

以溶膠－凝膠法製作二氧化鋯感測層在電解質－絕緣層 －半導體結構對pH及尿素生物感測之研究

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離子感測場效電晶體(Ion-sensitive Field Effect Transistor, ISFET)是由 Bergveld 在1970 年首先提出，由於它的尺寸小，反應速度快、可承受外部應力，且與現今的 CMOS 製程相容，所以在現在的感測元件開發中具有相當大的潛力。ISFET的主要結構是電解質－絕緣層－半導體(electrolyte-insulator-semiconductor, EIS)，藉由研究EIS 電容結構的特性，我們可以了解不同材料的離子感測性質。傳統上，大部份材料都是使用濺鍍和電漿輔助化學氣相沉積製程，需要高真空系統、靶材等昂貴的設備和材料。

於本論文我們提出溶膠－凝膠法在EIS電容結構上，製作二氧化鋯感測層作pH感測特性研究。本實驗可成功利用濃度及旋塗次數控制膜厚，並結合氧電漿和熱退火處理製作出具有高介電係數的二氧化鋯感測層。為了讓製程成本降低且方法簡便，

使用銀網版印刷電極作為EIS電容及Ag/Ag_xO參考電極的基板材料，更具有延伸電極的優點。另外，本實驗同時研究二氧化鋯pH感測器的非理想特性，包含遲滯效應和時漂效應，以對薄膜品質和感測性質有進一步了解。

在酵素生物感測的應用上，我們結合了尿素酶和二氧化鋯pH感測器作尿素檢測的應用。酵素EIS結構的尿素生物感測器可用來量測不同濃度的尿素電位差分析，濃度範圍約在3到40 mM。本研究在製程上的優點是便宜、簡便及低溫，並發展出溶膠-凝膠法製作二氧化鋯感測層在pH量測及尿素生物感測的應用。



The study of sol-gel-derived ZrO₂ sensing film based on electrolyte–insulator–semiconductor for pH detection and urea biosensing

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ABSTRACT

ISFET(Ion-sensitive Field Effect Transistor) was first developed by Bergveld in 1970s, and because of its small size, fast response, rigidity and compatibility with standard CMOS process, ISFET is an attractive candidate of modern sensor device. By studying the characteristics of EIS capacitor, we can understand the nature of ion sensitivity to different materials. Traditionally, the majority of sensing membranes are fabricated by sputter and PECVD process, which require high vacuum systems, targets and other expensive equipment and materials.

In this study we propose the ZrO₂ high-κ materials which act as pH sensitive layers of EIS capacitor by the sol-gel processes. This experiment can successfully control the thickness by concentration and the number of spin-coating of solution, and then

combined with oxygen plasma and thermal annealing to produce a high- κ ZrO_2 sensing layer. In order to reduce the cost and simplify the procedure, Ag screen-printed electrode (Ag-SPE, Zensor Inc.) was used as the substrate for extending electrode of EIS capacitor and Ag/ Ag_xO reference electrode. In addition, this study will examine the non-ideal phenomena of ZrO_2 EIS capacitor, including hysteresis and drift effects, to study the quality of ZrO_2 film and have a better understanding of sensor properties.

As a demonstration case of EnFET-based biosensing, urea detection was performed by configuring a hybrid structure encompassing the EIS-based pH sensor. The enzymatic EIS-based urea biosensor allowed the potentiometric analysis of urea, at concentrations ranging from 3 to 40mM. The attractive features in this study are low cost, flexible, easy fabrication and low processing temperature, and the present work has provided some fundamental data for the use of ZrO_2 thin film for EIS-based pH detection and the extended application for biosensing.



