CHAPTER 6

Conclusions

In this thesis we have addressed some of the issues of biopolymers (mostly DNA) under confinement. We have employed the concept of statistical mechanics to obtain the equilibrium properties of biopolymers. Using the self-avoiding walk model of polymer on lattice, we have obtained the partition function of the system under various constraint, such as, geometrical confinement (cone-shaped channel), entropic trap, impenetrable surface to model membrane or interface, and solvent gradient.

The simple model developed here captures the essential physics of biopolymer. For example, the effect of entropic trap on the migration of polymers has been studied by constructing a geometrical trap where the solvent quality differs from the solvent quality of the channel. The application of the Fokker-Planck equation allowed us to calculate the free energy landscape and first passage time of migration. The model presented here showed that the entropic trap increases the migration time. This is in accordance with the experiment. Our studies further revealed that at a certain value of $\Delta\epsilon$, the migration time due to entropic trap may reduce. This is surprising and may be difficult to observe experimentally. We have provided the theoretical explanation for this and proposed how one can observe it *in vitro*. We have further extended our model studies to explore the effect of transverse gradient on the free energy barrier. Lastly we would like to emphasize that polymer migration through entropic trap may influence the configurational shape of the polymer arising due to gradient inside the trap. The radius of gyrations associated with x and y component indicates "mushroom" shape conformation of polymer which has potential application on the formation of micelles.

The SAW model of polymer has been extended to study the equilib-

rium properties of DNA where two strands of the DNA are modeled by two mutually attracting self avoiding walks (MASAWs) on the square lattice. We studied simultaneous adsorption and force induced melting and explored different phases of DNA. It was observed that the melting is entropically dominated which can be substantially reduced under the application of the applied force. We consider two cases where the surface is weakly attractive and highly attractive. In the first case the DNA desorbed from the surface and acquired the conformation of melted state with the rise of temperature. However, for a strongly attractive surface, the one strand of DNA gets unzipped, while the other strand remains adsorbed on the surface. We observed non-monotonic behavior of the reaction coordinate, where the reaction coordinate y_2 first increases with the temperature and after a certain temperature, it decreases and acquires the bulk value. This has been explained on the basis of a simple thermodynamic argument where the applied force stretches the polymer and acquires the conformation of stretched state at low temperature. Rise in temperature gives enhanced contribution of entropy and hence y_2 decreases.

Model has been extended to study the effect of confinement on the melting profile and free energy barrier of DNA as it translocates across a cone shaped channel. Depending on the solvent conditions, the DNA will remain either in *cis* or *trans* side. Such study has potential applications in understanding DNA translocation across MSPA pore, α-HL pore , etc. We observed that at low temperature and same solvent condition across pore, DNA always remains in the *cis* side. As we increase temperature, dsDNA comes out of the pore in a zipped form and denatures in *trans* side. There is a competition between the reduced entropy and base-pairing energy in a cone-shaped channel, where at low temperature base-pairing energy of DNA in *cis* side dominates and at higher temperature, entropy of separated strands in *trans* side dominates. In between, at a critical temperature where both factors contribute equally and DNA comes out of the pore in the zipped form. Our studies warrant further investigations by varying the angle of cone-shaped channel to explore hitherto free energy

barriers and metastable states during the translocation of dsDNA.

Further, we have studied the effect of solvent gradient on the transfer of DNA from one side of the wall to the other inside a strip of finite width. The lattice model of DNA developed here is able to show that the solvent gradient drives the DNA from the lower layer (High temperature side) to the upper layer which is kept at lower temperature. For small chain length of DNA, we have used the exact enumeration technique whereas Monte Carlo simulations have been used for the longer chain. We observed that for a short chain, low interaction gradient is required for successful transfer from one side (hot) of the wall to another (cold) compared to a longer chain. Here, we have increased base-pair interaction by by varying the solvent quality *i.e* dielectric constant. The system always prefers to be in zipped like structure to minimize its free energy. We have also observed the effect of sequential preferences on the transfer of DNA inside the strip, *i.e* the GC rich DNA will transfer to higher solvent interaction gradient side earlier in comparison to both AT-GC sequence and AT rich DNA. All results obtained for short chain using exact enumeration are in nice agreement with the results obtained from Monte Carlo simulation for longer chain. We indicate that if one applies an external field (like gravitation), one may observe the convection like flow within the confined strip [139, 140, 143] under solvent gradient. We anticipate that Molecular Dynamics simulation may explore such non-equilibrium behaviour.