

Design and Fabrication of Novel Micro Electromagnetic Actuators and Pumps

陳震徽、李佳言

E-mail: 9706717@mail.dyu.edu.tw

ABSTRACT

A novel technique for the fabrication of electromagnetic micro actuator and micro pump is proposed. The constituent parts of the designed actuator are comprised of a diaphragm, a micro-coils, and a magnet. When an electrical current is applied through the micro-coils, a magnetic force between the magnet and the coil is produced and causes the diaphragm to deflect, which becomes the source of actuation. Photo-lithography, Electron Beam Evaporation, and Electroplating are used in the fabrication process. The structure of the actuating device uses PDMS as the vibrating diaphragm, polyimide as the insulating layer and electroplated copper as the coils. The diaphragm deflection can be regulated by varying the current passed through the micro-coil and hence the actuating effects can be controlled. In this study, three types of micro coils are presented as the micro actuator 75 μm line width with 90 μm spacing, 100 μm line width with 120 μm spacing and 125 μm line width with 150 μm spacing, respectively. The proposed micro actuator has a maximum displacement of 30.33 μm . The micro-channel dimensions are 11.35 mm long and 50 μm deep. The experimental results indicate a maximum flow rate of 1.4 ml/s with a driving frequency of 60 Hz and a coil current of 0.36 A.

Keywords : Design and Fabrication of Novel Micro Electromagnetic Actuators and Pumps

Table of Contents

封面內頁 簽名頁 授權書.....	iii	中文摘要.....	iii
..... iv 英文摘要.....	iv	..... v 誌謝.....	v
..... vi 目錄.....	vi	..... vii 圖目錄.....	vii
..... xi 表目錄.....	xi	..... xiv 符號說明.....	xiv
..... xv 第一章 緒論 1.1 前言.....	xv	..... xv 第一章 緒論 1.1 前言.....	xv
..... 1 1.2 微機電系統之概述與發展.....	1	..... 2 1.3 微型致動器發展之概述.....	2
..... 2 1.4 微型幫浦發展之概述.....	2	..... 3 1.5 文獻回顧.....	3
..... 3 1.6 研究動機與目的.....	3	..... 6 第二章 微型致動器 2.1 研究目的.....	6
..... 9 2.2 致動器微小化之優點.....	9	..... 9 2.3 微型致動器之類型.....	9
..... 10 2.3.1 電磁式致動器.....	10	..... 10 2.3.2 電熱式致動器.....	10
..... 12 2.3.3 靜電式致動器.....	12	..... 15 2.3.4 壓電式致動器.....	15
..... 16 第三章 微型幫浦 3.1 研究目的.....	16	..... 17 3.2 微型幫浦之類型.....	17
..... 18 3.2.1 壓電式微幫浦.....	18	..... 18 3.2.2 靜電式微幫浦.....	18
..... 19 3.2.3 熱驅動式微幫浦.....	19	..... 20 3.2.4 記憶合金式微幫浦.....	20
..... 20 3.2.5 電磁式微幫浦.....	20	..... 21 3.3 微幫浦之應用.....	21
..... 21 第四章 微型電磁式致動器製程技術 4.1 研究目的.....	21	..... 24 4.2 電鍍技術.....	24
..... 24 4.3 電鍍銅金屬.....	24	..... 24 4.4 銅鍍液之種類.....	24
..... 25 4.5 電鍍控制條件.....	25	..... 26 4.6 適用於電鍍的光阻.....	26
..... 27 4.7 電鍍基本配備.....	27	..... 28 4.8 PDMS之特性概述.....	28
..... 28 4.9 製程步驟簡介.....	28	..... 30 4.9.1 蒸鍍種子層.....	30
..... 31 4.9.2 厚膜光阻微影製程.....	31	..... 32 4.9.3 電鍍線圈通道.....	32
..... 36 4.9.4 定義線圈圖形.....	36	..... 37 4.9.5 蒸鍍線圈.....	37
..... 40 4.9.6 電鍍線圈.....	40	..... 43 4.9.7 PDMS薄膜製程.....	43
..... 45 4.9.8 電鍍磁性薄膜.....	45	..... 46 4.9.9 線圈與上層板結合.....	46
..... 50 第五章 微型電磁式微幫浦設計與製造 5.1 研究背景.....	50	..... 52 5.2 BOE蝕刻液之概述.....	52
..... 52 5.3 製程簡介.....	52	..... 53 5.3.1 玻片清洗.....	53
..... 54 5.3.2 定義流道.....	54	..... 54 5.3.3 BOE蝕刻.....	54
..... 55 5.3.4 上板孔徑定義.....	55	..... 56 5.3.5 流道接合.....	56
..... 57 5.4 微型幫浦結合.....	57	..... 57 第六章 結果與討論 6.1 微型電磁式致動器.....	57
..... 59 6.1.1 磁場強度.....	59	..... 59 6.1.2 磁場梯度.....	59
..... 62 6.1.3 位移量測.....	62	..... 64 6.2 微型電磁式微幫浦.....	64
..... 67 6.2.1 不同電流下流率量測.....	67	..... 69 6.2.2 不同頻率下流率.....	69

