Development of a Low Cost Electronic Nose

NUR SHAHADAH BINTI RAGIMI

This Report is submitted in Partial Fulfilment of Requirements for the Bachelor Degree of Electronic Engineering (Industrial Electronics)

Fakulti Kejuteraan Elektronik dan Kejuteraan Komputer
Universiti Teknikal Malaysia Melaka

JUNE 2015

UNIVERSTI TEKNIKAL MALAYSIA MELAKA

FAKULTI KEJURUTERAAN ELEKTRONIK DAN KEJURUTERAAN KOMPUTER

BORANG PENGESAHAN STATUS LAPORAN

PROJEK SARJANA MUDA II

Tajuk Projek : DEVELOPMENT OF A LOW COST ELECTRONIC NOSE

Sesi Pengajian :

1	4	/	1	5

Saya NUR SHAHADAH BINTI RAGIMI

mengaku membenarkan Laporan Projek Sarjana Muda ini disimpan di Perpustakaan dengan syarat-syarat kegunaan seperti berikut:

1. Laporan adalah hakmilik Universiti Teknikal Malaysia Melaka.
2. Perpustakaan dibenarkan membuat salinan untuk tujuan pengajian sahaja.
3. Perpustakaan dibenarkan membuat salinan laporan ini sebagai bahan pertukaran antara institusi pengajian tinggi.
4. Sila tandakan (**√**) :

☐	**SULIT***	*(Mengandungi maklumat yang berdarjah keselamatan atau kepentingan Malaysia seperti yang termaktub di dalam AKTA RAHSIA RASMI 1972)
☐	**TERHAD****	**(Mengandungi maklumat terhad yang telah ditentukan oleh organisasi/badan di mana penyelidikan dijalankan)
☐	**TIDAK TERHAD**	

Disahkan oleh:

_____ _____

(TANDATANGAN PENULIS) (COP DAN TANDATANGAN PENYELIA)

"I hereby declare this report was produced by my own except for quotes as cited in the references."

Signature :

Author's Name : NUR SHAHADAH BINTI RAGIMI

Date : 12 JUNE 2015

"I hereby declare that I have read this report and in my opinion this report is sufficient in terms of the scope and quality for the award of Bachelor Degree of Electronic Engineering (Industrial Electronics) With Honours."

Signature :

Supervisor's Name : DR. LOW YIN FEN

Date : 12 JUNE 2015

To my beloved family especially my parents.

ACKNOWLEDGEMENT

I would like to take this opportunity to thanks my family especially my beloved parents. Thank you for believe me and let me studying in the engineering field even though divergent from my previous studies. I would also want to thanks my siblings especially my brother who gave me encouragement, inspiration and challenge me whenever tasks involve with electronics. Thanks a lot to my competent supervisor, Dr. Low Yin Fen for always help me through guidance, and sharing the ideas in order to accomplish this project. Last but not least, thank you also towards engineers, Mr. Raymundo, Mr. Sun Joe Him, and Mr. Rusydan for giving me some ideas on how to conduct this project, sharing knowledge and interesting ideas how to develop a good project.

ABSTRACT

Electronic Nose (E-Nose) utilizes as an array of chemical sensors of different specificities which responds to the volatile organic compounds (VOCs) present in the gases. The demand of electronic nose has been in the market for improving the food quality control, environment monitoring, oil and gas industry, beverages and cosmetic products. However, the constraint of the electronic nose is that the choice of sensors is quite large. Besides that, the electronic nose is expensive, not portable and their performance is relatively slow. Therefore, a low-cost and portable electronic nose is expected to be developed. In this project, electronic nose is designed by using different types of gas sensors such as alcohol sensor (MQ-3) and natural gas sensor (MQ-4). The electronic nose is implemented by utilizing Arduino programming and it will read the sensitivity smell of the tester in ppm (parts per million). Once the smell is detected by the electronic nose and the reading is above the set point value (i.e., 500 ppm), the reading and the sign "DANGER" will be displayed on the LCD display. At the same time, the LED and the buzzer will be activated. On the other hand, if the sensor reading is below the set point, the sign "SAFE" will be displayed on the LCD display, LED and buzzer will be inactive.

