Nanoscale diffusion and interactions of ligand-passivated colloidal nanoparticles directly observed by quantitative graphene liquid cell transmission electron microscopy

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The diffusion of colloidal nanoparticles in liquid and their interactions with each other are of fundamental importance in nanoscience but are difficult to access quantitatively, primarily because of the absence of the proper analytical tools and interpretations that can describe the dynamics of individual particles at the nanoscale. Here, we directly tracked the motion of gold nanoparticles with a diameter less than 5 nm using graphene liquid cell (GLC) transmission electron microscopy (TEM), and quantitatively interpreted the observed motion with a new theoretical model developed for nanoparticle dynamics. The nanoparticles in a GLC show diffusive motion in a dynamically heterogeneous environment, likely due to confined geometries and surface-passivating ligands on the nanoparticle surface. Furthermore, our extensive statistical and kinetic analysis on the motion of nanoparticles reveals surface-passivating ligands play a critical role in the formation of a transient nanoparticle complex and the subsequent coalescence of nanoparticles.