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Microcantilever deflection induced to hybridization of monomolecular DNA films: lower immobilization densities lead to larger deflections?

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ABSTRACT

Experimental results show that specific binding between a ligand and surface immobilized receptor such as hybridization of single-stranded DNA (ssDNA) immobilized on a microcantilever surface leads to cantilever deflection. The binding induced deflection may be used as a method for detection of biomolecules, such as pathogens and biohazards. Mechanical deformation induced because of hybridization of surface immobilized DNA strands is a commonly used system to demonstrate the efficacy of microcantilever sensors; therefore, hybridization induced cantilever deflection has been reported for range of parameters that chain distributions – ssDNA immobilization densities, hybridization efficiencies, and ssDNA conformation [1–7]. However, it has been hard to draw general conclusions on the DNA hybridization induced deflections because a large range of deflections has been reported for similar density of hybridized DNA strands on the cantilever. To understand the mechanism underlying the cantilever deflections, a theoretical model that incorporates the influence of ligand/receptor complex surface distribution, conformation, configuration, and empirical interchain potential is developed to predict the binding induced deflections. The cantilever bending induced because of hybridization of DNA strands is predicted for different receptor immobilization densities, hybridization efficiencies, receptor configuration, and spatial arrangements. Predicted deflections are compared with experimental reports to validate the modeling assumptions and identify the influence of various components on mechanical deformation. Comparison of numerical predictions and experimental results suggest that initial immobilization density of receptors is a primary factor that determines the conformation and distribution of hybridized DNA strands and in turn, the cantilever deflection associated with DNA hybridization. Contrary to our expectations, the cantilever deflections are found to be larger for smaller receptor immobilization densities. For high immobilization densities, hybridization-induced mechanical deformation is determined primarily by immobilization density and hybridization efficiency as the hybridized DNA strands are restricted to be in standing-up conformation, whereas at lower immobilization densities, different conformations and spatial arrangement of hybridized chains need to be considered in determining the cantilever deflection. In addition, for similar immobilization densities, changing the immobilized receptor configuration from one end-tethered to both end-tethered leads to larger cantilever deflection on hybridization. Comparison of numerical predictions and experimental results highlights the importance of immobilized receptor configurations, immobilization density, and spatial disorder imposed during immobilization and hybridization on the hybridization induced cantilever bending.