Cooperative Jahn-Teller effect and engineered long-range strain in manganese oxide/graphene superlattice for aqueous zinc-ion batteries

Kun Huang, Rahul Raveendran Nair, Guoxiu Wang
National Graphene Institute, Booth Street East, Manchester, United Kingdom, M13 9SS
kun.huang-4@manchester.ac.uk

Abstract (Arial 10)

The Jahn-Teller and cooperative Jahn-Teller effects are phenomena that induce asymmetry in individual ions and solid-state lattices and are commonly observed in structures containing specific transition metals, such as copper and manganese. Although the Jahn-Teller effect causes lattice distortions that stress electrode materials in rechargeable batteries, strategically utilising the strain generated by cooperative Jahn-Teller distortions can enhance structural stability. Here we introduce the cooperative Jahn-Teller effect on MnO_2 by constructing a two-dimensional superlattice structure with graphene crated in the bulk MnO_2/graphene composite material. The strong interaction between MnO_2 and graphene increases the concentration of high-spin Mn^{3+} ions, creating orderly long-range biaxial strains that are compressive in the out-of-plane direction and tensile in the in-plane direction. These strains mitigate Zn^{2+} intercalation stress and proton corrosion, enabling over 5000 cycles with 165 mAh g^{-1} capacity retention at 5 C (1 C = 308 mA g^{-1}) in aqueous zinc-ion batteries. Our approach offers an effective strategy to significantly enhance the lifetime of rechargeable batteries by introducing the cooperative Jahn-Teller effect that overcomes the stress of ion insertion in electrode materials.

References

[1] Wang, S., Guo, X., Huang, K. *et al.* Cooperative Jahn-Teller effect and engineered long-range strain in manganese oxide/graphene superlattice for aqueous zinc-ion batteries. *Nat Commun* **16**, 5191 (2025).

Figures

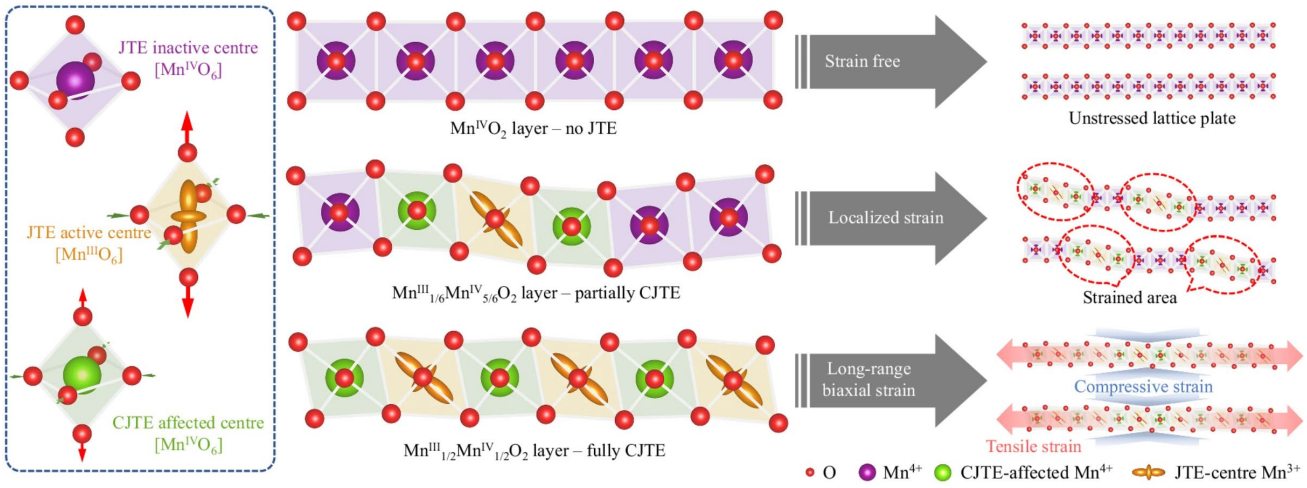

Figure 1: Schematic illustration depicting the distinct structural scenarios in layered MnO_2, including no Jahn-Teller effect (JTE), partially cooperative Jahn-Teller effect (CJTE), and fully CJTE