Fluorogenic Polydiacetylene Nanosomes: Application to Label-Free Nanobio Sensors

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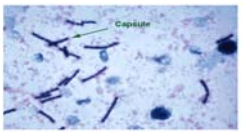
Needs for Sensors

New & Mutated Infectious Diseases

SARS

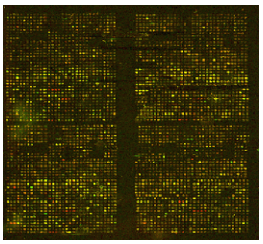
Mutated Cholera, etc.



Anthrax

Astronomical cost spent each year worldwide !

Diagnoses & Drug Discovery



Bio Chips & Chemical Chips

Need for Disease Monitoring

Safety for Processed Food

Outline

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

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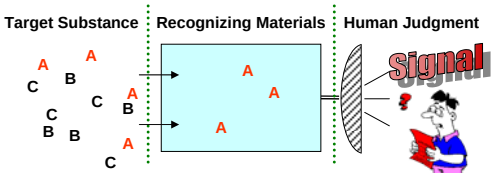
Current Concept for Sensing Systems and Chips

- **Sensor Systems**



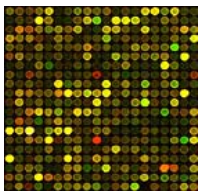
Interface I
Target / Sensor Matrix

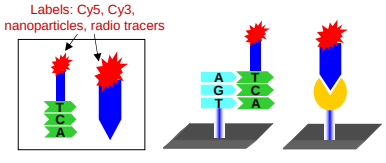
Affinity
Shape
Size

Interface II
Sensor Matrix / Human

Signal Transducer
Transistors / Optics
Electrochemistry
Mechanics / Nanowires

- **Diagnostic Array Chips**





Pre-treatments
For Labeling Analytes

DNA Chip

Protein Chip

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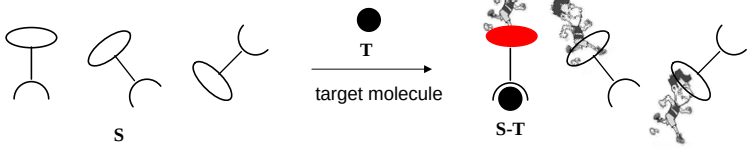
Why Conjugated Systems?

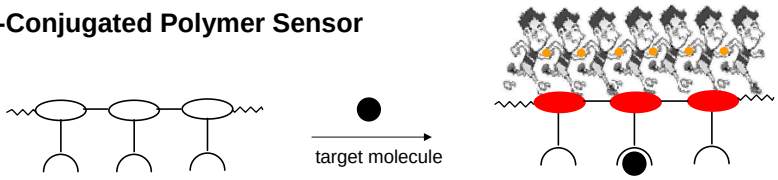
- **Conventional Chemosensor**



Sensitivity depends on the equilibrium constant.

$K_{eq} = [S\text{-}T] / [S] [T]$

- **π-Conjugated Polymer Sensor**



Signal amplification can be achieved.

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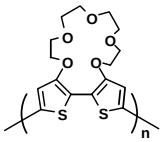
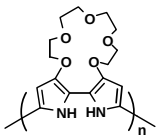
π-Conjugated Polymers

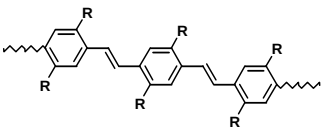
- **π-Conjugated Polymers**



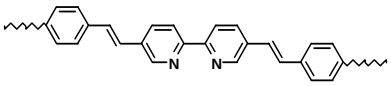
Polythiophene



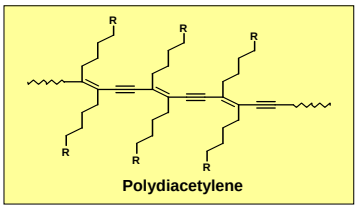
Polypyrrole



Poly(phenyleneethylene)



Combination (PPE + Bipyridil)



Polydiacetylene

- **Electrical and/or optical properties**

Easily dispersed into aqueous media !

