Fundamentals of field-assisted self-assembly

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A self-assembly process is characterized by the spontaneous and ordered aggregation of similar components, such as colloids or other particles, to form structures of micro-, meso- and macroscopic dimensions. Self-assembly is most evident during the growth of biological structures. Due to its natural elegance, there is considerable interest in investigating similar methods in the physical and chemical sciences. At the supramolecular level, dynamic self-assembly can be used to prepare adaptive materials for photonic and MEMS devices. Self-assembly is characterized by a competition between at least two forces – one attractive and the other repulsive – in systems that are not in thermodynamic equilibrium, and it is associated with energy dissipation. Several researchers have described self-assembly in configurations where biological or chemical mediation, electrostatic, magnetostatic, capillary or fluid dynamic forces have provided the motive potentials. Except the electrostatic and magnetic forces, all the other forces responsible for self-assembly are generally some contact forces or short-range forces. Precise manipulations of self-assembly processes caused by these contact forces are therefore very difficult when the site of the self-assembly process is inaccessible (e.g., in a MEMS device). On the contrary, electrostatic and magnetic field-induced forces are effective even from a distance, permitting "action at a distance" to create self-assembled structure with a better controllability. The principle of field-induced self assembly utilizes the interaction between an imposed electric or magnetic field and the induced field around the dielectric or magnetic features or the self-assembled components. Dipole-dipole interaction between the components of self-assembled structures also plays important role in the process. For instance, the self-assembly of ferromagnetic nanoparticles is a promising technique for producing high-density magnetic data storage devices, three dimensional memory chips or microscopic architecture in microfluidic devices. Here we discuss the principle of field-induced self-assembly, shed light on a few examples, and show avenues of harnessing the phenomena in bottom-up approach of microfabrication and self-assembly-based operation of MEMS and BioMEMS devices.