Self-assembly of Nanoparticles in Sensing Platforms

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Outline

• Introductory Concepts
  – Lab on a chip for DNA sequencing
  – Approach to trace air monitoring
  – Micro-trap modulated detection
  – Carbon Nanotubes: Concepts, synthesis and images

• Results
  • Carbon nanotube micro-traps
  • Silica nanoparticle SPEs

• Summary and Final Thoughts
Lab-on-a-chip for DNA Sequencing

- Cell Lysis
- SPE of DNA
- PCR
- Extraction
- Purification
- Pre-concentration
- Electrophoresis
- Laser-Induced Fluorescence Detection
Approach to Trace Air Monitoring

1. Sample Collection
2. Sample Preconcentration
3. Separation/Processing
4. Detection
Microtrap Modulated Detection


Response of Microtrap Pulsed Detection

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<th>DIRECT - FID</th>
<th>PULSED - FID</th>
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Detector Output

Time (seconds)

0  60  120  180  240  300  360

Concentration (ppm)

0.01  0.1  1  10  100
Single wall carbon nanotubes (SWNTs)

Individual SWNTs usually assemble as 0.5 to 20 nm bundles

Synthetic Routes:

• Laser Ablation
• Arc Discharge
• Catalytic CVD

NJIT
\[
\begin{align*}
\text{C}_2\text{H}_4 & \leftrightarrow \text{CNT} + \text{C}_2\text{H}_2 + \text{C}_2\text{H}_6 + \text{C}_3\text{H}_6 + 1\text{-C}_4\text{H}_8 \\
& \quad + 1,3\text{-C}_4\text{H}_6 + \text{H}_2 \quad (1) \\
2\text{CO} & \leftrightarrow \text{CNT} + \text{CO}_2 \quad (2)
\end{align*}
\]

Self Assembly of Nanotubes in Microtrap by CVD

- Argon
- Ethylene
- Hydrogen

Steel Tubing

Flow Controllers

Vacuum Guage

To Vacuum Pump

Bubbler
Catalyst Electrodeposition

Electrochemical cell

Potentiostat

Cycle of 5 pulses/sec For 400secs of –1.1V max.

Auxiliary electrode (Pt wire)
Anodic reaction: \( \text{H}_2\text{O} = 4\text{H}^+ + 4\text{e}^- + \text{O}_2 \)

Cobalt Nitrate (2mM)
NaNO\(_3\) (0.2M)

Reference electrode (Ag/AgCl)

Working electrode (Steel tubing)
Cathodic reaction: \( 2\text{Co}^{2+} + 4\text{e}^- = 2\text{Co} \)
CVD Assembly of CNT in Microtrap

$\text{C}_2\text{H}_4$

$\text{CO}$
Oriented CNT Assembly by Ethylene CVD in a Microtrap
Microtrap by CO-CVD
Microtrap by Ethylene CVD
Breakthrough on MWNT- Microtraps made using Ethylene and CO-CVD (untreated steel, 5 hours)
Breakthrough on Silico-steel vs. Untreated steel: MWNT Assembled from C$_2$H$_4$-CVD for 5 hours.
Factors Affecting Trapping Characteristics

- Compounds used in CVD
- CVD conditions – temperature, pressure, time
- Surface and Catalyst Preparation
Lab-on-a-chip for DNA Sequencing

- Cell Lysis
- SPE of DNA
- PCR
- Extraction
- Purification
- Pre-concentration
- Electrophoresis
- Laser Induced Fluorescence Detection
Microfabricated SPE on PDMS Microchannels

D. Jed Harrison’s Group; U. Alberta, Canada
• ODS beads were trapped in glass substrates.
• Electrophoretic flow

Laser detection
Sol-gel immobilized nano-silica
Hydrolysis of the sol-gel precursors trimethoxymethylsilane and trimethoxypropylsilane
The hydrolysis products of the Sol-gel precursor undergo polycondensation reactions.
3-D polymeric sol-gel network chemically bonded to the silanol moieties on the PDMS surface
SEM Image of the Sol-Gel Entrapped Silica Particles
Sol-gel Immobilized Silica Nano Particles
SEM of the Cross Section of the Silica Packed Channel at 541X Magnification.
Percentage Recovery of DNA extractions from E.coli crude lysates using SPE chips filled with sol-gel immobilized nano silica particles (14nms). Average DNA Recovery is 78 ± 13% (X ± RSD).

[Extraction conditions: 10µl of load, 5µl of wash (80% IPA) and 60µl of elution buffer (0.1M Tris HCL, pH 7.5) were used at a flow rate of 10µl/min. Crude lysate load solution contained about 10ng/µl DNA. DNA quantification was done by fluorescence imaging of Sybr green stained DNA at 488nm excitation and emission settings at 520nm BP 40, 600V, normal sensitivity using TyphoonTM 9410 Variable Mode Imager (Amersham Biosciences, Uppsala, Sweden)].
Summary and Final Thoughts

- Nanoparticles offer:
  1. Large surface area.
  2. Unique sorption characteristics

- Fabrication requires self assembly techniques.

- The process can be fine-tuned to specifications by functionalization of nanoparticles – particularly carbon nanotubes.
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