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(Year/Month/Day)_2011/01/21___

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Research Project

Title	Confinement Induced Phase Transitions in Neutral and Charged Polymers: Polystyrene and DNA
Duration	2010/11/01 to 2011/01/15

Please summarize your activities and results during your stay in Kyoto University.
Also please describe how your stay has been beneficial to the graduate students in the host institute. You can add a sheet, if you need more space.
You can also write any comments and requests to the GCOE program.

This project intended to observe confinement effect on charged and polymer molecules at microscopic and nanoscopic scales, respectively. In the first category, we have observed micron size droplets of DNA. It is known bulk mixtures of semi-flexible polyelectrolyte DNA and flexible neutral polymer PEG becomes phase separated in presence of salt, due to depletion interaction, depending on their relative concentrations, generally high. We started with a homogeneous mixture of DNA-PEG-NaCl with NaCl concentration 250 mM, stabilized against evaporation by mixing it with mineral oil and dispersing as micro-droplets by vortexing. These droplets were then transferred to a glass cell and studied with confocal, fluorescence (dyeing the DNA with YOYO) and polarization microscopy. Confocal microscopy image showed all

droplets to be attached to lower glass slide of the cell. Fluorescence microscopy (image in Fig. 1a) showed initially all droplets were homogeneous and no birefringence was observed (Fig. 1a′) with polarization microscopy. With time, we observe fluorescence only from the contact line of the droplets (Fig. 1b), as well as birefringence (Fig. 1b′). Further on in time, middle part of the droplet shows birefringence (Fig. 1c′) but no fluorescence (Fig. 1c), which means that with time DNA molecules move to the contact line of the droplet and PEG remains at center. Hence even when the starting bulk mixture is homogeneous, phase separation occurs within the droplet signifying enhancement of depletion force under micro-confinement. This proposition is further strengthened by the fact that for larger droplets it takes longer to exhibit phase segregation. We suggest that due to diffusion of water into oil there is a radial flow of molecules towards the contact line of the droplet as maximum diffusion occurs there. This radial flow pushes the rod-like DNA molecules to the contact line, where the condensed DNA molecules order orientationally and give birefringence. In this process PEG molecules become condensed at center of the droplet and form crystalline phase which shows birefringence.

With increase in NaCl concentration to 1M the phase separation takes longer time. This behavior can be attributed to the fact that at increased salt concentration DNA remains at globule form which hinders depletion interaction and hence the phase segregation is also hindered.

