Sensors and Actuators B*, *Scientific Reports*, *Talanta*, *Trends in Analytical Chemistry*, *Nanotechnology*, *Nanoscience and Nanotechnology Letters*, *Nanoscale Research Letters*, and *Virologica Sinica*

OUTREACH EXPERIENCE

- Principal investigator, RIT-Rochester Prep High School Capstone Project, 2021 – now: We recruited high school students to participate our research program. For the first project, students independently deposit gold microstructures on a silicon substrate via a stencil lithography process
- Principal investigator, RIT Beyond 9.8, 2019 – now: We offer interactive sessions for 6th grade students of Theodore Roosevelt School in Rocheste. Activates include mixing food dyes with PDMS based microfluidic chip, taking images of insects under an optical microscope, and preparing super-hydrophobic surfaces with NeverWet liquid repelling treatment. Students bring all the tested samples home as gifts.

TEACHING EXPERIENCE

Instructor for Heat Transfer, Rochester Institute of Technology, 2018 – now
Adjunct Instructor for several engineering courses, Diablo Valley College, 2017 – 2018

BOOK CHAPTER (†: equal contribution; * : corresponding author; students/postdoctoral fellows mentored)

Hass, K., Xu, Z., Hu, H., Yao, B., Yuan, X., Wang, C., Qin, P., and **Du, K***. Recent advances in nucleic acid analysis and detection with micro-and nanofluidics, for the book titled Multidisciplinary Microfluidic/nanofluidic Lab-on-a-chip: Principles & Applications, Elsevier, in press.

JOURNAL PUBLICATIONS (†: equal contribution; * : corresponding author; students/postdoctoral fellows mentored)

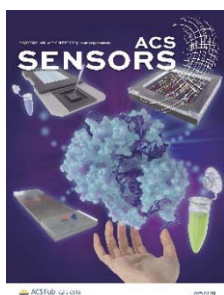
Google scholar citation > 950; h-index: 19 (August 2021)
<https://scholar.google.com/citations?user=rli9MCOAAAAJ&hl=en>

ResearchGate: https://www.researchgate.net/profile/Ke_Du4

After joining RIT:

1) Bao, M., Yang, F., Chen, J., Chang, Y., Liu, L., Waitkus, J., Qin, P., and **Du, K***. Recent advances of rapid diagnosis of viral hemorrhagic fevers (VHFs), in preparation.

2) Bao, M., Chen, Q., Xu, Z., Jensen, E., Liu, C., Waitkus, J., Yuan, X., He, Q., Qin, P., and **Du, K***. (2021). Challenges and opportunities for clustered regularly interspaced short palindromic repeats based molecular biosensing, *ACS Sensors*, 6, 2497. (Featured as supplementary cover)



3) Yang, J., He, Y., Zhang, X., Yang, W., Li, Y., Li, X., Chen, Q., Chen, X., and **Du, K.**, Yang, Y. Improving the Electrical Conductivity of Copper/Graphene Composites by Reducing the Interfacial Impurities using Spark Plasma Sintering Diffusion Bonding, submitted.

4) Yang F., Liu, L., Neuenschwander, P., **Du, K.**, and Yi, G. Synthesis of engineering phage peptide for the specific binding of the SARS-CoV-2 spike receptor, in preparation.

5) Xu, S., Stranick, M., Hines, D., **Du, K.**, and Pan, L. Super high quality SEM/FIB imaging of dentine structures without collagen fiber loss through a metal staining process, submitted.

6) Chen, X., Zhang, S., Gan, Y., Li, T., Liu, R., Wang, R., Lapizco-Encinas, B., and **Du, K***. Understanding the deformable microfluidics via microbeads stacking and its role in plasma separation and blood cells retrieval, in revision.