ABSTRAK

Hidung Elektronik (E-Hidung) menggunakan pelbagai sensor kimia dengan ciri – ciri yang berbeza bertindak balas terhadap sebatian organik meruap (VOC) yang hadir dalam gas. Permintaan hidung elektronik telah berada di pasaran untuk meningkatkan kawalan mutu makanan, pemantauan alam sekitar, industri minyak dan gas, minuman dan produk kosmetik. Walau bagaimanapun, kekangan hidung elektronik adalah bahawa pilihan sensor agak besar. Selain itu, hidung elektronik itu mahal, tidak mudah alih dan prestasi mereka agak perlahan. Oleh itu, hidung elektronik kos rendah dan mudah alih dijangka dibangunkan. Dalam projek ini, hidung elektronik direka dengan menggunakan pelbagai jenis sensor gas seperti pengesan alkohol (MQ-3) dan sensor gas asli (MQ-4). Hidung elektronik dilaksanakan dengan menggunakan pengaturcaraan Arduino dan ia akan membaca bau sensitiviti penguji dalam ppm (bahagian per juta). Apabila bau dikesan oleh hidung elektronik dan bacaan melebihi nilai titik set (iaitu 500 ppm), bacaan dan tanda "BAHAYA" akan dipaparkan pada paparan LCD. Pada masa yang sama, LED dan buzzer akan diaktifkan. Sebaliknya, jika bacaan sensor adalah di bawah titik set, tanda "SELAMAT" akan dipaparkan pada paparan LCD, LED dan buzzer akan menjadi tidak aktif.

TABLE OF CONTENT

CHAPTER	CONTENT	PAGE
	TITLE	**i**
	VERIFICATION FORM	**ii**
	RECOGNITION	**iii**
	RECOGNITION	**iv**
	DEDICATION	**v**
	ACKNOWLEDGEMENT	**vi**
	ABSTRACT	**vii**
	ABSTRAK	**viii**
	TABLE OF CONTENT	**ix**
	LIST OF TABLES	**xii**
	LIST OF FIGURES	**xiii**
	LIST OF ABBREVIATIONS	**xvi**
I.	**INTRODUCTION**	**1**
	1.1 Problem Statement	2
	1.2 Objectives	2
	1.3 Scope of Project	3
	1.4 Thesis Organization	3
II.	**LITERATURE REVIEW**	**5**

	2.1	History in a Development of an Electronic Nose	5
	2.2	Biological and Artificial Olfaction	12
	2.3	Sensory Organ: The Nose and Nasal Cavity	12
	2.4	Interpretation of Smells	13
	2.5	Classical Electronic Nose based on Chemical Gas Sensor	15
	2.6	Sensing Technologies	16
	2.7	Gas Sensor Operation	17
	2.8	MOSFET	18
	2.9	Semiconducting Metal Oxide (MOS)	19
	2.10	Conducting Polymer Sensors	22
	2.11	Application Areas	24
	2.12	Food and beverage	24
	2.13	Environmental Monitoring	24
	2.14	Disease Diagnosis	25
III.	**METHODOLOGY**		**27**
	3.1	Hardware Implementation	27
IV.	**RESULTS AND DISCUSSION**		**29**
	4.1	Implementation of an alcohol gas sensor (MQ – 3)	29
	4.2	LCD display 16x2	37
	4.3	Buzzer	40
	4.4	Arduino with Smoke Detector (MQ-4 gas sensor)	42
	4.5	Combination of Both MQ-3 and MQ-4 Gas Sensor	47

4.6 The analysis of the electronic nose 55

V. CONCLUSION 59

REFERENCES 60

APPENDIXES 66

LIST OF TABLES

NUMBER	TITLE	PAGE
2.1	Author of the Paper Research on Electronic Nose, Type of Sensor, Concept, and Benefits of the Sensors Used Benefits [11]	8
2.2	The advantages and disadvantages of MOS sensor [35]	20
2.3	List of examples commercially available SnO_2 sensors provided by the Figaro Engineering Company [29]	20
2.4	Physical changes in the sensor of active film and the sensor devices that used to transduce them into electrical signals [36]	22
2.5	Application techniques used to deposit carbon black based composites [36]	23
4.1	Datasheet of LED	34
4.2	Result on simulation of perfume as a tester	56
4.3	Result on simulation of water as a tester	57
4.4	Result on simulation of nail polish as a tester	58