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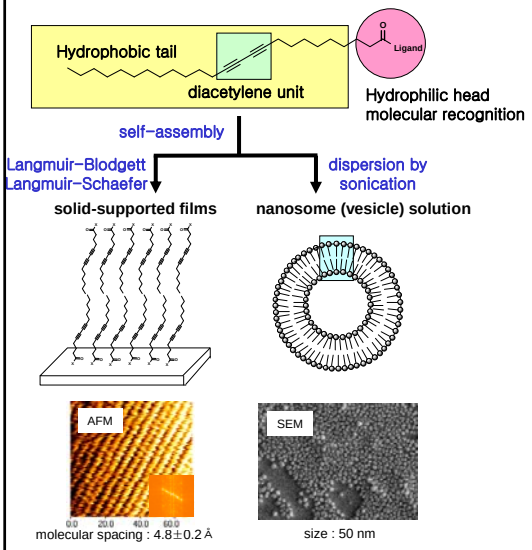
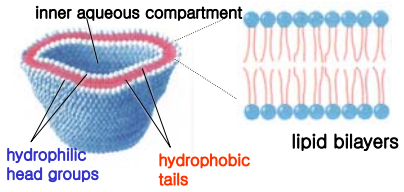
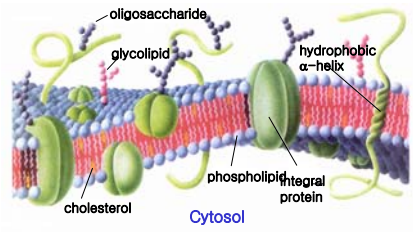
Polydiacetylene Supramolecules

- **Synthetic Diacetylene Supramolecules**



- **Natural Cell Membranes**





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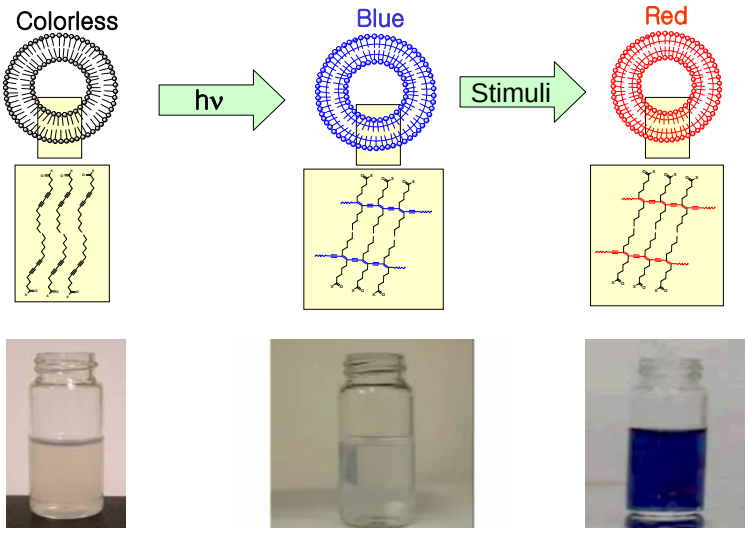
Optical Characteristics



Real-Time
Observation

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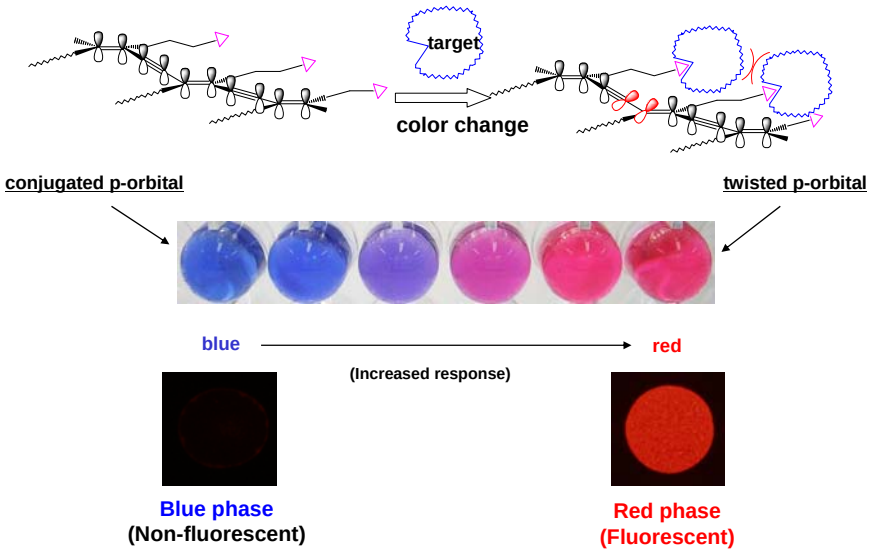
Polydiacetylene-Based Sensor Systems