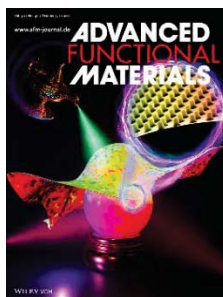
7) Kim, J., Bao, M., Bushnell, R., Tobin, G., He, J., **Du, K.**, and Park, M. Sensitive SARS-CoV-2 detection with a miniaturized fluorometer and CRISPR-Cas12a assay, in preparation.

8) He, Q., Chen, Q., Li, F., Yuan, X., Liu, C., Xu, L., Zhong, X., Wei, J., Kumar Pandey, V., Yu, D., Dong, Y., Zhang, Y., Deng, L., **Du, K.**, and Qin, P. Amplification-free detection of viral RNA by super resolution microscopy-based CRISPR/Cas13a system, in preparation.

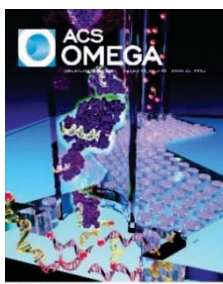
9) Layouni, R., Dubrovsky, M., Bao, M., Chung H., **Du, K.**, Boriskina S., Weiss, S., and Vermeulen, D. (2021). High contrast probe cleavage detection on porous silicon biosensors via quantum dot labeled DNA probes, *Optics Express*, 29, 1.

10) Liu, Y[†], **Du, K[†]**, Wathuthanthri, I., Xu, W., and Choi, C. (2020). Free-standing photoresist (PR) film: A versatile template for three-dimensional (3D) micro- and nanofabrication, *Advanced Functional Materials*, 30, 2004129. (Featured as inside front cover)

†: Equal contribution



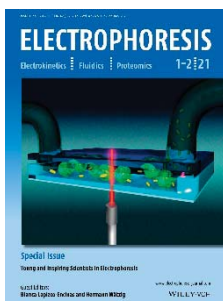
11) Hass, K (RIT undergraduate student)., Bao, M., He, Q., Liu, L., He, J., Park, M., Qin, P., and Du, K*. (2020). Integrated micropillar polydimethylsiloxane accurate CRISPR detection (IMPACT) system for rapid viral DNA sensing, *ACS Omega*, 5 (42), 27433-27441. (Featured as supplementary cover)



12) Yuan, X., Yang, C., He, Q., Yu, D., Li, J., Zhai, S., Qin, Z., Du, K*, Chu, Z., and Qin, P. (2020). Current and perspective diagnostic techniques for COVID-19, *ACS Infectious Diseases*, 6 (8), 1998-2016. (Featured as supplementary cover)



13) Korensky, G (RIT undergraduate student)., Chen, X., Bao, M., Miller, A., Lapizco-Encinas, B., Park, M., and Du, K*. (2021). Single molecule Chlamydomonas reinhardtii (CR) separation and auto-fluorescence monitoring via a nano-sieve channel, *Electrophoresis*, 00, 1-8. (Featured as front cover)



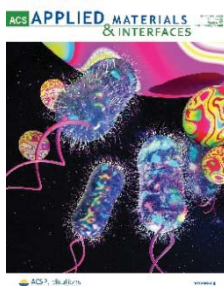
14) Bao, M., Jensen, E., Chang, Y., Korensky, G (RIT undergraduate student)., and Du, K*. (2020). Magnetic bead-quantum dot (MB-Qdot) clustered regularly interspaced short palindromic repeat assay for simple viral DNA detection, *ACS Applied Materials and Interfaces*, 12, 39, 43435-43443.

15) He, Q., Yu, D., Bao, M., Korensky, G (RIT undergraduate student)., Chen, J., Shin, M., Kim, J., Park, M*, Qin, P*, and Du, K*. (2020). High-throughput and all-solution phase African Swine Fever Virus (ASFV) detection using CRISPR-Cas12a and fluorescence based point-of-care system, *Biosensors and Bioelectronics*, 154, 112068.

