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微纳技术与精密机械

多级“Y”型流管无阀压电泵的原理与试验验证(实验视频)

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摘要： 针对目前微流体混合器多需要外接动力源，且多数微混合器只能进行液体混合而不能输送液体的问题，提出将无阀压电泵引入微混合器领域，并研制了一种集混合与输送于一体的多级“Y”型流管无阀压电泵。首先，提出了多级“Y”型流管，进而设计了多级“Y”型流管无阀压电泵，并分析其工作原理；然后，对该无阀压电泵的流管流阻特性及泵流量进行理论分析；同时，利用有限元软件对多级“Y”型流管无阀压电泵进行了流场模拟，结果表明该压电泵具有单向传输作用。最后，制作了多级“Y”型流管无阀压电泵样机，并进行了泵流量与背压试验。试验结果显示：驱动电压峰峰值为100 V，频率为16 Hz时，流量达到最大，为16.2 ml/min；驱动电压峰峰值为100 V，频率为14 Hz时，输出背压最大，约为64 mm水柱。得到的试验数据证明了多级“Y”型流管无阀压电泵的有效性。(实验视频)

关键词： 多级"Y"流管 压电泵 无阀泵 微混合器

Theory and experimental verification on valveless piezoelectric pump with multistage Y-shape tubes

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Abstract: This paper researches how to improve the performance and applications of micromixers used in mixing micro-liquids, because most of the existing micromixers need external power sources, and can only mix fluids but can not transport them. A valveless piezoelectric pump with multistage Y-shape tubes which integrates both functions of mixing and transporting is developed to overcome above shortcomings. Firstly, a multistage Y-shape tube is proposed, then a valveless piezoelectric pump with multistage Y-shape tubes is designed and its working principle is analyzed. Furthermore, the flow resistance characteristics and the flow rate of the valveless piezoelectric pump are analyzed theoretically. Meanwhile, finite element software is employed in simulating the flow fields of the pump numerically. The results show that the piezoelectric pump has a function of one-way transmission. Finally, the valveless piezoelectric pump is fabricated, the relationships between flow rate and driving frequency, as well as that between back pressure and driving frequency are experimentally investigated. The experimental results show that the maximum flow rate is 16.2 mL/min under a peak-to-peak voltage of power supply in 100 V(16 Hz), and the maximum back pressure is obout 64 mmH2O under a peak-to-peak voltage of power supply in 100 V (14 Hz). The obtained experimental results validate the feasibility of the valveless piezoelectric pump with multistage Y-shape tubes.

Keywords: multistage Y-shape tubes piezoelectric pump valveless pump micro mixer

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参考文献：

[1]林炳承，秦建华.微流控芯片实验室[M].北京：科学出版社，2006. LIN B CH, QIN J H. Laboratory on a Microfluidic Chip [M]. Beijing: Science Press, 2006. (in Chinese) [2]GOBBY D, ANGELI P, GAVRIILIDIS A. Mixing characteristics of T-type microfluidic mixers[J]. Journal of Micromechanics and Microengineering, 2001, 11(2): 126-132. [3]JOHNSON T J, ROSS D, LOCASCIO L E. Rapid mircofluidic mixing[J]. Analytical Chemistry, 2002, 74(1):45-51. [4]STROOCK A D, DERTINGER S K W, AJDARI A, et al.. Chaotic mixer for microchannels[J]. Science, 2002, 295(5555):647-651. [5]RIFE J C, BELL M I, HORWITZ J S, et al.. Miniature valveless ultrasonic pumps and mixers[J]. Sensors and Actuators A: Physical, 2000, 86(1-2): 135-140. [6]YANG Z, MATSUMOTO S, GOTO H, et al.. Ultrasonic micromixer for microfluidic systems [J]. Sensors and Actuators A: Physical, 2001, 93(3): 266-272. [7]LU L H, RYU K S, LIU C. A magenetic microstirrer and array for microfluific mixing [J]. Journal of Microelectromechanical Systems, 2002, 11(5):462-469. [8]夏齐霄，张建辉，李洪.非对称坡面腔底无阀压电泵[J]. 光学 精密工程，2006，14(4)：641-647. XIA Q X, ZHANG J H, LI H. Valveless piezoelectric pump with unsymmetrical slope chamber bottom [J]. Opt. Precision Eng., 2006, 14(4): 641-647. (in Chinese) [9]XIA Q X，ZHANG J H， LEI H，et al.. Analysis on flow field of the valveless piezoelectric pump with two inlets and one outlet and a rotating unsymmetrical slopes element[J]. Chinese Journal of Mechanical Engineering, 2011, 25(3): 474-483. [10] ZHANG J H, XIA Q X, HUANG Y, et al.. Theory and experimental verification of valveless piezoelectric pump with rotatable unsymmetrical slopes [J]. Science China: Technological Sciences, 2011, 54(11): 3070-3077. [11]张建辉, 黎毅力, 夏齐宵, 等. “Y”形流管无阀压电泵振动分析及泵流量计算[J].光学 精密工程, 2007, 15（6）: 922-929. ZHANG J H, LI Y L, XIA Q X, et al..

