Assembly of colloidal strings in a simple fluid flow

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Self-assembly of colloidal particles suspended in fluid is an area of increasing interest. Colloidal particles self-assemble into various structures in fluid flows (1-9). These mesoscopic scale structures are practically important for coating and biomedical processes (6), where the interactions between fluid flows and colloidal particles are frequently encountered, and are also of fundamental interest for probing general organizing principals of non-equilibrium systems.

Ordered colloidal structures are especially interesting, because of their use as photonic materials, sensors, nanoscale light emitting diodes and single-electron transistors (10-11). Although many techniques for creating 2D or 3D colloid crystal have been invented, few methods are available for assembling 1D colloid crystals. Theoretically, it is difficult for colloidal spheres to grow along a preferential direction due to the isotropic nature of the inter-particle forces. As such, 1D colloidal crystals can only be formed through limited special processes including template-directed crystallization (12) and electromagnetic field-assistant crystallization (13), which necessarily require specific tools such as nanofabrication that are not easily accessible.

Figure. 1 Flow-aligned string structures near a solid boundary

In this research, we report a simple experimental method for constructing 1D colloidal crystals, where colloidal particles self-assemble into flow-aligned string structures near a solid boundary under unidirectional flow (Figure 1). Using fast confocal microscopy, we have systematically studied the formation of colloidal strings in simple fluid flows. By varying the control parameters such as flow rate, the strength of the electrostatic forces and the dimension of microfluidic channels, we have delineated the conditions for the formation of colloidal strings.

Compared with previous methods, our work provides a much simpler procedure for assembling a large number of colloidal strings. Based on our systematic study and theoretical analysis, we have also proposed a simple mechanism that qualitatively explains this intriguing non-equilibrium self-assembly process. Although our model is minimalistic and includes several approximations, it is able to capture the essential mechanism for the formation of colloidal strings. We propose that through the delicate balance between the hydrodynamic coupling and the electrostatic interactions between particles and between particles and the system's boundary, charged colloidal particles can self-assemble into 1D ordered structures, which are potentially useful for manipulating the optical and mechanical properties of coating layers.

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