16) Chen, X., Miller, A., Cao, S., Yu, G., Zhang, J., He, Q., Wang, R., Yong, X., Qin, P., Lapizco-Encinas, B., and Du, K*. (2020). Efficient Escherichia coli trapping, concentrating, and retrieval via nano-sieve packed

magnetic microbeads array, *ACS Applied Materials and Interfaces*, 12 (7), 7888-7896. (Featured as supplementary cover)

Media coverage: *Rutgers Today, *Nanowerk, *Science Daily, *The Medical News, *EurekAlert (press release)



17) He, Q., Bao, M., Hass, K (RIT undergraduate student)., Lin, W., Qin, P*, and Du, K*. (2019). Perspective of molecular diagnosis in healthcare: From barcode to pattern recognition, *Diagnostics*, 9, 75.

18) Chen, X., Falzon, L., Zhang, X., Wang, R*, and Du, K*. (2020). Experimental and theoretical study on the microparticle trapping and release in a deformable nano-sieve channel, *Nanotechnology*, 31, 05LT01.

19) Qin, P., Park, M., Alfson, K., Tamhankar, M., Carrion, R., Patterson, J., Griffiths, A., Yildiz, A., Mathies, R., and Du, K*. (2019). Rapid and fully microfluidic Ebola virus detection with CRISPR-Cas13a, *ACS Sensors*, 4 (4), 1048-1054. (Featured as supplementary cover)

Media coverage: *RIT news, *Yahoo Finance, *WHAM, *The Science Times, *EurekAlert (press release), *Materials Post, *News Medical Life Sciences, *R&D, *ERIE NEWS NOW, *WRCBtv, *Agenparl, *News9, *WFMJ



20) Du, K., Wathuthanthri, I., Ding, J., Choi, C. H. (2018). Superhydrophobic waveguide: Liquid-core air cladding waveguiding platform for optofluidics, *Applied Physics Letters*, 113, 143701.

Before joining RIT:

1) Du, K., Jiang, Y., Liu, Y., Wathuthanthri, I., and Choi, C. H. (2018). Manipulation of superhydrophobicity of plasma-etched polymer nanostructures. *Micromachines*, 9, 304.

2) Du, K., Jiang, Y., Huang, P., Ding, J., Gao, T., and Choi, C. H. (2018). Self-formation of polymer nanostructures in plasma etching: mechanisms and applications. *Journal of Micromechanics and Microengineering*, 28, 014006.

3) Du, K., Park, M., Griffiths, A., Carrion, R., Patterson, J., Schmidt, H., and Mathies, R. (2017). Microfluidics for the detection of Viral RNA in whole blood samples using digital-coded barcode fluorescence dye and photo-cleavable capture probe. *Analytical Chemistry*, 89 (22), 12433-12440.

4) Du, K*, Park, M., Ding, J., Hu, H., and Zhang, Z. (2017). Sub-10 nm patterning with DNA nanostructures: a short perspective. *Nanotechnology*, 28, 442501.

5) Du, K., Ding, J., Wathuthanthri, I., and Choi, C. H. (2017). Selective hierarchical patterning of silicon nanostructures via soft stencil lithography. *Nanotechnology*, 28, 465303.

6) Du, K., Wathuthanthri, I., and Choi, C. H. (2017). The rise of scalable micro/nanopatterning. *Micromachines*, 8, 275.

7) Jiang, Y., Xu, J., Lee, J., Du, K., Yang, E. H., Moon, W., and Choi, C. H. (2017). Nanotexturing of conjugated polymers via one-step maskless oxygen plasma etching for enhanced tunable wettability. *Langmuir*, 33 (27), 6885-6894.

8) Chauvin, A., Stephant, N., **Du, K.**, Ding, J., Wathuthanthri, I., Choi, C. H., Tessier, P. Y., and El Mel, A. A. (2017). Large-scale fabrication of porous gold nanowires via laser interference lithography and dealloying of gold-silver nano-alloys. *Micromachines*, 8, 168.

*Feature paper

9) Du, K., Ding, J., Liu, Y., Wathuthanthri, I., and Choi, C. H. (2017). Stencil lithography for scalable micro- and nanomanufacturing. *Micromachines*, 8, 131.