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Detection Examples

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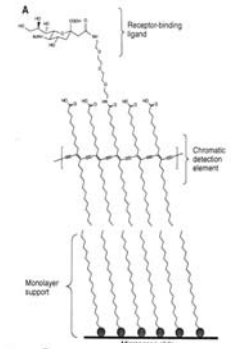
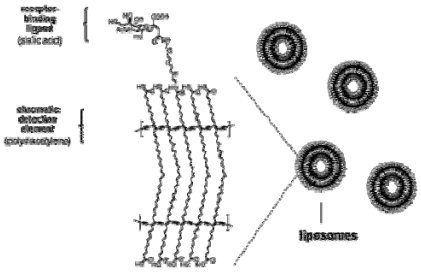
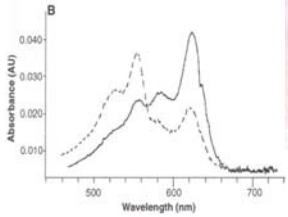
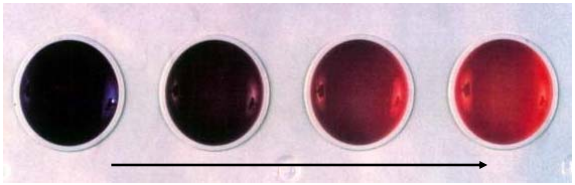
Detection of Influenza Virus A

Charych et al., *Science*, 261, 585 (1993); *J. Am. Chem. Soc.*, 117, 829 (1995).









increase of virus concentration

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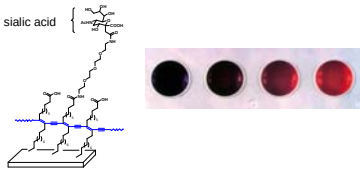
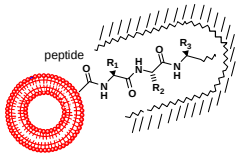
Detection Examples

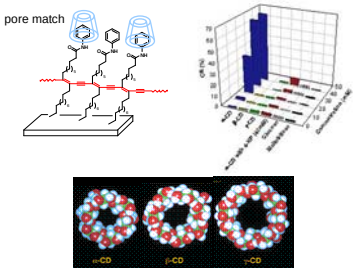
- **Influenza Virus A: Charych (1993, 1995)**



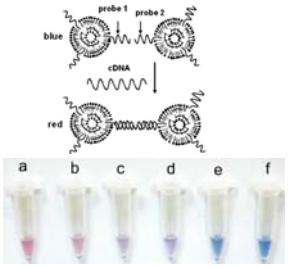
- **Antibody: Jelinek (2001)**



- **Small Molecule (Cyclodextrin): Ahn & Kim (2003, 2004)**



- **DNA: Wang & Ma (2005)**



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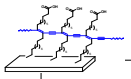
"Conceptual Evolution"



Films on Substrates

Method: Langmuir-Schaefer
Use: Film-type Sensor
Low Signal
One Binding Event per Film

integration

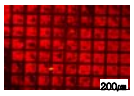
Nanosome Solutions

Method: Sonication
Use: Solution-type Sensor
Medium-High Signal
One Binding Event per Solution

New Concept

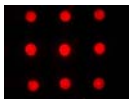
Surface Immobilized Nanosomes

Method: Surface Chemistry
***Advanced Materials*, 15, 1118 (2003).**



Patterned Nanosomes

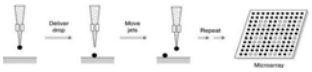
Method: Microcontact Printing
Use: Sensor
One Binding Event per Patterned Nanosome Surface



Self-Emitting Fluorescence
"Label-Free System"

"Nanosome Chips"

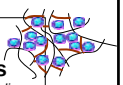
Method: Inkjet Spotting
Use: Chemical & Biological Chip
Simultaneous Screening & Detection



***J. Am. Chem. Soc.*, 127, 17580 (2005).**

Embedded Nanosomes

Method: Polymer Blending



"Nanosome Strips"
"Nanosome Fibers"

