MEMS Bio-Probe Devices for Monitoring of Various Blood Properties

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Abstract — **A set of MEMS Bio-Probes is designed, fabricated over a five-week period, then packaged and tested for functionality. The devices were fabricated to near completion however they were not brought to a point where they could be electrically tested. The fabrication of the devices went remarkable well. This indicates that there is potential for the device to work as originally intended.**

I. Introduction

MEMS biological devices are relatively new and unexplored in the semiconductor industry. The devices themselves have a range of applications especially for metrology use. This particular project involves the design and fabrication of MEMS bio probe devices. These are essentially micro-scale probes that are intended to be inserted into the blood stream of an organism to monitor various properties such as temperature, flow and chemical detection. For the scope of this project these mentioned properties are what the various probes will be used to detect/measure. Testing will not be done on living organisms but instead a simulated artery or vein will be utilized.

II. Theory

The following fig.1 illustrates a probe tip device designed to count passing red blood cells. There are three channel formed between four oxide structures. On the base of each of these channels is a photo diode. The channels are 15um to filter out larger particles in the blood stream and to only allow 12-15um diameter red blood cells to pass through. The probe tip would be inserted into the blood stream, light would be shown down onto the topside of the tip and as red blood cells pass through the channels there would be an interruption in the output current. For this device to operate correctly an amplifier circuit is required.

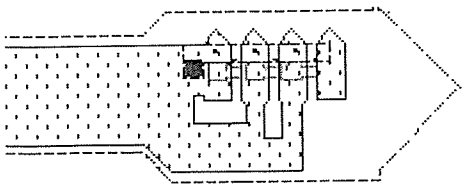

Figure 1 Blood Counting Bio-Probe Tip

Fig. 2 illustrates a flow sensing device. The thin probe tip has a small 'T' etched out of it so that when the device is placed perpendicular flow the center section will act like a sail. The force of the fluid flow will bend this center 'T' section which in turn stresses a poly-silicon resistor. Due to Piezo-resistivity the initial resistance value of the poly-silicon feature will change under this induced stress. The change in resistances can be calibrated to certain flows so that the device can measure with accuracy and consistency. For detection of the signal the device will require electronics to place a voltage across the resistor and then any change in resistance can be seen through amplified current or voltage change.

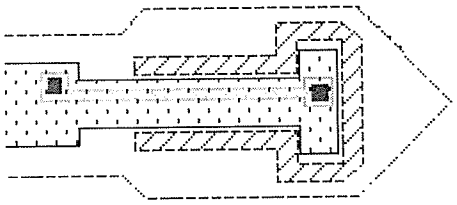

Figure 2 Flow Sensor Bio-Probe Tip

Fig. 3 illustrates a temperature sensing device. This device is quite simple in construction in that the main component is a coiled poly-silicon resistor. When the device is placed into a liquid the change in temperature will also change the resistance value of the poly-silicon coil. This is another instance where the device will need to be calibrated to certain set values in order to output accurately. Signal detection will require an electronics circuit that applies a set voltage and detects current change when the device is exposed to higher temperatures.

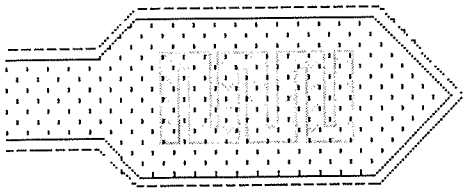

Figure 3 Temperature Sensor Bio-Probe Tip

Fig. 4 represents an additional device that was originally intended to be a form of oxygen level sensor. This particular device was not brought to completion in the mask design layout however it was decided that it just be incorporated into the final design as it is.