LIST OF FIGURES

NUMBER	FIGURE	PAGE
2.1	A summary of milestones in sensor development [1, 11-12]	5
2.2	The schematic demonstrate the possible conditions for a reliable odour measurement [19]	10
2.3	The schematic demonstrate the possible conditions for a reliable odour measurement on concomitant gas [19].	11
2.4	The olfactory nerve connects the olfactory system to the central nervous system allows processing of odour information [20]	13
2.5	Odorant receptors and the organization of olfactory system [21]	14
2.6	Sequence of events during chemical detection and recognition [11]	16
3.1	The fabrication of the electronic nose involves	27
3.2	Flowchart on execute implementation of an electronic nose	28
4.1	Connection of LEDs on Arduino Digital I/O Pins	29
4.2	The potentiometer used	30
4.3	Port of connection of alcohol gas sensor (MQ3)	30
4.4	Simulation on alcohol gas sensor (MQ3) using Arduino microcontroller	31
4.5	Series connection of LEDs	32
4.6	Parallel connection of LEDs	33
4.7	Simulation on MQ3 gas sensor by using 330 Ω of resistors	34
4.8	Simulation on MQ3 gas sensor by using 220 Ω of resistors	34

4.9	Measure forward voltage, V_d	36
4.10	Measure forward current, I_F	36
4.11	Schematic diagram of LCD display using Fritzing software	37
4.12	Programming of LCD display	38
4.13	Simulation using Proteus software	38
4.14	LCD display does not display any characters	39
4.15	LCD display after troubleshoot	39
4.16	Simulation of piezo buzzer using Proteus software	41
4.17	Hardware simulation of piezo buzzer	42
4.18	Schematic design of MQ-4 gas sensor	43
4.19	Simulation on MQ-4 gas sensor	44
4.20	Initialize the parameter that were used	44
4.21	Safe and danger condition coding of MQ-4 gas sensor	45
4.22	Hardware simulation of MQ-4 gas sensor	45
4.23	Before troubleshoot the connection of the piezo buzzer on the breadboard	46
4.24	After troubleshoot the connection of the piezo buzzer on the breadboard	47
4.25	The flowchart of the interface between MQ-3 gas sensor and MQ-4 gas sensor	48
4.26	Circuit simulation of both sensors	50
4.27	Declaring all the parameters that are involved	50
4.28	Set up the output parameters and activate the sensor	51
4.29	Display the conditions of gas sensor based on reading achieved	52
4.30	Both sensors had readings that exceed the set Point	52

4.31	Both sensors had readings that below the set Point value	53
4.32	MQ-3 gas sensor had readings that above the set Point value and MQ-4 gas sensor had readings that below the set Point value	53
4.33	MQ-3 gas sensor had readings that below the set Point value and MQ-4 gas sensor had readings that above the set Point value	54
4.34	Graph of different tester that was tested on electronic nose	55
4.35	Graph of perfume as a tester that was tested on electronic nose	56
4.36	Graph of water as a tester that was tested on electronic nose	57
4.37	Graph of nail polish as a tester that was tested on electronic nose	57

LIST OF ABBREVIATIONS

VOC	Volatile Organic Compounds
MOS	Metal Oxide Semiconductor
CP	Conducting Polymer
SAW	Surface Acoustic Wave
QCM	Quartz Crystal Microbalance
RGTO	Rheotaxial Growth and Thermal Oxidation
MOSFET	Metal Oxide Semiconductor Field Effect Transistor
TGS	Taguchi Gas Sensor
PWM	Pulse Width Modulation

LIST OF ATTACHMENTS

NUMBER	TITLE	PAGE
1.1	Datasheet MQ-3 Gas Sensor	66
2.1	Datasheet MQ-4 Gas Sensor	68

CHAPTER I

INTRODUCTION

Since past two decades electronic nose technology has quietly advanced and the commercial models has been equipped with sensor arrays in the mid - 1990s, besides they are used to analyze food flavors, distinguished wine brand, and sort lumber [1]. In 1982, Persaud and Dodd [2] constructed an electronic nose using semiconductor transducers and incorporating the design features. Electronic nose was well known since 2,000 BC and has been used by both the Greeks and the Chinese used to diagnose diseases [3]. An electronic nose (e-nose) is a device that functions to detect and recognizes chemical volatile substances by using an array of gas sensors, and other some kind of signal preprocessing and a pattern recognition algorithm [4]. Nowadays the applications of an electronic nose in environmental monitoring are great interest because the instruments' proven capability of recognizing and discriminating between a variety of different gases and odors using just only a small number of sensors [5].

