Fluorogenic Polydiacetylene Nanosomes: Application to Label-Free Nanobio Sensors

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Needs for Sensors

New & Mutated Infectious Diseases
SARS
Mutated Cholera, etc.

Diagnoses & Drug Discovery
Anthrax

Need for Disease Monitoring

Safety for Processed Food

Astronomical cost spent each year worldwide!

Bio Chips & Chemical Chips

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Outline

- Polydiacetylene Supramolecules
- Detection Examples
- Nanosome-Based Chips
- Nanosome Strips and Fibers
- Summary

Current Concept for Sensing Systems and Chips

- **Sensor Systems**
  - Target Substance: A, B, C
  - Recognizing Materials: A, B, C
  - Human Judgment: A
  - Interface I: Target / Sensor Matrix
  - Interface II: Sensor Matrix / Human
  - Affinity
  - Shape
  - Size
  - Signal Transducer: Transistors / Optics, Electrochemistry, Mechanics / Nanowires

- **Diagnostic Array Chips**
  - Labels: Cy5, Cy3, nanoparticles, radio tracers
  - Pre-treatments For Labeling Analytes
  - DNA Chip
  - Protein Chip
Why Conjugated Systems?

• Conventional Chemosensor

\[
K_{eq} = \frac{[S-T]}{[S][T]}
\]

Sensitivity depends on the equilibrium constant.

• π-Conjugated Polymer Sensor

Signal amplification can be achieved.

π-Conjugated Polymers

• π-Conjugated Polymers

- Polythiophene
- Polypyrrole
- Poly(phenyleneethylenes)
- Combination (PPE + Bipyridil)
- Polydiacetylene

• Electrical and/or optical properties

Easily dispersed into aqueous media!
Polydiacetylene Supramolecules

- Synthetic Diacetylene Supramolecules
  - Hydrophobic tail
  - Diacetylene unit
  - Self-assembly
  - Langmuir–Blodgett
  - Langmuir–Schaefer
  - Solid-supported films
  - Nanosome (vesicle) solution
  - Molecular recognition

- Natural Cell Membranes
  - Inner aqueous compartment
  - Hydrophilic head groups
  - Hydrophobic tails
  - Lipid bilayers
  - Cholesterol
  - Phospholipids
  - Proteins

Optical Characteristics

- Colorless
  - Blue
    - Stimuli
  - Red
    - Real-Time Observation

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Polydiacetylene-Based Sensor Systems

Detection Examples
Detection of Influenza Virus A

Detection Examples

- Influenza Virus A: Charych (1993, 1995)
- Antibody: Jelinek (2001)
Nanosome-Based Chips

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Nanosome Array Chips

< Ink-jet Microarrayer >

Inkjet (non-contact), single tip

< Microarray of Nanosomes >

Pre-spot Nanosome Library
Solutions in 96 or 384 well plates

1 spot (4 nL), width: 200 μm

• Conventional sol’n analysis: 0.1 mL
• 25,000-fold saving
• Tiny amount of analytes
• Simultaneous multiple screening

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Microarray-Based Fluorescence Profiles

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A Label-Free Detection of Protein-Protein Interaction


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A Label-Free Detection of Bacteria

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Detection of *E. Coli*

PCDA-Aniline + PCDA-EDEA-s-NHS

![Image A](image1.png)

PCDA + PCDA-EDEA-s-NHS

![Image B](image2.png)

when primary antibody is absent

![Image C](image3.png)


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DNA Detection Sensitivity

3’ - GAT GGA TGC CCA TTG - 5’-NH₂

5’ - CTA CCT ACG GGT AAC - 3’

*E. coli* lethal factor sequence 15 mer.

![Spotting of vesicle-probe DNA complex](image4.png)

Polymerization

![Target DNA](image5.png)

![Graph](image6.png)

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DNA Detection Selectivity: Perfect Match vs. Single-Base Mismatch

Nanosome Strips and Fibers
Nanosome-Embedded Strip Films

PCDA liposomes in PVA

Drying

Confocal Fluorescence Microscopic Image

Thermal Response

α-CD
β-CD
γ-CD

“Litmus-Type” Strip Sensors for Chemicals

control strip solution

Image Display Using Nanosome-Embedded Films

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*Advanced Functional Materials, 16, 2103 (2006).*

Electrospun Polydiacetylene Fibers

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*Advanced Materials, 19, 521 (2007).*
Visual Detection of Food Transmutation

- beef, pork
- hairtail, croaker, skate, etc
- chicken

Liquid Analytes

Gas Analytes

Visual Alarm System
(Example Case: Formaldehyde)

HCHO detection

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Summary of Sensor Research

Label-Free Chips and Strip Sensors

Reuseable or Continuous-Monitoring System

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