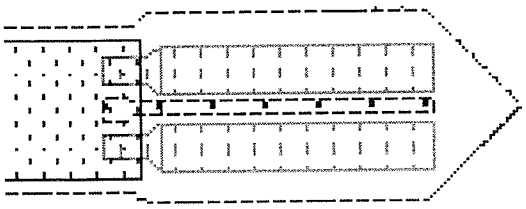

Figure 4 Oxygen Sensor Bio-Probe Tip

III. Experimental Procedure

A. Fabrication

Fabrication for these devices was based off of the RIT MEMS bulk process that had been developed primarily by Dr. Lynn Fuller. This process is used in the MEMS course to build projects for an entire class onto one wafer. It is considered a bulk process due to the fact that several unique MEMS devices are created using only one process. This process was chosen for sake of time in that a new, unique process did not need be developed but mainly because it is a proven process. It has proved to fabricate working MEMS devices in the past so it will be appropriate for the scope of this project.

1 Obtain qty 10, 4" n-type wafers
2 Wafer grind to 300um
3 Polish back side
4 CMP Clean
5 RCA Clean
6 Grow masking oxide 5000 Å, Recipe 350
7 Photo 1 P+ diffusion
8 Etch Oxide, 12 min, Rinse, SRD
9 Strip Resist
10 Spin-on Glass, Borofilm 100, include dummy
11 Dopant Diffusion Recipe 110
12 Etch SOG and Masking Oxide, 20min BOE
13 Four Point Probe Dummy Wafer
14 RCA Clean
15 500Å Pad Ox - recipe 250
16 Deposit 1500Å Nitride
17 Coat back of wafer and protect edge
18 Plasma Etch Nitride on front of wafer, Lam-490
19 Strip backside resist
20 Remove pad oxide - 1min BOE
21 RCA Clean
22 Grow 5,000Å of oxide - recipe 350
23 Photo 2 N+ diffusion
24 Etch oxide
25 N+ SOG
26 Strip resist, RCA clean
27 N+ drive -in
28 Photo 6 Backside Diaphragm
29 Coat front of wafer and protect edge
30 Etch oxynitride, 1 min 10 1HF
31 Plasma Etch Nitride on back of wafer, Lam-490
32 1.5min 10 1 HF to remove Pad ox
33 Remove resist - solvent strip 5min + 5min rinse
34 RCA Clean
35 Deposit 6000Å Poly LPCVD
36 Spin on Glass, N-250
37 Poly Diffusion, Recipe 120
38 Etch SOG
39 4 pt Probe
40 Photo 3, Poly
41 Etch poly, LAM490
42 Strip resist
43 RCA Clean
44 Oxidize Poly Recipe 250
45 Deposit 8,000Å TEOS or LTO Oxide
46 Photo 4, Contact Cut
47 Etch Oxide in BOE, Rinse, SRD
48 Strip Resist
49 RCA Clean, include extra HF step
50 Deposit Aluminum, 10,000Å
51 Photo 5, Metal
52 Etch Aluminum, Wet Etch
53 Strip Resist
54 Deposit 10,000Å LTO2
55 Deposit top hole mask - Aluminum 5,000Å
56 Photo 7, Top Hole
57 Top Hole Aluminum etch
58 Deposit 4,000Å LTO PROTEK Adhesion
59 Spin coat PROTEK on front of wafer
60 Etch Diaphragm in KOH, ~4 hours
61 Strip PROTEK
62 Decontamination clean
63 Top Hole Silicon etch
64 Remove aluminum top layer
65 Test

Table 1 – MEMS Bulk Process

Table 1 seen above is the complete RIT MEMS Bulk process. The process takes about 5 to 6 weeks to complete in the RIT fab due to sharing of equipment and other time constraints. The detailed process also offers alternate steps for certain lithography and etching steps.

B. Testing

Ultimately the released devices would be tested on a simulated vein or blood vessel. This is to be achieved through fine surgical tubing, a reservoir of liquid and a small pump to transport liquid through this tubing. This would simulate a vein in a living organism. The liquid being tested could have particles placed into it for blood cell simulation and also could be heated to see if temperature is detectable.

If the devices were to behave correctly in a simulated environment then perhaps they could be introduced to a living organism. This has certain ethical issues tied to it so the likelihood of this being actually carried out on this level is fairly unlikely.

