
Contents

Abbreviations	XI
1 Introduction	1
2 Miniaturized Metal-Oxide Sensors	5
2.1 Overview of Microhotplates for Gas Sensing Applications	5
2.2 Microhotplates in Industrial CMOS Technology	10
2.3 Basic Sensing Mechanisms in Tin-Oxide Materials	10
2.3.1 Nanocrystalline Tin-Oxide Thick-Film Layers	10
2.3.2 Catalyst Doping	13
2.3.3 Sensitive-Layer Fabrication	15
3 Thermal Modelling of CMOS Microhotplates	17
3.1 Modelling Approach	17
3.2 Microscopic Description and Model Assumptions	20
3.3 FEM-Simulations	23
3.4 Lumped Microhotplate Model	24
3.5 AHDL-Model for System Simulations	27
4 Microhotplates in CMOS Technology	29
4.1 Circular Microhotplate	30
4.1.1 Design Considerations	30
4.1.2 Fabrication	32
4.1.3 Physical Microhotplate Characterization	35
4.1.4 Calibration of the Temperature Sensors	36
4.1.5 Comparison of Thermal Characterization and Simulation Results	37
4.2 Assessment of Microhotplate Temperature Distributions	39
4.2.1 Device Description	39
4.2.2 Comparison of Simulations and Measurements	40

4.2.3	Temperature Distribution Assessment of a Coated Microhotplate	43
4.3	Microhotplate with Pt Temperature Sensor	43
4.3.1	Design Considerations	43
4.3.2	Fabrication	47
4.3.3	Thermal Characterization	49
4.4	Microhotplate with MOS-Transistor Heater	49
4.4.1	Basic Heater System Architectures	49
4.4.2	System Description	50
4.4.3	Analytical Model for the MOS-Transistor Heater	52
4.4.4	Electrothermal Characterization and Comparison with Simulations	55
4.5	Calorimetric Sensing Mode for Operation at Constant Temperature	58
5	Monolithic Gas Sensor Systems	61
5.1	Single-Ended Mixed-Signal Architecture	61
5.1.1	System Description	61
5.1.2	Bulk Chip Temperature Sensor	63
5.1.3	Logarithmic Converter	65
5.1.4	Temperature Control Loop and Geometric Mean Circuitry	66
5.1.5	I ² C Serial Interface, Instruction Set, and Register Bank	68
5.1.6	Sensor Packaging	70
5.1.7	Electrical Characterization	71
5.1.8	Gas Test Measurement Setup	74
5.1.9	Gas Test Measurements	75
5.2	Differential Analog Architecture for Operating Temperatures up to 500 °C	78
5.2.1	System Description	78
5.2.2	Temperature Control Loop	80
5.2.3	Sensor Measurements	82
6	Micsensor Arrays	87
6.1	Single-Ended Analog Architecture	87
6.2	Differential Mixed-Signal Architecture	92
6.2.1	System Description	92
6.2.2	Temperature Control Loop	92
6.2.3	I ² C Serial Interface, Instruction Set, and Register Bank	96
6.3	Digital Array Architecture	98
6.3.1	System Description	98
6.3.2	Microhotplate and Chip Layout	99
6.3.3	Temperature Control Loop and Sensor Resistance Readout ..	102

6.3.4	Circuitry Assessment	102
6.3.5	Gas Test Measurements	104
7	Conclusion and Outlook.....	107
References		113
Subject Index		123