QUANTUM-NANOMATERIALS & DEVICES WORKSHOP PROGRAM

16 October, 2023

8:45 AM - 2:00 PM

QNC 0101

AGENDA

16 OCTOBER

Start	End	Event	Location
8:45	**9:00**	**Breakfast**	QNC 0101
9:00	**9:15**	**Opening Remarks**	
9:00	9:05	**Bernard Duncker,** Associate Vice-President (Research and International)	
9:05	9:10	**Sushanta Mitra**, WIN Executive Director	
9:10	9:15	**Norbert Lütkenhaus**, IQC Executive Director	
9:15	**11:15**	**Technical Presentations**	
9:15	9:30	**Jonathan Baugh,** Chemistry, WIN & IQC	
9:35	9:50	**Adrian Lupascu,** Physics and Astronomy, WIN & IQC	
9:55	10:10	**Dmytro Dubyna,** representing Chris Wilson, Electrical and Computer Engineering, IQC	
10:15	10:30	**Holger Kleinke,** Chemistry, WIN	
10:35	10:50	**Fan Ye** representing Kevin Musselman, Mechanical and Mechatronics Engineering, WIN	
10:55	11:10	**Michael Pope,** Chemical Engineering, WIN	
11:15	**12:15**	**WIN DLS & Keynote Speaker:** **Jiwoong Park,** Chemistry, University of Chicago	
12:15	12:30	Q&A	
12:30		**Networking Lunch & Poster Session**	

PRESENTERS

Jonathan Baugh

Professor
Chemistry
IQC & WIN
University of Waterloo

Jonathan Baugh is working toward the physical realization of quantum information processors in solid-state semiconductor devices. Past work has focused magnetic resonance of electron and nuclear spins, with more recent work on quantum transport in low-dimensional systems such as 2D electron/hole gases, nanowires and quantum dots. Prior to joining IQC and the Department of Chemistry in 2007, he was a JSPS Fellow at the University of Tokyo. He was previously a Postdoctoral Fellow at IQC, and received a PhD in Physics in 2001 from the University of North Carolina at Chapel Hill.

PRESENTATION:

InSb Surface Quantum Wells for Proximity Superconductivity

We report on transport characteristics of field effect two-dimensional electron gases (2DEGs) in surface indium antimonide (InSb) quantum wells. The topmost 5 nm of the 30 nm wide quantum well is doped and shown to promote the formation of reliable, low resistance Ohmic contacts to surface InSb 2DEGs. High quality single-subband magnetotransport with clear quantized integer quantum Hall plateaus is observed to filling factor $\nu = 1$ in magnetic fields up to $B = 18$ T. We show that the electron density is gate-tunable, reproducible, and stable, with peak mobilities exceeding 24,000 cm2/Vs. Large Rashba spin–orbit coefficients are obtained through weak anti-localization measurements. We conclude that this InSb surface quantum well system is a promising platform for realizing Majorana zero modes, i.e. topological qubits.

PRESENTERS

Adrian Lupascu

Associate Professor
Physics and Astronomy
IQC & WIN
University of Waterloo

Adrian Lupascu received his PhD at Delft University of Technology in 2005, working under the supervision of Professor J. E. Mooij on the development of quantum measurements for superconducting qubits. After a short postdoctoral position in Delft, he became a Postdoctoral Fellow at Ecole Normale Superieure Paris, in the group led by Professor S. Haroche, where he did research on trapping of cold atoms in superconducting traps, Rydberg atoms, and superconducting detectors. He joined the Institute for Quantum Computing and the Department of Physics and Astronomy at the University of Waterloo in March 2009. Lupascu is the recipient of the Marie-Curie postdoctoral fellowship (2007), the Alfred P. Sloan Research Fellowship award (2011), and Ministry of Research and Innovation Early Researcher award (2011), and the Waterloo Institute for Nanotechnology Research Leader Award (2018, 2022). Lupascu's current research is in the area of superconducting devices, and includes topics ranging from fundamental studies in quantum mechanics to applications in quantum information. The main topics of research currently are the improvement of coherence of superconducting devices, encoding information in multilevel systems, quantum sensing, and fundamentals investigations of open quantum system.

PRESENTATION:

Superconducting Quantum Devices – A Platform for Quantum Computing and Quantum Sensing

Superconducting qubits are currently one of the most promising candidates for implementation of quantum computers and a promising platform for quantum sensing. I will discuss some of our recent work that has particularly strong connections with the field of nanotechnology. The first topic is the development of a new method for advanced microfabrication of these circuits, focused on the development of air-bridge crossovers based on a grayscale electron beam lithography process. The second topic is the development of quantum sensors, with potential prospects for probing materials and devices at the nanoscale. Finally, I will discuss the connections between quantum coherence in superconducting devices and nanoscale material properties.

