Faculty of Engineering

DESIGN OF AN EHD PUMP FOR MICROFLUIDIC APPLICATION

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DESIGN OF AN EHD PUMP FOR MICROFLUIDIC APPLICATION

CHUA SWEE NING

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To my beloved family and friends

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ABSTRAK

Projek ini merupakan pengajian tentang pam mikro EHD penyerekan ion dan merekabentukkan satu rekabentuk yang lebih bagus dan siap-sedia untuk dibinakan. Pembelajaran ini memfokuskan pada ciri-ciri yang boleh meningkatkan prestasi mengepam oleh pam mikro tersebut. Laporan ini bermula dengan pengajian aspek teori bendalir mikro yang berkaitan dengan sistem pengepaman tersebut dan berikuti dengan prinsip pengepaman EHD penyerekan ion. Kaedah-kaedah pembinaan untuk pam mikro telah dielaborasi demi mencari kos pembinaan yang efektif dan disah oleh aspek teknikal. Parylene dan SU-8 adalah pilihan bahan yang utama kerana kelebihannya yang murah dan mudah untuk dibina sebagai pembentukan rangka pam mikro tersebut. Emas digunakan sebagai elektrod oleh sebab konduktivitinya baik, tegangan sisa yang rendah dan mudah dideposisikan. Perbandingan daripada beberapa keputusan oleh penyelidik lain telah dilakukan dan menunjukkan bahawa rekabentuk elektrod, jurang pasangan elektrod dan ketinggian saluran memainkan peranan penting utama dalam peningkatkan prestasi pengepaman dan kemuanya berkaitan dengan arus balik pada medan elektrik-bendalir. Rekabentuk akhir pam mikro pnyerekkan ion mencadangkan pam yang mempunyai elektrod selari, dengen perbaikan struktur penyinjaban untuk mengurangkan kesan arus balik.

ABSTRACT

This project is about studies of ion-drag EHD micropump and to design a ready-to-fabricate improved design. The study mainly focuses on the factors that can improve the pumping performance of the micropump. This report started with the studies of theoretical aspect of microfluidics which are related to micropump system and then the principle of the ion-drag EHD pumping. The fabrication methods of micropump are elaborated which to find the cost effective and technically validated fabrication. Parylene and SU-8 will be the main choice of the material due to its cheap and easy to fabricate advantages, to form the skeletal structure of the micropump. Gold is used as electrode of its good conductivity, low residual stress and ease of deposition. A synthesis of comparison results of pumping performance of ion-drag micropump from a few previous testing by other researchers is conducted. The comparisons showed that electrode designs, electrode pair gap and channel height played the main important roles of improving the pumping performance, and they are all related with backflow effect of electric-fluidic field. The final design of the ion-drag micropump is a parallel electrodes micropump, with proposed improvement by valving structure to reduce backflow effect.

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LIST OF ABBREVIATIONS

μTAS	-	Micro Total Analysis System
AC	-	Alternating current
Au	-	Gold
$CeSO_4$	-	Caesium sulphate
CF_4	-	Fluorocarbon
CFD	-	Computational Fluid Dynamics
Cr	-	Chromium
CVD	-	Chemical Vapour Deposition
E-beam	-	Electron beam
EFAB^{TM}	-	Precision Photo Chemical Machining and Etching
EHD	-	Electrohydrodynamic
EO	-	Electroosmotic
HCL	-	Hydrochloric acid
HF	-	Fluoric acid
IC	-	Integrated circuits
KI	-	Potassium iodide
KOH	-	Potassium hydroxide
LOC	-	Lab-on-a-chip
LCP	-	Liquid Crystal Polymer
LIGA	-	*Lithographie Glvanoformung Abformung*
LP	-	Low pressure
MEMS	-	Microelectromechanical Systems

MHD	-	Magnetohydrodynamic
O_2	-	Oxygen
PDMS	-	Poly-dimethylsiloxane
PMMA	-	Methyl methacrylate
PR	-	Photoresist
PVD	-	Physical Vapour Deposition
PE	-	Plasma enhanced
RIE	-	Reactive ion etching
Si	-	Silicon
Si_3N_4	-	Silicon nitride
UV		Ultraviolet

LIST OF SYMBOLS

°C	-	Degree Celsius
S	-	Siemens
m	-	Metres
u	-	Velocity
ρ	-	Fluid density
p	-	Fluid pressure
η	-	Fluid dynamics viscosity
g	-	Gravity acceleration
C_p	-	Specific heat
T	-	Temperature
T	-	Time coordinate
K	-	Thermal conductivity
Φ	-	Viscous heating
λ	-	Electrical conductivity
		Electric potential applied tangential
ψ		Double-layer potential
ρ_e		Charge density
c		Concentration
D		Diffusion coefficient
μ_{ep}		Electrophoretic mobility
I_l		Ionization energy
V_0		Conduction band energy

