DYNAMICS OF 2D COLLOIDAL CRYSTALS IN THE PRESENCE OF LOCALIZED INTERNAL STRESSES CREATED BY ACTIVE PARTICLES

Jacob John and Giovanniantonio Natale

Department of Chemical and Petroleum Engineering, Schulich School of Engineering, University of Calgary, Canada

Structured interfaces such as 2D colloidal crystals are model systems to study the mechanics of various natural and engineered systems. Active colloidal particles exhibit self-propelling motion by exploiting chemical, temperature, or force gradients around individual particles. The presence of active particles as impurities in 2D colloidal crystals can be considered as simplified models to understand the motion of bacterial cells in biofilms[1], stability of Pickering emulsion microreactors[2] , human crowd behavior[3] and the motion of molecular motors at cell membranes[4]. In this work, we report the dynamics and rheology of 2D colloidal crystals formed using spherical polystyrene (PS) particles at oil-water interfaces in the presence of active PS-Platinum Janus particles. The particle dynamics is studied using video microscopy and image analysis. The rheological behavior of the interface is investigated using interfacial shear rheology and microrheology. At high surface coverage of the particles and low ionic strength, the passive particles form a two-dimensional crystal with a hexagonal lattice structure due to dipole-dipole repulsive interactions. These interfaces exhibit a viscoelastic solid-like behavior in linear regimes and reversible structural rearrangements at large strains. However, with an increase in the number of active particles, the crystal loses its orientational and spatial order and forms multiple domains of crystals separated by grain boundaries, even in the absence of activity. In the presence of activity, the overall crystal becomes more dynamic and heterogeneous and loses its hexagonal order. Particle tracking microrheology and interfacial shear rheology quantify the transition to the liquid-like nature of the interface due to the presence of active impurities. We show how local perturbations can have long-range effects on the dynamics of particles in 2D colloidal crystals and their overall viscoelasticity. We identify the electrostatic repulsion between particles and the propagation of internal stress as two competing forces that exist in the crystal in the presence of activity. This work provides insights into the motion of bacterial cells in crowded biofilms, how stress relaxation occurs in crystals with defects and internal stresses and how particle arrangements at interfaces of Pickering emulsion microreactors are affected by interfacial chemical reactions.

REFERENCES

1. Boyang Q., Chenyi F., Andrew A. B., Ameya A. M., Howard A. S.,Ned S. W., Bonnie L. B., Cell position fates and collective fountain flow in bacterial biofilms revealed by light-sheet microscopy, *Science*, **369**, 71-77, 2020.

2. Chun Y. X., Shi X. M., Long H. X., Rui X. B., Xin Y., Yaolei W., Zhong P. Q., Bernard P.

B., Ting G., and Tao M., Light and Magnetic Dual-Responsive Pickering Emulsion Micro-Reactors, *Langmuir*, **33**, 14139-14148, 2017.

3. Shreetam B., Debi P. D., Malay B., Partha P. R., Understanding Crowd Flow Patterns Using Active-Langevin Model, *Pattern Recognition*, **119**, 1-12, 2021.

4. Víctor G. L., Fang C., Lizanne G. N., Guillaume D., Amir A., Anatoly B. K., Jacob T. R., Gufeng W., Robert P. and James M. T., Molecular machines open cell membranes, *Nature*, **548**, 567-572, 2017.