Fabrication and Characterization of Nanofluidic Channels for Studying Molecular Dynamics in Confined Environments

P. Mao, J. Han, M. Previte, P.T.C. So, A.G. Balducci, P.S. Doyle

Sponsorship: MIT Lincoln Lab, NSF NSE and CAREER program

Hindered transport of macromolecules in liquid-filled pores is important to biological membrane processes associated with cell biology and medical physiology, chromatography, separation, and heterogeneous catalysis [1]. It is highly desirable to conduct well-controlled, model-based studies of molecular and fluidic transport process in a confined space. Compared to nanoporous track-etched membranes, micromachined nanofluidic structures offer unique advantages, including well-controlled physical and chemical properties, compatibility with various single molecule detection (SMD) methods, and easy integration to µTAS [2]. We characterized glass-glass and glass-Si bonding processes for the fabrication of nanofluidic channels as thin as 20 nm (Figure 1). We demonstrated that glass-glass nanofluidic channels as thin as 25 nm, with a high aspect ratio of 2000 (width to depth), can be achieved with this glass-glass bonding technique. We also found that silicon-glass nanofluidic channels, as thin as 20 nm, with an aspect ratio of 250, can be reliably obtained with the anodic bonding technique. Cross-sectional scanning electron microscopy (SEM) analysis after bonding was performed to prove that there is no significant change in the depth of the nanofluidic channels due to anodic bonding and glass-glass fusion bonding processes [3]. We examined the conformation and diffusion of a single λ-DNA molecule confined in a slit glass nanochannel using epifluorescence video microscopy (Figure 2(A)) [4]. The diffusivity is characterized as a function of the degree of chain confinement (depth of the channel). In addition, the effects of spatial confinement and surface boundary layer on the diffusivity of small biomolecules within a nanochannel are being investigated by two-photon fluorescence correlation spectroscopy (FCS), shown in Figure 2(B). The potential impact of this research would be significant, both scientifically and technologically, by offering a better understanding of molecular diffusion and transport in confined environments, as well as generating new concepts of molecular sorting and manipulation technology.

Figure 1: Cross-sectional SEM images of the 25 nm glass-glass channel (A) and 20 nm silicon-glass channel (B).

Figure 2: (A) Schematic diagram of a large DNA molecule confined to a slit glass nanochannel with a depth of H. (B) Schematic diagram of detecting single, small molecules by two-photon FCS in a slit nanochannel with vertical confinement.

REFERENCES: