

Mikhail 'Mike' Shekhirev

General information

Address Bossone 325, 3140 Market St, Drexel University, Philadelphia, PA, USA, 19104
E-mail ms4986@drexel.edu
Current position Postdoctoral Researcher, Drexel Nanotechnology Institute

Research at Drexel

My current research is related to chemical modification and functionalization of 2D transition metal carbides and/or carbonitrides, also known as MXenes. Using approaches of organic and inorganic chemistry, this research aims to improve performance of MXenes for electronic applications, which includes electrical conductivity and oxidation stability. As a part of my research, I am actively performing characterization of the material using Scanning Probe Microscopy techniques.

Research Profiles

ORCID <https://orcid.org/0000-0002-8381-1276>
Google Scholar <https://scholar.google.com/citations?user=4TybyTAAAAAJ&hl=en&oi=ao>

Education

- 2004 – 2008 **B.S. in Materials Science (magna cum laude)**
Department of Materials Science, Lomonosov Moscow State University, Moscow, Russia
Studies included inorganic materials fabrication and common characterization methods.
Thesis: Resorbable ceramics based on calcium phosphates
- 2008 – 2010 **M.S. in Chemistry (magna cum laude)**
Department of Materials Science, Lomonosov Moscow State University, Moscow, Russia
Thesis: Microstructure formation of the boiceramics based on hydroxyapatite with the presence of biocompatible chloride melts
- 2012 – 2017 **Ph.D. in Chemistry**
Department of Chemistry, University of Nebraska-Lincoln, Lincoln, USA
Thesis: Atomically precise graphene nanoribbons: aggregation, thin film fabrication and gas sensing properties.

Internships

- June 2015 – April 2016 **Commercialization Analyst**
NUtech Ventures (Technology Transfer Office, University of Nebraska-Lincoln)
I performed prior art research to determine patentability of new technologies, assessed their commercialization and marketability potentials and identified companies potentially interested in licensing the technologies.

Teaching experience

- Fall 2010 **Chemistry and Nanochemistry of elements**
Department of Materials Science, Moscow State University
Read “popular-science”-type lectures for high-school students on recent advances in nanochemistry and materials science
- Fall 2013 **Fundamental Chemistry I Laboratory**
Department of Chemistry, University of Nebraska-Lincoln
Led 2 laboratory sections, graded lab reports and General Chemistry exams, and met with students during office hours
- Spring 2014 **Organic Chemistry I Laboratory**
Department of Chemistry, University of Nebraska-Lincoln
Led 2 laboratory sections, graded reports, quizzes and organic chemistry exams, met with students during my office hours
- Fall 2015, 16, 17 **Inorganic Chemistry Laboratory**
Department of Chemistry, University of Nebraska-Lincoln
Led 1 laboratory sections (8 hours/week, 2 credits) and participated in lecture part of the class. I helped to develop the class curriculum and was involved in planning/organizing the class. I developed two new laboratory experiments, one of which was published in the *Journal of Chemical Education* and wrote several experimental procedures. I prepared lecture materials, templates and made tutorials for students on scientific presentation/data presentation and scientific writing. I also was responsible for demonstration of different scientific equipment to students (sample measurements, lecturing on basic operating principles).
- Spring 2017 **General Chemistry II Recitation**
Department of Chemistry, University of Nebraska-Lincoln
In charge of 4 recitation sections, included development of the materials, lecturing and solving problems to prepare students for the exam.
- Fall 2019 **Advanced Materials Laboratory**
Department of Materials Science and Engineering, Drexel University
I worked as a TA, Lab coordinator and lecturer (substitute for the professor) for this course. It involved preparing and reading lectures on selected characterization techniques, coordinated students (25) and specialists for hands-on demonstration of different techniques, developing exams, grading lab reports and presentations.

Mentorship

I supervised multiple undergraduate students as a part of Undergraduate Research in Chemistry class, The Undergraduate Creative Activities and Research Experience (UCARE) and Research Experience for Undergraduates (REU) programs. It resulted in publications in top-tier journals, such as Nature Communication, Journal of Chemical Education and Journal of Physics: Condensed Matter.