Important to note that before any of this testing can be done the electronic circuits must be created in order to actually measure what they were intended for and to amplify these signals. These signals must then be observed, discerned and then calibrated to known measurements so that the consistency and behavior of the devices can be established.

IV. Results and Analysis

The following figures (5-8) are the resulting fabricated devices that can be compared to figures 1 through 4 respectively.

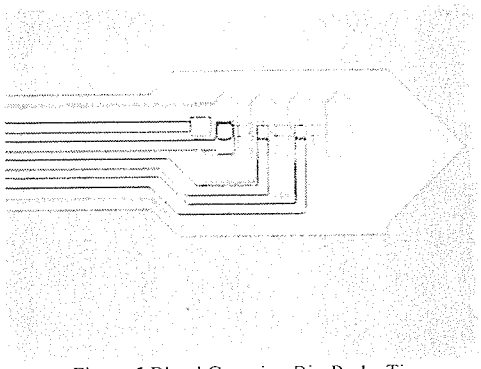

Figure 5 Blood Counting Bio-Probe Tip

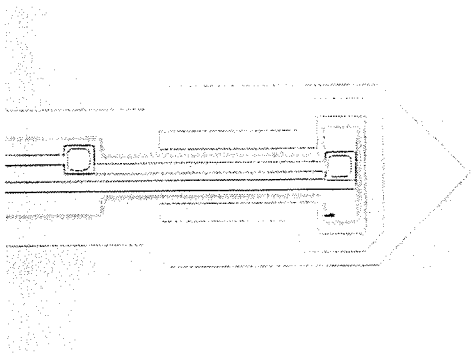

Figure 6 Flow Senor Bio-Probe Tip

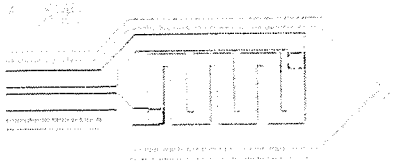

Figure 7 Temperature Sensor Bio-Probe Tip

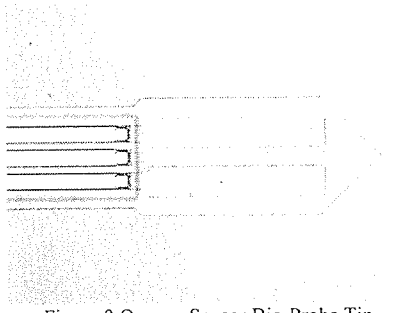

Figure 8 Oxygen Sensor Bio-Probe Tip

The fabrication of the devices went very well. The project started out with only 2 wafers for processing due to CMP complications. With over 70 steps of processing there were no wafers broken and only two minor errors that were easily rectified. The wafers are still not top hole etched but that is due only to time constraints and not a processing malfunction. All of the 8 levels of lithography were near-perfect aligned and came out very crisp.

Testing of the bio-probe devices was not carried out due to a problem at the last few processing steps. The devices are required to have a blanket coating of oxide and aluminum everywhere but the areas that would receive top hole etch. On the last couple days of fabrication the top hole etch was not able to be completed due to a residue blocking the etching plasma. Since then the wafers have had the residue removed although there was not time to finish the top hole etch. This means that the

V. Conclusion

A set of MEMS Bio-Probe devices was successfully designed and fabricated however unsuccessfully tested. Due to time constraints the project was not all the way completed. The device wafers as they stand right now are ready for a final processing step and then electrical testing. Before testing can begin the electrical circuits must be created for each individual device so that measurements can properly be detected and analyzed.

The amount of processing done for this project was a feat all in itself and it was only accomplished through the help of fellow students and RIT staff. Even though there are no testing results for the devices they are constructed and ready for future work.