Dmytro Dubyna

Representing Chris Wilson
Electrical and Computer Engineering
IQC
University of Waterloo

PRESENTATION:

Robustness Test of Topological States in Su-Schrieffer–Heeger Model

Just like in the second half of the twentieth century electronic analog computers have been used for simulating dynamics of classical systems while digital computers were in embryonic state, nowadays, analog quantum simulators (AQSs)AQSs reveal dynamics of complex quantum systems while the emergence of full-scale quantum computers is yet to come. Our AQS is a superconducting quarter-wave coplanar waveguide resonator which is terminated by an asymmetric Superconducting Quantum Interference Device (SQUID). In particularly, I'm going to presentWe present results on simulating the Su-Schrieffer–Heeger (SSH) model, which is paradigmatic topological model. We realized different topological states depending on the intercell-intracell coupling ratio and the parity of the sites in the SSH lattice. We also tested robustness of topological states against disorders in the both coupling strengths and site energies by injecting into the lattice a squeezed state and measuring cross-correlation between sites of the lattice. This work is complimentary to works published by our group on simulating bosonic Creutz ladder [Phys. Rev. Lett., 127, 100503 (2021)1] and bosonic Kitaev chain [arXiv:2309.061782] that demonstrate that superconducting parametric cavity is a flexible and programmable platform for AQS.

1. J.S.C. Hung, J.H. Busnaina, C.W.S. Chang, A.M. Vadiraj, I. Nsanzineza, E. Solano, H. Alaeian, E. Rico, and C.M. Wilson, Phys. Rev. Lett., 127, 100503 (2021).
2. J.H. Busnaina, Z. Shi, A. McDonald, D. Dubyna, I. Nsanzineza, J.S.C. Hung, C.W.S. Chang, A.A. Clerk, and C.M. Wilson, arXiv:2309.06178 (2023).Phys. Rev. Lett., 127, 100503 (2021)

PRESENTERS

Holger Kleinke

Chemistry
WIN
University of Waterloo

Holger Kleinke's research focuses on finding and optimizing new thermoelectric materials. Thermoelectrics are capable of converting heat into electrical energy and vice versa. This environmentally friendly energy conversion currently has several applications, but is limited by its low efficiency. His research group is attempting to increase the efficiency so that thermoelectrics may be used to recover electricity from the nowadays abundant waste heat, e.g. in the exhaust of automobiles. One of Holger Kleinke's newest projects is to utilize Cu ion mobility to lower the thermal conductivity of thermoelectric materials. This mobility has to be localized within each unit cell in order to inhibit Cu ion migration throughout the material, which would otherwise cause device degradation. Since the thermoelectric properties depend on the thermopower as well as on the electrical and thermal conductivity, various property measurements are routinely carried out in the group. The syntheses are guided by calculations performed by students who are fascinated by the theoretical aspects of chemical research.

PRESENTATION:

Thermoelectric Quantum Materials: Bismuth Chalcogenides

An intriguing correlation exists between two physical phenomena, namely the thermoelectric effect and the topological insulation. The thermoelectric effect may be used to convert waste heat into useful electricity, for example from automobile engines and industrial processes and body heat. Practical applications of topological insulators are still scarce, but the thermoelectric energy conversion may be one of those in the near future. As presented in my talk, several materials are doubling up as both thermoelectric materials and topological insulators.

PRESENTERS

Fan Ye

Representing Kevin Musselman
Mechanical and Mechatronics Engineering
WIN
University of Waterloo

Dr. Fan Ye is currently a postdoctoral fellow in Prof. Kevin Musselman's group at the University of Waterloo. After completing his M.Sc. in mechanical engineering at the University of Saskatchewan and working in industry for two years, he joined Prof. Musselman's group for his PhD. His PhD project involved using a femtosecond laser to synthesize nanomaterials for photothermal cancer therapy. His research interests focused on exploring light-matter interactions in the ablation process and investigating the formation mechanisms of nanomaterials. His current interests also include controlling the shape of nanomaterials produced by pulsed laser ablation in liquid and exploring the applications of laser-synthesized nanomaterials.

PRESENTATION:

Synthesis of Nanomaterials by Femtosecond Laser Ablation of Powders in Liquids

With the growing applications of nanomaterials in various fields such as semiconductor, medicine, energy, catalysis, etc., the interest in novel synthesis methods is also increasing. Conventional approaches to prepare nanomaterials, including top-down and bottom-up methods, require either high temperatures or extended periods. Pulsed laser ablation in liquid (PLAL) has been proven to be a simple and efficient method for preparing colloidal nanomaterials, as it can operate at room temperature and in atmosphere. It can be used to ablate a bulk target immersed in liquid or powder dispersed in liquid with a focused pulsed laser beam. Thanks to the high peak intensity of the laser pulses, especially femtosecond laser pulses, the interactions between light and matter create extreme conditions with high temperatures and high pressures locally, leading to efficient ablation of the illuminated materials or chemical reactions that form novel metastable nanomaterials. The first part of my talk introduces the formation of sub-stoichiometric molybdenum oxide (MoO3-X) by reactive laser ablation of molybdenum sulfide (MoS2) powder in water/ethanol mixing solvents, explores the oxidation process of MoS2 and discusses the formation mechanism of blue-colored MoO3-X. The second part focuses on discussing the fragmentation mechanisms of ablated molybdenum selenide powder particles and the formation mechanisms of spherical nanoparticles formed in the early stages of PLAL.

