An Electrically Addressable, Liquid Release Well Array for a Hand-held Scented Material Dispense System

K. Lamers[1], P. Chiang[2], R. Flynn[1], and Y.R. Rau[3]
Departments of [1]Mechanical Engineering, [2]Electrical Engineering, and [3]Chemical Engineering, Stanford University

This project demonstrates a MEMS-based handheld device that stores and dispenses scented materials, allowing users to select and release a variety of combinations of stored scents. Small volume, low power consumption and low cost are the most important device constrains for consumer application, leading to a disposable burst pump design.

The initial design consists of a 2x10 array of cylindrical sealed wells, each measuring 1mm in diameter and 500μm deep. The wells are designed to store a quantized amount of .2μL scent oil and alcohol. Wells are electrically addressable so that any combination of scents can be dispensed simultaneously. The dispense mechanism is rupturing the seal of the well by heat. Further design requirements are: a) The wells must sustain pressure of at least 5psi for at least a month; b) The walls of the wells must be hydrophilic so scents are not absorbed by them; and c) The release time of quantized scents must be within 0.5s in order for them to mix in air.

Figure 1 shows a top-down view of the device. Each well is sealed on the bottom by a full diameter compliant membrane of PDMS or high tack wafer saw tape that deflects inward to pressurize the chamber. A molded PEEK backplate layer positioned against the back membrane compresses air trapped in each well, providing 5 PSI of force for liquid expulsion. Wells are sealed on top by a thin membrane of uncured SU-8. One-shot liquid dispensers have been widely demonstrated [1, 2, 3, 8, 9]. Attempting to replicate Ahn's implementation [2], our implementation was designed to use a 1V, 300mA, low duration (0.3s) electrical impulse delivered to an Al heater on the well containing the desired scent [3]. Through Joule heating of the aluminum trace, the underlying SU-8 layer is heated above the glass transition temperature of SU-8 until the membrane ruptures and the stored scent fluid is expelled. The device contains four heater designs to investigate the effect of resistance on pump actuation.

The fabrication process is shown in figure 1. The surface of untreated PDMS is hydrophobic [5]. The PDMS surface is made hydrophilic by exposure to oxygen plasma and kept hydrophilic by continuous contact with the scented material in the device [6]. The thickness of the well sealing SU-8 layer was varied to determine optimum thickness, from 5μm to 50μm thick. Al heater thicknesses were varied from 0.5μm to 1.5μm.

To test our devices, either a PEEK back plate or polycarbonate fluidic ports were clamped to the chip, and the heater pads were connected through on-die AC/ DC wafer probes. Pictures of completed and tested devices are in Figure 2. Results from a high speed camera, capturing the well image before and after applied heat, clearly show membrane cracking/rupture, demonstrating the feasibility of these burst pumps.

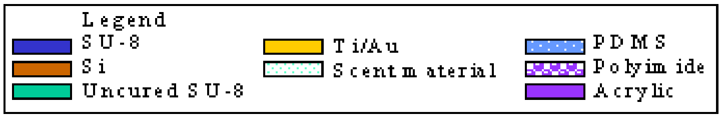
In initial testing, heaters with 0.5μm Al thickness and 20μm width on 50μm thick SU-8 had resistance of 18 Ohms. Using a thermocouple to measure heat dissipation, nominal well temperature increases from 22 to 71 degrees C after application of 100mW. The devices with 1.5μm thick Al on 5um thick SU-8 reliably burst, but the necessary voltage and pressure to detonate the pumps were 5-8 times predicted values. Bursting results for several devices and a graph of voltage versus pressure measurements are shown in Figure 3. Future work will focus on reducing voltage and pressure requirements to reasonable levels for a small, battery-driven device through decreasing SU-8 thickness, increasing the size of the uncured SU-8 area, and increasing heater width and thickness.

