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Investigation of solid liquid interface in ultra-thin liquid films via single particle tracking of colloidal particles

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1. Introduction

It has been well known for some years that thin liquid films form layered structures near smooth surfaces and free interfaces [1]. Thereby it is apparent that the dynamical properties of these films differ from those of bulk liquids. Besides the altered film structure, films at interfaces will be subject to hydrodynamic boundary conditions (HBC) [2]. We used 5 nm silica particles doped with Rhodamine 6G as a probe to investigate the alteration of the hydrodynamic features of the liquid films (TEHOS – deposited on a Si wafer with 100 nm thermal grown SiO_2) by varying the film thickness. The particles have been prepared by Shubhra Gangopadhyay. Previous experiments with dye molecules revealed a heterogeneous behaviour of diffusion, which is slowed down in comparison to bulk diffusion [3]. Recent measured time series of 7 nm thin films proved the influence of solid tracer interaction on the tracer mobility.

2. Results and Discussion

In 7 nm, 10 nm and 30 nm thin films we could analyse trajectories which consist of more than 50 frames and cover an area of more than 1.1 µm². For the detected trajectories we calculated the diffusion coefficient by weighted mean squared displacements [4]. The obtained distribution of diffusion coefficients could be fitted with two Gaussian curves for all three film thicknesses as shown in Fig 1. From this it follows that there exist at least two mean diffusion components D_α and D_β. The slow diffusion component D_α remains constant within experimental accuracy by increasing the film thickness. We believe that this part of the observed distribution is caused by the diffusion of particles along the silica substrate. A possible reason is the interaction of the particles with silanol groups on the surface [4].

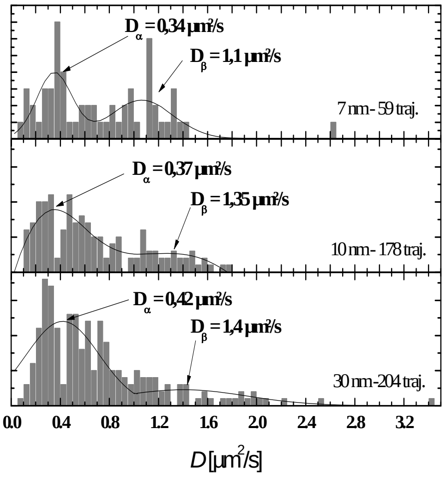

Fig 1: Distribution of diffusion coefficients of 7 nm, 10 nm and 30 nm thin films and fitted Gaussian curves.

For the fast component D_β we could monitor an increase dependent on the film thickness. Comparing the experimental results for D_β with the expected theoretical values the diffusion is slowed down by a factor of about 5.5. Furthermore with increasing film thickness the fraction of immobile periods decreases as anticipated. Additional measured time series of 7 nm thin films reveal contrarily to our expectations that both diffusion components increase within 49 hours. Similar time series for Rhodamine B exhibit the same behaviour [6]. In both experiments it appears that these changes are related to a decreasing fraction of immobile periods. Therefore we believe that these variations are caused by chemical reaction of TEHOS with the silica substrate. This results in shielding the hydroxyl groups on the silica surface [7]. Hence the number of adsorption sides decreases leading to an increase of both diffusion coefficients.

3. Conclusion

According to the distribution of diffusion coefficients for various film thicknesses we could confirm our previous results that the mobility is slowed down compared to the bulk diffusion. Additional measurements exhibit a strong dependence of the tracer mobility on sample ageing.

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