Research experience

- 2004 – 2012 **Research assistant**
Department of Materials Science, Lomonosov Moscow State University, Moscow, Russia
Adviser: Prof. Valery Putlyaev
Synthesis and sintering of ceramics based on calcium phosphates (hydroxyapatite, tricalcium phosphate, calcium pyrophosphate).
- February 2008 **Visiting researcher**
Chemistry Department, University of Duisburg-Essen, Essen, Germany
Adviser: Prof. Matthias Epple
Synthesis and investigation of calcium phosphates using SEM and XRD techniques. Fabrication of calcium pyrophosphate (CPP, Ca₂P₂O₇) powders with different particle size and shape.
- October 2017 **Visiting researcher**
Center for Functional Nanomaterials, Brookhaven National Laboratory, Upton, NY, USA
Adviser: Dr. Percy Zahl
Assisted Dr. Zahl in synthesis and LT-STM/nc-AFM characterization of atomically precise graphene nanoribbons. Results were published in *ACS Nano* journal, see list of publications below
- 2012 – 2017 **Research assistant**
Department of Chemistry, University of Nebraska-Lincoln, Lincoln, NE, USA
Adviser: Prof. Alexander Sinitskii
Investigation of atomically precise graphene nanoribbons (GNRs). The main focus was on characterization of GNRs, their aggregation behavior and fabrication of thin films for thin film-transistors and gas sensors. I also performed synthesis of monomers for GNR fabrication.
- 2018 – 2019 **Postdoctoral Research Associate**
Departments of Electrical & Computer Engineering and Mechanical & Materials Engineering, University of Nebraska-Lincoln, Lincoln, NE, USA
Advisers: Profs. Peter Sutter and Eli Sutter
Synthesis and programmable self-assembly of DNA-functionalized gold nanoparticles. *In-situ* AFM studies of the self-assembly process.
- 2019 – present **Postdoctoral Researcher**
Department of Materials Science and Engineering, Drexel University, Philadelphia, PA, USA
Adviser: Prof. Yury Gogotsi
Investigation of intrinsic properties and surface chemistry of MXenes. Chemical modification of the material and characterization using Scanning Probe Microscopy techniques.

Service

Reviewer for *Green Chemistry* (1) and *Journal of Materials Science & Technology* (1)

Awards, Grants and Fellowships

- 2018 University of Nebraska-Lincoln Postdoc Travel Grant
- 2017 Robert Marianelli Outstanding Graduate Research Assistant Award
- 2016 Nebraska Center for Materials and Nanoscience Graduate Research Fellowship
- 2014 University of Nebraska-Lincoln Department of Chemistry Travel Fellowship
- 2010 Medal of Russian Academy of Science in inorganic materials technology
- 2009 A.V. Novoselova prize in Inorganic chemistry and chemistry of materials
- 2008 Moscow State University grant for talented students, graduate students, young scientists
- 2008 Leonard-Euler Research Fellowship, DAAD (German Academic Research Service), Germany

Patents

Application 62548729 "Carbon nanostructure based gas sensors and method of making same" filed Aug 22, 2017.

Book chapters

M. Shekhirev and A. Sinitskii. Solution Synthesis of Atomically Precise Graphene Nanoribbons. Published in Chemistry of Carbon Nanostructures, ed. by K. Muellen and X. Feng. De Gruyter (**2016**), ISBN: 978-3-11-028450-8.

Publications

M. Shekhirev, A. Lipatov, A. Torres, N.S. Vorobeva, A. Harkleroad, A. Lashkov, V. Sysoev, A. Sinitskii. Highly selective gas sensors based on graphene nanoribbons grown by chemical vapor deposition. *ACS Applied Materials & Interfaces* **2020**, 12, 6, 7392-7402.

M. Shekhirev, E. Sutter, P. Sutter. In-Situ Atomic Force Microscopy of the Reconfiguration of On-Surface Self-Assembled DNA-Nanoparticle Superlattices. *Adv. Funct. Mater.* **2019**, 1806924.

