

Electrochemistry under confinement: 2D materials for energy storage applications

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The understanding of electrolyte ion dynamics at the electrolyte/electrode interface as well as the organization of ions in the bulk of active material is of key importance for improving the charge storage in battery electrodes. The degree of interaction between ions and the host material is highly related to the charge storage mechanism, with mainly two processes clearly identified, with (1) purely electrostatic, non-Faradaic electrosorption of fully solvated ions forming the electric double layer (EDL), known as the capacitive storage, and (2) a purely Faradaic process with full charge transfer to the host material following by the intercalation of fully desolvated ions such as Li, Na... occurring in the last generation of metal-ion battery electrodes (see Figure).

In this work, we used 2D materials as model materials to understand how the confinement of electrolyte between the interlayer spacing affects the charge storage capacity by using advanced electrochemical techniques.

Electrochemical Quartz Crystal Microbalance (EQCM), Electrochemical Dilatometry (ECD) and in-plane electrode impedance spectroscopy techniques were employed to track ion fluxes during cation insertion in 2D materials such as TiS₂, rGO and MXene [1-3]. The results highlight the key role of electrolyte-material interactions and suggest that the observed improvements in electrochemical performance could be attributed to partial desolvation of electrolyte ions due to their confinement in interlayer spacing [3,4].°

Understanding confined electrochemical systems and coupling between chemical, electrochemical, and transport processes in confinement may open tremendous opportunities for designing materials with improved performance for energy storage applications.

References

- [1] J. Miranda-Castro, G. Franklin, T. S. Mathis, P.L. Taberna, P. Simon, *Energy Storage Materials*, 65, (2024), 103105
- [2] K. Ge, H. Shao, E. Raymundo-Piñero, P.-L. Taberna & P. Simon, *Nature Communications* 15, 1935 (2024).
- [3] Z. Bo et al., *Nature Communications* (in press, 2025).
- [4] Fleischmann, S. et al. *Nat. Energy* 7, 222-228 (2022).

Figures

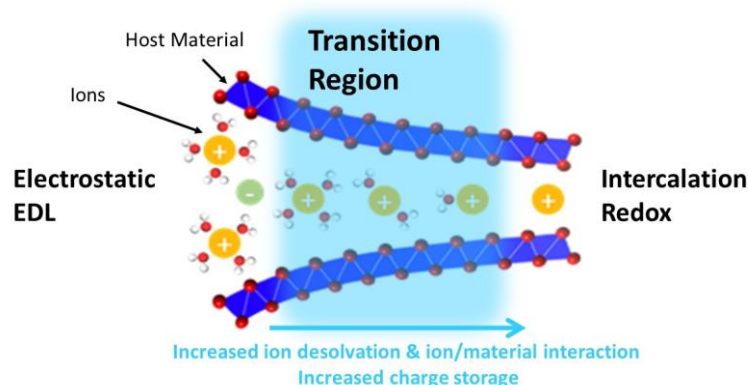


Figure 1: Transition in the charge storage mechanism when increasing the confinement of ions inserted in a host structure. The ion desolvation resulting from confinement increases the capacity.