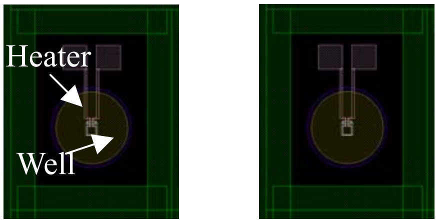
Word Count: 587

References:

[1] Santini, J.T., et. al., Nature, v 397, n 6717, 28 Jan. 1999, p 335-8
[2] Ahn, C. H., et. al., Proceedings of IEEE, Volume 92, Issue 1, Jan 2004 Page(s):154 – 173.
[3] Hong, C.-C., et. al., Micro Electro Mechanical Systems, 2002. IEEE Intl. Conf. Jan. 2002 pp. 240 – 243.
[4] Blanco, F.J., et. al., Journal of Micromechanics and Microengineering, v 14, n 7, July 2004, pp. 1047-56.
[5] Ng, J. M. et. al., Electrophoresis, Vol. 23, No. 20, 2002 pp. 3461-3473.
[6] McDonald, J. C. et al., Electrophoresis, Vol. 21, No. 1, 2000 pp. 27-40.
[7] Tuomikoski, Santeri, et. al., Sensors and Actuators, A: Physical, v 120, n 2, May 17, 2005, pp. 408-41.
[8] Nijdam, A.J., et. al., Sensors and Actuators, A: Physical, v 120, n 1, Apr 29, 2005, pp. 172-183.
[9] Yawen L., et. al., 2nd Intl IEEE-EMBS Conf. on Microtech. in Medicine and Bio. Cat. No.02EX578, 2002 pp. 390-3

Figure 1. Process Flow and Top-down view of Well Layout from Cadence Schematic





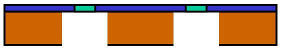
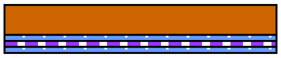
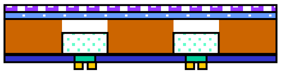
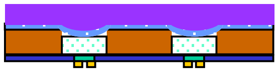
	•Spin 50µm SU-8 on Si. Softbake 15 min. at 65C and 10 min. at 95C for 50µm film. •Pattern leaving small unexposed areas to burst. PEB at 60C for 30 min., slow ramp.
	•Coat 10µm SPR220-7 resist on wafer back and pattern with well mask. •Bake one hour at 110C to harden resist •DRIE wells in Si. Remove resist.
	•Evaporate .5-1.5µ m •Mask with 1.6um Shipley 3612 and wet etch heater pattern. Remove resist.
	•Flip wafer and fill reservoirs with 80% alcohol and 20% scent with a micropipette
	•On separate wafer, deposit PDMS/Polyimide/PDMS. Expose to 100W O2 plasma. •Peel off Polyimide with top PDMS layer
	•Bond Polyimide/PDMS to Si wafer using tweezer pressure. Peel off Polyimide •Alternatively, high tack wafer saw tape can replace PDMS for quick testing.
	•Scribe and break wafer to singulate die. •Clamp on backplate

Figure 2. Top-down view of single burst pump device (a) etched well with uncured spot. (b) heater over UV uncured SU-8. (c) heater separated from UV spot for clarity of imaging. (d) cracked heater after testing. (e) burst heater.

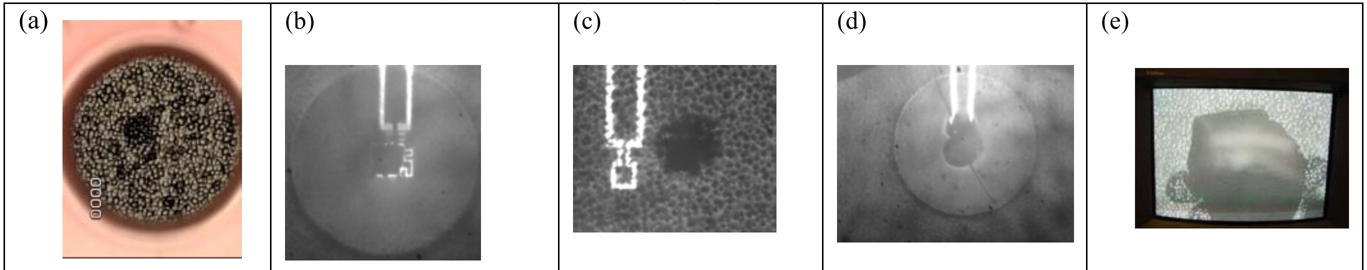


Figure 3. Test results for 1.5um Al on 5um SU-8

Heater Resistance (Ohms)	Pressure (psi)	Voltage (V)	Power (W) * Electromigration not considered	Result
21	90	2	0.19047	Cracked and liquid came out UV area
7	30	5	3.571428	Blew well cover away
6	20	5.5	5.041666	Blew well cover away
7.9	30	5.5	3.829113	Blew well cover away
16	10	3.1	0.600625	Heater failed, SU8 intact
16.8	20	4	0.952380	Small break. When pressure increased to 40psi, cover blew away