JASMAC
Conference of the Japan Society of Microgravity Application

P05

微小重力下における荷電コロイド粒子の会合体形成

Cluster Formation of Charged Colloidal Particles in microgravity.

〇三木裕之 [1], 石神瑛圭 [1], 土井眞帆 [2], 森優月 [2], 豊玉彰子 [1], 奥薗透 [1], 山中淳平 [1], 足立聡 [3], 坂下哲也 [3], 島岡太郎 [4], 永井正恵 [4], 渡邉勇基 [5], 福山誠二郎 [5]

〇Hiroyuki MIKI[1], Teruyoshi ISHIGAMI[1], Maho DOI[2], Yuzuki MORI[2], Akiko TOYOTAMA[1], Tohru OKUZONO[1], Junpei YAMANAKA[1], Satoshi ADACHI[3], Tetsuya SAKASHITA[3], Taro SHIMAOKA[4], Masae NAGAI[4], Yuki WATANABE[5] and Seijiro FUKUYAMA[5]

1 名市大院薬, Graduate School of Pharmaceutical Sciences, Nagoya City University,
2 名市大薬, Faculty of Pharmaceutical Sciences, Nagoya City University,
3 国立研究開発法人宇宙航空研究開発機構, Japan Aerospace Exploration Agency (JAXA),
4 一般財団法人日本宇宙フォーラム, Japan Space Forum (JSF),
5 株式会社 エイ・イー・エス, Advanced Engineering Services Co., Ltd. (AES)

1. Introduction

Micron-sized colloidal particles, charged with opposite signs, self-assemble in water due to electrostatic interactions between particles and form various cluster structures (**Figure 1(a)**). When either positive or negative particles are present in excess, isolated clusters consisting of a small number of particles are formed. Among them, tetrahedral clusters (**Figure 1(b)**) are the building blocks of diamond lattices and are expected to be a new photonic material with the ability to confine light. Thus, controlling the structure of colloidal clusters is important for material applications of colloids. We have investigated controlling the number of clusters by varying the salt concentration of the medium and controlling the Coulomb forces between particles.

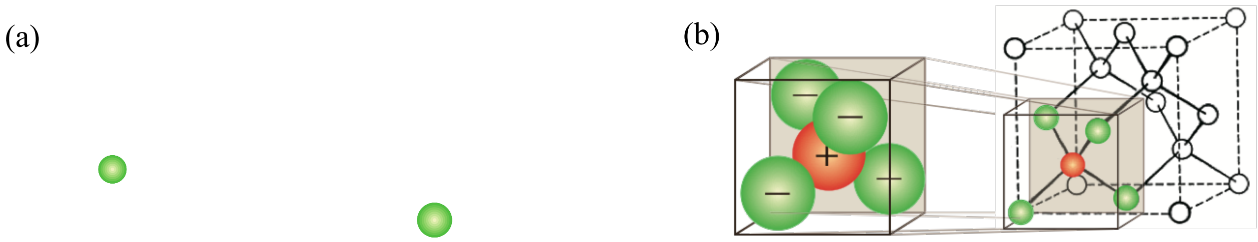

Figure 1. Illustrations of (a) clustering of oppositely charged particles due to Electrostatic attraction. (b) tetrahedral cluster and diamond lattice.

For applications in optical materials, including photonic crystals, it is necessary to use particles with a high refractive index. However, materials with a high refractive index generally also have high specific gravity and settle on the ground due to gravity. For example, titanium dioxide particles have a refractive index, n_r, of ~2.4 but a specific gravity, ρ, of ~3, so amorphous aggregates are formed by sedimentation on the ground. The microgravity environment of the International Space Station (ISS), where the effect of sedimentation is negligible, is ideal for structure formation experiments of such colloidal particles with a high refractive index. The cluster formation experiment (project name: JAXA Colloidal Clusters[1)]) was conducted in the microgravity environment of the ISS in July 2020, and the space experiment sample arrived at the Nagoya City University laboratory on March 11, 2021, and has been analyzed since then. In this report, we present the analysis results of the space experiment and the ground control experiment.

2. Space Experiments

Figure 2 shows the sample bag used in the space experiment. Two containers with a volume of 3 mL are connected with a seal between them that opens upon compression. Dilute aqueous dispersions of positively and negatively charged colloidal particles (total particle concentration about 0.05 vol%) were introduced into the two bags. Charged polystyrene (n_r = 1.60; ρ = 1.05), silica (n_r = 1.45; ρ = 2.1), and titania (TiO_2, n_r = 2.0; ρ = 3.0) were used in the experiments. These samples were dissolved with a reagent that gels when exposed to ultraviolet light. The samples were mixed by the space crew on the ISS by pressing the sample bag to break the seal and further rubbing and unraveling. The samples were held on the ISS for two days to reach near equilibrium and then irradiated with ultraviolet light in a microgravity environment to gelatinize them. All returned space samples were successfully gel-fixed and no supernatant due to precipitation was observed.

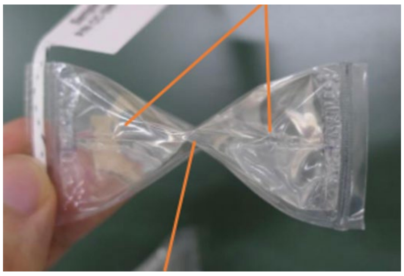

Figure 2. A sample bag for the space experimnets equipped with a breakable separator.

3. Clustering of Charged Particles

Figure 3 shows an example of microscopic images of clusters of the polystyrene particles obtained in the space experiment. It was observed that clusters of positively and negatively charged particles, having various association numbers, were produced in the space. For samples of various salt concentrations, about 1000 clusters were observed under a microscope to count the number of clusters, and the distribution of the associated numbers was determined. The symmetry of the tetrahedral clusters was evaluated by the bond orientation order parameter. Despite the relatively low specific gravity of the polystyrene particles, the average number of associations was higher and more symmetric in the space experiment than in the ground control experiment. This suggests that the slight sedimentation and convection occurring in the ground experiment may have affected the aggregation structure. In the titania system, macroscopic aggregation was observed in

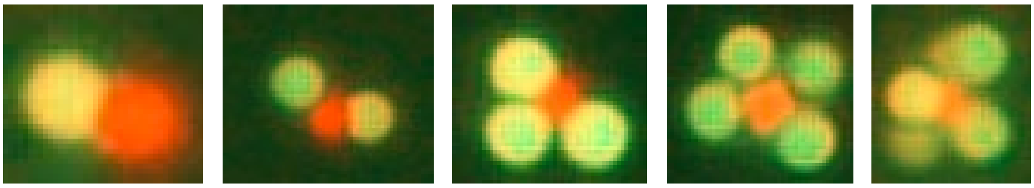

Figure 3. Colloidal clusters of positively (red) and negatively (green colored) charged polystyrene particles having various association numbers, obtained from the space experiments. Particle diameter = 789 nm and 1025 nm, respectively.

many cases, but isolated clusters were also formed. The analysis of the salt concentration dependence confirms the influence of electrostatic interactions on the formation of titania clusters, which is difficult on the ground.

4. Conclusions

The effect of gravity on the clustering of micron-sized colloidal particles was investigated through the space experiment. Even for polystyrene with a relatively low specific gravity (ρ = 1.05), differences were observed in the number distribution and symmetry of cluster between the space experiment and the ground control experiment. The effect of electrostatic interaction was also confirmed for titania, whose clustering behavior was hard to study on the ground due to sedimentation.

References

1) JAXA Web page, https://humans-in-space.jaxa.jp/kibouser/subject/science/70504.html