量測.....	75 第七章 結論 7.1 結論.....	77 7.2 未來與展望.....
.....	78 參考文獻.....	79

REFERENCES

- [1] 余錦漢，以高分子聚合物技術進行濕度感測元件之研究，中原大學電子工程學系，碩士學位論文，2004。
- [2] Riethmuller, W. and Benecke, W., " Thermally Excited Silicon Microactuators, " IEEE Transactions on Electron Devices, Vol. 35, pp. 758 -763, Jun. 1988.
- [3] Guckel, H., Klein, J., Christenson, T., Skrobis, K., Laudon, M., and Lovell, E.G., " Thermo-Magnetic Metal Flexure Actuators, " Solid-State Sensor and Actuator Workshop, 5th Technical Digest, IEEE, pp. 73 – 75. 1992.
- [4] M. Khoo, C. Lin, " A Novel Micromachined Magnetic Membrane Microfluid Pump " , Proceedings of the 22nd Annual EMBS International Conference, July 23-23, pp. 2394-2397, 2000.
- [5] D. Xu, L. Wang, G. Ding, " Characteristics and fabrication of TiNi/Si diaphragm micropump, " Sensors and Actuators A, Vol. 93, pp. 87-92, 2001.
- [6] C. H. Chen, J. G. Santiago, " A Planar Electroosmotic Micropump, " Journal of Microelectromechanical Systems, Vol. 11, No. 6, pp. 672-683, 2002.
- [7] J. M. Berg, R. Anderson, M. Anaya, B. Lahlouh, M. Holtz, T. Dallas, " A two-stage discrete peristaltic micropump, " Sensors and Actuators A, Vol. 104, pp. 6-10, 2003.
- [8] J. H. Kim, C. J. Kang, Y. S. Kim, " A disposable polydimethylsiloxane-based diffuser micropump actuated by piezoelectric-disc, " Microelectronic Engineering, Vol. 7, pp. 119-124, 2004.
- [9] 吳朗，感測與轉換原理元件與應用，全欣科技圖書，2001。
- [10] 松井信行著，編譯：蕭旭烈，致動器入門，複文書局，1987。
- [11] 廖德章、陳文祥、李名洋、林淑玲，高性能的工程塑膠，科學發展，356期，2-10，2002。
- [12] 王禹翔，應用於高氣體流速微懸臂流量感測器，大葉大學，碩士論文，2006。
- [13] 謝秉儒，微型甲醛氣體感測器製作，大葉大學，碩士論文2006。
- [14] 黃仕強，整合型分子模版微流體晶片應用於表面電漿共振生物感測器之檢測，國立成功大學工程科學系，碩士論文，2004。
- [15] 楊啟榮，微機電製程之精密電鑄技術，國立台灣師範大學。
- [16] Lee C.Y., Lee G.B., Micromachine-based humidity sensors with integrated temperature sensors for signal drift compensation, Journal of Micromechanics and Microengineering, 626-631, 2003.
- [17] 章賢聰，用於無閥阻抗微幫浦之新型微電磁致動器之設計、製作與最佳化，大葉大學，博士論文，2007。
- [18] 吳家鴻，新型壓電致動器及壓電平台，國立成功大學工程學系，Motor Express 202期，7-15，2006。
- [19] 鄭有清，壓電無閥式微幫浦驅動系統之研製，逢甲大學，碩士論文，2004。
- [20] 陳振宏，微幫浦之Nozzle/Diffuser之研究，逢甲大學，碩士論文，2005。
- [21] 鄭德駿，無閥式壓電微幫浦製程之探討，國立雲林科大學，碩士論文，2003。
- [22] 許哲維，微流體裝置之設計與製作-微致動器與微混合器，大同大學，2004。
- [23] 黃偉銘，無閥式磁控微幫浦之設計、製作與分析，國立成功大學，2006。
- [24] Shuxiang Guo, Zhi Pei, Tian Wang, Xiufen Ye, " Development of Pulseless Output Micropump Using Magnet-Solenoid Actuator, " Proceedings of the 2007 IEEE International Conference on Mechatronics and Automation August 5 - 8, 2007, Harbin, China.
- [25] C. H. Chen, J. G. Santiago, " A Planar Electroosmotic Micropump, " Journal of Microelectromechanical Systems, Vol. 11, No. 6, pp. 672-683, 2002.
- [26] E. Kalvesten, " The First Surface Micromachined Pressure Sensor for Cardiovascular Pressure Measurements " ,IEEE, MEMS-98, pp.574-579, 1998.10.
- [27] Kurt E. Petersen, " Silicon as a Mechanical Material " , Proceedings of the IEEE, Vol. 70, No. 5, pp. 420-457, 1982.
- [28] G Balaji, A Singh and G K Ananthasuresh, " Electro-magnetically Actuated Minute Polymer Pump Fabricated using Packaging Technology " Mechanical Engineering, Indian Institute of Science, Bangalore 560012, India.
- [29] Hyoung J. Cho and Chong H. Ahn, " A Bidirectional Microactuator Using Electroplated Permanent Magnet Arrays, " IEEE 1057-7157/02, 2002.
- [30] C.Y.Wen, C.H.Cheng, C.N.Jian, T.A.Nguyen, C.Y.Hsu and Y.R.Su " A Valveless Micro Impedance Pump Driven by PZT Actuation " Proceeding of ICAM 2005 :2005 International Conference on Advanced Manufacture Nov 28 – Dec 2, Taipei, Taiwan.
- [31] Jack Chen, Jonathan Engel, Max Chang, and Chang Liu, " 3D Out-of-Plane Flow Sensor Array with Integrated Circuits " ,Euroensors XVI, Rome 2004.
- [32] Hsien-Tsung Chang, Chia-Yen Lee, Chih-Yung Wen, " Design and modeling of electromagnetic actuator in mems-based valveless impedance pump, " Microsystem Technology, pp. 1615-1622, Volume 13, Number 11-12/07, 2007.

