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Brownian motion of DNA-functionalized magnetic nanoparticles

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Brownian motion provides access to hydrodynamic properties of nanoscale objects independent of their optical resolvability. Here, we present a diffusion-based approach to infer effective particle size distributions of DNA-functionalized nanoparticles in a regime where direct geometric sizing is limited by optical diffraction. Using multi-particle tracking microscopy, we analyze the Brownian dynamics of polystyrene beads grafted with double-stranded DNA (dsDNA) of varying contour length under low-salt conditions. A physically motivated model is introduced that relates dsDNA contour length to an effective hydrodynamic diameter via an attenuated corona description. The measured diffusion coefficient distributions exhibit a systematic and monotonic dependence on dsDNA length in quantitative agreement with the model. While the tracked objects are predominantly dsDNA-mediated agglomerates rather than isolated nanoparticles, clustering does not obscure the length-dependent signal. Instead, the dsDNA corona determines the hydrodynamic scaling, whereas agglomeration mainly introduces an offset and distribution broadening. These results demonstrate that Brownian dynamics enables robust readout of biomolecular length scales even far below the optical resolution limit. The distribution-based approach is inherently tolerant to polydispersity and aggregation, making diffusion-based tracking a simple and promising strategy for future biotechnological and biomedical assays.

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