Maria Mukhina, PhD

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PROFILE

I am a biophysicist, with a background in microscopy, semiconductor and DNA nanotechnology, *in vivo* sensing, engineering, and image processing, which I apply to study the mechanics of chromosomes. My dream job is in research and/or tool development and demands my diverse scientific expertise to tackle major challenges in the way of breakthrough biological discoveries.

RESEARCH ACCOMPLISHMENTS

Microscope for fast imaging and mechanical stimulation

- Built a customizable optical microscopy system with the capacity to integrate up to 7 automatic controls.
- Developed custom hardware and software to apply mechanical deformation with nanoscale precision and record induced optical response with sub-millisecond temporal resolution of 1580 fps [mariavmukhina.github.io].

Nanoprobes for *in situ* quantitative mapping of intracellular forces

Nanoprobe I: mechanoluminescent nanocrystals

- Conceived a concept of *in vivo* mechanoluminescent* force nanoprobe, which does not require photoexcitation and as such is free of autofluorescent background and phototoxicity; *in mechanoluminescence, a crystal deformed as a result of force application produces photons, thus serving as a force sensor with a direct optical readout.
- Discovered nanoscale mechanism of mechanoluminescence in ZnMnS microparticles (too big for *in vivo* applications); showed that this mechanoluminescence operates at excitation pressures in the range of intracellular forces.
- Predicted and synthesized (with external collaborators) novel mechanoluminescent nanomaterial suitable for intracellular use; tested these nanorods to show that they do indeed exhibit exceptionally bright mechanoluminescence.
- Developed data analysis pipeline integrating imaging and mechanical data.

Nanoprobe II: dynamic DNA origami with force-sensitive photoluminescence color

- Designed and synthesized DNA origami, which switches between two states characterized by different colors of photoexcited luminescence in response to the forces on the scale just above the thermal bath.
- Developed *in vitro* microfluidic assay for measuring compressive depletion forces.

- Used click-chemistry for genome-wide targeting of the nanoprobes to chromatin in living cells
- Developed CRISPR dCas9-based nano-bio interface for locus-specific targeting of the nanoprobes to chromatin in living cells
- Developed *in vivo* assay for 4D (space + time) mapping of micron-scale force fields in the genomes of living cells.
- Developed *in vivo* image processing pipeline producing 4D maps of intra-chromatin force fields.

Chromosome mechanics

Bacterial chromosome

- Created an algorithm to extract frequencies of the oscillations in length of bacterial chromosomes from a 4D super-resolution datasets [mariavmukhina.github.io].
- Introduced a framework of thinking linking mitotic spindle-independent chromosome segregation to the presence of standing thermo-elastic waves steering bacterial genome.

Mammalian chromosomes

- Performed geometrical analysis of super-resolution images of protein axes holding together copes of mitotic chromosomes in the preparation for cell division.
- Defined the mechanical patterns derived from the geometrical analysis as multiple helical perversions.
- Contributed to creation of the model of chromosome-wide mechanical communication.

Semiconductor nanophysics / bio-nano interfaces

- Created molecular tweezers to separate nanocrystal enantiomers.
- Designed *in vitro* microfluidic assay for real-time detection of molecular recognition between chiral nanocrystals and amino acids.
- Demonstrated enantioselectivity in cellular uptake of chiral nanocrystals.
- Developed 3 methods of spatial alignment of nanocrystals; used these methods to study anisotropy of the optical properties of the nanocrystals.

RESEARCH EXPERIENCE

2016-present	Postdoctoral Fellow, Laboratory of Prof. Nancy Kleckner, Department of Molecular and Cellular Biology, Harvard University, USA
07.2019 02.2019 09.2018	Visiting Researcher, Laboratory of Prof. Paul Alivisatos, Department of Chemistry, University of California, Berkeley, USA
2014-2016	Research Associate, Center of Information Optical Technologies, ITMO University, Russia
09-11.2015	Visiting Researcher, Laboratory of Nanoscience and Spectroscopy, School of Chemistry, the University of Manchester, UK
03.2013 03.2014	Visiting Researcher, Laboratory of Inorganic and Materials Chemistry, School of Chemistry, Trinity College Dublin, Ireland
2008-2013	Engineer, Center of Information Optical Technologies, ITMO University, Russia

