Hydrodynamic effects of Particle Motions in Colloidal Crystal

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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.

Hydrodynamic interactions are thought to play crucial roles in this system, but it is difficult to treat analytically. So these effects are not incorporated in simple OBS model.

Using this model, we have succeeded in explaining mean-square displacement of a particle (MSD, which is identical to autocorrelation function) in colloidal crystals by included hydrodynamic couplings as effective viscous resistance. However x-MSD (cross-correlation function) can not be explained by use of the same viscous drag coefficient and spring constant that could fit observed MSD, and x-MSD was much large that the predict of the OBS model.

Here, we report the $\boldsymbol{q}$ (wavevector) dependence of viscous resistance for particles in colloidal crystals obtained from the relaxation time of each mode. We observed the displacement of 168 particles in colloidal crystals by digital video microscopy, performed a discrete Fourier transform to these observed data, and calculated the correlation functions of the amplitude of each Fourier component. By assuming these correlation functions to be single exponential functions, we obtained the disparsion relation of amplitude and relaxation time. From the ratio of amplitude / relaxation time, viscous drag coefficient was proved to be in proportion to about $\boldsymbol{q}^{0.5}\sim\boldsymbol{q}^{0.6}$ (see Figure 1). This means that viscous resistance is small in modes of small q with cooperative motions of particles in colloidal crystal.

The results of fitting calculation based on the OBS model with assumed $\boldsymbol{q}$ dependence of viscous resistance were in good agreement with the experimental results (see Figure 2).

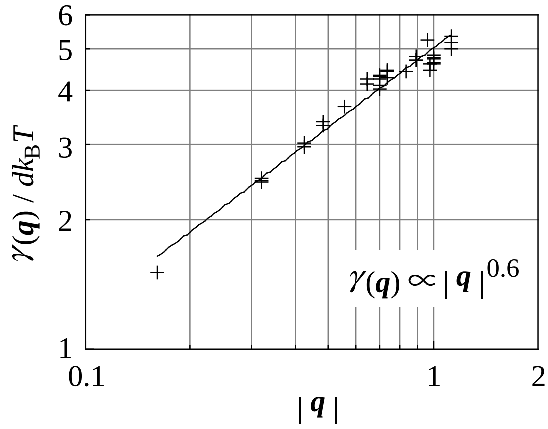

Figure 1: $\boldsymbol{q}$ dependence of viscous drag coefficient, γ, for particles in colloidal crystal.

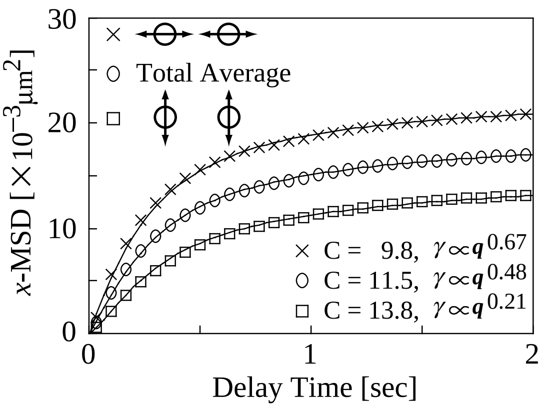

Figure 2: The observed x-MSDs are plotted. The lines are the fitting curves. C [fN/μm] is spring constant. γ is normalized viscous drag coefficient of water at maximum of $\boldsymbol{q}$.

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).