VI. Appendix

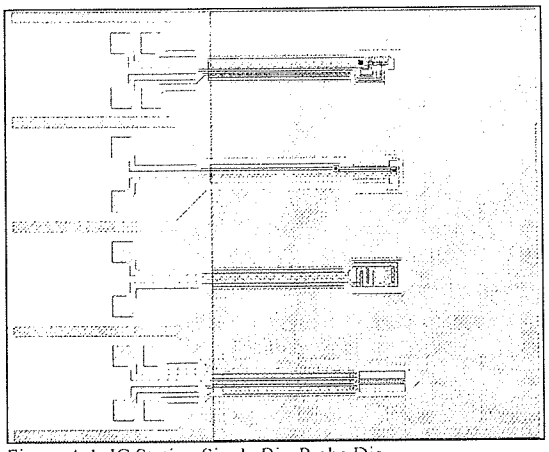

Figure A.1 IC Station Single Bio-Probe Die

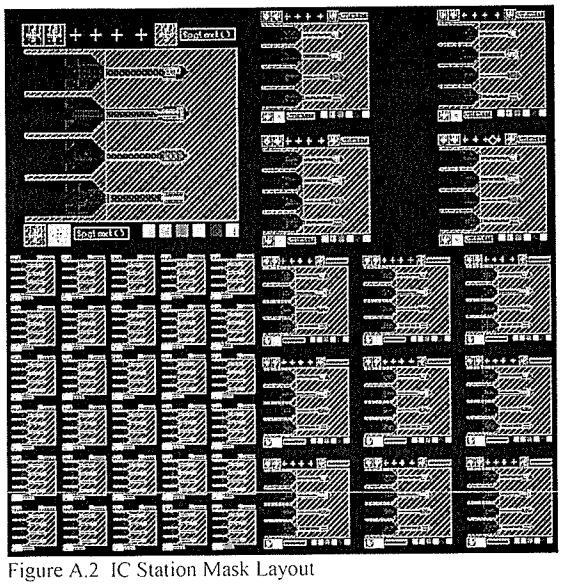

Figure A.2 IC Station Mask Layout

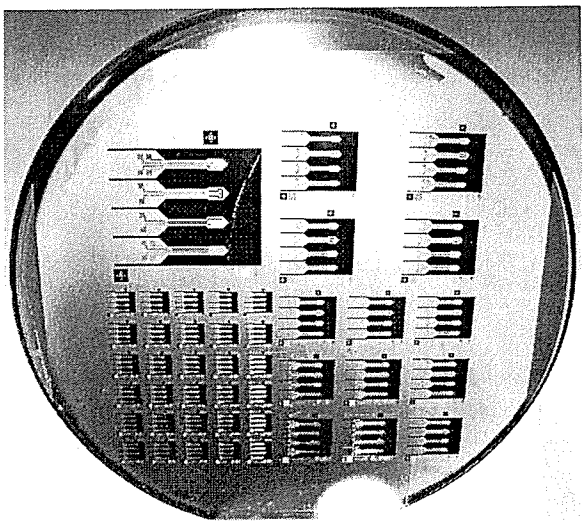

Figure A.3 Device wafer before Top Hole etch

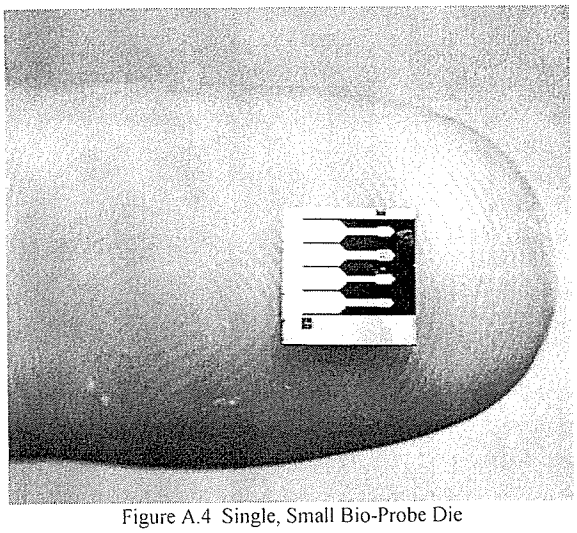

Figure A.4 Single, Small Bio-Probe Die