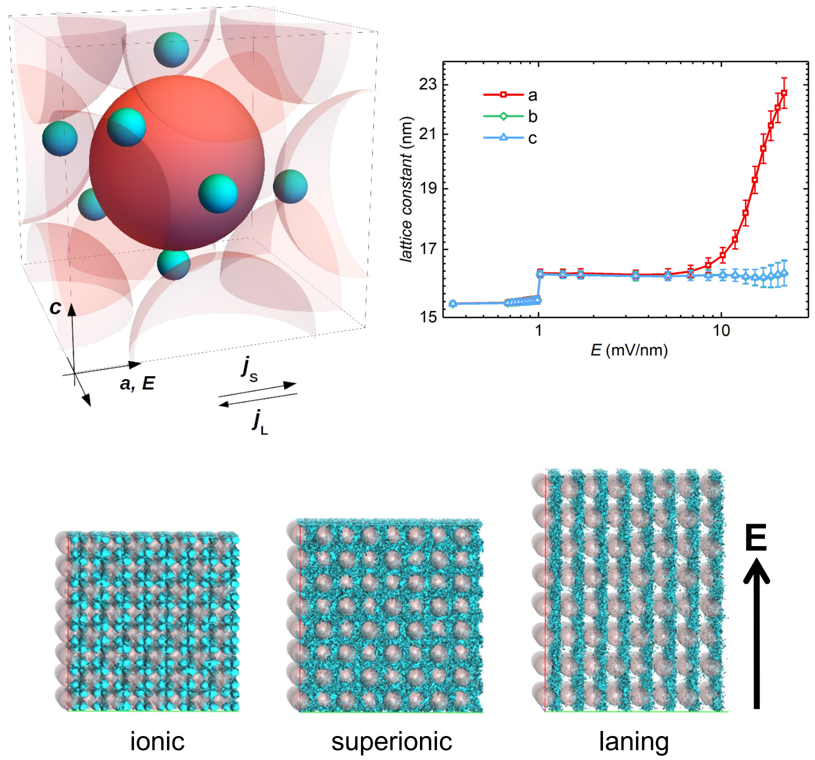
Colloidal Superionic Conductors



Field-induced phenomena in charged colloidal crystal. (Top left) A scheme of the simulation model. (Top right) The lattice constants in three dimensions as functions of the field strength. (Bottom) The structural transitions of the crystal from ionic to superionic to laning.

Y. Lin, & M. Olvera de la Cruz, (2023). Colloidal superionic conductors. PNAS, 120(15), e2300257120.

Scientific Achievement

We find the electric-field-induced superionicity in size-asymmetric charged colloidal crystals via the computer simulation. When the strength of applied field exceeds a certain value, the mobility of colloidal particles exhibits a dramatic increase and is comparable to ion mobilities in the water. We observe the lane formation as well as a lattice elongation by further enhancing the field, marking the transport limit. Moreover, we explain the particle diffusion by a linear transport model. Finally, we validate the tradeoff relationship between a higher dissipation and more precise charge currents. We prove this relationship is controlled by the damping degree of the system.

Superionic conductors are promising materials for the next-generation of solid-state batteries. Our results deepen the understanding of the dependence of charge carrier density and the diffusion mechanism, which are vital for the design of new superionic materials. Also, we confirm the possibility of colloidal crystals with switchable superionicity.

Research Details

- Simulate the colloidal crystal with underdampled Langevin dynamics using a coarse-grained model.
- Sample the dynamic quantities and fit them by the transport model.
- Derive the product of the dissipation and the precision of currents, and validate it by the simulation data.