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Dry and Wet Assembly Approaches for Arranging Ordered Particle Monolayers and Arrays

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Summary

Our group focuses on developing versatile assembly methods, primarily dry approaches, of colloidal particles into ordered monolayers and arrays in an open format, potentially for Lab-on-a-Chip analytical systems [1,2]. To address the assembly of ordered arrays, we proposed a novel, more automatable, and completely dry assembly method to attain a non-closely packed array of silica, polystyrene, or PMMA, microspheres within 10 s [3]. As shown in Fig. 1a, the agglomerated microspheres are offered to an electrostatic cell, which is fluidized by applying an electric field. Subsequently, the particles are attracted to a perforated silicon device by applying a vacuum force and a brushing step to remove excess particles. From Figs. 1b-c, compared to most existing methods in literature, this system's merit is that any desired geometrical particle array can be assembled on a large scale. Furthermore, we demonstrate that these arrays can be transferred to other soft elastomeric surfaces, paving the way for the potential fabrication of hierarchical materials or the desired ordered packing structures for High-Performance Liquid Chromatography (HPLC) columns using a layer-by-layer strategy in a bottom-up approach [2]. Another approach that we recently reported involves the manual rubbing of dry powders (silica and PMMA) on fluorocarbon-patterned substrates using a PDMS stamp to rapidly (≈ 20 s) obtain ordered arrays of hexagonal closely packed (HCP) crystals of powder particles with diameters ranging between 500 nm to 10 µm (cf. Fig. 1d) [4]. Our findings elucidate that the triboelectric charging and contact mechanics force are critical contributors to attain tunable HCP crystal patterns on a wafer-scale (as shown in Figs. 1e-f) [4]. We envision these assembled arrays as a promising open microfluidic platform for performing bioassays and other biosensing applications.

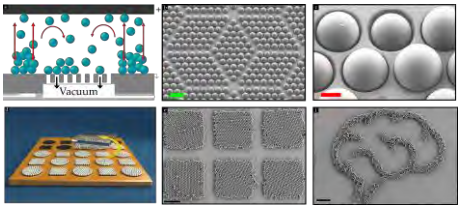

Figure 1. (a) Dry powder is offered to an electrostatic cell, which is levitated by applying an electric field E≥1.5 MVm-1 and subsequently captured on a perforated silicon device using a vacuum force. (b-c) Any geometrical array can be assembled. (d) Schematic illustration of the manual rubbing technique to assemble dry powder into closely packed crystal (HCP) structures on substrates using a PDMS (rubber) stamp. (e-f) SEM images of patterned HCP crystal structures comprising PMMA microspheres. Scale bar: green = 20 µm; red = 2 µm; black = 100 µm.

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