*Highlighted by Microfluidic Technology Review

10) **Du, K.**, Cai, H., Park, M., Wall, T., Stott, M., Alfson, K., Griffiths, A., Carrion, R., Patterson, J., Hawkins, A., Schmidt, H., and Mathies, R. (2017). Multiplexed on-chip sample preparation and sensitive detection of Ebola virus. *Biosensors and Bioelectronics*, 91, 489-496.

11) El Mel, A. A., Chettab, M., Gautron, E., Chauvin, A., Humbert, B., Mevellec, J. Y., Cyril, D., Thiry, D., Stephant, N., Ding, J., **Du, K.**, Choi, C. H., and Tessier, P. Y. (2016). Galvanic Replacement Reaction: A Route to Highly Ordered Bimetallic Nanotubes. *The Journal of Physical Chemistry C*. 120 (31), 17652-17659.

12) El Mel, A. A. E., Tessier, P. Y., Buffiere, M., Gautron, E., Ding, J., **Du, K.**, Choi, C. H., Konstantinidis, E., Snyders, R., Bittencourt, C., and Molina-Luna, L. (2016). Controlling the Formation of Nanocavities in Kirkendall Nanoobjects through Sequential Thermal Ex Situ Oxidation and In Situ Reduction Reactions. *Small*, 12 (21), 2885-2892.

13) Chauvin, A., Delacôte, C., Molina-Luna, L., Duerrschabel, M., Boujtita, M., Thiry, **Du, K.**, Ding, J., Choi, C. H., Tessier, P. Y., and El Mel, A. A. (2016). Planar arrays of nanoporous gold nanowires: when electrochemical dealloying meets nanopatterning. *ACS Applied Materials & Interfaces*, 8 (10), 6611-6620.

14) Thiry, D., Molina-Luna, L., Gautron, E., Stephant, N., Chauvin, A., **Du, K.**, Ding, J., Choi, C. H., Tessier, P. Y., and El Mel, A. A. (2015). The Kirkendall Effect in Binary Alloys: Trapping Gold in Copper Oxide Nanoshells. *Chemistry of Materials*, 27 (18), 6374-6384.

15) **Du, K.**, Wathuthanthri, I., Liu, Y., Kang, Y. T., and Choi, C. H. (2014). Fabrication of polymer nanowires via maskless O₂ plasma etching. *Nanotechnology*, 25 (16), 165301. (Featured as cover article)



16) Ding, J., **Du, K.**, Wathuthanthri, I., Choi, C. H., Fisher, F. T., and Yang, E. H. (2014). Transfer patterning of large-area graphene nanomesh via holographic lithography and plasma etching. *Journal of Vacuum Science & Technology B*, 32 (6), 06FF01.

*Most read JVST article

*Editor's pick

17) El Mel, A. A., Molina-Luna, L., Buffiere, M., Tessier, P. Y., **Du, K.**, Choi, C. H., Kleebe, H. J., Konstantinidis, S., Bittencourt, C., and Snyders, R. (2014). Electron Beam Nanosculpting of Kirkendall Oxide Nanochannels. *ACS Nano*, 8 (2), 1854-1861.

18) **Du, K.**, Liu, Y., Wathuthanthri, I., and Choi, C. H. (2013). Fabrication of hierarchical nanostructures using free-standing trilayer membrane. *Journal of Vacuum Science & Technology B*, 31 (6), 06FF04.

19) Wathuthanthri, I., Liu, Y., **Du, K.**, Xu, W., and Choi, C. H. (2013). Simple Holographic Patterning for High-Aspect-Ratio Three-Dimensional Nanostructures with Large Coverage Area. *Advanced Functional Materials*, 23 (5), 608-618.

20) Lu, Y., Sarshar, M. A., **Du, K.**, Chou, T., Choi, C. H., and Sukhishvili, S. A. (2013). Large-amplitude, reversible, pH-triggered wetting transitions enabled by layer-by-layer films. *ACS Applied Materials & Interfaces*, 5 (23), 12617-12623.