Method: Molding & Spinning
Use: Chemical & Bio Sensor

Blue
Blue
Blue
Purple
Pink
Red

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

***Advanced Materials*, 19, 521 (2007).**

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Nanosome-Based Chips

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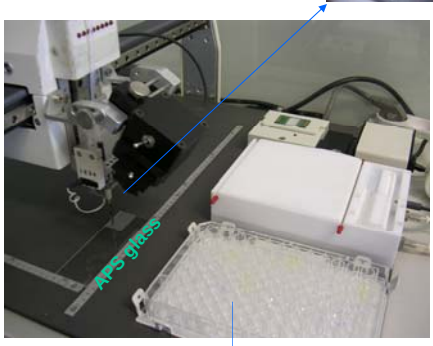
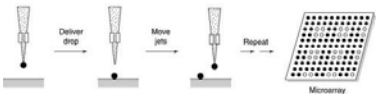
Nanosome Array Chips

< Ink-jet Microarrayer >

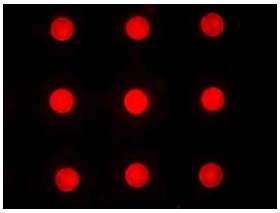


Pre-spot Nanosome Library
Solutions in 96 or 384 well plates

Inkjet (non-contact), single tip



< Microarray of Nanosomes >



1 spot (4 nL), width: 200 ㎛

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

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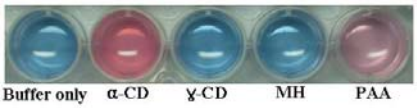
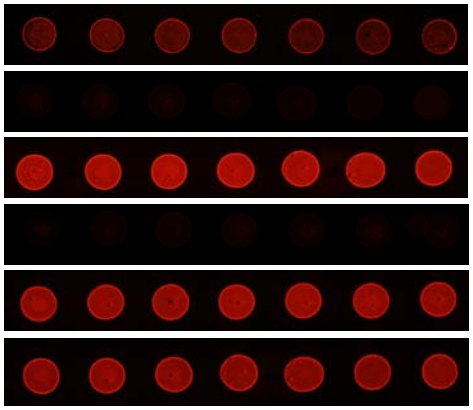
Microarray-Based Fluorescence Profiles





α-CD (30mM)

ɣ-CD (30mM)

ɣ-CD → Heating

Linear Carbohydrate :
Maltoheptaose(30mM)

Maltoheptaose → Heating

Polyacrylic acid (30mM)

Ahn et. al., *J. Am. Chem. Soc.*, 127, 17580 (2005).

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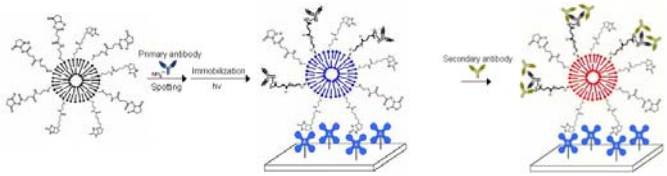
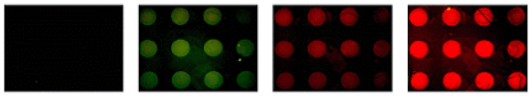
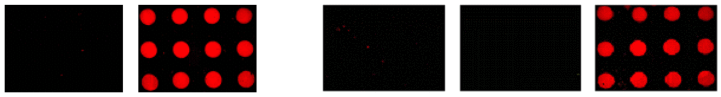
A Label-Free Detection of Protein-Protein Interaction





initial | after exposure to anti-rabbit secondary antibodies | after heated



when primary antibody is absent | after heated | after exposure to anti-mouse secondary antibodies | after heated

***Advanced Functional Materials* (2007); *Macromolecular Research* (2006).**

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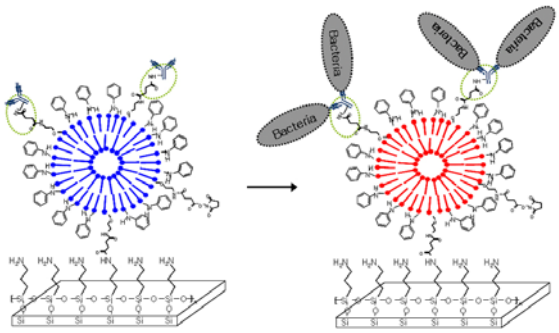
A Label-Free Detection of Bacteria



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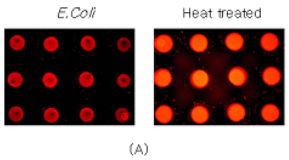
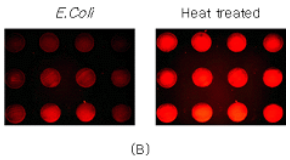
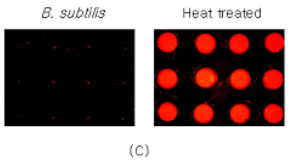
Detection of *E. Coli*