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Contents

Abstract (in Chinese)	i
Abstract (in English)	iii
Acknowledgement	v
Contents	vi
Figure Captions	viii
Table Captions	xi
Chapter 1 Introduction	1
1.1 Brief history of ISFET.....	1
1.2 The evolution of the double layer models.....	2
1.2.1 Helmholtz Double Layer.....	3
1.2.2 Gouy-Chapman Double Layer.....	4
1.2.3 Stern Modification of the Diffuse double Layer.....	5
1.3 Introduction to ISFET.....	7
1.4 Introduction to SPE (screen-printed electrode).....	8
1.5 Motivation of this work.....	8
1.6 References.....	10
Chapter 2 Theory Description	13
2.1 Introduction.....	13
2.2 Importance of Ion-sensitivity.....	13
2.3 Definition of pH	14
2.4 The method for pH detection.....	14
2.5 The theory of ISFET.....	15

2.5.1 From MOSFET to ISFET.....	16
2.5.2 The Response of pH at the Oxide-Electrolyte Interface.....	22
2.6 The mechanism of sol-gel processes	25
2.6.1 Application of the sol-gel processes in ISFET fabrication	26
2.6.2 O ₂ plasma in the sol-gel processes	27
2.7 Non-ideal phenomena of ISFET: Optical effect, Hysteresis and Drift	28
2.7.1 Optical effect	29
2.7.2 Hysteresis	29
2.7.3 Drift	29
2.8 References.....	32
Chapter 3 Experiment and Measurement.....	35
3.1 Introduction.....	35
3.1.1 Reagent.....	35
3.2 Fabrication Process.....	36
3.3 The key steps of the experiment.....	40
3.3.1 Sensing layers fabrication.....	41
3.3.2 Ag/Ag _x O reference electrode.....	41
3.3.3 Photo Lithography	41
3.3.4 Urea biosensor.....	42
3.4 Analyze structural properties	44
3.4.1 Scanning electron microscope (SEM)	44
3.4.2 Atomic force microscopy (AFM)	44
3.4.3 X-ray crystallography (XRD)	44
3.5 Measurement system.....	45
3.5.1 Preparation of measurement.....	45

3.5.2 Capacitance-Voltage measurement set-up.....	45
3.5.3 Drift measurement set-up.....	47
3.5.4 Hysteresis measurement set-up.....	47
3.5.5 Urea biosensor measurement set-up	47
3.6 References.....	48
Chapter 4 Results and Discussions.....	49
4.1 Introduction.....	49
4.2 Structural properties	49
4.2.1 Scanning electron microscope (SEM)	49
4.2.2 Atomic force microscopy (AFM)	50
4.2.3 X-ray crystallography (XRD)	52
4.2.4 Summary	53
4.3 C-V curves of ZrO ₂ to MIS capacitors	54
4.4 pH sensing performance of ZrO ₂	55
4.4.1 Summary	64
4.5 The drift phenomenon to pH buffer solution	64
4.6 The influence on the hysteresis	67
4.7 Demonstration case for urea biosensing	71
4.7.1 Summary	77
4.8 Conclusions.....	78
4.9 References.....	79
Chapter 5 Future Work.....	81
5.1 Future work.....	81

Figure captions

- Figure 1-1 Schematic representation of the side-binding model
- Figure 1-2 Schematic representation of the Helmholtz double layer model (a) The charge distribution, (b) The potential distribution
- Figure 1-3 Schematic representation of Gouy – Chapman – Stern model (a) The charge distribution, (b) The potential distribution
- Figure 1-4 Flowchart of the process in this study
- Figure 2-1 C-V characters of an ideal MIS capacitor (a) C-V curves of an MIS structure, (b) The charge distribution of an MIS capacitor
- Figure 2-2 Schematic representation of (a) MOSFET, (b) ISFET
- Figure 2-3 Charge density and potential distribution of the interface to EIS capacitor
- Figure 2-4 EIS system represented by equivalent capacitor structure
- Figure 2-5 Energy band diagrams of an ideal MIS capacitor
- Figure 2-6 Energy band diagrams of the interface to EIS capacitor
- Figure 2-7 Potential profile and charge distribution at an oxide electrolyte solution interface
- Figure 2-8 Mechanism of Zr-based sol-gel solution treated with oxygen plasma
- Figure 3-1 Fabrication process flow
- Figure 3-2 Schematic representation of $\text{ZrO}_2/\text{SiO}_2/\text{Si}$ EIS capacitor structure
- Figure 3-3 Fabrication process flow of urease immobilization
- Figure 3-4 Measurement setup
- Figure 4-1 SEM image of one layer spin-coated ZrO_2 layer
- Figure 4-2 AFM image of ZrO_2 film surface (annealing at 350°C)
- Figure 4-3 AFM image of ZrO_2 film surface (annealing at 450°C)