M. Shekhirev, P. Zahl, A. Sinitskii. Phenyl Functionalization Of Atomically Precise Graphene Nanoribbons For Engineering Inter-Ribbon Interactions And Graphene Nanopores. *ACS Nano* **2018**, 12 (8), pp 8662–8669. This publication was also featured in the Highlights of the Center for Functional Nanomaterials at Brookhaven National Laboratory.

C.C. Ilie, F. Guzman, B. Swanson, I. Evans, P. Costa, J. Teeter, **M. Shekhirev**, N. Benker, S. Sikich, A. Enders, P.A. Dowben, A. Sinitskii and A.J. Yost. Inkjet printable-photoactive all inorganic perovskite films with long effective photocarrier lifetime. *J. Phys.: Condens. Matter.* **2018**, 30, 18LT02.

M. Shekhirev, T.H. Vo, D.A. Kunkel, A. Lipatov, A. Enders and A. Sinitskii. Aggregation of atomically precise graphene nanoribbons. *RSC Advances* **2017**, *7*, 54491-54499.

J. Teeter, P. Costa, P. Zahl, T.H. Vo, **M. Shekhirev**, W. Xu, X.C. Zeng, A. Enders and A. Sinitskii. Dense monolayer films of atomically precise graphene nanoribbons on metallic substrates enabled by direct contact transfer of molecular precursors. *Nanoscale* **2017**, *9*, 18835-18844.

M. Mehdi Pour, A. Lashkov, A. Radocea, X. Liu, T. Sun, A. Lipatov, R.A. Korlacki, **M. Shekhirev**, N. Aluru, J. Lyding, V. Sysoev and A. Sinitskii. Laterally extended atomically precise graphene nanoribbons with improved electrical conductivity for efficient gas sensing. *Nature Communications* **2017**, *8*:820.

M. Shekhirev, J. Goza, J. Teeter, A. Lipatov, A. Sinitskii. Synthesis of cesium lead halide perovskite quantum dots. *Journal of Chemical Education* **2017**, *94*(8) 1150-1156.

M. Shekhirev and A. Sinitskii. Solution Synthesis of Atomically Precise Graphene Nanoribbons. *Physical Sciences Reviews* **2017**, *2* (5). This article is also available as a chapter in the following book: Chemistry of Carbon Nanostructures, ed. by K. Muellen and X. Feng. De Gruyter (**2016**), ISBN: 978-3-11-028450-8.

M. Shekhirev, T.H. Vo, M. Mehdi Pour, A. Lipatov, S. Munukutla, J.W. Lyding, A. Sinitskii. Interfacial Self-Assembly of Atomically Precise Graphene Nanoribbons into Uniform Thin Films for Electronics Applications. *ACS Applied Materials & Interfaces* **2016**, *9* (1), 693-700.

T.H. Vo, G.U. Perera, **M. Shekhirev**, M. Mehdi Pour, D.A. Kunkel, H. Lu, A. Gruverman, E. Sutter, M. Cotlet, D. Nykypanchuk, *et al.* Nitrogen-Doping Induced Self-Assembly of Graphene Nanoribbon-Based Two-Dimensional and Three-Dimensional Metamaterials. *Nano Letters* **2015**, *15*, 5770–5777.

A. Lipatov, P. M. Wilson, **M. Shekhirev**, J.D. Teeter, R. Netusil, A. Sinitskii. Few-Layered Titanium Trisulfide (TiS₃) Field-Effect Transistors. *Nanoscale* **2015**, *7*, 12291–12296.

P.M. Wilson, F. Orange, M. Guinel, **M. Shekhirev**, Y. Gao, J.A. Santana, A.A. Gusev, P.A. Dowben, Y. Lu, A. Sinitskii. Oxidative Peeling of Carbon Black Nanoparticles. *RSC Advances* **2015**, *5*, 92539–92544.

J.S. Lee, A. Lipatov, L. Ha, **M. Shekhirev**, M. Nahid Andalib, A. Sinitskii, J.Y. Lim. Graphene substrate for inducing neurite outgrowth. *Biochemical and Biophysical Research Communications* **2015**, *460*, 267-273.

