Dynamics of Thin-Layered Colloidal Crystals from Single Layer to Multi Layers; Crossover Behavior from 2D to 3D

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Colloidal crystals are known as a visible model of crystals. In recent years, a single particle motion has been analyzed in real space by digital video microscopy. To explain the dynamics of colloidal crystal, we have developed the overdamped bead-spring lattice (OBS) model [1, 2].

In OBS model, colloidal crystal is regarded as a bead-spring lattice immersed in viscous media. Since the system is immersed in viscous media, the motion of the particles is overdamped and can hardly oscillate. So each normal vibration mode is transformed into each normal relaxation mode. As the result, the motion of the particles is described as the superposition of the normal relaxation modes with eigen-amplitude and eigen-relaxation time.

Here, we report the analysis of particle motions in thin-layered colloidal crystals. We succeeded in observing the particle motions in single layered (2D), 2-layered, 3-layered, 4-layered, 5-layered, and 3 dimensional (3D) colloidal crystals by high speed digital video microscopy (250 fps). The essential feature of the time evolution of mean-square displacement (MSD) for the thin-layered colloidal crystals, that is essential to 2D system, is a logarithmic divergence in a large delayed time region (see Figure 1). These results are consistent with the relation between dimension of systems and stability of crystals known as the theorem of Mermin-Wagner. We found that this divergence approached rapidly to a convergence of 3D crystal with the increase of the layers. It is very surprising to see that mere 5-layered colloidal crystal shows the behavior so close to that of 3D crystals in the time range studied here.

The results of theoretical calculation based on the OBS model were in good agreement with the experimental results, but it was necessary to improve the method of calculating the lattice factor. Thin-layered crystals are neither 2D nor 3D crystals, and show the crossover behavior, so it is necessary to be treated as thin-layered crystals theoretically. By considered the wavevectors $\boldsymbol{q}$ as appropriate layers in first Brillouin zone, the flamework of OBS model is adapted to understand the dynamics of thin-layered colloidal crystals. We also present the new theoretical treatment for the dynamics of thin-layered colloidal crystals.

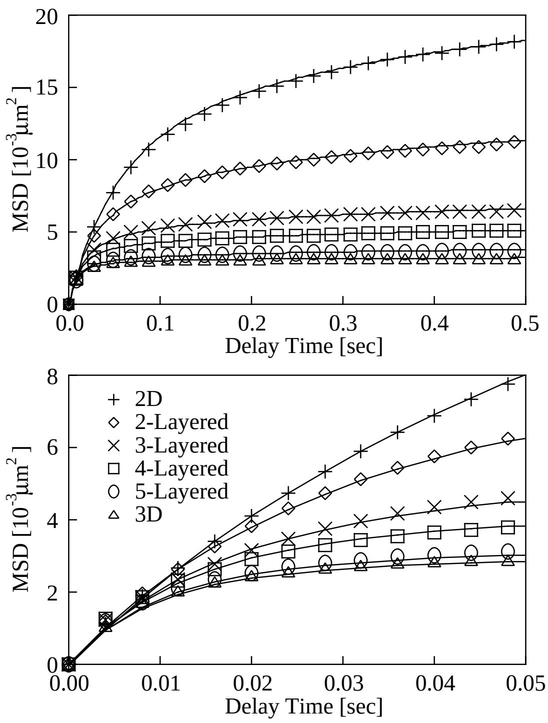

Figure 1: MSD for the thin-layered colloidal crystals. MSD in 2D, 2-layered, 3-layered, 4-layered, 5-layered, and 3D colloidal crystal are shown from the top on down. The lines are the fitting curves by theoretical calculation. (Top) Long time scale. The observed data points are plotted every 5 points. (Bottom) Shorter time scale. Here all the observed data points are plotted.

References

[1] Y. N. Ohshima and I. Nishio, J. Chem. Phys. **114**, 8649 (2001).

[2] Y. N. Ohshima, K. E. Hatakeyam, M. Satake, Y. Homma, R. Washidzu, and I. Nishio, J. Chem. Phys. **115**, 10945 (2001).