OBSERVATION OF MOBILE LATTICE DEFECTS IN A COLLOIDAL CRYSTAL

Makiko Sakabe[1], Yoshihisa Suzuki[2], Takahisa Fujiwara[1], Atsushi Mori[2], Shin-ichiro Yanagiya[2], Katsuhiro Tamura[2]
[1] Graduate School of Advanced technology and Science, The University of Tokushima, Japan
[2]Institute of Technology and Science, The University of Tokushima, Japan
*Email: Suzuki@chem.tokusima-u.ac.jp

Introduction

Colloidal crystals have attracted much attention as a photonic material because of their high controllability of light when the diameter of particles is comparable to the wavelength of light.

However, practical applications of colloidal crystals have not been achieved yet, since the crystals generally contain many lattice defects. The control of the lattice defects is necessary for practical applications of colloidal crystals.

To find the control method of lattice defects, colloidal crystals should be observed and characterized at the particle level. In this study, we observed lattice defects in a silica colloidal crystal in fluorescence solutions using a confocal fluorescence microscope, and analyzed the state of lattice defects in the crystal [1].

Experimental

Silica particles (diameter: 540 ± 20 nm) were dispersed in a 6.5mM aqueous rhodamine B solution. A laser confocal fluorescence microscope (OLYMPUS, FV300, IX71) and an objective (Olympus, UPlan SApo 100×/1.40 oil) were used for the observation of a colloidal crystal at the bottom of an observation container.

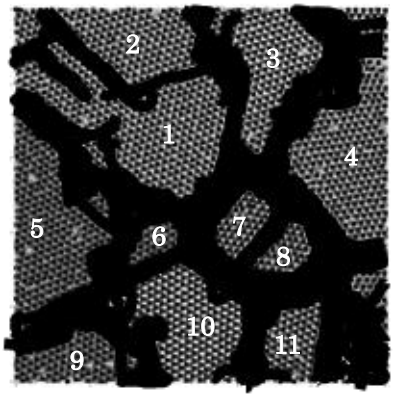
We observed 9 layers of particles from the bottom of the container. Stacking structures of the colloidal crystal at the same position of the container were observed at t = 5, 10, 15 days after the start time of settling of particles.

To characterize the lattice defects we defined the area of grain boundaries S as the whole area in the 9 layers where the particles did not form ordered structure. We measured S and point defect density d. The area of ordered structures was defined as the area in which each triangular lattice formed a regular triangle by visual judgment. d was defined as the number of point defects per unit volume of the crystal.

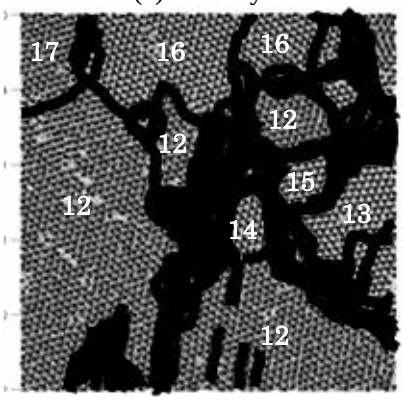
Results and Discussion

The largest face-centered cubic (FCC) grain was found at t =10 days. However, we could not find the FCC structure at t = 15 days (Fig.1).

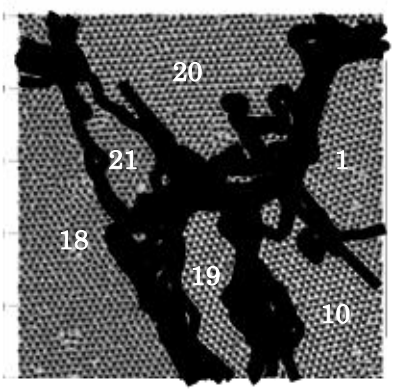
The result was beyond expectation, since the FCC structure is known to be the most stable one [2, 3]. Further observation over a longer-time period should be needed.



(a) t =5 days



(b) t = 10 days



(c) t = 15 days

Fig.1 Superposition patterns of 9 layers of particles .Black area in each pattern shows superposition of grain boundaries. Stacking orders of triangle lattice layers in numbered regions are shows below .The stacking order of region 12 shows FCC stacking.

