Preparation, properties, and perspectives of non-close packed arrays of nanoparticles on planar and concave-structured surfaces

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Non-close packed two-dimensional arrays of colloidal particles are needed for various applications such as antireflection coatings and superhydrophobic surfaces as well as plasmonic structures. Up to now, most of these structures are prepared by laborious, multi-step procedures, but the need for simple and reliable preparation methods for such structures is ongoing. We have developed an approach, where positively charged amino-functionalized silica nanoparticles are self-assembled from dispersion on gold surfaces.[1] Since the nanoparticles are exerted to a drying process after the arrangement from dispersion, the system is exposed to capillary forces. To prevent aggregation of the nanoparticles during this process, the roughness of the nanoparticles surface is increased. By exploiting frictional forces between the nanoparticles and the rough gold surface, the formation of aggregates during the drying process is suppressed. If additionally, the chemistry of the linkage between the nanoparticles and the gold is enhanced, extended (1 cm^2) well-ordered arrays result.[1] The distance between the nanoparticles can be adjusted by the ionic strength or the dielectric constant of the solvent. The as-prepared structures can then serve themselves as templates for the ordering of a second type of nanoparticles, the formation of arrays of nanoparticle dimers, or they can be further modified by attaching metal clusters or coating with a metal layer.
If not a planar but a concave-structured surface consisting of gold half shells is used as substrate, plasmonic interactions between the nanoparticles and the gold can be tuned. This is especially attractive if fluorescent molecules or upconversion nanoparticles are embedded in silica shells. Extended ordered arrays of gold bowls are prepared by using a colloidal crystal as a template. However, it is challenging to obtain an ordered array of silica nanoparticles in such a concave gold substrate, even if the diameter of the nanoparticles corresponds to the dimensions of the gold bowls since it turned out that electrostatic interactions between the silica nanoparticles govern their interparticle distances and not the geometry of the gold bowls. However, the distance between the charged nanoparticles on the surface can be adjusted by the ionic strength of the dispersion medium and particles outside the gold bowls can be selectively removed by ultrasound treatment. In this way, extended ordered arrays (1 cm^2) of silica nanoparticles in gold bowls are obtained.