Microfluidic Circuit Fabrication and Packaging for Surface-Controlled Bioprocesses in BioMEMS

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Electrochemical deposition of chitosan

**Chitosan and MEMS**

Chitosan (polysaccharide)
- Cationic polyelectrolyte (NH3+)  
- pH dependent solubility (pH < 6.3)  
- Selective deposition  
- Rich amine groups (DNA, protein, cell adhesion)  
- Good interface material

**MEMS technology**

**Chitosan film deposition**

- DC Power Supply  
- Chitosan Solution  
- pH gradient  
- Localized high pH region generated electrochemically due to hydrogen evolution  
- Chitosan molecules deproteinate and immobilize at electrode surface  
- Electrochemical reaction rate depends on current density

**Microfluidic system**

- Leak free microfluidics  
- Incorporation of electrode structure and integrated optical waveguides  
- Reliable exchange of BioMEMS systems through reusable packaging  
- Combinatorial analysis with process parameters

**Chitosan film**

- Hydrogel formation  
- Aquous biocompatible environment  
- 3D structure (Microfluidic channel, barriers, valves)  
- Spatial selectivity (20μm)

**Design and image**

- Side view of microfluidic system with PDMS gasket on substrate

**Chip**

- Pyrex® substrate, Kapton® substrate  
- SU8 Microfluidic channels (w/d ~500/150 μm)  
- Knife edges and PDMS gasket  
- Electrodes for surface deposition and biofunctionalization

**Packaging**

- Polycarbonate packaging material  
- Leak free packaging by clamping action  
- Clear access for in-situ optical microscopy  
- Parallel connection of fluidic and electrical inputs/outputs

**Biofunctionalization in microfluidic system**

**The Idea: Microfluidic Biomolecular Factory**

- Bioprocesses controlled by surface functionalization and reactions at specific sites in microfluidic network

**Flexible and sequential protein assembly through chemical conjugation to deposited chitosan**

- Nucleophilicity of chitosan’s primary amine groups can also be exploited for chemical conjugation of proteins onto electrodeposited chitosan scaffold

**Chitosan deposition in microfluidic system**

- Chitosan solution  
- T% (w/v), pH 5  
- Labeled with NHS-fluorescein  
- Counter electrode  
- Void volume: 1~1.5μm

**Packaging test**

- Successful leak tight system  
- Flow rate: 0.1 mL/min  
- Knife edge Channel

**Successes**

- Chitosan solution
- Deposition conditions
- Flow rate: 1.0 mL/min  
- Current density: 6A/m²  
- Successful chitosan deposition on working electrode in microfluidic channel  
- Estimated thickness: 1~1.5μm  
- Closest working electrode has most deposition