Φ	Work function of the metal
E	Energy
ε	Permittivity
σ_e	Conductivity
τ_e	Charge relaxation time
τ_m	Mechanical transport time
Re	Reynolds Numbers

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CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION

Microfluidics deal with development of miniature devices and manipulate small amounts of fluids. Microfluidic systems are presumably achieved by miniaturizing the existing technology from macro scale to micro and nano scale. In microfluidics, the fundamentals of physics and chemistry law are the same as of the traditional fluidics, however the difference is that some effects that are dominant at macro scale had become insignificant in micro scale, and vice versa *(S. Hardt and F. Schönfeld, 2007).*

The interest of this micropump project is promoted by the great breakthrough of micro- and nano- fabrication technologies near 21th century. Having less power consumption, functioned at lower voltage, reduced space and weight usage, these are the great advantages of miniaturized system over traditional methods. For example, in detection and analysis for chemical and biological purposes, the task required least amount of sample, generating precise, sensitive, fast and repetitive results, in addition, reducing the cost of the task carried.

To be general, the study field of micropump is subset of microfluidics, which deals with study of fluidics in micro and nano scale and to manipulate the desired application for certain microsystem. The applications of microfluidics in recent development more or less are used for chemical or biological detection and analysis, microfluidic integrated circuits and heat transfer in microdevices *(A.R. Jha, 2008).*

There are two titles of microfluidic system that are generally spoken, namely microelectromechanical systems (MEMS) and lab-on-a-chip (LOC) systems. MEMS is considered as a microsystem that structured in 2D or 3D dimensions, while LOC is a conceptual microsystem that operated like an electronic chip. LOC sometimes also known as Micro Total Analysis System (μTAS), both are used for analytic purposes in chemistry and biology.

Microfluidic system required tiny amount of liquid to operate. Due to magnification of some molecular level of effects such as meniscus, capillary and surface tension of liquid, manipulating fluid in droplets and bubbles become available. Such this study is known as microdrops. The ability to manipulate micro droplets gives rise of digital fluidic system, which the droplets is subjected with digital binary system to carry variety of functions *(J. Berthier, 2008).*

1.2 OVERVIEW OF ION-DRAG EHD MICROPUMP

Micropump played as an important role of microfluidic devices of controlling the amount and flow rate of the fluid. There are various types of micropump been proposed to handle the fluids with each having their own advantages. This project focuses on ion-drag EHD micropump, which uses the injection of ions into working fluid to produce the pumping mechanism. The advantage of ion-drag micropump is that it consists of simple structures that having no moving parts as well as its ease of fabrication, making it an attractive candidate as small sized, high ability to be integrated with other devices, and low cost micropump. Furthermore, this micropump has higher pumping performance when it is getting more miniaturized.

1.3 OBJECTIVES AND PROJECT OUTLINE

Ion-drag micropump is always issued with electrode damages during its pumping process due to the transmissions of ions between electrodes in the fluid medium. It is the major measure of this micropump designing project.

The basic study of microfluidic components and the mechanism of ion-drag pumping are included so that it gives the whole perspectives of the microfluidic system to help in designing the micropump.

Next is the understanding of fabrication methods of microfluidic system, which is to find out the feasible technology and available materials to realize the micropump design, in the other hand, the technology that limiting the design itself.

A synthesis of comparative result from a few previous works of researchers is conducted, which is to determine and reasoning the optimal parameters for having the best pumping performance and then inputted into design parameter.

The result is a new designed ion-drag micropump, where new parameters are introduced and how the performance can be improved is described.

Finally, it is the conclusion and recommendation that based on the new design.

CHAPTER 2

LITERATURE REVIEW

2.1 CURRENT MICROPUMPS APPROACH

By engineering concept, microfluidics can be defined into a few functional groups: pumping, valving, mixing, separation, sensing and detection, manipulating bubbles or droplets, and, integration of digital fluids *(S. Hardt and F. Schönfeld, 2007).*

In traditional pump, all of the pumping power is generated by mechanical displacement of movable boundary disregard any types of energy input (Heat, electromagnetic, hydraulic etc.). Some basic physical aspects of traditional pump are still preserved respected to micropump, such as: ability to provide large force, amount of volume of each stroke, response time, and power consumption of the actuation *(C. Yamahata, 2002).*

In the case of microfluidics, the pumping power can be directly transferred from the energy source compared to traditional methods. To clarify the different micropump approaches, it needs to be considering the following two aspects: actuation methods and pumping principles, which will be discussed in following topics.