21) **Du, K.**, Wathuthanthri, I., Liu, Y., Xu, W., and Choi, C. H. (2012). Wafer-Scale pattern transfer of metal nanostructures on polydimethylsiloxane (PDMS) substrates via holographic nanopatterns. *ACS Applied Materials & Interfaces*, 4 (10), 5505-5514.

22) Liu, Y., **Du, K.**, Wathuthanthri, I., and Choi, C. H. (2012). From nanocone to nanodisc: Structural transformation of gold nanoarrays via simple mechanical stresses. *Journal of Vacuum Science & Technology B*, 30 (6), 06FF10.

23) El Mel, A. A., Buffière, M., Tessier, P. Y., Konstantinidis, S., Xu, W., **Du, K.**, Wathuthanthri, I., Choi, C. H., Bittencourt, C., and Snyders, R. (2013). Highly ordered hollow oxide nanostructures: the kirkendall effect at the nanoscale. *Small*, 9 (17), 2838-2843. (Featured frontispiece)



24) **Du, K.**, Liu, Y., Wathuthanthri, I., and Choi, C. H. (2012). Dual applications of free-standing holographic nanopatterns for lift-off and stencil lithography. *Journal of Vacuum Science & Technology B*, 30 (6), 06FF04.

25) **Du, K.**, Wathuthanthri, I., Mao, W., Xu, W., and Choi, C. H. (2011). Large-area pattern transfer of metallic nanostructures on glass substrates via interference lithography. *Nanotechnology*, 22 (28), 285306.

*Cited over 50 times

26) Locke, C., Kravchenko, G., Waters, P., Reddy, J. D., **Du, K.**, Volinsky, A. A., Frewin, C. L., and Sadow, S. E. (2009). 3C-SiC films on Si for MEMS applications: mechanical properties. *Materials Science Forum* (Vol. 615, pp. 633-636). Trans Tech Publications.

SELECTED CONFERENCE PROCEEDINGS

1) Liu, Li, Dubrovsky, M., Gundavarapu, S., Vermeulen, D., and **Du, K.***. Viral nucleic acid detection with CRISPR-Cas12a using high contrast cleavage detection on micro-ring resonator biosensors. International Society for Optics and Photonics (SPIE), 2021.

2) Liu, Y., **Du, K.**, Wathuthanthri, I., Xu, W., and Choi, C. H. (2012, January). 3-D nanofabrication using nanostructured photoresist film as free-standing appliqué. In Micro Electro Mechanical Systems (MEMS), 2012 IEEE 25th International Conference on (pp. 192-195).

3) Chauvin, A., Delacôte, C., Molina-Luna, L., Boujita, M., Thiry, D., **Du, K.**, Ding, J., Choi, C. H., Humbert, B., Mevellec, J. Y., Tessier, P. Y., and El Mel, A. A. (2016, May). Two-step approach for the nanofabrication of highly ordered ultra-long porous gold nanowires with an adjustable porosity for SERS-based sensors. In 2016 TechConnect World Innovation Conference.

4) Volinsky, A. A., **Du, K.**, and Lusk, C. (2009, May). Compliant MEMS Device Actuation and Fracture. In ICF12.

5) **Du, K.**, Pang, X., Chen, C., & Volinsky, A. A. (2008). Mechanical properties of evaporated gold films. hard substrate effect correction. MRS Online Proceedings Library (OPL), 1086.

6) El Mel, A. A., Buffière, M., Tessier, P. Y., Xu, W., **Du, K.**, Choi, C. H., Konstantinidis, S., Bittencourt, C., and Snyders, R. (2013, January). Fabrication of highly ordered hollow oxide nanostructures based on nanoscale Kirkendall effect and Ostwald ripening. In Nanoelectronics Conference (INEC), 2013 IEEE 5th International (pp. 46-48).