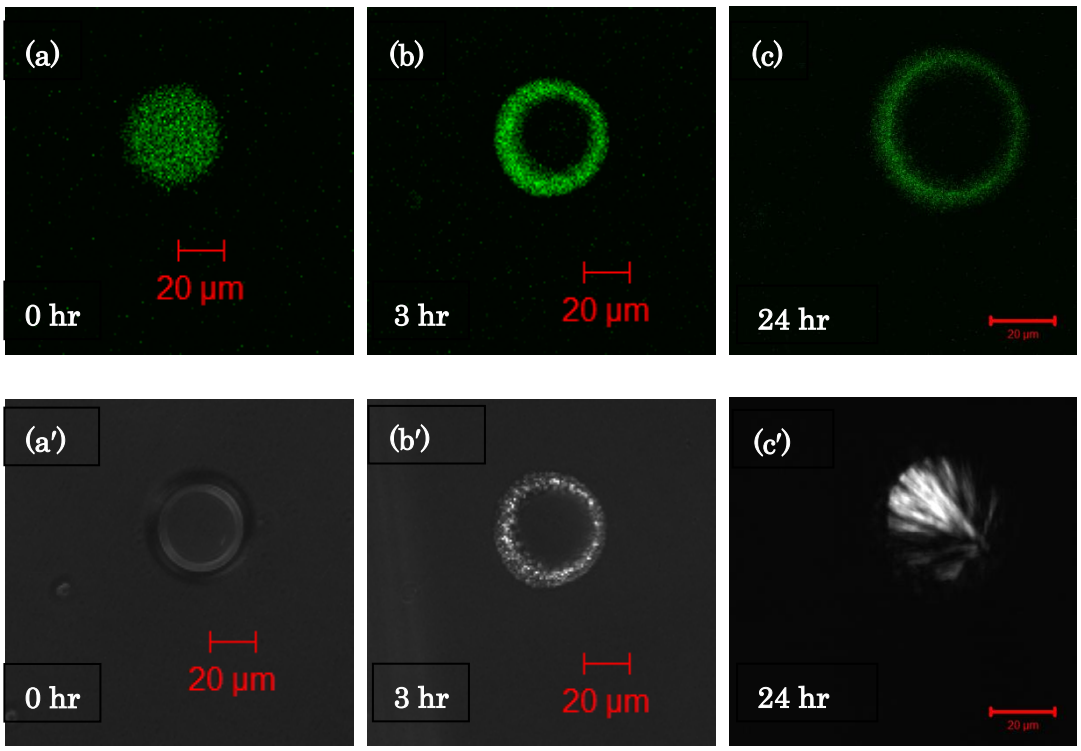

Fig 1: Phase separation within a 50 μm droplet of DNA-PEG-NaCl mixture with time. (DNA 175mg/ml, PEG 400mg/ml, NaCl 250mM). (a)-(c) are fluorescence microscopy images. (a′)-(c′) are corresponding polarization microscopy images at cross-nicol condition.

Besides the polyelectrolyte DNA we have also observed neutral polymer polystyrene of different

molecular weights in nano-confined thin films to explore confinement effect in nano-scale. We have performed X-ray reflectivity studies of thin films to extract out-of-plane information on the electron density distribution. This information would help us to conclude about the molecular arrangement within the thin film and hence inter and intra-molecular entanglement between the molecules. The analysis of this data is underway. Fig. 2 shows reflectivity profiles of polystyrene (molecular weight 18 kDa (PS18)) thin films of different thicknesses.

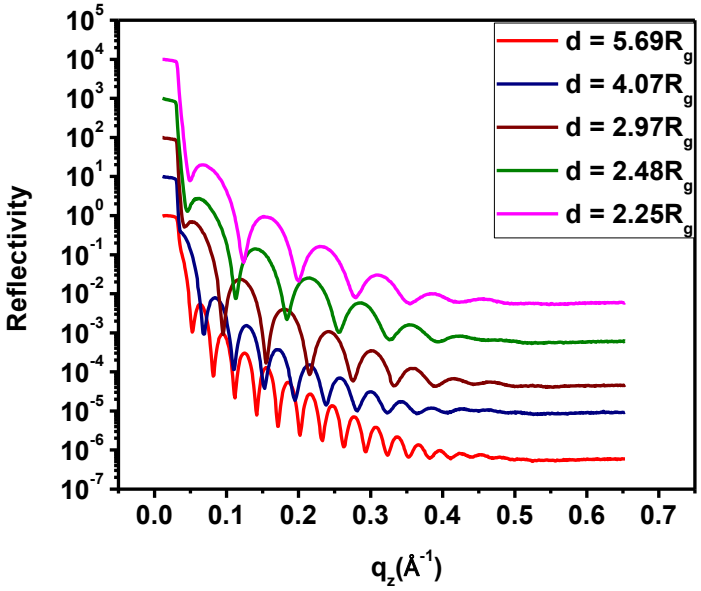

Fig. 2: Reflectivity profiles of thin films of polystyrene of molecular weight 18000 (PS18) of different thicknesses. Graphs have been up-shifted for clarity.

During my experiments I interacted with students of Yoshikawa laboratory. I have been benefitted by discussion with them and we have performed the experiments together. I hope they have been also benefitted in similar way.

I would like to acknowledge GCOE, Kyoto University for providing the support. I thank my host researchers, Prof. Yoshikawa, Prof. Seto and my supervisor Prof. Datta. I also thank Prof. Ichikawa for his help and advice during experiments. I also express my sincere gratitude to all members of Yoshikawa laboratory.