Research on vibration and pump flow rate of valveless piezoelectric pump with Y-shape tubes [J]. Opt. Precision Eng., 2007, 15(6): 922-929. (in Chinese) [12]张建辉，黎毅力，刘菊银，等. “Y”形流管无阀压电泵模拟与试验[J]. 光学 精密工程, 2008, 16(4): 669-675. ZHANG J H, LI Y L, LIU J Y, et al.. Simulation and experiment of valveless piezoelectric pump with Y-shape tubes[J]. Opt. Precision Eng., 2008, 16(4): 669-675. (in Chinese) [13]FELDT C, CHEW L. Geometry-based macro-tool evaluation of non-moving-part valvular microchannels [J]. J. Micromech. Microeng., 2002, 12: 662-669. [14]FRIED E, IDELCHIK I E. Flow Resistance: A Design Guide for Engineers[M]. New York: Hemisphere, 1989. [15]OKA K, NOZAKI T, ITO H. Energy losses due to combination flow at tees [J]. Jap. Soc. Mech. Engrs Int. J., 1996, 39(3): 489-498. [16]张也影.流体力学[M].北京：高等教育出版社, 1999. ZHANG Y Y. Fluid Mechanics[M]. Beijing: Higher Education Press, 1999. (in Chinese) [17]张建辉，王守印. 压电锥形流管无阀泵的研究—单向流动原理及泵流量[J]. 压电与声光，2001，23(1)：23-25. ZHANG J H,WANG SH Y. A study of piezoelectric valveless diffuser/nozzle-based fluid pump: one-way flow principle and the pump flow [J]. Piezoelectrics & Acoustooptics, 2001, 23(1):23-25. (in Chinese)

本刊中的类似文章

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2．胡笑奇, 张建辉, 黄毅, 夏齐霄, 黄卫清.仿尾鳍式变截面摆动振子无阀压电叠堆泵的结构设计[J]. 光学精密工程, 2011,19(6): 1334-1343

3．刘勇, 杨志刚, 吴越, 刘磊, 董景石.压电泵吸程出流现象及其成因研究[J]. 光学精密工程, 2011,19(5): 1104-1109

4．张平,，胡亮红，，刘永顺,.

主辅通道型微混合器的设计与制作

[J]. 光学精密工程, 2010,18(4): 872-879

5．彭太江,杨志刚.双腔体压电泵设计方法研究[J]. 光学精密工程, 2009,17(5): 1078-1085

6．唐可洪, 阚君武, 彭太江, 朱国仁, 高俊峰.压电叠堆泵驱动的新型直线马达[J]. 光学精密工程, 2009,17(1): 145-150

7．吴丽萍[1,2];程光明[1];曾 平[1];杨志刚[1];吴银柱[2].单振子双腔体无阀压电泵结构设计与机理分析[J]. 光学精密工程, 2007,15(7): 1044-1048

8．张建辉[1,2];黎毅力[2];夏齐霄[3];路计庄[2]."Y"形流管无阀压电泵振动分析及泵流量计算[J]. 光学精密工程, 2007,15(6): 922-929

9．杨志刚[1];孙晓锋[1,2];张德君[1];程光明[1];李欣欣[1].双腔串联两阀与三阀压电泵的性能研究[J]. 光学精密工程, 2007,15(2): 219-223

10．夏齐霄, 张建辉, 李洪.非对称坡面腔底无阀压电泵[J]. 光学精密工程, 2006,14(4): 641-648

11．孙晓锋, 杨志强, 刘晓论, 李欣欣, 林敬国.整体开启阀与悬臂梁阀压电泵性能研究[J]. 光学精密工程, 2006,14(4): 648-651

12．赵明丽, 黄琴, 张玮, 李欣欣.悬臂梁阀单腔压电泵设计方法研究[J]. 光学精密工程, 2006,14(4): 607-611

13．张建辉, 路计庄, 夏齐霄, 王守印.压电振子及流体对泵近场噪声的影响[J]. 光学精密工程, 2006,14(4): 628-634

14．曾 平[1];程光明[1];刘九龙[1];孙晓锋[1,2];赵艳龙[1].双腔薄膜阀压电泵的实验研究[J]. 光学精密工程, 2005,13(3): 311-317

15．杨树臣;程光明;刘国君;刘建芳.微型压电泵系统的设计研究[J]. 光学精密工程, 2005,13(3): 318-323