Fabrication of a Bistable Electromagnetic Actuator for Microvalve

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This paper presents the fabrication processes of an electromagnetic actuator for a microvalve, which will be used to open /close the pressurize fuel reservoir in a direct methanol fuel cell, shown schematically in figure 1. Previous designs of electromagnetic microvalves have high power consumption [2], or have been bulky [3]. This microvalve is designed for low power consumption by employing a bistable structure, achieved through either a buckling membrane, or flat membrane with a permanent magnet. The mechanical design and simulation of the microvalve has been presented [1]. The fabrication process is presented, as shown in the figure 2, for the flat membrane with permanent magnet.

A brief discussion of the fabrication steps are as follows: After 0.5 μm PECVD Si_3N_4 on the back side of wafer, photolithography mask #1 creates a mold of pulsed electroplating NiFe and 0.5 μm of Au, to facilitate wire bonding. PECVD SiO_2 layer on top of the wafer provides insulation, followed by a Ti/Cu seed layer. Mask #2 defines the pattern for etching contact window and then the seed layers and SiO_2. Mask #3 defines mold for Cu coils and Au for wire bonding. Mask #4 defines mold for the valve structure formed by NiFe electroplating. Mask #5 defines mold for NiFe membrane, electroplated to the thickness of 3 μm. Finally, strip the all PR, seed layer, and attach the permanent magnet on the back of the wafer.

Figure 5 shows the SEM pictures of the completed actuators. The actuators operate in the energy less than 0.15 Joule/cycle. Table 1 shows the coils resistance measurement for 8 μm (w) x 10 um (h) and coil gap of 28 μm. The overall size of microvalve actuator is 1000 μm in diameter (figure 3) that contains Cu coils with the smallest feature of 4 μm and outside diameter of 400 μm. The membrane to coils separation distance was 15 μm and the mechanical time constant was less than 0.01s.

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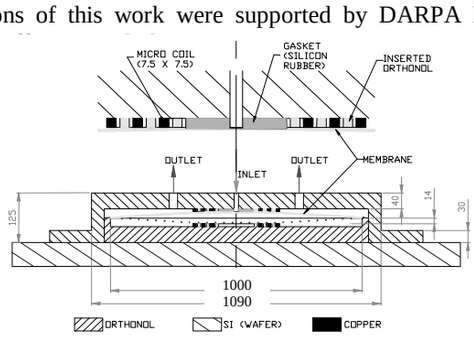


Figure 1: Schematic Cross Section of the microvalve

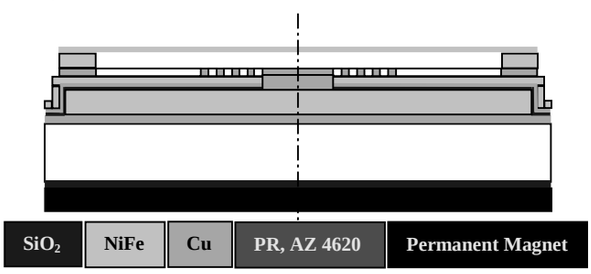
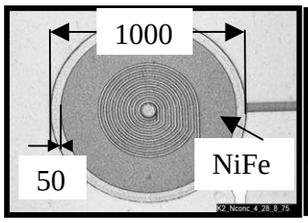


Figure 2: the microvalve fabrication steps



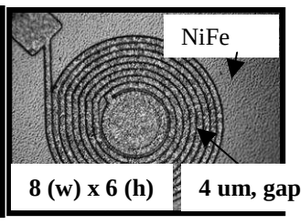


Figure 3 and 4: Cu electroplating mold and Cu coils

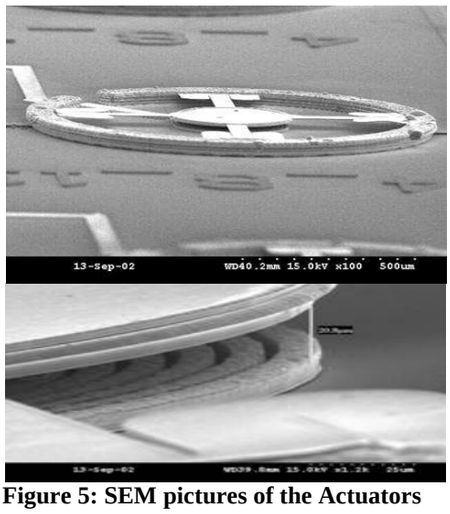


Figure 5: SEM pictures of the Actuators

Table 1: Coils Resistance Measurement

NO turns	THEORY (Ohm)	MEASUREMENT (Ohm)
5	3	6.4
6	4	7.8
7	5	10.5