

Table of contents

中文摘要.....	I
Abstract	II
Acknowledgement	III
Table of contents	i
List of Figures	ii
List of tables.....	iv
Chapter 1 Introduction	1
1.1 Motivation.....	1
1.2 Literature overview	2
1.2.1 Energy scavenging technologies.....	2
1.2.2 Vibration-to-electricity conversion	4
1.3 Thesis objective and organization.....	7
Chapter 2 Design.....	9
2.1 Principle	9
2.2 Characteristics of vibration	12
2.3 Device design.....	14
2.3.1 Variable capacitor.....	14
2.3.2 Dynamic analysis.....	20
2.3.3 Simulations and parameter optimization	23
2.4 Spring design	27
2.5 Discussion	30
Chapter 3 Fabrication.....	31
3.1 Process flow	31
3.2 Processing issues.....	33
3.2 Fabricated device	37
Chapter 4 Measurements and discussions.....	41
4.1 Mechanical measurement.....	41
4.2 Electrical measurement.....	47
4.3 Output power measurement	52
Chapter 5 Conclusion and future work	53
5.1 Conclusion	53
5.2 Future work.....	53
Reference	55
Appendix Detailed Simulink model.....	59

List of Figures

Figure 2.1	Principle of the electrostatic energy converter	9
Figure 2.2	Schematic of the conversion dynamic model.....	11
Figure 2.3	Vibration spectra by Roundy et al. [11].....	12
Figure 2.4	Vibration spectra of (a) pump and air conditioner (b) air conditioner.....	13
Figure 2.5	Cross-section of the out-of-plane gap closing type.....	15
Figure 2.6	Top view of the in-plane overlap type.....	15
Figure 2.7	Top view of the in-plane gap closing type.....	15
Figure 2.8	Output power vs. initial finger gap.	20
Figure 2.9	Squeeze film damping effect simulations.....	22
Figure 2.10	Dynamic simulation frame	25
Figure 2.11	Max displacement z and spring constant k for various attached mass m	25
Figure 2.12	Simulation of displacement Z	26
Figure 2.13	Simulation of output voltage V_o	26
Figure 2.14	Spring structure top view.....	28
Figure 2.15	Schematic and cross-section of device.....	30
Figure 3.16	Process flow.....	32
Figure 3.2	Cross-section view of thick PR patterning.....	34
Figure 3.3	Initial undercut and wavy sidewall of deep RIE.....	35
Figure 3.4	Bended fingers due to protection photoresist before release.....	36
Figure 3.5	Bended fingers due to protection photoresist after PR removed.....	36
Figure 3.6	Bended fingers pushed back using probe.....	36
Figure 3.7	RIE leg effect.....	37
Figure 3.8	SEM top view of the corner of device.....	38

Figure 3.9 Displacement indicator (a) top view (b) close up view (c) layout.....	39
Figure 3.10 Shrunk finger width	40
Figure 3.11 Cross section view of fingers.....	40
Figure 4.1 Device and the optical microscope stage.....	41
Figure 4.2 Releasing test: (a) before push (b) after push.....	42
Figure 4.3 Measurement setup (a) Schematic (b) photograph.....	43
Figure 4.4 Fingers under (a) 0 Hz and (b) 800Hz vibration.....	44
Figure 4.5 Frequency response of the device.....	45
Figure 4.6 Lateral spring constant versus spring width.....	46
Figure 4.7 Vertical spring constant versus spring width.....	47
Figure 4.8 Wire bonding of device.....	48
Figure 4.9 Electrical measurement setup.....	48
Figure 4.10 Modified application schematic.....	49
Figure 4.11 Current measurement setup.....	50
Figure 4.12 Particles making parasitic resistance.....	51
Figure 4.13 Particles in the gap.....	51
Figure 5.117 Flexible variable capacitance chart.....	54

List of tables

Table 1.1 Comparison of power scavenging and energy sources [1,12].....	4
Table 2.1 Optimal design parameters.....	25
Table 2.2 Spring design and safety factor.....	29

