DESIGN AND DEVELOPMENT OF A PZT BASED ACTIVE MICROFLUIDIC DROPLET GENERATOR FOR LAB ON A CHIP DEVICES

Nikku Handi Roshel Gehan Melroy

208063K

Master of Science (Major Component Research)

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Thesis submitted in partial fulfilment of the requirements for the degree

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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. I retain the right to use this content in whole or part in future works (such as articles or books).

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The above candidate has carried out research for the Masters thesis under my supervision. I confirm that the declaration made above by the student is true and correct.

Name of Supervisors: Prof. Y.W.R. Amarasinghe

Dr. Van Thanh Dau

Dr. Pubudu Kumarage

Signature of the Supervisor: ***UOM Verified Signature*** Date: 17/12/2025

Signature of the Supervisor: ***UOM Verified Signature*** Date:22/12/2025

Signature of the Supervisor: ***UOM Verified Signature*** Date:22/12/2025

DEDICATION

I dedicate this dissertation to my family and my teachers. I owe a special debt of gratitude to my parents, Mr. N.H.S. Wanshanatha and Mrs. S.D.P. Vijamali, whose constant encouragement and example of perseverance have guided me throughout my life.

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Mr. N.H.R.G. Melroy,
M.Sc. Postgraduate,
Department of Mechanical Engineering,
University of Moratuwa.

ABSTRACT

Microfluidic droplet generation is a critical technique in Lab on a Chip (LoC) system, where precise size control and stability are important than throughput. This thesis presents the design, modelling, fabrication, and experimental validation of an active microfluidic droplet generator. The multilayer device design integrates two piezoelectrically actuated valveless micropumps to a Polymethyl Methacrylate (PMMA) based droplet generation geometry layers. The methodology combined numerical simulation and experimental evaluation of the active microfluidic droplet generator. In this study, water and coconut oil were used as the dispersed phase and the continuous phase, respectively. Initially, the effect of the flow-rate ratio between the dispersed phase and the continuous phase on the droplet diameter was numerically simulated. In the experiments, the dispersed phase fluid flow was pulsed, hence generating an intermittent flow in the droplet generator. The ON-time of the piezoelectric micropump, which drives the dispersed phase, affects the droplet diameter. Therefore, the ON-time injection dose of the micropump was evaluated. Numerical simulations employed the Volume-of-Fluid (VOF) method as the baseline steady-flow behaviour, while the level-set method was used for intermittent actuation due to its superior interface tracking. In the experiments, repeatable droplet formation was observed, with average diameters of 1.98 ± 0.03 mm and 3.96 ± 0.14 mm under different flow rate and ON-time conditions for the dispersed phase, while the continuous phase conditions were unchanged. Furthermore, increasing the dispersed phase voltage increased the flow rate of the dispersed phase. This produced larger droplets at higher dispersed phase voltages for a fixed actuation cycle time (ON/OFF), showing tuneable droplet generation. In addition, the droplet generation frequency was between 5.4 and 14.8 droplets/min for different flow/actuation conditions. Therefore, this work demonstrates that intermittent piezoelectric actuation enables repeatable, tuneable, and low-throughput droplet generation.

Keywords: microfluidics, droplet generation, piezoelectric micropump, active actuation, intermittent actuation, Lab-on-a-Chip.

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LIST OF ABBREVIATIONS

Abbreviation	Description
LoC	Lab on a Chip
MEMS	Micro-Electro-Mechanical Systems
PCR	Polymerase Chain Reaction
PDMS	Polydimethylsiloxane
PZT	Lead Zirconate Titanate
PoC	Point-of-Care
μTAS	Miniaturised Total Analysis Systems
EOP	Electroosmotic Pumps
EWOD	Electrowetting-on-Dielectric
EHD	Electrohydrodynamic
DEP	Dielectrophoresis
SAW	Surface Acoustic Waves
Re	Reynolds Number
Ca	Capillary Number
We	Weber Number
VOF	Volume of Fluid
OFN-AEOP	Orthogonal Flow Channel Network with Asymmetric Extended Outlet Port
RS-TCA	Radially Symmetric Flow Channel with Tapered Converging Arms
Q_D	Dispersed Phase Volumetric Flow Rate
Q_C	Continuous Phase Volumetric Flow Rate
W/O	Water-in-Oil

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