D15-060

Design and Fabrication of Monolithic CMOS/MEMS System with HV-ESD Clamp Potected Inkjet Printhead

設計與製程單石噴墨晶片整合 HV-ESD Clamp 於多準位輸出積體電路

隊名 單石 CMOS/MEMS 晶片系統
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作品摘要

噴墨列印晶片技術包含高壓驅動、低壓邏輯訊號處理、及微機電結構陣列，如圖 1 所示，以小滴的墨水滴到紙上，組合成像，墨滴非常小，僅有 50 到 60 微米（Micron、一百萬分之一米），比人的頭髮（70Micron）還細。滴墨的位置靠噴墨頭（InkHead）準確的精細移動，每寸可高達 1000 點以上，用多個不同彩色的墨水匣，可以列印出完全色彩的影像。本作品以設計與製程單石噴墨晶片整合 HV-ESD Clamp 於多準位輸出積體電路，包含有高壓驅動功率元件陣列、低壓邏輯電路、及微機電元件結構陣列整合於一個矽基板製程，能耐 HBM（+/-4kV）、MM（+/-400V）的防護電路測試。

要解決的問題：

傳統噴墨晶片技術，原來使用 NMOS 製程邏輯定址技術，轉換成由 CMOS 元件技術達成整合高壓驅動陣列及低壓 CMOS 邏輯技術，此技術完全掌控邏輯訊號處理準位，噴墨晶片電路技術功能為精確達成定址（Addressing），傳統晶片電路是以 NMOS 元件處理數位訊號的「0」與「1」準位，但是因 NMOS 元件本身的準位轉換是無法由「1」切換成 100% 之狀態「0」準位。整合邏輯時序 CMOS 控制電路，可同時達大電流大電壓之驅動元件，且能與噴墨致動元件整合之晶圓製程。結合高密度高頻之微流結構（microflow architecture）設計，加上噴墨頭封裝精度之提升，將噴墨技術提升到最高等級。此技術除供開發一般噴墨列印之產品外，因能有更高之噴印速度與更小噴印線寬，可將噴液技術之應用推到更細密之層次。

Multiplexer Jet Head 晶片電路設計

Logic multiplexer on Chip 邏輯電路的部份以 CMOS 元件組成，將噴墨晶片製程在 CMOS 積體電路上，MEMS device on CMOS 如圖 2，需要 IC 設計、IC 軟體硬體驗證、下晶片 Layout 建立一套完全新的具有邏輯控制電路的噴墨印頭晶片的設計流程，下一階段要將此一完成設計的 Schematic 轉化成 Layout，再確認 Schematic 與 Layout，及設計製程法則是否吻合，也就是所謂 LVS、DRC 電腦輔助軟體檢查，以驗證 Layout 是根據 HSPICE 電路模擬得出每一個元件、邏輯 CELL 的 Layout Size，和將委託代工廠的 Process Minium Rule 的檢查，完成以上檢查工作後就準備製作此一全新的具有邏輯控制電路的噴墨印頭晶片。

引入 CMOS 製程，可比 HP NMOS Depletion Load 邏輯準位更準，如圖 3 所示，及臺灣代工廠易配合等優勢；元件密度大幅提高，製程數增加，晶片製程與電性難度提高。

- CMOS 100% 由 1 close to 0
- CMOS 切換速度快（1000 級以上 Logic gate）
- 任意模式選擇噴孔
- CMOS 與 Depletion NMOS （/ Enhancement NMOS）的切換比較整合邏輯多工驅動元件噴墨印頭（integrated multiplexer head）設計開發，640 噴嘴 / 1200npi/ 5pL/ 28kHz，列印解析度 2400╳1200dpi

完成技術問題：

IC 設計、下晶片 Layout 建立一套完全新的具有邏輯控制電路的噴墨印頭晶片的設計流程，由標準 CMOS 積體電路製程智慧型控制電路，在懸接後段 MEMS 噴墨晶片製程，並有整合 HV-ESD Clamp 保護積體電路。