EDUCATION

2017	MCB188 Chromosomes, Harvard University, USA
2010-2013	Ph.D. in Optics, ITMO University, Russia Thesis: Macroscopic orientation of the luminescent semiconductor anisotropic nanocrystals
2008-2010	Master in Photonics and Optical Computer Science, ITMO University, Russia Thesis: Luminescent properties of semiconductor and carbon nanoparticles in aqueous solution
2004-2008	Bachelor in Technical Physics, ITMO University, Russia

AWARDS

2015-2017	The Scholarship of the President of the Russian Federation for Young Scientists and Graduate Students
2015	ITMO Grant for Young Scientists (Principal Investigator, led the group of 7 people)
2015	Researcher Links Travel Grant

SELECTED PUBLICATIONS, 5 most important are highlighted ‡

Maria Mukhina. Bringing Chiral Functionality to In Vivo Applications of Nanomaterials. Light: Science & Applications, 11 (157) (2022)
Invited paper

Lingluo Chu, Zheng Zhang, **Maria V. Mukhina**, Denise Zickler, Nancy E. Kleckner. Sister chromatids separate during anaphase in a three-stage program as directed by inter-axis bridges. PNAS, 119 (10), e2123363119 (2022)

‡**Maria V. Mukhina**, Jason S. Tresback, Justin C. Ondry, Austin Akey, A. Paul Alivisatos, and Nancy Kleckner. Single particle studies reveal a new mechanism for elastic, bright, and

repeatable ZnS:Mn mechanoluminescence in a low pressure regime. ACS Nano, 15 (3) 4115-4133 (2021)
Highlighted in ACS monthly feature In Nano

‡Lingluo Chu*, Zhangyi Liang*, **Maria Mukhina***, Jay K. Fisher, John Hutchinson, Nancy Kleckner. One-dimensional spatial patterning along mitotic chromosomes: a mechanical basis for macroscopic morphogenesis. PNAS, 117 (43) 26749-26755 (2020)
**These authors contributed equally to this work*

Lingluo Chu, Zhangyi Liang, **Maria Mukhina**, Jay Fisher, Nadine Vincenten, Zheng Zhang, John Hutchinson, Denise Zickler, Nancy Kleckner. The 3D Topography of Mitotic Chromosomes. Molecular Cell, 79, 1–15 (2020)

‡**Maria V Mukhina,** Anvar S Baimuratov, Ivan D Rukhlenko, Vladimir G Maslov, Finn Purcell Milton, Yurii K Gun'ko, Alexander V Baranov, Anatoly V Fedorov. Circular Dichroism of Electric-Field-Oriented CdSe/CdS Quantum Dots-in-Rods. ACS Nano, 10, 8904-8909 (2016)

‡**Maria V Mukhina**, Ivan V Korsakov, Vladimir G Maslov, Finn Purcell Milton, Joseph Govan, Alexander V Baranov, Anatoly V Fedorov, Yurii K Gun'ko. Molecular Recognition of Biomolecules by Chiral CdSe Quantum Dots. Scientific Reports, 6, 24177 (2016)

Finn Purcell-Milton, Joseph Govan, **Maria V Mukhina,** and Yurii K. Gun'ko. The chiral nano-world: chiroptically active quantum nanostructures. Nanoscale Horizons, 1, 14-26 (2016)

‡**Maria V. Mukhina**, Vladimir G. Maslov, Alexander V. Baranov, Anatoly V. Fedorov, Anna O. Orlova, Finn Purcell-Milton, Joseph Govan, and Yurii K. Gun'ko. Intrinsic Chirality of CdSe/ZnS Quantum Dots and Quantum Rods. Nano Letters, 15 (5), 2844-2851 (2015)

Mícheál P Moloney, Joseph Govan, Alexander Loudon, **Maria Mukhina**, Yurii K Gun'ko. Preparation of chiral quantum dots. Nature Protocols, 10(4) 558-573 (2015)

M.V. Mukhina, V.G. Maslov, A.V. Baranov, M.V. Artemyev, A.O. Orlova, A.V. Fedorov**.** Anisotropy of optical transitions in ordered ensemble of CdSe quantum rods. Optics Letters, 38(17) 3426-3428 (2013)

