Drag Reduction by DNA-grafting for Single Microspheres in a Dilute λ-DNA Solution

The fluid resistance of single micrometre-sized blank and DNA-grafted polystyrene microspheres under shear flow is compared in purified water and dilute λ-DNA solutions by means of optical tweezers experiments with a high spatial (±4 nm) and temporal (±0.2 ms) resolution.

The measurement results show that the drag experienced by a colloid in a dilute λ-DNA solution (molecular weight of 48502 bp per molecule, radius of gyration of 0.5 μm) is significantly decreased if the microsphere bears a grafted DNA brush. This newly discovered drag reduction effect is studied for different parameters, comprising the molecular weight of the grafted DNA molecules (250 bp, 1000 bp and 4000 bp), the concentration of the λ-DNA solution (11, 17 and 23 μg ml⁻¹, all being significantly smaller than the critical entanglement concentration), the microsphere core diameter (2 μm, 3 μm and 6 μm) as well as the flow speed of the medium (10 to 50 μm s⁻¹).

The maximum extent of the drag reduction is found to amount to compared to the λ-DNA-induced contribution on the drag acting on blank colloids. We propose a theoretical explanation of this effect based on the combination of the drift diffusion model of Rauscher and co-workers [*c²020%2] and the stagnation length theory of polymer brushes, as it was established by Kim, Lobaskin et al. [3]. In particular, the solution of the Stokes equation (i.e., the Navier-Stokes equation for creeping flow) for the studied system yields a numerical prediction that is found to be in full accord with our experimental results within measurement uncertainty.

References

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