MnF Research

Multivalent recognition at interfaces

Molecular printboards

Although supramolecular chemistry is typically solution chemistry, both in terms of selective molecular recognition as well as in terms of self-assembly, there is an increasing interest in these phenomena at interfaces. A very attractive way to assemble molecules is the self-assembly of molecules on clean (and flat) surfaces like mica, SiO₂, or gold. In contrast to solutions in such monolayers the molecules (or assemblies) are confined in time and space. This extends the methods for studying supramolecular structures and molecular recognition phenomena (see Figure) e.g. by scanning probe microscopy, surface plasmon resonance spectroscopy (SPR), ellipsometry etc. Moreover, molecular recognition phenomena can be "read" at the molecular level by electrochemistry, SPR, or scanning near-field microscopy.


Single nanostructure manipulation

Single molecule science requires the ultimate nanotechnology, i.e. the detection, handling, and manipulation of individual molecules, particles, or nanostructures. The most interesting systems can only be obtained when combined with other knowledge as described above. Some of the current systems have been described in the selected references of this section.


guest complexes probed under thermodynamic equilibrium: thermodynamics and AFM force spectroscopy

Dynamic molecular recognition in bilayer membranes

Molecular recognition at the interface between dynamic bilayer membranes (Figure 3) and their aqueous surroundings is essential to all living organisms. Amphiphilic cyclodextrins assembled in bilayer vesicles are a versatile model system to investigate recognition through specific hydrophobic interaction. We use this system for vesicle-vesicle and vesicle-surface recognition, which is conceptually close to complex cell-cell interactions. Alternatively, we attempt to mimic bio-recognition processes by embedding synthetic self-assembled receptors (rosettes) in vesicles to perform bio-molecular recognition events in the outer shell, as an initial step to artificial cell mimicking.


Inhibition of nonspecific protein interactions to the molecular printboard

The development of a supramolecular method for the inhibition of nonspecific protein interactions to surfaces has been shown in the selected reference. To this purpose an adamantyl-modified hexa(ethylene glycol) guest molecule (AdHEG) was synthesized. The hexa(ethylene glycol) chain prevents nonspecific protein adsorption, while the adamantyl part ensures specific interaction to the molecular printboard. It was shown that AdHEG is efficient in preventing the nonspecific interactions of SAv, the histidine-tagged maltose binding protein (His-

PEG-surfaces, as developed by, amongst others, Whitesides. Furthermore, it was also shown that AdHEG still allowed the specific immobilization of SAv and His-

linker and an adamantyl-modified Ni-

Selective immobilization and patterning of proteins to the molecular printboard

The attachment of streptavidin (SAv) to the molecular printboard via orthogonal linkers and the heterofunctionalization of surface-confined SAv has been shown. SAv was assembled via monovalent and divalent orthogonal linkers. The divalent linker allowed the stepwise adsorption of SAv to the molecular printboard. The availability of the free biotin-binding pockets in the stepwise immobilized SAv at the printboard was shown by patterning studies in which the divalent ligand was patterned to which SAv was attached (see Figure). The subsequent attachment of biotin-4-fluorescein showed the availability of the free binding pockets.

The possibility of antibody (AB) attachment to the molecular printboard via multiple orthogonal binding motifs has been studied. Patterning studies in which a bionanostructure of SAv, biotinylated protein A (bt-PA), and a fluorescently labeled Fc fragment of a human immunoglobulin (IgG-Fc) was built up, showed that the assembly process is selective (see Figure).

M. J. W. Ludden, M. Peter, D. N. Reinshoudt, J. Huskens, Small 2006, 2, 1192-1202.
Nanofabrication

Nanoscience and nanotechnology will only flourish with the development of general nanofabrication methods. These will be developed both along the lines of miniaturization (top-down) and self-assembly (bottom-up). In particular the combination of these will lead to functional, more complex, and more reliably submicron nanofabrication schemes. Current interests encompass the (further) development of soft-lithographic techniques, such as microcontact printing, and other top-down techniques, such as nanoimprint lithography and shadow mask evaporation, in combination with self-assembly, e.g. of (functional) monolayers and nanoparticles (see selected references).


X.-M. Li, J. Huskens, D. N. Reinhoudt, *Nanotechnology* 2003, 14, 1064-1070; "Towards in-plane metathesis polymerization at self-assembled monolayers of norbornene adsorbates on gold surfaces"

X.-M. Li, M. Péter, J. Huskens, D. N. Reinhoudt, *Nanoletters* 2003, 3, 1449-1453; "Catalytic microcontact printing without ink"


Nanofabrication with Nanoparticles

Nanoparticles constitute a versatile class of building blocks that can be used in various applications. We are interested in functionalizing the nanoparticle interface in order to direct the assembly of nanoparticles onto substrates and/or to induce specific recognition with molecules in solution and at interfaces. We extend these methods by the development of layer-by-layer assembly to yield multilayers of nanoparticles and to combine the nanoparticle assembly with top-down nanofabrication methods such as nanoimprint lithography (see Figure).


Functionalized nanoparticles as an interface between monolayers on gold and solution chemistry

Functionalized nanoparticles offer unique ways: (i) for studying binding behavior at interfaces using regular solution techniques which cannot be employed for investigating flat interfaces; (ii) for nanofabrication and surface patterning. Current lines followed are along the functionalization of nanoparticles with molecular recognition sites for making ordered arrays of particles at surfaces by molecular recognition, and the preparation of surfaces functionalized with individually addressable functional groups, e.g. for the development of single molecule templates allowing combinatorial screening.


