

# A New Magnetically Actuated Microvalve for Liquid and Gas Control Applications

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## ABSTRACT

In this paper, we describe the design, fabrication, and testing of a prototype microvalve which makes use of a novel magnetic microactuator. The completed device consists of three layers, with the bottom two layers making up the normally closed valve. The top layer (actuator) contains the flux generator on its top surface combined with Ni/Fe plated through holes for guiding the flux to the valve. The actuator and valve components are separately fabricated and then mounted onto a glass motherboard which contains both fluid flow channels and patterned gold traces for making electrical connections. In addition to providing an easy means for testing, the motherboard will allow for the later attachment of other microfluidic components to create a complete microfluidic total analysis system ( $\mu$ -TAS) on a single substrate. Preliminary test results show that the valve is capable of controlling gas and liquid flow in the range of submicroliters to hundreds of  $\mu\text{L}/\text{min}$ .

## INTRODUCTION

### Microfluidic Components Require:

- Wide Range of Controllable Flow Rates
- Minimal Leakage
- Low Dead Volume
- IC Level Driving Voltages
- Low Power Consumption

### Applications for Microvalves in the Emerging Field of Microfluidics:

- Microfluidic Total Analysis Systems ( $\mu$ -TAS)
- Portable Drug Delivery Systems
- Chemical/Biological Detection Systems

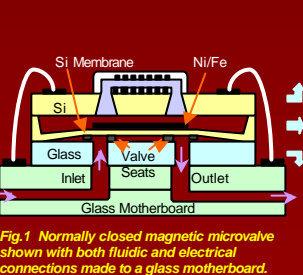


Fig. 1 Normally closed magnetic microvalve shown with both fluidic and electrical connections made to a glass motherboard.

## SPECIFICATIONS

### Design

- Inductors: 60 turns (coil), Ni/Fe plated through-holes
- Si membrane:  $3000\ \mu\text{m} \times 5000\ \mu\text{m} \times 10\ \mu\text{m}$
- Ni/Fe permalloy:  $2000\ \mu\text{m} \times 2000\ \mu\text{m} \times 7\ \mu\text{m}$
- Valve seats:  $340\ \mu\text{m}$  ID,  $600\ \mu\text{m}$  OD,  $3\ \mu\text{m}$  high

### Fabrication / Packaging

- Magnetic Actuators: planar solenoid inductors
- Microvalves: Si membrane, polyimide valve seats
- Motherboard: glass-glass, teflon bonding

### Operation

- Power consumption: 0 - 400 mW (0 - 600 mA)
- Flow rate: 0 - 600  $\mu\text{L}/\text{min}$  (gas), 0 - 1  $\mu\text{L}/\text{min}$  (liquid)

## FABRICATION OF ACTUATORS

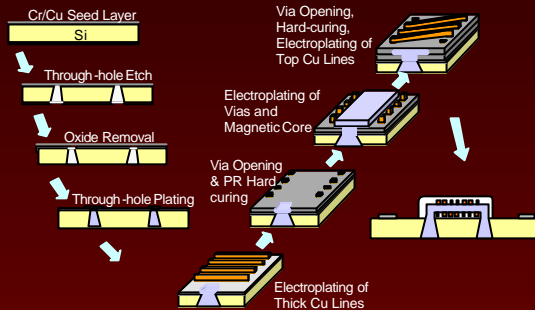


Fig. 2 Magnetic Actuator Fabrication Steps.

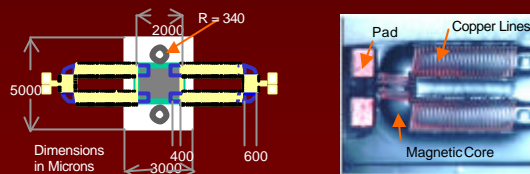


Fig. 3 Top Schematic View of Actuators

Fig. 4 Photograph of Completed Horseshoe Electromagnet.

## FABRICATION OF MICROVALVES AND PACKAGING

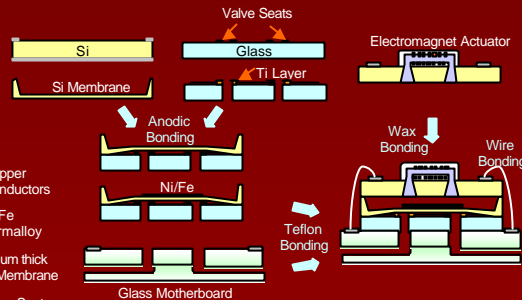


Fig. 5 Microvalve Fabrication Steps and Packaging

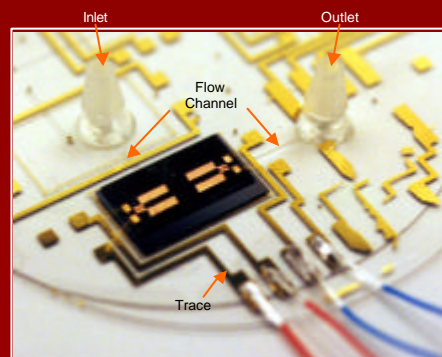


Fig. 6 Photograph of Assembled Microvalve on Glass Motherboard

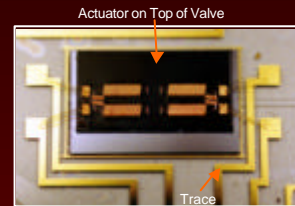


Fig. 7 Top View of Microvalve on Glass Motherboard

## EXPERIMENTAL RESULTS

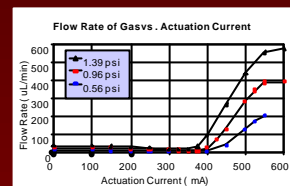


Fig. 8 Flow Rate of Nitrogen vs. Actuation Current.

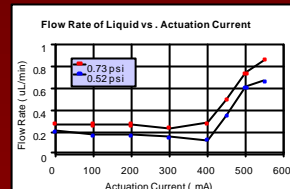


Fig. 9 Flow Rate of DI Water vs. Actuation Current.

## CONCLUSIONS

- Developed a new magnetic actuator using horseshoe electromagnet and permalloy plated through-holes.
- Designed, fabricated and characterized a new microvalve using magnetic micro actuator.
- Developed a new packaging technique by mounting a valve on a glass motherboard.
- Performed flow characterization for both gas ( $300\ \mu\text{L}/\text{min}$  @  $500\ \text{mA}$  and  $0.96\ \text{psi}$ ) and liquid ( $0.8\ \mu\text{L}/\text{min}$  @  $500\ \text{mA}$  and  $0.73\ \text{psi}$ ) with a power consumption of  $350\ \text{mW}$
- Measured some leakage through the valves, but additional design changes are currently being investigated to insure better sealing.

## ACKNOWLEDGEMENT

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