DESIGN AND DEVELOPMENT OF PZT BASED MICROPUMP FOR MICROFLUIDIC APPLICATIONS

Fathima Rehana Munas

148054T

Thesis submitted in fulfillment of the requirements for the degree of Master of Philosophy

Department of Mechanical Engineering

University of Moratuwa
Sri Lanka

January 2020

DECLARATION

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

Also, I hereby grant to University of Moratuwa the non-exclusive right to reproduce and distribute my dissertation, in whole or in part in print, electronic or other medium. I retain the right to use this content in whole or part in future works (such as articles or books).

Signature Date

The above candidate has carried out research for the MPhil thesis under my supervision.

Name of the supervisor: Dr. Y.W.R. Amarasinghe

Signature of the supervisor: Date

ABSTRACT

The present technical context is promptly growing in implementing onsite microfluidic utensils utilized in microfluidics owing to their great demand. The microfluidics mainly involves in implementing minuscule devices to deal with minute volumes of fluids. Manufacturing these microfluidic devices like micropumps is a great challenge and micropumps are very much indispensable to regulate and convey fluid in minute scale.

In this research a PZT based micropump was designed and developed for microfluidic applications. A PZT actuated brass diaphragms and a comprehensive flow arrangement are the important elements of this micropump structure. Basically, the design prominences on a cross junction, engendered by a nozzle jet with a pump chamber and two inlet and an outlet channel respectively. In this sense, the fluid flow rectification is done by nozzle jet feature to expedite the fluid path within the system during every vibration cycle of PZT diaphragm. This micropump device was developed with layer by layer fabrication of polymethyl methacrylate (PMMA) plates using laser cutters and all the layers were squeezed in to attain required structure.

In order to recognize the physiognomies of flow and to verify the experimental outcomes with simulated data, numerical simulation analysis in ANSYS were carried out. In addition, the PZT diaphragms were under taken for eigenfrequency study analysis in COMSOL Multiphysics as well. In this sense, the applied frequency of the piezoelectric diaphragms was varied by using the prescribed control system developed for this device. As per the test results, the maximum flow rate of 31.15 ml/min achieved at the frequency of 100 Hz. In addition, the thin film deposition techniques and the thermo elastic damping analysis on PZT actuators were also analyzed to identify the performance enhancement of this micropump.

Since monitoring pressure and getting response is vital in microfluidic devices, design and simulation of MEMS based piezoresistive pressure sensor has been carried out. According to the piezoresistive structural coupled field analysis, the optimal diaphragm structure was chosen among three kinds of diaphragms considered for this study. Further, the thermo mechanical behavior of piezoresistive pressure sensors have also been considered in this research.

At last, the complete numerical simulation was done for the micropump fluid flow coupled with the designed pressure sensor. According to this analysis, the pressure sensor gives the favorable sensitivity variation over micropump discharge pressure. Hence the developed micropump is not only for a specific application but also worthwhile in a wide range of microfluidic applications.

Keywords: PZT, valveless, micropump, MEMS, Piezoresistive, Pressure Sensor

DEDICATION

This thesis work is dedicated to my family and my teachers. A special feeling of gratitude to my loving parents, who have always loved me unconditionally and whose good examples have taught me to work hard for the things that I aspire to achieve. Also, I am truly thankful to my husband who has been a constant source of support and encouragement during the challenges.

ACKNOWLEDGMENT

I take this great opportunity to express my profound gratitude and deep regards to my research supervisor Dr. Y.W.R. Amarasinghe for his exemplary guidance, monitoring and constant encouragement throughout my research. Without his keen supervision none of this work would have been possible for myself alone.

I consider myself very fortunate for being able to work with such a resourceful individual. I also express my sincere gratitude to my co-supervisors Dr. Van Thanh Dau and Dr. Pubudu Kumarage for their cordial support, valuable information and guidance, which helped me to carryout simulations in this task through various stages. I also would like to remind Prof. Dzung Viet dao and Dr. Van Thanh Dau for their valuable feedbacks and guidance in my publications even they are busy with their schedule.

Moreover, I’m particularly grateful to the Head of the Department of Mechanical Engineering as well as one of the panel members of this research Prof. R.A.R.C. Gopura, for his tremendous support and guidance. Furthermore, I would like to extend my utmost gratefulness to Dr. A.G. Buddhika P. Jayasekara who is the chair of the progress review panel appointed for this research, for his valuable comments and advices given to me throughout this research. I also thankful to Dr. Damith Chathuranga who is the research coordinator of the Department of Mechanical Engineering.

I would like to especially thank to the Final year project students N.H.R.G. Melroy, G.C.B. Abeynayake and H.L. Chathuranga who helped me in the fabrication process. I also thank to the staff of the Mechatronics and MEMS/NEMS laboratory of Department of Mechanical Engineering for providing me the facility required for conduction my research works whenever required.

I especially thank to Mr. Eranga De. Silva, Mr. Isururu Udayange, Mr. Pesan Sampath, Mr. Janaka Basnayake and Mr. Uditha Roshan for their valuable support in the mechatronic laboratory. I also owe my thankfulness to the Head of the Department of Mechanical Engineering, Faculty of Engineering, South Eastern University of Sri Lanka for his great support.

Last but not the least I express my sincere gratitude to everyone who supported me throughout my research work.

Fathima Rehana Munas,
MPhil Postgraduate,
Department of Mechanical Engineering,
University of Moratuwa.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

Abbreviation	Description
DRIE	Deep Reactive Ion Etching
EHD	Electro Hydro Dynamic
EO	Electro Osmotic
EW	Electro Wetting
FEM	Finite Element Method
FI	Fluid Inertia
ICPF	Ion Conductive Polymer Films
ITO	Indium Tin Oxide
KOH	Potassium Hydroxide
LOC	Lab On a Chip
MEMS	Micro Electro Mechanical System
MHD	Magneto Hydro Dynamic
μTAS	Micro Total Analysis System
PCB	Printed Circuit Board
PDMS	Poly Di-Methyl Siloxane
PEEK	Polyether Ether Ketone
PGA	Polyglycolide/ Polyglycolic Acid
PLA	Polylactide/ Polylactic Acid
PMMA	Poly methyl methacrylate
POCT	Point Of Care Testing
PZT	Lead Zirconate Titanate
SDM	Shape Deposition Manufacturing

Abbreviation	**Description**
SFF	Solid Free Form Fabrication
SL	Stereo Lithography
SMA	Shape Memory Alloys
SOI	Silicon On Insulation