BAPVC Annual Project Report

Project Title: Large-Area, Fast, and Electric-Field Assisted Continuous Coating for Nanostructured Photon Management

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Summary:
The CSM group has achieved the fabrication of non-close packed colloidal patterns on conducting substrates with the assistance of both AC and DC electric fields. They have demonstrated the potential to fabricate uniform photonic/plasmonic structures for photon management. We have also observed the fabrication of chiral colloidal structures which have potentials for unique and novel light-matter interactions.

Key Accomplishments:

1. Electric-field assisted coating of non-close packed pattern

We employ a low-power alternating current (AC) electric field to manipulate a number of attractive and repulsive forces between colloidal particles, which generate non-close packed hexagonal particle arrays in solution. We then apply direct current (DC) pulses to induce an electrophoretic force that points towards the bottom substrate. The particles are permanently fixed on the substrate when the DC current is larger than a critical value. The periodic structures can be maintained even after solvent evaporation. The experiment setup that combines both AC and DC fields is shown in **Fig.**1. The strength of the DC electric field is critical. **Fig.** 2 demonstrates that a low DC current does not disturb the pattern formed in solution but could not fix the particles permanently. A high DC current introduces significant lateral movement of individual particles. Although it can fix the particles, the ordered pattern cannot be maintained. With an intermediate DC current, we can fix the particles while maintaining the ordered array. Moreover, we have demonstrated that this method is based on physical principles that can be applied to a variety of particles with different materials properties. A manuscript is in preparation.

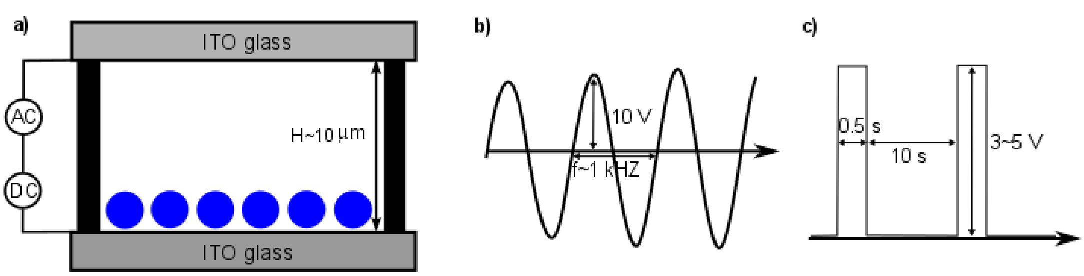

Fig. 1 a) a cross-section view of the experimental setup. b) AC electrical field employed to form non-close packed particle pattern. c) DC pulses employed to fix the particles on the bottom substrate.

2. The formation of chiral colloidal clusters

Shown in **Fig. 3**, two to four dielectric dimers are assembled into compact clusters that exhibit left and right handedness in configuration. Similarly, the metallodielectric Janus spheres can also orient their metallic parts into chiral clusters. The cluster configuration is primarily determined

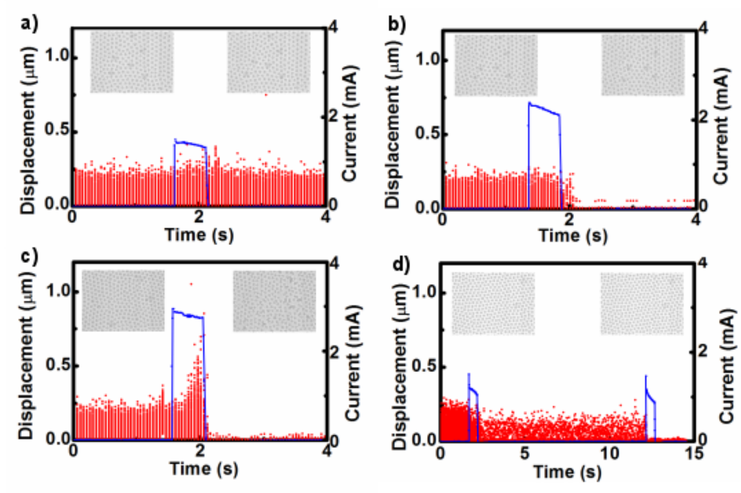

Fig. 2 Particle displacement (red dots) under different DC voltage pulse (blue curves). a) 3V DC pulse cannot fix the particles. b) 3.5V DC pulse can fix the particle while maintain the pattern c) 4V DC pulse can fix the particle but would destroy the pattern. d) Multi rounds of 3V DC pulse can fix the particle while maintain the pattern.

by the induced dipolar interactions between constituent dimers. Our theoretical model reveals that in-plane dipolar repulsion between petals in the cluster favor the achiral configuration, while out-of-plane attraction between the central dimer and surrounding petals favor a chiral arrangement. It is the competition between these two interactions that dictates the final configuration. The structures shown in **Fig. 3** could be excellent candidates for studying unique optical response of individual clusters, as well as periodic arrays of them.

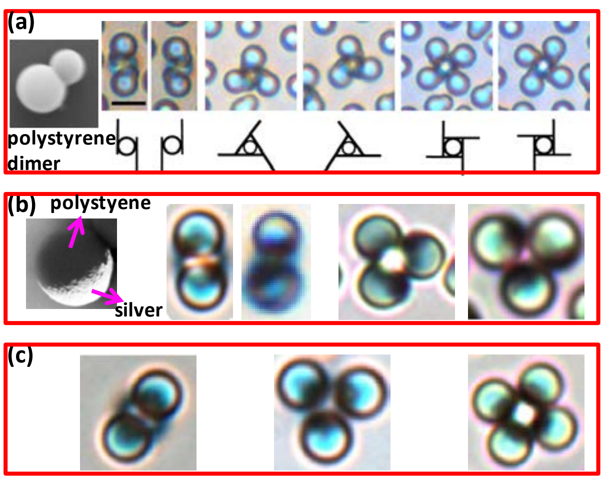

Fig. 3 Chiral and achiral structures formed by the self-assembly of dielectric and metallodielectric building blocks under AC electric fields. (a) Left- and right-handed chiral clusters formed by an increasing number of dielectric dimers. (b) Chiral clusters formed by silver-polystyrene metallodielectric spheres. (c) Achiral clusters for comparison.

Future Work:

We will keep investigating the flow-coating method, with the goal to increase the coating speed and reducing the density of defects. We will also continue the study that combines the electric-field assembly with the flow coating technology. Our final goal is to fabricate the non-close packed particle arrays that can be applied to both dielectric and metallic particles on conducting substrates.

References

1. Fuduo Ma, Sijia Wang, David T. Wu, Ning Wu, "Electric-field–induced assembly and propulsion of chiral colloidal clusters", *Proceedings of the National Academy of Sciences* **112**, 6307–6312, 2015.