



A Micromechanical Biosensor Using Chitosan Polymer

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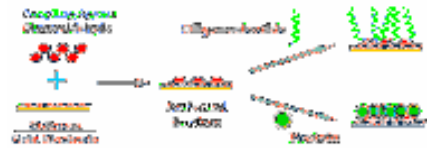
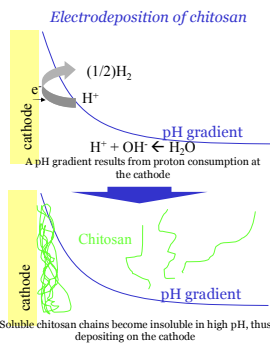
MEMS Sensors and Actuators Laboratory (MSAL)

Introduction

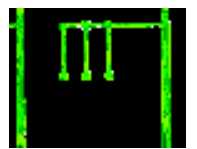
- Microcantilevers with probe biomolecules are highly sensitive and specific detectors of target biomolecules (e. g. proteins, nucleic acids) and allow label-free detection
- Creating an interface between probe biomolecules and microfabricated surface is challenging because their functionality must be preserved
- Chitosan, an amino polysaccharide derived from naturally occurring chitin, was used as an interface between **biological and nonbiological** components
- Electrodeposition of chitosan enables facile patterning of biomolecules with temporal control and is an improvement over printing-based patterning techniques

Chitosan Biointerface

- Responsive to Electrical Stimuli – **Electrodepositable**
 - Chitosan has pH dependent solubility due to its amine groups with pKa ~6.3
 - Electrodeposition enables spatial and temporal control of chitosan film
- Amine Rich Biopolymer - **Biofunctionalizable**
 - The primary amines can be functionalized through a range of standard and enzymatic coupling chemistries
 - Biomolecules can be assembled in BioMEMS devices on the chitosan interface



Biofunctionalization of chitosan using standard glutaraldehyde-based chemistries



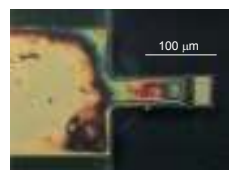
Fluorescent chitosan selectively patterned on cathode

Fabrication

- Cantilever defined by two contact lithography steps, wet etching of metal layer, and RIE of Si₃N₄ layer
- Cantilever released by KOH etching of Si substrate, features aligned along (100)
- Chitosan electrodeposited after fabrication by applying negative potential to cantilever
- Devices can be reused by dissolving chitosan in acidic solution and re depositing it



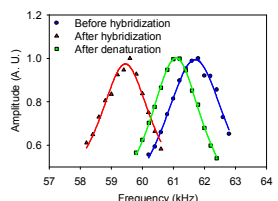
SEM of released cantilever after fabrication



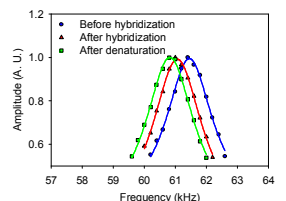
Optical micrograph (DIC) of cantilever after chitosan deposition

Detection of DNA Hybridization

• Dynamic Mode



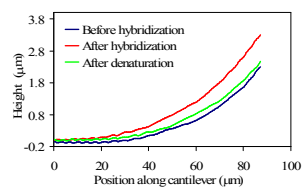
Frequency response of cantilever to complementary DNA



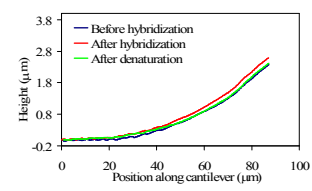
Frequency response of cantilever to noncomplementary DNA

- DNA hybridization causes significant resonant frequency decrease in complementary experiments compared to noncomplementary
- Frequency shift is reversed by denaturation, confirming that change was caused by reversible hybridization

• Static Mode



Deflection of cantilever caused by complementary DNA



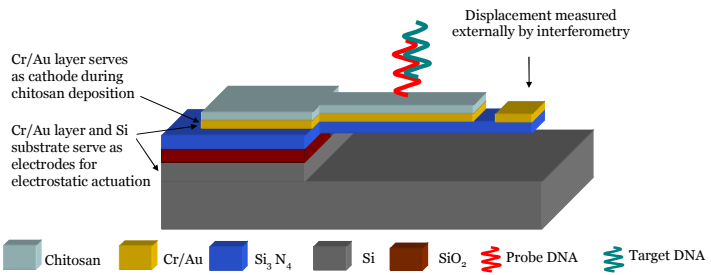
Deflection of cantilever caused by noncomplementary DNA

- Hybridization induces tensile surface stress in complementary experiments, causing cantilever to bend up out of plane. Bending in noncomplementary case is minimal
- Denaturation reverses the bending, indicating that the stress was caused by reversible hybridization

Device Design

- Principle of detection:
 - **Resonant frequency** of cantilever shifts after target biomolecule binding due to added mass (Dynamic Mode)
 - **Deflection** of cantilever changes after target biomolecule binding due to induced surface stress (Static Mode)
- Cantilever displacement in both Static and Dynamic mode measured with optical interferometer (Veeco NT1100 with DMEMS module) after drying of sample
- Cantilever actuated electrostatically by applying potential between metal layer and substrate
- Device operation demonstrated with amine terminated ssDNA as the probe species and its complementary sequence as the target species
- Operation can be extended to other probe/target molecules with same device and test setup with appropriate chitosan coupling chemistry

Cross-sectional schematic of microcantilever biosensor with electrodeposited chitosan



Conclusions

- Electrodeposited chitosan was used to immobilize biomolecules on microcantilevers
- Biological recognition was transduced to a mechanical signal, indicating that the biomolecules preserved their functionality
- Chitosan has many potential advantages as a biointerface material for micromechanical sensors

Acknowledgments

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