- Figure 4-4 XRD pattern of ZrO₂ to EIS capacitor (annealing at 350°C)
- Figure 4-5 XRD pattern of ZrO₂ to EIS capacitor (annealing at 450°C)
- Figure 4-6 C-V curves of ZrO₂ to MIS capacitors
- Figure 4-7 Normalized C-V curves of ZrO₂ to EIS capacitor without O₂ plasma
- Figure 4-8 Normalized C-V curves of ZrO₂ to EIS capacitor (annealing at 250°C)
- Figure 4-9 Normalized C-V curves of one layer ZrO₂ to EIS capacitor (a) annealing at 350°C, (b) annealing at 450°C
- Figure 4-9 Normalized C-V curves of three layers ZrO₂ to EIS capacitor (a) annealing at 350°C, (b) annealing at 450°C
- Figure 4-11 Normalized C-V curves of ZrO₂ to EIS capacitor (annealing at 350°C)
- Figure 4-12 Sensitivity characteristic of ZrO₂ to EIS capacitor (annealing at 350°C)
- Figure 4-13 Normalized C-V curves of ZrO₂ to EIS capacitor (annealing at 450°C)
- Figure 4-14 Sensitivity characteristic of ZrO₂ to EIS capacitor (annealing at 450°C)
- Figure 4-15 Normalized C-V curves of ZrO₂ to EIS capacitor after photo-lithography (annealing at 450°C)
- Figure 4-16 Sensitivity characteristic of ZrO₂ to EIS capacitor after photo-lithography (annealing at 450°C)
- Figure 4-17 Time to drift in pH7 buffer solution of EIS capacitor for 8 hours (annealing at 350°C) (a) V_{ref} with time, (b) ΔV_{ref} with time
- Figure 4-18 Time to drift in pH7 buffer solution of EIS capacitor for 8 hours (annealing at 450°C) (a) V_{ref} with time, (b) ΔV_{ref} with time
- Figure 4-19 Hysteresis phenomenon to time of EIS capacitor (annealing at 350°C) (a) pH 7→4→7→10→7, (b) pH 7→10→7→4→7
- Figure 4-20 Hysteresis phenomenon to time of EIS capacitor (annealing at 450°C) (a) pH 7→4→7→10→7, (b) pH 7→10→7→4→7

Figure 4-21 Efficiency of hydrolysis at variable buffer pH values (different amounts of urea)

Figure 4-22 Normalized C-V curves of ZrO_2 to EIS capacitor (from pH 4.8 to 8.4)

Figure 4-23 Sensitivity characteristic of a ZrO_2 EIS capacitor (from pH 4.8 to 8.4)

Figure 4-24 Normalized C-V curves of a ZrO_2 EIS capacitor (annealing at $450^\circ C$) toward various urea concentrations

Figure 4-25 Sensitivity characteristic of a ZrO_2 EIS capacitor (annealing at $450^\circ C$) toward various urea concentrations

Figure 4-26 Normalized C-V curves of ZrO_2 which immobilized urease to urea biosensor (annealing at $450^\circ C$)

Figure 4-27 Sensitivity characteristic of ZrO_2 which immobilized urease to urea biosensor (annealing at $450^\circ C$)



Table captions

Table 4-1 The comparison of the structure and sensitivity characteristics at different annealing temperature

Table 4-2 Hysteresis phenomenon to time of EIS capacitor at different annealing temperature

Table 4-3 The pH values of urea solutions (from 3 mM to 40 mM in pH 7 buffer solutions)

Table 4-4 The pH values of urea solutions after catalyzed by urease (from 3 mM to 40 mM in pH 7 buffer solutions)