1.ABACBCBCB	2.ABACACBCB	3.ABABACABC
4.ABACBACAB	5.ABCBCBABA	6.ABCBCACBA
7.ABABCBACB	8.ABABCBCBA	9.ABCACBABC
10.ABABACABA	11.ABACBCABA	12.ABCABCABC
13.ABABCACAB	14.ABACBACBA	15.ABABCABCA
16.ABCABABCA	17.ABCABABCA	18.ABCACABAC
19.ABABACACB	20. ABACBCABC	21.ABCABCBAC

S decreased monotonously with time, while *d* once increased with time (at 10 days), then decreased (at 15 days). The temporary increase in *d* is probably due to the fragmentation of *S* with time (Fig.2).

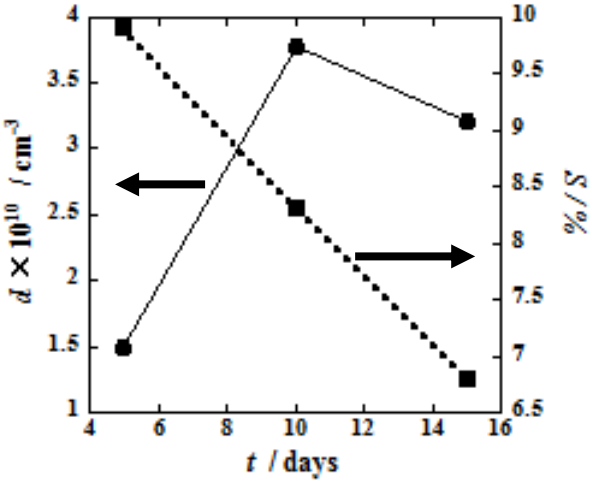


Fig. 2 Changes in *d* and *S* due to with time. *d*(●) increased with time (at 10 days), then decreased (at 15 days). *S*(■) decreased monotonously with time.

During the above experiment, the average volume fraction of the crystal ϕ did not change too much (almost constant)(Fig.3).

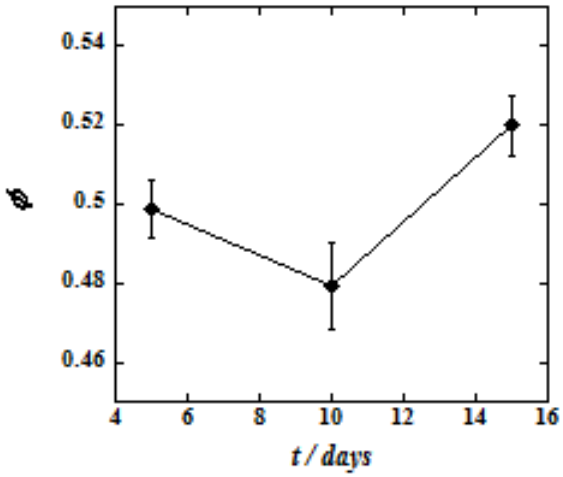


Fig. 3 The volume fraction (ϕ) of crystal

Conclusion

In this study, we observed mobile lattice defects in a colloidal crystal using a laser confocal fluorescence microscope. Key results found in this paper are as follows.

(1) Mobile particle layers were observed, for the first time in a colloidal crystal.

(2)The area of grain boundaries *S* decreased monotonously with time.

(3) The density of point defects *d* once increased (at 10 days), and then decreased (at 15 days). The temporary increase in *d* is probably due to the fragmentation of *S*.

Reference

[1] Schall, P., Cohen. I., Weitz, A.D., Spaepen, F., Visualization of Dislocation Dynamics in Colloidal Crystals, Science **305**, (2004) 1944-1948.

[2] Woodcock, L. V., Entropy difference between the face-centred cubic and hexagonal close-packed crystal structures, Nature **385**, (1997) 141-143.

[3] Bolhuis, P. G., Frenkel, D., Man, S-C., Huse, D. A., Woodcok, L.V., Entropy difference between crystal phases, Nature **388**, (1997) 235-236.