Design and Characterization of DNA and Peptide Biointerfaces

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Abstract
Molecular biointerfaces are formed when biomolecules, including DNA, peptides, and proteins, interact with inorganic or synthetic surfaces. Such biointerfaces are intrinsically interesting and versatile systems in terms of their properties as well as underlying physics, chemistry, and biology. They guide the formation of biomaterials, underpin functions of biomedical devices, and provide a way to exploit the assembly and recognition of biomolecules for self-assembly and self-organization of nanostructures in bionanotechnology.

The first critical step toward rational design of molecular biointerfaces is understanding the interactions between biomolecules and solid surfaces. Physics and chemistry provide the tools for quantitative analysis of biointerfaces, which typically contain too few molecules for detection by the standard bioanalytical methods. Physics also suggests a reductionist approach for elucidating the properties of biointerfaces, whereby the initial focus is placed on investigating simple model systems that can be unambiguously analyzed and controlled. Subsequent model systems are designed to have systematically increasing chemical, physical, and structural complexity. Such systematic model studies are used to infer the basic principles that govern the structure and function of molecules at biointerfaces. Finally, those general principles are translated into rational design rules for new platforms that can be used in both research and applications.

This interdisciplinary approach has been successfully implemented for DNA biointerfaces by adapting complementary optical and electron spectroscopies for analyzing DNA immobilized on surfaces. In particular, model DNA sequences of uniform composition, i.e., homo-oligonucleotides, are amendable for spectroscopic analyses [1-3]. Investigations of homo-oligonucleotides deposited on gold provided the basic information for rational design of more complex model and realistic systems. For example, quantitative analysis of DNA-surface interactions led to the discovery of an intrinsically high affinity of adenine nucleotides for gold [4]. This discovery provided rational design rules for creating unique DNA brushes, for which grafting density and conformation can be independently and deterministically controlled [5]. These DNA brushes with novel properties, in turn, opened possibilities both for further progress in understanding DNA-surface interactions and for creating prototypical functional elements for bionanotechnology [6, 7]. A similar general approach is now being implemented for elucidating and exploiting unique properties of peptides at molecular biointerfaces [8-10].

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