In addition, the development of the electronic nose was encouraged by the desire for reasonably priced, quick, and also portable device capable of calculating complex mixtures of volatile organic compounds (VOCs) [6]. Since the electronic nose have used in wide area application, these noses cost between range of US $5000 to $100 000 but the prices could easily drop to under a dollar by 2020 [1]. Axel and Buck won the Nobel Prize in Physiology or Medicine, 2004 for their research on "Odorant receptors and the organization of the olfactory system" [7]

which can see that the interest and value of the research on olfaction. VOCs presented to the sensor array that produces a signature or pattern of characteristics of the vapor [8].

Besides that, one of the most popular gas transducers is Metal Oxide Semiconductor (MOS) because of their high sensitivity and low price which typically under 10 euro for each [9]. However, MOS need to be pre-heated at temperatures up until 200 to 500 ^{o}C to facilitate the interaction with the target gas [9]. Besides that, the acquisition cycle is very long due to their slow response especially when recovering the baseline level after the exposure to the target ends [10]. In fact the baseline levels show that the sensor output in their absence of target gases, besides varies with temperature and humidity among sensors.

1.1 Problem Statement

A number of different sensors have been developed for multi-sensor arrays. Those sensors demonstrate physical and chemical interactions with the chemical compounds when gases in contact with the sensors. However, the choice of sensors is quite large. Besides that, the constraints of the electronic nose are:

- high costs of implementation
- long time analysis
- low samples throughput

1.2 Objectives

The objectives of this project are to:

- investigate and study the behavior of the electronic nose,
- identify which types of sensors are most suitable for electronic nose application,

- develop a low cost electronic nose to detect and discriminate among complex odors using a sensor array.

1.3 Scope of project

In this project, electronic nose is designed by using different types of gas sensors such as alcohol sensor (MQ-3) and natural gas sensor (MQ-4). In this project, the electronic nose is implemented by utilizing Arduino programming and it will read the sensitivity smell of the tester in ppm (parts per million). Once the smell is detected by the electronic nose and the reading is above the set point value (i.e., 500 ppm), the reading and the sign "DANGER" will be displayed on the LCD display. At the same time, the LED and the buzzer will be activated. On the other hand, if the sensor reading is below the set point, the sign "SAFE" will be displayed on the LCD display, LED and buzzer will be inactive.

1.4 Thesis Organization

The thesis is organized as below:

- Chapter 1 (Introduction) – In this chapter, it focus on the roughly understanding on the electronic nose behavior, and the problem statement involved. With the problem statement arise, the objectives of the thesis are identified and the scope of project was being explained.
- Chapter 2 (Literature Review) – This chapter is well explaining on the behavior of the electronic nose and types of sensors that possibly involved and can be conducted for the electronic nose application
- Chapter 3 (Methodology) - In this chapter, the flowchart is used to explained the process of the electronic nose implementation.

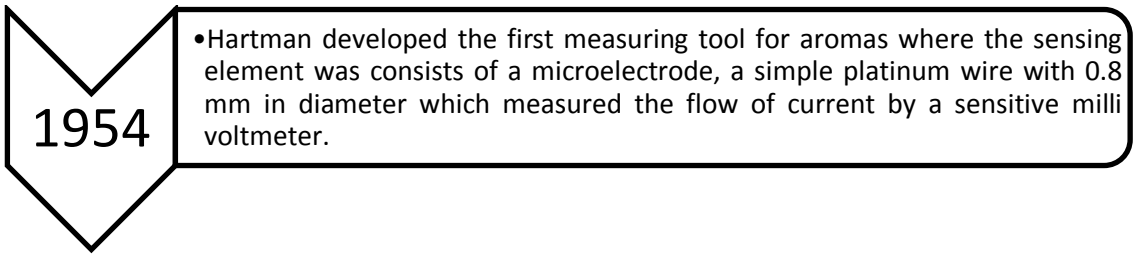
- Chapter 4 (Results and Discussion) – The result was represented by using Arduino programming, Proteus Professional 8, and Multisim for the software simulaton. Next, the hardware simulation also was being conducted in order to compare the result Proteus simulation. After the electronic nose had been completely implemented, the analysis of the product is conducted.
- Chapter 5 (Conclusion) – The thesis outcomes are concluded.