- [33] Udai Neda, Kenichi Nakamura, Tsugihiko Takumi, " A polysilicon flow sensor for gas flow meters, " Sensors and Actuators A, 54, pp. 626-631, 1996.
- [34] Jirachai Getprechawsawas, Ivan Puchades, Bobby Hournbuckle, Lynn Fuller, Robert Pearson, Sergey Lyshevski, " An Electromagnetic MEMS Actuator for Micropumps " MEMSTECH'2006, May 24-27, 2006, Lviv-Polyana, UKRAINE.
- [35] 邱重榮，電熱式微致動器疲勞實驗與分析，國立成功大學，2003。
- [36] 裘常新，新式微蠕動幫浦之設計製作及操控，國立台灣海洋大學，2006。
- [37] Shuxiang Guo, Jian Wang, Qinxue Pan, Jian Guo, " Solenoid Actuator-based Novel Type of Micropump, " Proceedings of the 2006 IEEE International Conference on Robotics and Biomimetics December 17 - 20, 1-4244-0571 2006, Kunming, China.
- [38] 陳皓楨，微型感測器與致動器之設計與應用，大葉大學，碩士論文，2007。
- [39] 方維倫、吳名清、楊學安，微機構的元件型式與運動特性，國立清華大學動力機械工程學系，微系統暨奈米科技協會會刊第九期，2002。
- [40] 劉政志，電磁致動式微幫浦之最佳效能分析，國立成功大學，碩士論文，2002。
- [41] 張崇賢，熱動式微閥與微混流道控制之研究，逢甲大學，碩士論文，2003。
- [42] 涂智凱，新式無閥門微幫浦之開發，國立台灣大學，碩士論文，2004。
- [43] 張瑞斌，微電鍍技術及其在生物晶片之應用，國立成功大學，碩士論文，2002。
- [44] Trifon M. Liakopoulos, Wenjin Zhang, and Chong H. Ahn, " Electroplated Thick CoNiMnP Permanent Magnet Arrays For Micromachined Magnetic Device Applications, " 1996 IEEE.
- [45] Yulian Zhang, Pingcan Gu, Xiqiu Fan, " Progress on Research of MEMS-Based Micropump, " 2006 IEEE. 2006 7th International Conference on Electronics Packaging Technology.