PURDUE UNIVERSITY

Birck Nanotechnology Center Seminar

Chris Leighton is a Distinguished McKnight University Professor of Chemical Engineering and Materials Science and a graduate faculty member in Physics at the University of Minnesota (UMN). Following a Bachelor's Degree in Physics at the University of Durham in the UK (1994), and a Ph.D. in Condensed Matter Physics at the same institution (1998), he pursued post-doctoral research at UC San Diego under Prof. Ivan Schuller (1998-2001). He joined the Chemical Engineering and Materials Science faculty at UMN in 2001 as an Assistant Professor, rising to Associate Professor in 2007, and Professor in 2011. His research deals with electronic and magnetic properties of novel materials including complex oxides, oxide heterostructures, metallic spintronics, complex alloys, organic conductors, and earth-abundant photovoltaics. He has authored around 210 publications, which have accumulated over 10,500 citations. He has received honors that include the Cozzarelli Prize from the Proceedings of the National Academy of Sciences, Fellowship in the American Physical Society (APS) and the Institute of Electrical and Electronics Engineers (IEEE), and UMN's Taylor Career Development Award, McKnight Presidential Fellowship, Taylor Distinguished Research Award, Amundson Professorship, Distinguished McKnight University Professorship, and Tate Award for Undergraduate Advising. He serves as Lead Editor of the APS journal *Physical Review Materials*.

Electrolyte Gating of Functional Materials

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Monday, April 6, 2020

1:30pm in BRK 1001

Abstract: Recently, incorporation of electrolytes such as ionic liquids into field-effect transistors has been shown to enable electric double layer transistors (EDLTs), which can induce very large (up to 10^{15} cm^{-2}) charge carrier densities at surfaces. These densities correspond to significant fractions of an electron or hole per unit cell in most materials, sufficient to *electrically control* electronic phase transitions. While this has stimulated great interest, challenges remain, including understanding the gating mechanisms (electrostatic *vs*. electrochemical), developing *operando* characterization, and assessing the full power and universality of the approach. Here, after some description of our work applying this method to organic semiconductors [1,2], I will review electrolyte gating of functional oxides (*e.g*., $La_{1-x}Sr_xCoO_{3-\delta}$) using solid ion gels, focused on electrical control of magnetism [3-6]. The latter is an important goal, with high potential for ultra-low-power data storage and processing. Our findings greatly clarify the issue of electrostatic *vs*. electrochemical response, culminating in a picture where electrostatic gating *vs*. oxygen vacancy creation/ annihilation can be understood and predicted based on bias polarity, and the enthalpy of formation and diffusivity of oxygen vacancies [3-8]. This was achieved *via* development of *operando* probes, such as synchrotron X-ray diffraction [4,8] and neutron reflectometry [4,5]. Electrical control of magnetism in $La_{1-x}Sr_xCoO_{3-\delta}$ is then demonstrated using both electrochemistry and electrostatics, yielding modulation of the ferromagnetic Curie temperature over record 200 K and 160 windows, respectively [4,5].

[1] S. Wang, M. Ha, M. Manno, C.D. Frisbie and C. Leighton, *Nat. Commun*. **3**, 1210 (2012).
[2] W. Xie, S. Wang, X. Zhang, C. Leighton and C.D. Frisbie, *Phys. Rev. Lett*. **113**, 246602 (2014).
[3] J. Walter, H. Wang, B. Luo and C. Leighton, *ACS Nano* **10**, 7799 (2016).
[4] J. Walter, G. Yu, B. Yu, A. Grutter, B. Kirby, J. Borchers, Z. Zhang, H. Zhou, T. Birol, M. Greven, and C. Leighton, *Phys. Rev. Mater*ials **1**, 071403(R) (2017).
[5] J. Walter, T. Charlton, H. Ambaye, M. Fitzsimmons, P.Orth, R. Fernandes, B. Shklovskii and C. Leighton, *Phys. Rev. Mater*ials **2**, 111406(R) (2018).
[6] P.P. Orth, R.M. Fernandes, J. Walter, C. Leighton and B.I. Shklovskii, *Phys. Rev. Lett*. **118**, 106801 (2017).
[7] C. Leighton, *Nat. Mater.* **18**, 13 (2019).
[8] H. Wang, J. Walter, K. Ganguly, B. Yu, G. Yu, H. Fu, M. Greven and C. Leighton, *Phys. Rev. Mater*ials **3**, 075001 (2019).

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