An Ultra Sensitive Nano-mechanical Polymer Composite Platform for Explosive Detection

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Highly sensitive self standing SU-8 cantilevers with embedded CB

Packaged Polymer Composite Cantilever Dies

SEM of the released SU-8/CB microcantilever
## Explosive Detection Challenges

<table>
<thead>
<tr>
<th>Popular Name</th>
<th>Chemical Formula</th>
<th>Decomposition Temp. (°C)</th>
<th>Molecular Mass (g/mol)</th>
<th>Density at 20°C (g/cm³)</th>
<th>Vapor Pressure at 25°C (torr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TNT</td>
<td>$\text{C}_7\text{H}_5\text{N}_3\text{O}_6$</td>
<td>240</td>
<td>227.13</td>
<td>1.654</td>
<td>$\sim 6.0 \times 10^{-6}$</td>
</tr>
<tr>
<td>RDX</td>
<td>$\text{C}_3\text{H}_6\text{N}_6\text{O}_6$</td>
<td>170</td>
<td>222.12</td>
<td>1.820</td>
<td>$\sim 5.0 \times 10^{-9}$</td>
</tr>
<tr>
<td>PETN</td>
<td>$\text{C}_5\text{H}<em>8\text{N}</em>{12}\text{O}_4$</td>
<td>190</td>
<td>316.14</td>
<td>1.773</td>
<td>$\sim 1.5 \times 10^{-8}$</td>
</tr>
</tbody>
</table>

Currently available sensor systems suffer from several problems, viz. cost, size, sensitivity, selectivity
Cantilever based Explosive Detection @ IIT Bombay

- Surface coatings
  - (a) 4-mercaptobenzoic acid (4-MBA)
  - (b) Fluoroalcohol polysiloxane polymer (SXFA)
  - (c) Porphyrin coating on cantilevers
  - (d) 6-Mercaptonicotinic Acid [6- MNA]
  - (e) Other proprietary coatings

- Electrical Transduction
Polymer nanocomposite microcantilever sensor

Faster response with smaller flow cell

(b) Effect of nitrogen flow rate
Graph A: Voltage vs. Time
- T: TNT ON, N₂ OFF
- N: N₂ ON, TNT OFF

Graph B: TNT Concentration vs. Output [mV]
- Slope ≈ 1.04 mV/ppb
**Explosive experiments-TNT**

<table>
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<tr>
<th>Experimental details</th>
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<tr>
<td>Flow rate from MFC</td>
<td>30 SCCM</td>
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<tr>
<td>Temperature</td>
<td>65°C</td>
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<td>Duration of dry N2 purging before starting the experiment</td>
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<td>Functionalization</td>
<td>4-MBA</td>
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**Graph:**

Microcantilever response for two consecutive cycles of TNT and Nitrogen. Duration/cycle for TNT = 3 minutes, Duration/cycle for Nitrogen = 5 minutes.
### Explosive experiments-TNT

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<th>Flow rate from MFC</th>
<th>30 SCCM</th>
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<tr>
<td>Temperature</td>
<td>70°C</td>
</tr>
<tr>
<td>Duration of dry N2 purging before starting the experiment</td>
<td>1 hour</td>
</tr>
<tr>
<td>Functionalization</td>
<td>4-MBA</td>
</tr>
</tbody>
</table>

**Experimental details**

**Microcantilever signal outputs for different flow rates of carrier gas**

- **TNT ON**
- **TNT OFF**
- **N₂ ON**
Flow rate from MFC: 30 SCCM
Temperature: 65°C
Duration of dry N2 purging before starting the experiment: 1 hour
Functionalization: 4-MBA

Experimental details:

Microcantilever response for two consecutive cycles of TNT and Nitrogen. Duration/cycle for TNT = 3 minutes, Duration/cycle for Nitrogen = 5 minutes
Microcantilever Response to test samples

A: Benzophenone
B: Diphenyl Acetic Acid
C: TNT
D: Dihydrocholestrol
E: 3,4-Dimethoxy-2,5-dimethyl ester of thiophene
F: diol diester of thiophene
G: m-Dinitrobenzene
H: 1-Chloro-2,4-dinitrobenzene
I: 3,5-dinitrobenzoic acid
Miniaturized wireless explosive detector

Packaged flow cell for explosive detection

Fully automated and stand off detection

PCBs for wireless explosive detector
Explosive Detector Prototype for RDX/TNT developed @ IIT Bombay

Seena et al., *IOP Nanotechnology*, 22 (2011) 295501
“E-Dog” to Sniff out Explosives

A real dog’s nose 100 to 10 Million times more sensitive than humans. In laboratory tests dogs were able to detect 1 to 2 parts billion routinely and in some cases 500 parts per trillion, below the detection limit of any available equipment today.

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An ultra-sensitive (parts-per-billion level) nano-electro-mechanical sensor

A rechargeable Li-Po battery

Wireless Transmission Module