**Electrochemistry of Nanoconfined electrolytes**

Conductive nanosized pores are at the heart of cutting-edge science and technology, playing a particularly important role in capacitive energy storage. In these lectures, I will begin with a concise overview of the key properties of room-temperature ionic liquids and concentrated electrolytes, as well as microporous electrodes, central to electrical double-layer capacitors. We will then delve into the fascinating physics of confined ions [1], uncovering phenomena such as the emergence of a superionic state [2], the intriguing effects of ionophobicity [3], and the role of quantum capacitance in electrodes [4]. A central focus will be steps toward maximizing energy storage efficiency [3-6]. Notably, we will reveal the counterintuitive benefits of ionophobic pores [3,7], examine how the separation between electrodes in an electrical double-layer capacitor can influence performance [6], and how low quantum capacitance can paradoxically enhance energy storage [4].

A special focus will be placed on the dynamics of ions, exploring the nuances of in-pore ion mobility [7-9] and the complex charging and discharging behaviors [10,11]. Despite extensive research, a consensus remains elusive regarding ion diffusion, as simulations and experiments present conflicting results [7-9]. We will explore diverse charging regimes [10], revealing how nanopore clogging fundamentally slows the charging process. Finally, I will highlight innovative strategies proposed to accelerate both charging [7,10,11] and discharging [11] dynamics, offering a glimpse into the future of faster, more efficient energy storage solutions.

**References:**

1. Kondrat, Feng, Bresme, Urbakh and Kornyshev, Theory and Simulations of Ionic Liquids in Nanoconfinement*,* [*Chem. Rev.*, **123**, 6668 (2023)](https://doi.org/10.1021/acs.chemrev.2c00728)
2. Kondrat and Kornyshev, Superionic state in double-layer capacitors with nanoporous electrodes, [*J. Phys.: Condens. Matter* **23** 022201 (2011)](https://iopscience.iop.org/article/10.1088/0953-8984/23/2/022201)
3. Kondrat and Kornyshev, Pressing a spring: what does it take to maximize the energy storage in nanoporous supercapacitors? [*Nanoscale Horiz.* **1**, 45-52 (2016)](https://doi.org/10.1039/C5NH00004A)
4. Verkholyak, Kuzmak, Kornyshev, Kondrat, Less is more: can low quantum capacitance boost capacitive energy storage? [*J. Phys. Chem. Lett.* **13**, 10976–10980 (2022)](https://doi.org/10.1021/acs.jpclett.2c02968)
5. Seltmann, Verkholyak, Gołowicz, Pameté, Kuzmak, Presser, and Svyatoslav Kondrat, Effect of cation size of binary cation ionic liquid mixtures on capacitive energy storage, [J. Mol. Liq. **391** 123369 (2023)](https://doi.org/10.1016/j.molliq.2023.123369)
6. Paolini, Antony, Raju, Kuzmak, Verkholyak, and Kondrat, Tuning Electrode and Separator Sizes For Enhanced Performance of Electrical Double-Layer Capacitors, [*ChemElectroChem* e202400218 (2024)](https://doi.org/10.1002/celc.202400218)
7. Kondrat, Wu, Quiao, and Kornyshev, Accelerating charging dynamics in subnanometre pores*,* [*Nature Mater.* **13**, 387 (2014)](https://doi.org/10.1038/nmat3916)
8. Péan, Merlet, Rotenberg, Madden, Taberna, Daffos, Salanne, and Simon, On the Dynamics of Charging in Nanoporous Carbon-Based Supercapacitors, [*ACS Nano* 8, 1576 (2014)](https://doi.org/10.1021/nn4058243)
9. Forse, Griffin, Merlet, Carretero-Gonzalez, Raji, Trease, and Grey, Direct observation of ion dynamics in supercapacitor electrodes using in situ diffusion NMR spectroscopy, [*Nat Energy* **2**, 16216 (2017)](https://doi.org/10.1038/nenergy.2016.216)
10. Breitsprecher, Holm, Kondrat, Charge Me Slowly, I Am in a Hurry: Optimizing Charge–Discharge Cycles in Nanoporous Supercapacitors, [*ACS Nano*, **12**, 9733 (2018)](https://doi.org/10.1021/acsnano.8b04785)
11. Breitsprecher, Janssen, Srimuk, Mehdi, Presser, Holm, Kondrat, How to speed up ion transport in nanopores, [*Nat Commun* **11**, 6085 (2020)](https://doi.org/10.1038/s41467-020-19903-6)