13th GOLDEN SILICON AWARDS

D13-009

Towards a Fully Integrated Electronic Nose SoC for Portable Biomedical applications

實現全整合電子鼻系統晶片可應用於可攜式生醫裝置

隊伍名稱

宅宅時代 / Homebody Times

隊長

邱仕文 清華大學電機工程學系

隊員

張光漢 清華大學電機工程學系
王仁和 清華大學電機工程學系
張庭豪 清華大學電機工程學系

作品摘要

本晶片設計的目的即是擁有「聞」能力的系統晶片，即電子鼻系統晶片，其具備高晶片相容、多用途、低成本、小體積、低功耗等特性。電子鼻應用於生醫領域方面，多用以辨識疾病，如肺癌、皮膚癌、尿道疾病等。目前在市面上的電子鼻儀器，雖然可以改善氣體感測的「即時性」，但是因為體積龐大，因此在「可攜性」上不符合需求。我們在標準製程晶片上，直接利用鍵合點開窗功能，製作指叉電極，再透過適當的滴定工具將感測材料塗佈在晶片表面，直接和下層電路做聯結，此方式類似三維堆疊的方式，可不採用其他後製程方式即可完成，實現全整合的電子鼻系統晶片。本晶片計畫應用於生醫疾病辨識，採用電子鼻原理，利用不同氣體在不同感測器中的電阻變化而產生的圖案以形成一個獨特的簽名。病人的氣體成分非常複雜，並且病人間的個體差異非常大，除了仰賴前端訊號處理的解析度和抗雜訊能力外，設計上，此晶片採用中央微控制器搭配獨特的數位處理單元，平衡對於微處理器的仰賴，並保有一定的操作彈性，也降低系統整體的操作頻率和電壓，同時降低功率上的消耗，符合可攜式裝置的製作精神。系統晶片主要分為五個部分：積體化感測器陣列（Sensor Array）、多通道感測器介面電路（Interface circuits，IE）、連續漸進式類比數位轉換器（Successive approximation ADC，SARADC）、數位訊號處理單元-連續值局限型波茲曼模型（Digital Continuous Restricted Boltzmann Machine，D-CRBM）、OpenRISC微控制器、以及靜態隨機處理記憶體（Static Random Access Memory，SRAM）。

圖1 > 嗅覺晶片: 具備氣味辨識能力、小體積、低功耗、低製造成本、高電子相容性等特性，可作為個人健康照護裝置並承載於消費性電子產品（如手機）中

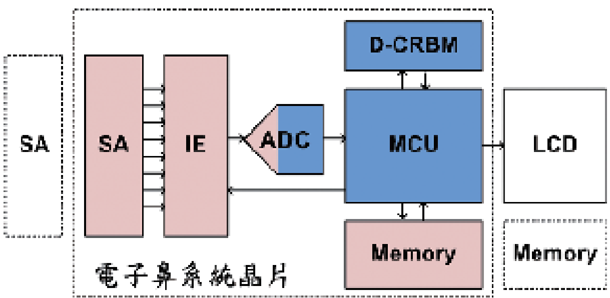

圖2 > 電子鼻系統晶片方塊圖

指導教授

鄭桂忠 / 清華大學電機工程學系

於 1996 年於臺灣大學電機系取得學士學位後，並分別於 1998 年、2001 年於加州理工學院電機系取得碩士與博士學位。2001 年至 2006 年於美國 Second Sight Medical Products 擔任資深工程師，2006 年進入清華大學電機系擔任助理教授，2011 年升任副教授。

研究領域

生醫系統設計、仿生晶片設計、氣體感測系統、混合信號 VLSI 設計。

Abstract

Portable electronic noses can be applied to biomedical areas to identify diseases such as lung cancer, skin cancer, and urinary tract disease. Although current electronic nose devices available in the market can improve the "real-time" gas sensing issue, they are restricted by bulky size (mostly laptops or desktop) and high price. Consequently, their "portability" does not meet the requirements for customer electronics such as smart phones. The purpose of the "smell" chip is to design a high electronically compatible, multi-purpose, low cost, small size, low power SoC. This chip is based on a carbon black-polymer sensor array to provide very stable sensor response to form odor fingerprints. The array has gas selectivity by choosing a variety of different polymers. We adopted the standard CMOS process technology to make the interdigitated electrodes with the top metal layer; the protecting layer was removed by PAD mask to define the sensing area, and then the sensing materials could be deposited to form the on-chip sensors. The sensors were connected to the signal processing circuits by the inner metal layers. In this way, we could fabricate the sensors without any post-MEMS/MEMS/pre-MEMS processing to achieve a fully integrated electronic nose SoC. The chip was designed to aim for biomedical disease detection. Because the gas composition is very complex from different individuals, the front-end signal processing required high resolution and noise immunity. The digital part of signal processing circuits was implemented by a microcontroller with a digital processing unit, to obtain flexibility and reduce dependence on the microprocessor. This also reduced power consumption, which is suitable for portable and consumer electronic devices. The electronic nose SoC could be divided into six blocks: an array of integrated sensors (SA), a multi-channel sensor interface circuit (IE), a successive approximation analog to digital converter (SAR-ADC), a digital signal processing unit - Continuous Restricted Boltzmann Machine (D-CRBM), an OpenRISC microcontroller, and a static random access memory (SRAM). The external components include a flash memory to load the program to SRAM during system initialization, a LCD to show the results of odor classification, and a quartz oscillator to offer the main operating frequency.

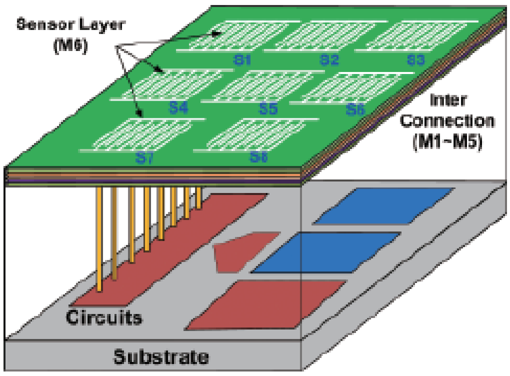

Fig.3 >The 3D structure of the E-Nose SoC

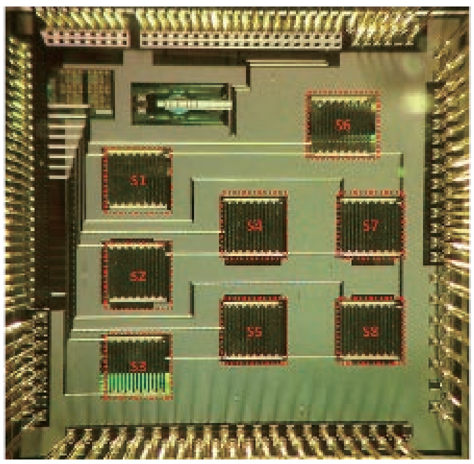

Fig.4 >Die photo of the E-Nose SoC with on-chip sensors (S1~S8)