- T.H. Vo, **M. Shekhirev**, A. Lipatov, R. A. Korlacki, A. Sinitskii. Bulk properties of solution-synthesized chevron-like graphene nanoribbons. *Faraday Discussions* **2014**, *173*, 105-113.
- T.H. Vo, **M. Shekhirev**, D. Kunkel, F. Orange, M. Guinel, A. Enders, A. Sinitskii. Bottom-up solution synthesis of narrow nitrogen-doped graphene nanoribbons. *Chemical Communications* **2014**, *50*, 4172-4174.
- T.H. Vo, **M. Shekhirev**, D. Kunkel, M. D. Morthon, E. Berglund, L. Kong, P. Wilson, P. Dowben, A. Enders, A. Sinitskii. Large-scale solution synthesis of narrow graphene nanoribbons. *Nature Communications* **2014**, *5*, 3189.
- S. Gusev, **M. Shekhirev**, T. Safronova, V. Putlayev, Z. Skvortsova, P. Protsenko. Wetting and Spreading of Molten NaCl and CaCl₂ over Polycrystalline Hydroxyapatite. *Mendeleev Communications* **2014**, *24*, 12–14.
- T. Safronova, V. Putlayev, **M. Shekhirev**. Resorbable Calcium Phosphates Based Ceramics. *Powder Metallurgy and Metal Ceramics* **2013**, *52*, 357–363.
- T. Safronova, V. Putlyaev, O. Avramenko, **M. Shekhirev**, A. Veresov. Ca-Deficient Hydroxyapatite Powder for Producing Tricalcium Phosphate Based Ceramics. *Glass and Ceramics* **2011**, *68*, 28–32.
- T. Safronova, V. Putlyaev, **M. Shekhirev**, Y. Tretyakov, A. Kuznetsov, A. Belyakov. Densification Additives for Hydroxyapatite Ceramics. *Journal of the European Ceramic Society* **2009**, *29*, 1925–1932.
- T. Safronova, A. Kuznetsov, S. Korneychuk, V. Putlyaev, **M. Shekhirev**. Calcium Phosphate Powders Synthesized from Solutions with $[Ca^{2+}]/[PO_4^{3-}]=1$ for Bioresorbable Ceramics. *Central European Journal of Chemistry* **2009**, *7*, 184–191.
- T. Safronova, **M. Shekhirev**, V. Putlyaev, Y. Tret'yakov. Hydroxyapatite-based ceramic materials prepared using solutions of different concentrations. *Inorganic Materials* **2007**, *43*, 8, 901-909.
- T. Safronova, V. Putlyaev, **M. Shekhirev**, A. Kuznetsov. Disperse Systems in Calcium Hydroxyapatite Ceramics Technology. *Glass and Ceramics* **2007**, *64*, 22–26.
- T. Safronova, V. Putlyaev, **M. Shekhirev**, A. Kuznetsov. Composite Ceramic Containing a Bioresorbable Phase. *Glass and Ceramics* **2007**, *64*, 102–106.
- T. Safronova, **M. Shekhirev**, V. Putlyaev. Ceramics Based on Calcium Hydroxyapatite Synthesized in the Presence of PVA. *Glass and Ceramics* **2007**, *64*, 408–412.

T. Safronova, V. Putlayev, A. Veresov, A. Kuznetsov, **M. Shekhirev**, K. Agahi. Biocompatible Ceramics for Implants Based on Calcium Phosphates. *MRS Proceedings* **2006**, 951, 0951–E12–31.

T. Safronova, V. Putlyaev, A. Belyakov, **M. Shekhirev**. Sintering of HAp Precipitated from Solutions Containing Ammonium Nitrate and PVA. *MRS Proceedings* **2005**, 887, 0887-Q06-10.