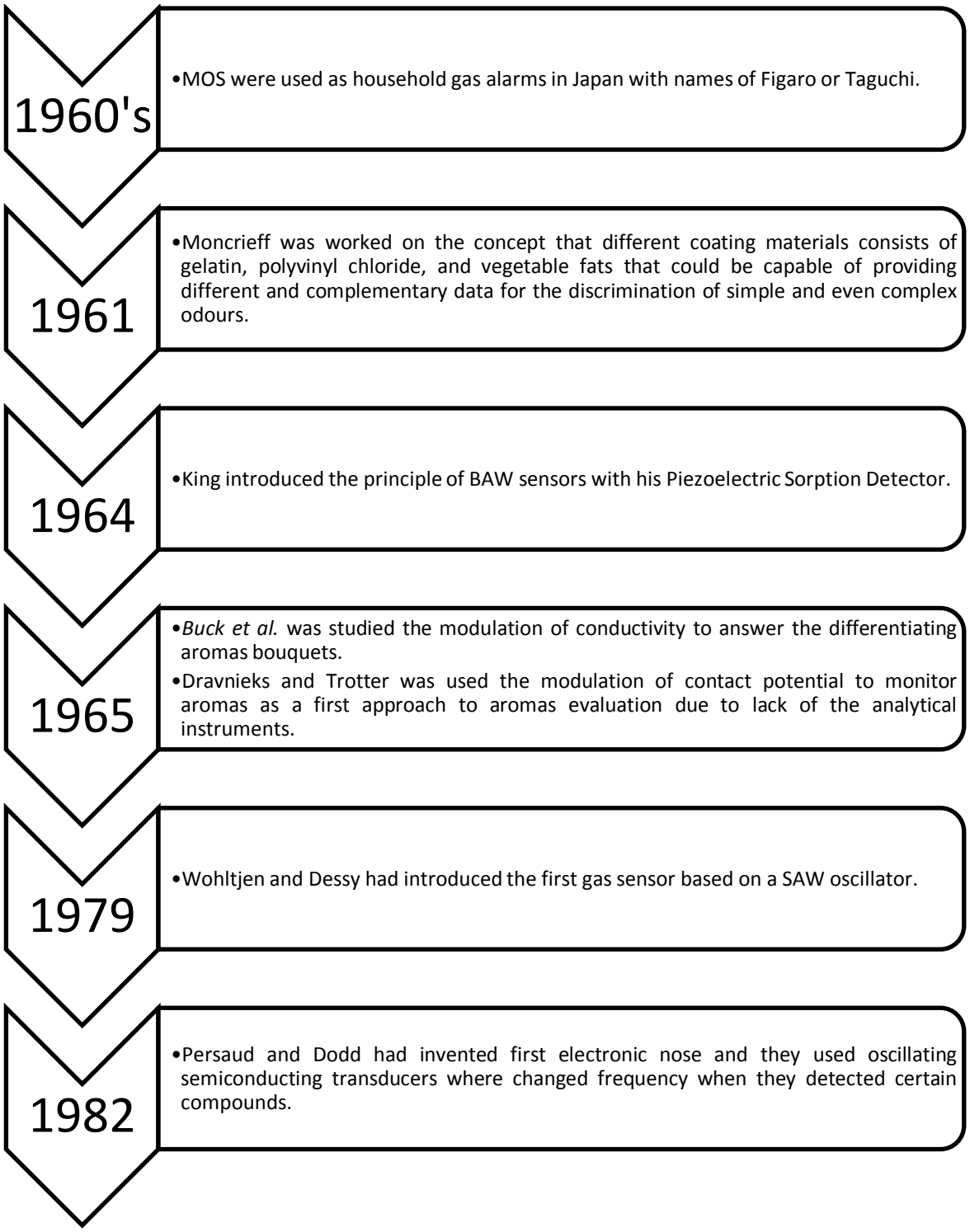
CHAPTER II

LITERATURE REVIEW

2.1 History in a Development of an Electronic Nose

During the past twenty years, electronic nose devices had received considerable attention in the field of sensor technology where largely due to the discovery of numerous applications derived from research in devices fields of applied sciences [13]. Figure 2.1 shows the milestones of the development of an electronic nose:





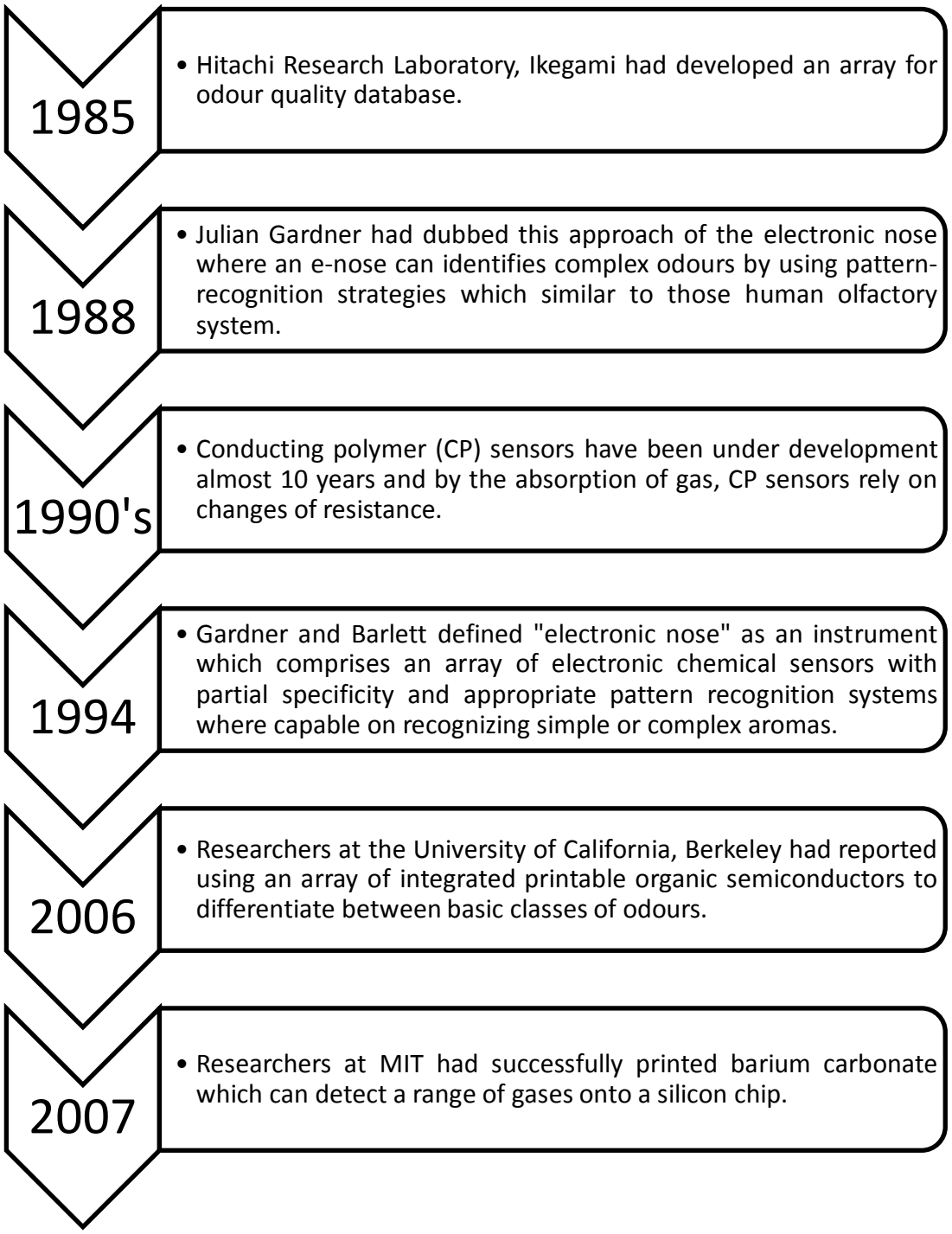


Figure 2.1: A summary of milestones in sensor development [1, 11-12].