M.V. Mukhina, V.G. Maslov, A.V. Baranov, A.V. Fedorov**,** K. Berwick. Photoinduced anisotropy in an ensemble of CdSe/ZnS quantum rods. RSC Advances, 3 20746-20749 (2013)

M.V. Mukhina, V.V. Danilov, A.O. Orlova, A.V. Fedorov, M.V. Artemyev, A.V. Baranov. Electrically controlled polarized photoluminescence of CdSe/ZnS nanorods embedded in a liquid crystal template. Nanotechnology, 23(32) 325101(1-6) (2012)

PATENTS

Baranov A., V.; Gunko Ju., K.; Maslov V., G.; Mukhina M., V.; Orlova A., O., Fedorov A., V. Method for Phase-Transfer of Inorganic Colloidal Semiconductor Nanocrystals. *RU2583097C2*, 2014-09-12

MICROSCOPY SOFTWARE AND HARDWARE

mariavmukhina.github.io

SCIENTIFIC SKILLS

Microscopy

Optical design

Super-resolution localization microscopy

Custom control software for microscopy

TTL circuits; printed circuit board design

Arduino; Diptrace; Zeemax

Microfluidics

Image processing and data analysis

In vivo image processing (denoising/segmentation/spot tracing)

Analysis of multi-dimensional datasets

Statistical analysis

Fast Fourier Transform (FFT) analysis

MATLAB, Python

CellProfiler, FIJI, ilastik

Nanophysics/Bioengineering/Spectroscopy

Condensed matter physics

Semiconductor/dislocation/microplasticity theory

Physics of nanostructures

Surface chemistry of nanostructures

Intracellular nanoprobes

Click chemistry

CRISPR dCas9 labeling

DNA origami design/synthesis

PL/UV-Vis/CD/CPL spectroscopy

Cell and molecular biology

Cell culture techniques/aseptic technique

In vivo imaging assays

PCR; gel electrophoresis

RECENT TALKS

2022	Institute Curie, online, France (**invited seminar**)
2022	Mechano-Genomics Seminar Series, online, Switzerland
2022	AEP Cornell, Ithaca, NY, USA (**invited seminar**)
2022	Bioengineering Department, Northeastern University, online, USA (**invited seminar**)
2021	Cell Bio Virtual 2021 - An Online ASCB|EMBO Meeting, online, USA
2021	EMBL Symposium «Seeing is Believing: Imaging the Molecular Processes of Life», online, Germany
2020	International Titisee Conference on Genome folding: physics and function, online, Germany
2019	MRS Fall Meeting 2019, Boston, MA, USA
2016	PCNSPA Conference 2016 - Photonic Colloidal Nanostructures: Synthesis, Properties, and Applications, Saint Petersburg, Russia
2015	Workshop «Nanoscale Assemblies of Semiconductor Nanocrystals, Metal Nanoparticles and Single Molecules: Theory, Experiment and Application», Max-Planck-Institut für Physik komplexer Systeme, Dresden, Germany
2015	MRS Spring Meeting 2015, San Francisco, CA, USA
2013	2013 World Congress on Advances in Nano, Biomechanics, Robotics, and Energy Research, Soul, South Korea

LEADERSHIP AND OUTREACH

ITMO Grant for Young Scientists: as the Principal Investigator, I led the group of 7 people, whose projects I formulated and guided; the project resulted in 4 peer-reviewed publications (2015-2016)

Mentor to 5 undergraduate and 2 graduate students, one of which won ITMO Best Master Thesis Award 2016

The Kleckner Lab: as laser and microscopy safety officer, I am responsible for training new group members and microscope maintenance; I introduced SOPs for the microscopes to improve safety culture; also, I volunteered to create and maintain the lab Slack channel sustaining the sense of community in COVID times

Science Mentoring Workshop Intensives for postdoctoral fellows who are mentoring Harvard undergraduates in the laboratory (2021)

Mentor at The Science Mentors, the program supports junior scholars by connecting them to their more senior colleagues all around the world (18 countries) in mentor-mentee pairs, since 2021

Volunteer at Sena Institute of Technology (SIT), the first private nonprofit research center dedicated to fundamental science in Ghana, since 2017; speaker at SIT African Seminar Series (2021)

Member of FAS Postdoctoral Association; after having a baby, I turned into an advocate for affordable childcare for Harvard postdocs, since 2022

REFERENCES

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