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The essential physics of supercapacitors and electroactuators at the nanoscale: electricity vs mechanics

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This lecture will discuss the science behind one of the hot and rapidly developing areas of energy harvesting and storage: electrolytic supercapacitors and electroactuators using ionic liquids as electrolytes*. It will focus on the following points.

1. Charge storage equilibria: from flat interfaces to nanoscale pores:

a) Electrical double layer and electrical capacitance at flat electrodes with ionic liquids.
b) Water as a 'poison'; electrosorption of water.
c) Renormalized interionic interactions in nanoconfinement: the superionic state in a nanopore.
d) Approximate and exactly solvable models of charge storage: the capacitance of single cylindrical and slit pores as a function of voltage and the size of the pore; calculating the stored energy.
e) The effect of pore size distribution and complexity of the pore space.

2. Charging dynamics and the laws of ion transport in nanoconfinement: theory versus simulations:

a) Charging of quasi single file pores.
b) Charging of slit pores. Cyclic voltammetry.

3. The energy-to-power trade-off: new optimization scenarios, and nano-engineering of electrodes. The "pressing-a-spring" concept and ionophobic pores.

4. Leading-to-degradation: the unwanted 'electroactuation' of supercapacitors (some first experiments and theories)

5. Electricity vs mechanics vs electricity: the 'wanted' electroactuation of a capacitor with bendable plates and single-mobile ion-carrier membranes:

a) Equilibrium laws and the 'electroactuation number'.
b) Electroactuation dynamics.

* References to pertinent literature will be presented during the lecture and would be available upon request.

Keywords: Nanoporous electrodes, supercapacitors, charging dynamics, stored energy, electrostatics, ionic liquids, electroactuation