INTEGRATED CHIP AND PACKAGE DESIGN FOR SURFACE-CONTROLLED BIOREACTION PROCESSES WITH ROBUST, REUSABLE FLUIDIC SEALING

J. J. Park\(^1,2\), T. M. Valentine\(^1,2\), R. Ghodssi\(^2,3\), and G. W. Rubloff\(^1,2\)

\(^1\)Department of Materials Science and Engineering, \(^2\)Institute for Systems Research and \(^3\)Department of Electrical and Computer Engineering, University of Maryland, College Park, MD 20742, USA

ABSTRACT

BioMEMS microfluidic system which accommodates a novel fluidic sealing and device integration has been designed and fabricated to provide a platform for post-fabrication, spatially selective biomolecular assembly and biofunctionalization.

Keywords: BioMEMS, microfluidics, package, reusable sealing

1. INTRODUCTION

Research aimed at multi-step, multi-site bioprocess reactions for sensing, synthesis, and metabolic engineering requires an integrated approach to microfluidic chip and packaging designs to accommodate fluidic, electrical and optical networks.\(^[1]\) We exploit surface-controlled bioreaction processes through electrodeposition of amine-rich chitosan biopolymer as the platform for biofunctionalization with proteins or nucleic acids.\(^[2]\) Robust fluidic sealing which can be subsequently removed is desirable for post-reaction analysis of materials and surfaces and for reuse of package and device components. We achieve this using SU8 microchannels and a PDMS sealing layer.\(^[3]\) Plexiglas plates above and below the bioMEMS device chip (Fig. 1) enable compression bolts in the package to compressively seal the microchannels while allowing the system to be opened and reused afterwards. The Plexiglas plates carry fluidic and electrical inputs/outputs (I/O’s) to external control systems. Finally the packaging system is built with transparent Plexiglas material and it allows visible observation to the bioreaction test site by microscope (Fig. 2).

Figure 1 Conceptual exploded view of microfluidic chip and package

Figure 2 Picture of the Plexiglas microfluidic packaging system
2. DESIGN AND STRUCTURE

BioMEMS device chips are fabricated from SU8 microchannels (500 µm wide, 130 µm deep) on pyrex substrates with patterned Au electrodes as the sites for the biomaterial assembly and functionalization (Fig. 3). The bioMEMS chip design shown includes 6 fluidic networks, their I/O’s, and Au electrodes for each microchannel. As indicated in the Fig. 3 insert, the SU8 pattern is restricted to a small lateral extent - a micro-knife-edge - on either side of each microchannel. A flexible thin film (~150 µm) of PDMS then forms a leak-tight gasket seal when pressed against the SU8 micro-knife-edge from the top (Fig. 4). The SU8 micro-knife-edge maximizes local PDMS compression to assure a robust seal.

Assembly is accomplished by placing the SU8/pyrex bioMEMS wafer on the Plexiglas bottom compression plate. The PDMS layer is spun onto a Plexiglas top sealing plate, inverted, and placed onto the SU8 layer. A Plexiglas top compression plate and then a Plexiglas I/O ring are added, and then the assembly is bolted together and tightened to seal the PDMS gasket against the SU8 micro-knife-edge structures which form the perimeter of each microfluidic network. Set screws in the Plexiglas top compression plate can supply an additional stress distribution to optimize sealing across the 4” wafer. Fluidic connectors, O-ring seals for them, and electrical contact structures mounted in the Plexiglas I/O ring accomplish connections to external sources and controls. The overall package allows optical access for real-time microscopy observations of bioprocesses from above.

3. RESULT AND DISCUSSION

To demonstrate robust channel fabrication and package, we performed a series of microfluidic leak tests using dye solutions, as shown in Figure 5. For this, we introduced blue dye solution into the BioMEMS microfluidic system for visible observation. Figure 5 shows the test results of the BioMEMS microfluidic system which is fully compressed with the system bolts and it shows that the microfluidic channels are successfully sealed by the SU8 micro-knife-edge and PDMS gasket. This result shows that our packaging strategy using a SU8 knife edge, PDMS gasket, compression bolts and the Plexiglas package provides robust leak-tight sealing and simple observation.

To demonstrate spatially selective biomolecular assembly in microfluidic system, we deposited NHS-fluorescein labelled chitosan film onto the Au electrode in microchannel. Chitosan solution (pH~5, 1 w/v %) was introduced into microfluidic channel by micropump.
with flow rate of 2 μl/min. Then the pump was turned off to provide static flow condition for chitosan film deposition. Voltage (2 A/m², 240 sec) was applied and electrodeposition of fluorescein labeled chitosan (Fig. 6) is clearly seen on the negative electrode. While important issues of preferential deposition and biofunctionalization remain, these results demonstrate the ability of this bioMEMS device and package design to support selective deposition of biofunctional platforms in a manner that ensures robust, leak-free fluid flow, and in a configuration that permits reuse and post-process materials and surface examination.

4. CONCLUSIONS
In conclusion, we designed and fabricated a BioMEMS microfluidic system - device chip and package - having non-permanent, reusable sealing technology, fluidic/electrical device integration, and optical access to test sites. We demonstrated that the micro-knife-edge and gasket sealing technology allows robust fluid sealing readily achievable. Further, we demonstrated post-fabrication biomolecular assembly in the microfluidic system by electrodeposition of fluorescein-labeled chitosan on the gold electrode.

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G. W. Rubloff, University of Maryland, 2145 A.V. Williams Bldg, College Park, MD 20742-3285, USA, Tel 301 405-2949, Fax 301 314-9920, Email: rubloff@umd.edu