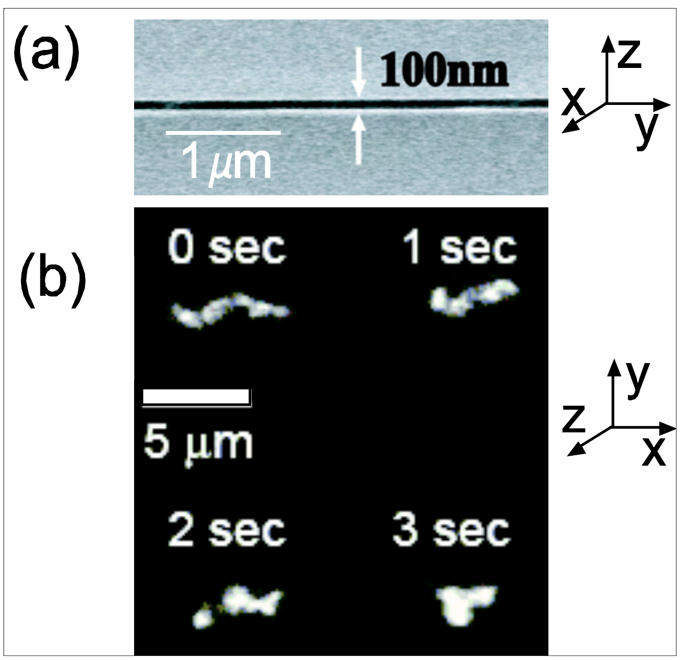
DNA Dynamics in Nanofluidic Devices

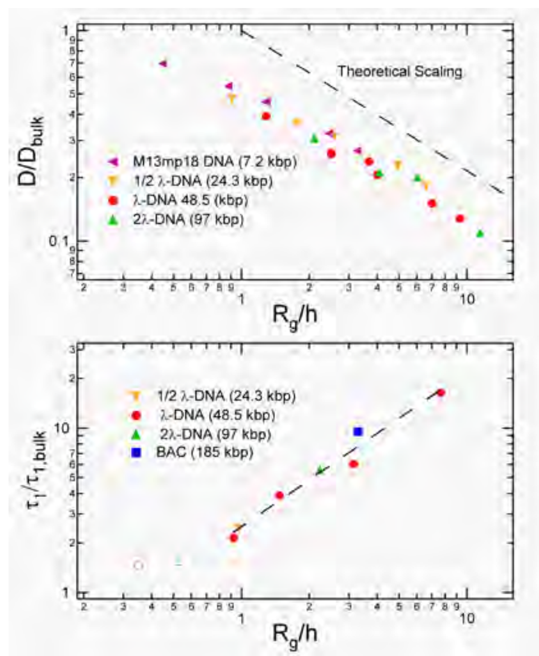
A. Balducci, C.-C. Hsieh, P.S. Doyle

In dilute polymer solutions, the shape, motion, dynamic response, and solvent-interaction (HI) of single polymer molecules change when geometric constraints reach the length scales of the equilibrium polymer conformation. Our study seeks to understand these changes using double-stranded DNA as a model polymer and to utilize these confinement effects to tune the dynamic response of single molecules. This ability is useful in processes that rely on controlling the conformation of a biomolecule for analysis [1] or in the manipulation of molecules for separations and/or reactions

Our experiments [2-3] use thermally-bonded pyrex channels with heights ranging from 75 to 500 nm and widths of 150 μm. The Brownian motion of stained DNA molecules is observed using epi-fluorescence microscopy. By following the time evolution of the center-of-mass and orientation of single molecules, we can obtain the diffusion coefficient (D) and longest relaxation time (τ_1) of the polymer independently. We find that scalings with molecular weight of both D and τ_1 agree with a free-draining polymer model, indicating that, in contrast to bulk solution, HI is not important in slit confinement at length scales comparable to the size of the molecule. We find that the relaxation time of the polymer increases with confinement, which promises easier manipulation of DNA conformations. Our results in well-defined nanofluidic devices may also provide insight into polymer behavior in the less-controlled confinement that occurs in concentrated polymer solutions. We are currently working to stretch DNA in confinement and to study the effects of confinement far from the equilibrium conformation of the polymer



▲ Figure 1: (a) An SEM micrograph of a 100-nm-tall channel. (b) Time-series images of a single 97-kbp DNA molecule undergoing Brownian motion in a 500-nm-tall channel.



▲ Figure 2: Variables D and τ_1 normalized by their bulk values versus a measure of confinement (equilibrium radius divided by gap height) for DNA molecules of varying molecular weight.

REFERENCES

[1] E.Y. Chan, N.M. Goncalves, R.A. Haeusler, A.J. Hatch, J.W. Larson, A.M. Maletta, G.R. Yantz, E.D. Carstea, M.Fuchs, G.G. Wong, S.R. Gullans, and R. Gilmanshin, "DNA Mapping using microfluidic stretching and single-molecule detection of fluorescent site-specific tags," *Genome Research*, vol. 14, no. 6, pp. 1137-1146, June 2004.

[2] A. Balducci, P. Mao, J. Han, and P.S. Doyle, "Double-stranded DNA diffusion in slitlike nanochannels," *Macromolecules*, vol. 39, no. 18, pp. 623-628, Aug. 2006.

[3] C.-C. Hsieh, A. Balducci, and P.S. Doyle, "An experimental study of DNA rotational relaxation time in nanoslits," *Macromolecules*, to be published.