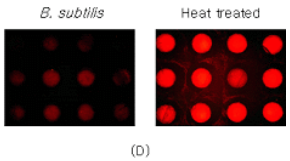
PCDA-Aniline + PCDA-EDEA-s-NHS



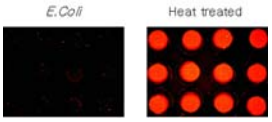
PCDA + PCDA-EDEA-s-NHS







when primary antibody is absent



***Submitted to Angew. Chem. Int. Ed.* (2007).**

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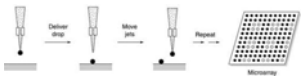
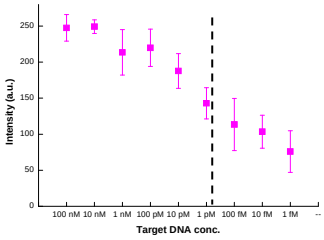
DNA Detection Sensitivity



3` - GAT GGA TGC CCA TTG - 5`-NH_2

5` - CTA CCT ACG GGT AAC - 3`

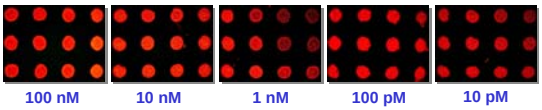
E. coli lethal factor sequence 15 mer.

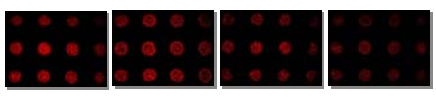


Spotting of vesicle-probe DNA complex

Polymerization

target DNA





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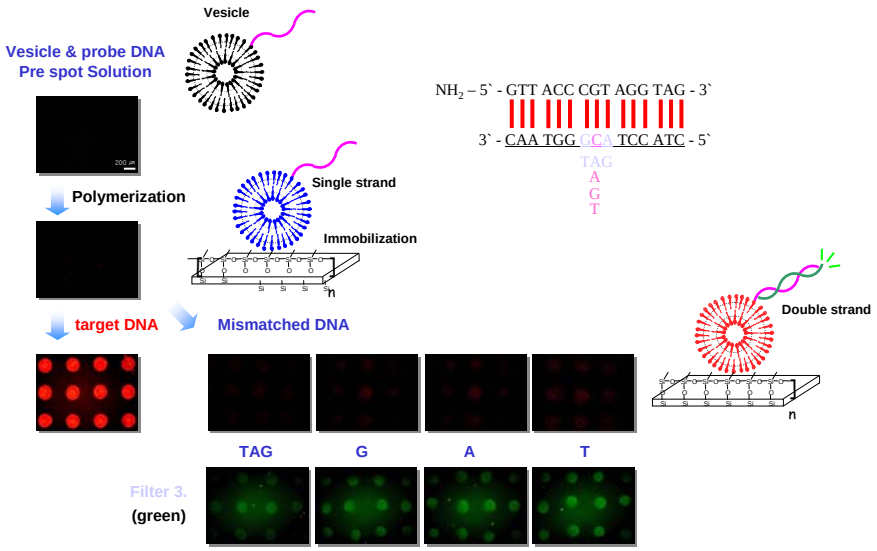
DNA Detection Selectivity: Perfect Match vs. Single-Base Mismatch



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Nanosome Strips and Fibers

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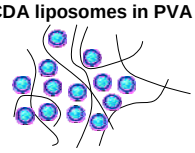
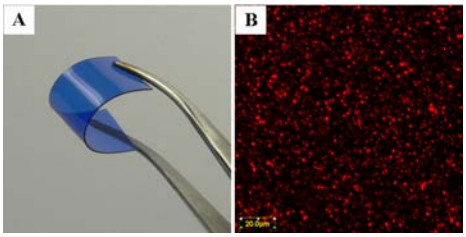
Nanosome-Embedded Strip Films

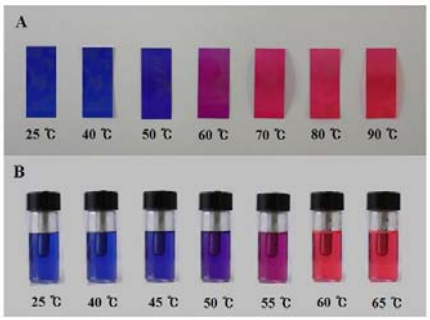
PCDA liposomes in PVA



Drying



Confocal Fluorescence Microscopic Image



Thermal Response

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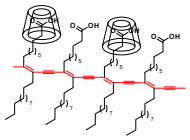
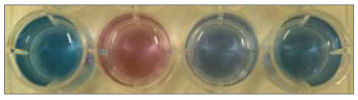
"Litmus-Type" Strip Sensors for Chemicals