Presentations

M. Shekhirev, E. Sutter, P. Sutter. In-Situ Atomic Force Microscopy of DNA-Mediated Nanoparticle Assemblies in Solution. *MRS Fall meeting* **2018**, Boston, MA, oral presentation

M. Shekhirev, T.H. Vo, M. Mehdi Pour, A. Lipatov, A. Lashkov, A. Sinitskii. Solution synthesis and assembly of atomically precise graphene nanoribbons. *Office of Naval Research review session* **2017**, Berkeley, CA, poster

M. Shekhirev, A. Lipatov, A. Harkleroad, A. Sinitskii. CVD films of narrow atomically precise graphene nanoribbons. *APS March Meeting* **2016**, Baltimore, MD, oral presentation

M. Shekhirev, A. Lipatov, T. Vo, M. Mehdi Pour, A. Sinitskii. Thin films of bottom-up synthesized graphene nanoribbons. *APS March Meeting* **2015**, San Antonio TX, oral presentation

M. Shekhirev, T.H.Vo, D. Kunkel, F. Orange, M. Guinel, Y. Zhao, A. Lipatov, R. A. Korlacki, X. C. Zeng, A. Enders, A. Sinitskii. Bottom-up graphene nanoribbons: solution synthesis and aggregation effects. *New Diamond and Nano Carbon* **2014**, Chicago IL, poster

M. Shekhirev, T.H. Vo, D. Kunkel, F. Orange, M. Guinel, Y. Zhao, A. Lipatov, R. A. Korlacki, X. C. Zeng, A. Enders, A. Sinitskii. Aggregation modes of bottom-up synthesized graphene nanoribbons. *APS March Meeting* **2014**, Denver CO, poster

M. Shekhirev, T. Safronova, V. Putlayev. Calcium pyrophosphate nanopowders for resorbable bioceramics preparation. *Russian-Chinese Symposium on New Materials and Technologies* **2009**, Jiaying, China, poster

M. Shekhirev, T. Safronova, V. Putlayev. Resorbable ceramics composites based on calcium phosphates *International conference on sintering* **2009**, Kiev, Ukraine, oral presentation

M. Shekhirev Synthesis of calcium pyrophosphate powder with small particle size. *International scientific conference for undergraduate and postgraduate students and young scientists Lomonosov* **2009**, Moscow, Russia, poster

M. Shekhirev, T. Safronova, V. Putlyaev. Nanoceramics for bone implants: synthesis of tricalcium phosphates and composites. *Nanotechnology International Forum 2008*, Moscow, Russia, poster

M. Shekhirev, T. Safronova, V. Putlyaev. Synthesis of composites based on hydroxyapatite and calcium pyrophosphate. *International scientific conference for undergraduate and postgraduate students and young scientists Lomonosov 2008*, Moscow, Russia, poster

Safronova T.V., Putlayev V.I., **Shekhirev M.A.**, Kuznetsov A.V., Steklov M.Yu., Korneychuk S.A., Sergeeva A.I.. Calcium phosphate powders containing tailoring product. *Mendeleev congress 2007*, Moscow, Russia, poster

M. Shekhirev, T. Safronova, V. Putlyaev. Synthesis and investigation of Zn-substituted hydroxyapatite. *International scientific conference for undergraduate and postgraduate students and young scientists Lomonosov 2007*, Moscow, Russia, poster

M. Shekhirev, T. Safronova. Ceramic materials based on hydroxyapatite synthesized in the presence of PVA. *Mendeleev conference of young scientists 2007*, Samara, Russia, poster

M. Shekhirev, T. Safronova. Ceramic materials based on hydroxyapatite synthesized from solutions of different concentrations. *Mendeleev conference of young scientists 2006*, UFA, Russia, poster

T.V. Safronova, V.I. Putlyaev, **M.A. Shekhirev**. Hydroxyapatite ceramics manufactured from precipitated powders. *Topical Meeting of the European Ceramic Society 2006*, Saint-Petersburg, Russia, poster

M. Shekhirev, T. Safronova. Microstructure investigation in ceramics based on hydroxyapatite. *International scientific conference for undergraduate and postgraduate students and young scientists Lomonosov 2006*, Moscow, Russia, poster