Self-assembled structures and applications of DNA hybrid materials

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Summary

In **chapter 1**, it has been described that chemical DNA nanotechnology with a focus on the combination of nucleic acids with synthetic polymers is an emerging field especially in regard to materials and life sciences. Of special interest are oligodeoxynucleotides that are connected to hydrophobic polymers to form amphiphilic linear DNA block copolymers (DBCs). Due to microphase separation, these materials self-assemble into spherical particles that were utilized as programmable, chemical nanoreactors, as scaffolds for enzymatic conversions or as multifunctional drug carrier system.

In the next chapter, these soft matter DNA nanoparticles were employed for loading virus capsids that have recently gained great interest with potential drug delivery and gene therapy applications. However, there has been no reported procedure for the facile loading of these nanocontainers, particularly with regard to hydrophobic molecules. **Chapter 2**, "Virus-like Particles Templated by DNA Micelles", suggests a general strategy for the self-assembly of Cowpea Chlorotic Mottle Virus Capsids around DNA amphiphilic micelles, which before can be easily loaded with either hydrophobic or hydrophilic moieties and allow efficient encapsulation of a large number of locally concentrated oligonucleotides. This result represents significant progress for utilizing these nanoobjects in biomedicine.

In **chapter 3**, DNA diblock copolymers (DNA-*b*-PPO) were utilized to form mixed micelles together with Pluronic™ triblock architectures (PEO-*b*-PPO-*b*-PEO). The formation and characterization of these blended micelles with a DNA/PEO corona and PPO core, which can be loaded with hydrophobic molecules and stabilized by the formation of a semi-interpenetrating network, are described. Furthermore, the corona is conveniently functionalized by hybridization either with dye-modified complementary DNA, with demonstrable distance control, or with DNA-labelled gold nanoparticles. The resulting objects represent excellent candidates for smart drug delivery vehicles with stealth function due to the presence of the PEO chains on the surface.

A systematic study on DNA micelles was carried out in **chapter 4**. This part describes the synthesis and characterization of a new family of DNA amphiphiles containing modified nucleobases. The hydrophobicity was imparted by the introduction of a dodec-1-yne chain at the 5-position of the uracil base, allowing the precise and simple tuning of the hydrophobic properties via solid-phase DNA synthesis. The micelles formed from these modified DNA sequences were characterized by a wide range of techniques. These experiments revealed the role of the quantity and location of the hydrophobic units in determining morphology and

stability of the micelles. The effects of hybridization on the physical characteristics of the DNA micelles were also studied, showing the potential for sequence-specific noncovalent functionalization of the self-assembled aggregates. This approach allows to control the size and the stability of DNA amphiphile aggregates precisely.

In **chapter 5**, "Polarizable DNA Nanoparticles", DNA block copolymer micelles with a polystyrene core and a single-stranded (ss) DNA shell were doped with ferrocene (Fc). Tapping mode atomic force microscopy was used to study the morphology of the doped and undoped block copolymer aggregates. The results show that introducing Fc molecules into the hydrophobic core does not affect the structural properties such as shape or size. In contrast, doping with Fc significantly changes the micelles' electrical properties, namely their polarizability. Electrostatic force microscopy measurements reveal that the undoped micelles show no significant polarization signal, while the Fc-doped aggregates exhibit strongly enhanced polarizability. Furthermore, the nucleic acid moieties were utilized in combination with complementary ssDNA strands to assemble single particles into linear arrays of hybrid nanoobjects. The ability to tune the electrostatic properties of the polymer core and the presence of nucleic acids might open the way for using these bioorganic nanoparticles as building blocks for nanoelectronic or biosensing devices.

The last chapter deals with the utilization of DBCs with the most promising nanomaterials, single-walled carbon nanotube (SWNT), for eventual incorporation into practical technologies. So far the use of SWNTs is limited by difficulties in solubilizing and isolating individual species and precisely manipulating the structures while preserving their exceptional properties. **Chapter 6** describes a potentially scalable solution to these obstacles using DBCs consisting of a single-stranded DNA block covalently connected to a hydrophobic polymer segment. This combination of materials enables each to contribute its full potential – self recognition and selective dispersion, respectively – to the utilization of SWNTs. It is demonstrated that one such hybrid is capable of the whole gamut of solution-based SWNT technologies, from selective dispersion to non-destructive functionalization to high-yield device fabrication such as field-effect transistors. These powerful applications are mediated by simple programmed DNA self assembly, opening the door to broader multidisciplinary materials research in the field of carbon nano-tubes.