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Colloidal Clusters 宇宙実験による荷電コロイド粒子の会合挙動の研究

Study on Clustering of Charged Colloidal Particles by Colloidal Clusters Space Experiments

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1. Introduction

Cluster formation of colloidal particles is observed in a variety of natural phenomenon, including random coagulations of unstable colloids and self-organization of proteins in living cells. One of the major driving forces of the clustering is the electrostatic attraction between the charged particles [1-4]. We have examined controlled clustering of various charged colloid formed in aqueous media, by tuning the electrostatic interparticle interaction. Fig. 1 is micrographs of the clusters of positively (red colored) and negatively (green colored) charged silica particles in water (diameter = 500nm). On the right some enlarged images of clusters with various association numbers are shown, where the figures following n and p are the numbers of positive and negative particles in the cluster. Tetrahedral clusters (n4p1) have been studied as components of diamond lattice structures, which have been attracting considerable attention as a novel photonic material with a perfect photonic band gap.

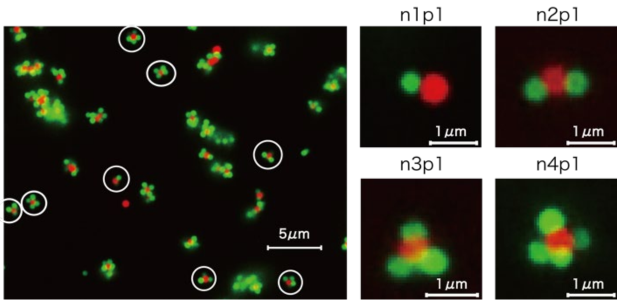

Fig. 1 Clusters of oppositely charged silica particles in water (diameter = 500nm).

For the photonic application, the colloidal particles having high refractive indexes (n_r) are often desired. For example, the perfect photonic band of the diamond lattices are obtained for n_r larger than approximately 2. However, materials having high refractive index usually have large values of specific gravity ρ at the same time. Thus, microgravity environment, where an effect of gravitational sedimentation is negligibly small, would be ideal for the structure formation of colloidal particles having high n_r values. From 27 July 2020 to 30 July 2020, the clustering experiment (Colloidal

Clusters)[5] was carried out under a microgravity environment of Japanese experiment module Kibo. The samples have returned to the ground in Mach 2021 and we have started the analysis. In this presentation we will report the details of the experiments and sample analysis.

Fig.2 Experimental setups. A sample bag having a breakable separator, and sample box equipped with UV LEDs.

2. Space Experiment

Fig.2 shows experimental setup for the space experiments. Dilute aqueous dispersions of negatively and positively charged colloidal particles (approximately 0.01vol % in total) are introduced in plastic bags (volume = 3mL each), separated by a breakable seal. We used charged polystyrene $n_r = 1.60$; $\rho = 1.05$), silica ($n_r = 1.45$; $\rho = 2.1$) and titania (TiO_2, $n_r = 2.5$; $\rho = 4$). UV-curable gelation reagents were dissolved in the sample. After mixed, the samples were kept standing for 2 days under the microgravity. Then the entire samples were gelled by an UV illumination.

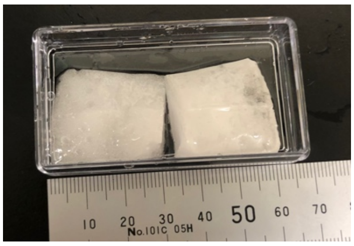

Fig.3 An overview of the gelled samples obtained in the space experiment (titania colloid).

Fig.3 and Fig.4 are an overview and a micrograph of the sample returned to the ground (titania sample). All the samples were successfully fixed with gel. We confirmed that there was no distinct supernatant region due to precipitation, and that the particles were quite uniformly distributed. In addition, traces of bubbles (nitrogen gas) generated by the reaction of the photoinitiator were found in the gels, suggesting that the gelation reaction proceeded successfully.

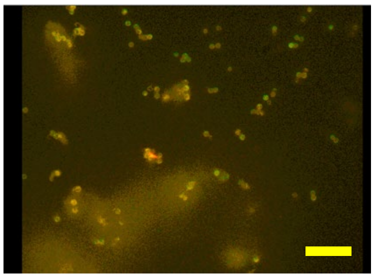

Fig.4 An optical micrograph of the gelled clusters made in space (titania colloid). Scale bar = 10μm.

Microscopic observation of the polystyrene particle samples showed that the clusters of positively and negatively charged particles were formed with various association numbers, including tetrahedral clusters. The distribution of the association number was almost the same as that obtained in the laboratory beforehand, confirming that the space experiment was conducted as expected.

As for the silica particle samples, large amount of the particles was free though clusters were formed. This appears to be due to the decrease in surface charge over time. In the ground control samples, the percentages of clusters were slightly higher, presumably due to the effect of sedimentation.

At present, we are analyzing titania samples. We are going to evaluate the elasticity of the gel matrix, identify the clusters of the titania particles, by microscopy and neutron scattering.

References

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