MICROFLUIDC PROCESSES TO CREATE STRUCTURED MICROPARTICLE ARRANGEMENTS AND THEIR APPLICATIONS

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Multifunctional microparticles have shown the great potentials in material science and bioengineering applications. The advance in particle synthesis allows for fine tuning of their physical properties and chemical functionality. Meanwhile, particle manipulation is still appealing, but challenging issue in colloidal science. Particle arrays can provide unmatched encoding capacities and rapid decoding capabilities that make them very attractive for a broad range of applications, such as microenvironment fabrication, multiplexed assay, and anti-counterfeiting. It is desired to manipulate large-scale of particles at precise locations, and achieve specific positioning depending on particle characteristics. In addition, technique should be applicable to all particles regardless of their chemical compositions. However, current approaches cannot simultaneously fulfill desired capabilities of arrangement: scalability, precision, specificity, and versatility.

This thesis focuses on the development of a new microfluidic platform, porous microwell arrays, to create structured large-scale microparticle arrays while fulfilling all four capabilities. Microwells are fabricated on top of porous membrane by a vacuum-assisted molding method. Particles are guided and assembled into wells by hydrodynamic force associated with fluid flow through pores in microwell. Iteration of assembly and washing steps ensures high-throughput, large-scale particle arrangement with high yields on filling and capturing. Scaling theory allows for the rational design of platform to specifically position microparticles depending on their physical characteristics (i.e. size, shape, and modulus), enabling the generation of complex patterns. We demonstrate the potential of this platform in bioengineering application and material sciences: microenvironment fabrication for neutrophil chemotaxis; and upconverting nanocrystal-laden covert 2D tags for anti-counterfeiting. Furthermore, we demonstrate the platform's capability to manipulate other soft biological colloids besides polymeric microparticles: high-throughput, large-scale single-cell arrangement; and large-scale microorganism patterning for the study of immune response.

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