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SPECIAL SEMINAR

March 20th 2023

Seminar Presentation: 9:30am – 10:30am

SME Room 248

"Quantum sensing with diamond at the single- to few-molecule regime"

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Abstract: Quantum sensing using fluorescent atomic-scale defects, such as the nitrogen–vacancy (NV) center in diamond, provides a route toward novel characterization of molecular systems and fresh insight into chemical functionality. Manipulated by light and microwave pulses, the NV enables highly localized detection of nuclear and electron spin dynamics in nearby molecules, analysis of spin and charge transport, and reaction monitoring. While the NV boasts exquisite magnetic-field sensitivity, nanoscale spatial resolution, biocompatibility, and operation under ambient conditions, challenges remain for chemical sensing with shallow (<10-nm-deep) NVs. Specifically, sensing approaches are limited by NV charge instability and spin decoherence near surfaces, while in addition necessitating robust methods of chemical attachment to diamond surfaces. In this talk, I will outline diamond surface engineering strategies needed for optimal termination and functionalization that overcome these challenges. Using defect centers hosted in diamond nanophotonic waveguides, I will show how single NVs can then be used for surface nuclear magnetic resonance (NMR) detection of fewer than 100 small molecules. Our sensing platforms are now being extended to investigate biomolecules covalently bound to the diamond surface. Specifically, we are monitoring conformations in surface-tethered DNA molecules using NV-NMR under varying environmental conditions. Such chemical characterization represents a critical step toward the lofty goal of unambiguous structure elucidation with the NV at the single-molecule level. Finally, I will highlight the capability of NVs to probe electron-spin-dependent and enantioselective charge transfer in chiral molecules resulting from the chiral-induced spin selectivity (CISS) effect. The mechanism and biological significance of CISS remain open questions, and our ongoing work will provide critical insight into relevant electron spin polarization lifetimes and coherences. Collectively, these efforts demonstrate the exciting and rapidly expanding potential of diamond-based quantum sensors to track spin dynamics in chemical systems at the single- to few-molecule level.

Educational Development and Training: I strongly encourage multi- and interdisciplinary approaches to research training in order to cultivate new and creative ideas and solutions to problems. Moreover, it expands one's collaborative network to be much more diverse and vibrant than when focusing on only one field. My winding academic career trajectory has taken me through different disciplines in chemistry, engineering, and physics. This path has not always been easy, and requires effort to strengthen some level of cohesion between knowledge bases and research experiences, as well as to overcome new learning curves. However, the people you work with make all of the difference, and it can be extremely rewarding with the opportunity to work alongside and learn from brilliant scientists and experts across different areas.

Biosketch: John Abendroth is a senior researcher and Swiss National Science Foundation Ambizione grant recipient in the Spin Physics and Imaging Laboratory headed by Prof. Christian Degen at ETH Zurich. He currently leads an independent research program focused on studying spin dynamics and chirality in molecular systems using diamond-based quantum sensors. John previously held postdoc positions in the Department of Physics at ETH Zurich with Prof. Degen and in the Department of Materials Science & Engineering at Stanford University with Prof. Jennifer Dionne. Before that, John earned his PhD in physical chemistry with Prof. Paul Weiss at the University of California, Los Angeles and his BSc in chemistry at the University of Florida.