PRESENTERS

Michael Pope

Associate Professor
Chemical Engineering
WIN
University of Waterloo

Prof. Pope is an Associate Professor in the Department of Chemical Engineering at the University of Waterloo (UW) and a member of the Waterloo Institute for Nanotechnology. He received his PhD from Princeton University in 2013 where he studied the production and processing of graphene-based materials into advanced batteries and supercapacitors. After working for two years as a research scientist at one of the world's first graphene companies, Vorbeck Materials, he joined UW and started the 2D Materials & Electrochemistry Group. His research focus is on improving large-scale exfoliation approaches and developing improved processing and integration strategies to incorporate exfoliated 2D materials into devices ranging from batteries to optoelectronics. Pope is the co-lead of an international graduate training program entitled "Scalable 2D-Materials Architectures" or 2D-MATURE involving 19 co-PIs across Canada and Germany.

PRESENTATION:

Understanding the Cathodic, Electrochemical Exfoliation Mechanism of Transition Metal Dichalcogenides

Transition metal dichalcogenides (TMDs) such as molybdenum disulfide (MoS2) exhibit significant layer-dependent changes to their optoelectronic properties. For example, MoS2 exhibits an indirect to direct bandgap transition upon thinning to a single layer which, combined with its high mobility and large absorption co-efficient making it a promising material for future transistors and photodetectors. In particular, exfoliating bulk TMD powders has the potential to produce inks which can be used for coating or printing on arbitrary substrates for applciations such as flexible or wearable electronics. Cathodic electrochemical exfoliation using tetraalkylammonium (TAA) salts has recently been shown to be effective in obtaining large 2D flakes, with lateral size greater than 1 μm and thickness less than 10 nm. Furthermore, employing larger TAA cations is desired over lithium-ion, as the former prevents excess electron injection into the host 2D material preventing unwanted phase transition to the 1T polymorph. In this talk, we discuss our recent efforts to improve upon a TAA-based cathodic electrochemical exfoliation using a novel, powder-based three-electrode electrochemical cell that can exfoliate commercial powder-based MoS2 precursors as opposed to expensive, MoS2 single crystals. To better understand the exfoliation mechanism, we operate this electrochemical cell in an H-cell configuration, with a reference electrode. This allows us to differentiate between intercalation and electrolyte decomposition events which provide useful insights to the exfoliation mechanism. In addition, I will discuss the solution processing of the TMDs and the utility of using solvent compressed Langmuir films to assess sheet size and thickness while probing the average surface area of the exfoliated materials.

WIN DLS & KEYNOTE

Jiwoong Park

Professor and Chair
Chemistry
University of Chicago

Jiwoong Park a professor in Chemistry and Molecular Engineering at the University of Chicago and chair of Department of Chemistry. His research group is working on the science and technology of atomically thin crystalline materials and has developed methods for chemically synthesizing and controlling 2D van der Waals crystals and molecular structures to produce real, large-scale materials useful for future applications. He authored more than 100 journal articles, including about 20 papers in Science and Nature.

He received a B.S. degree from Seoul National University (1996) and a Ph.D. from the University of California, Berkeley (2003; advisor: Prof. Paul McEuen). Before coming to the University of Chicago in 2016, he was a faculty member at Cornell University (2006-2016). Park currently serves as an associate editor of Nano Letters.

PRESENTATION:

Magical 2D Materials

Two dimensional (2D) electron transport has been one of the most important topics in science and technology for decades. It was originally studied in 3D semiconductors, and then continued in 2D van der Waals (vdW) crystals. In this talk, I will start with the large-scale processes for generating 2D crystalline semiconductor films and superlattices that could be used to fabricate atomically thin integrated circuits. Then we will discuss more recent directions, where we use these 2D materials to realize non-electronic, “magical” 2D transport phenomena, observed from phonons, photons, and mass. These new approaches could empower the development of 2D phononics, 2D photonics, and 2D mechanics.

POSTER PRESENTATIONS

Nikhil Barua

PhD Student, Holger Kleinke
Department of Chemistry

Madison Donohoe

PhD Student, Holger Kleinke
Department of Chemistry

Manila Valappil

Post Doctoral Fellow, Michael Pope
Department of Chemical Engineering

Denys Vidish

PhD Student, Kevin Musselman
Department of Engineering