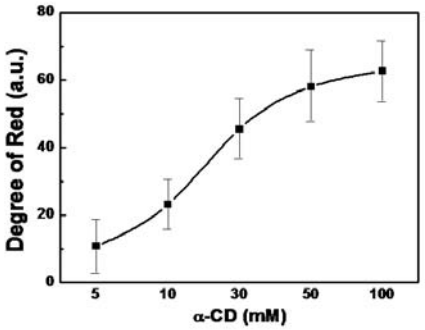


control α-CD β-CD γ-CD

strip

solution





Chemistry Letters, 35, 560 (2006).

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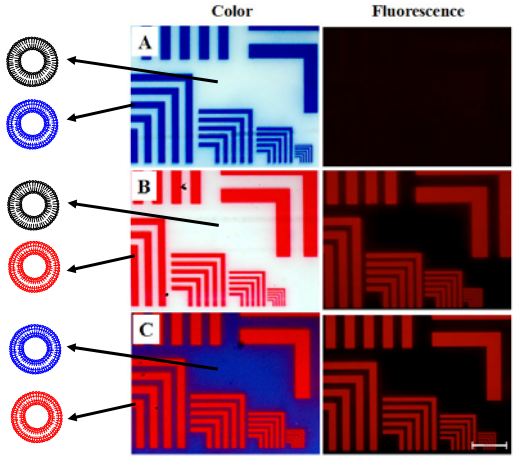
Image Display Using Nanosome-Embedded Films

Advanced Functional Materials, 16, 2103 (2006).



after photopolymerization thru a photomask

after heating

after photopolymerization of the remaining area

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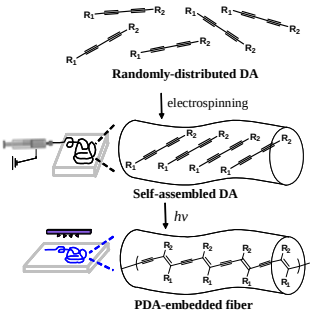
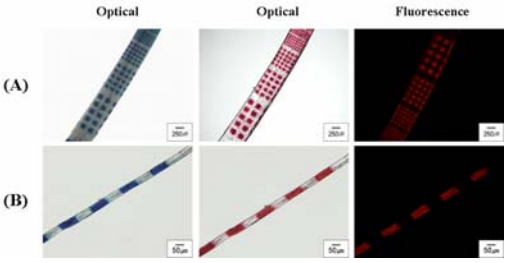
Electrospun Polydiacetylene Fibers





Advanced Materials, 19, 521 (2007).

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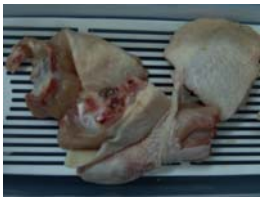
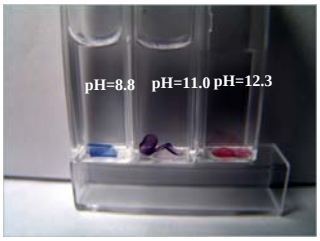
Visual Detection of Food Transmutation

beef, pork

hairtail, croaker, skate, etc



chicken



Liquid Analytes

Gas Analytes

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Visual Alarm System
(Example Case: Formaldehyde)

HCHO detection

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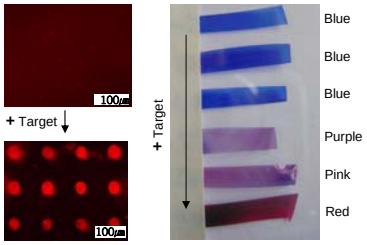
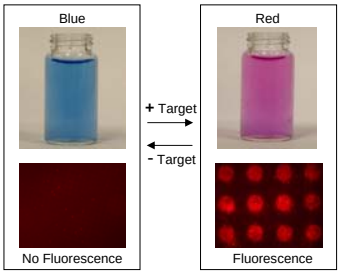
Summary of Sensor Research



Self-Emitting Fluorescence "Label-Free Chip System"

Color-Changing "Label-Free Strip System"

Label-Free Chips and Strip Sensors



Reusable or Continuous-Monitoring System

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