Contents

Acknowledgement vii

1 Introduction 1

2 Basics of MEMS capacitive inertial sensors 9
2.1 Working principle of MEMS inertial sensors . . . 9
2.1.1 Acceleration sensors . . . 10
2.1.2 Angular rate sensors . . . 10
2.1.3 Multi-functional / axis sensors . . . 11
2.2 Fabrication of MEMS inertial sensors . . . 12
2.2.1 Fabrication of the functional wafer . . . 12
2.2.2 Fabrication of the encapsulation wafer . . . 14
2.2.3 Fabrication of the stack . . . 14
2.3 Mechanisms influencing the cavity pressure . . . 17

3 Microchip calibration for cavity pressure estimation 19
3.1 Methods for cavity pressure estimation . . . 19
3.2 Damped oscillatory motion . . . 20
3.2.1 Quality factor and gas damping . . . 23
3.3 Measurements . . . 26
3.3.1 Experimental setup . . . 26
3.3.2 Results and discussion . . . 27
3.4 Summary . . . 29

4 Hydrogen release from PECVD thin films 31
4.1 Background to hydrogen in CVD dielectrics . . . 31
4.2 Methods for material characterization . . . 33
4.2.1 Inert Gas Fusion . . . 33
4.2.2 Fourier Transform Infrared Spectroscopy . . . 33
4.2.3 Temperature desorption spectroscopy . . . 35
4.3 Materials and experiments . . . 36
4.4 Results . . . 37
4.4.1 Inert Gas Fusion . . . 37
4.4.2 Fourier Transform Infrared Spectroscopy . . . 38
4.4.3 Temperature desorption spectroscopy . . . 41
4.4.4 Discussion . . . 45
4.5 Material modelling and simulation . . . 48
4.5.1 Single reaction model . . . 48
4.5.2 Multi-reaction model . . . 51
4.5.3 Estimation of reaction parameters . . . 53
4.5.4 Diffusion in thick films . . . 57

4.6 Application of models to use cases 60
4.6.1 Hydrogen release during wafer bonding 60
4.6.2 Hydrogen release from dielectric stack 62
4.7 Summary 66

5 Hydrogen release in microchip cavities **67**
5.1 Microchip variants and experiments 67
5.2 Results of cavity pressure in microchips 70
5.2.1 Microchips with a single PECVD layer 70
5.2.2 Microchips with PECVD dielectric stack 75
5.3 Discussion and proposed mechanisms 77
5.3.1 Cavity pressure in the absence of PECVD materials 77
5.3.2 Influence of a single PECVD thin film 78
5.3.3 Influence of PECVD dielectric stack 82
5.4 Summary 87

6 Summary and Outlook **89**

Appendix **93**
A Additional Figures 93
B Additional Tables 95
C ATR FT-IR depth of penetration 96

References **96**