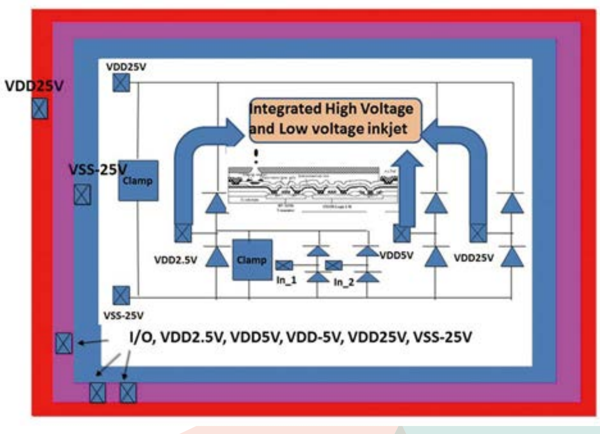

圖 1 / 單石噴墨晶片整合 ESD 於多準位輸出積體電路

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研究領域

系統晶片（SOC）設計、醫療電子晶片技術、矽光子光傳輸晶片系統（SoC）、智慧電子系統、光電系統整合、微奈米光學檢測、微奈米光機電元件與系統。

Abstract

The major customer requirements for printing system are high print quality, high speed, available colors, low cost, reliable hardware, and excellent software support. Thermal inkjet printing has several advantages compared with other technologies; low cost, high resolution, low noise, ease of color printing, and portability. The inkjet printhead is the key element in the inkjet printer because it determines the print quality, print speed, and maintenance cost. It proposed a monolithic CMOS/MEMS system with multi-level output voltage ESD protection system for protected inkjet printhead. High voltage power, low voltage logic and CMOS/MEMS architecture were integrated in inkjet chip. It used bulk micromachining technology (MEMS). On-chip high voltage electrostatic discharge (HV-ESD) protection design in smart power technology of monolithic inkjet chip is a challenging issue. The time interleaving scanning sequence is controlled spatially on the jet elements to avoid the strong interference caused by the excitation of the neighbor elements. A heating element, disposed on the substrate, includes a conductor loop which does not encompass the heating elements on the substrate. The configuration of the heater jet significantly reduces both electromagnetic and capacitance interference caused by the heating elements. The simulation and experience result has shown in the research.

A thermal bubble jet printhead suitable for high speed and long life printing has been developed. The smart printhead has been fabricated by a standard CMOS processes and using micromachining technology (MEMS). It combines micromechanics including heating actuators, temperature sensor, channels and nozzles with a smart CMOS circuit including D Flip-Flops signal-processing along with bi-directional data transfer and 12V power amplifiers in a printhead chip. A great step in the integration of the thermal bubble jet intimate electronics can be realized by enabling logic functions as well as power switches. Enhance of the number and array density of nozzles within an inkjet head chip is the key to raise the printing speed and printing resolutions. This study develops the integrated inkjet, driver, and logic multiplexer three kinds of different technology in LSI(large scale integrated circuit) inkjet printhead, there are ten thousand CMOS transistor devices . The characteristic is that logic multiplexer device transfer input signals to address and print enable. The spec of IMDH printhead is 640 nozzles/640 heaters, 5 pl of ejected droplet volume and with the operating firing frequency of 28kHz. Combining both the HDCI process and high-density micro-fluidic channel design architecture, IMDH inkjet head is the supreme product in the present state and is the same or even higher level with HP's highest end of commercial products. This technology could be applied not only on the inkjet printhead products but also on many other applications. This documents include the following topics as chip design process, system signal and electricity characteristic, multiplexer chip fabrication process and verification and module of printhead bonding. All of the jets of the printhead are controlled by very few input lines: a pulse shape (ENABLE), a data line (DATA), a bit shift clock (BIT SHIFT), a state clearing pulse, 5-volt supply for the logic devices, a higher voltage for energizing the heater resisters, and a ground line. To optimize long-lifetimes of printhead, different passivation layers of SiNx/SiCx/Ta will be deposited and patterned. With these technologies, we have fabricated a chip size 9000um×8000um printhead with 640 nozzles have a 5 pl. ink drop volume and life time is 5×10^9. In order to examine the effects of higher voltage potentials, test subjects were charged to +/-4 kV (8kV) for HBM and charged to +/- 400V for MM.

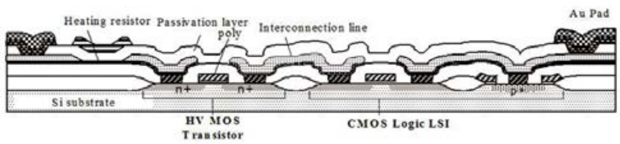

Fig.2 / MEMS device on CMOS

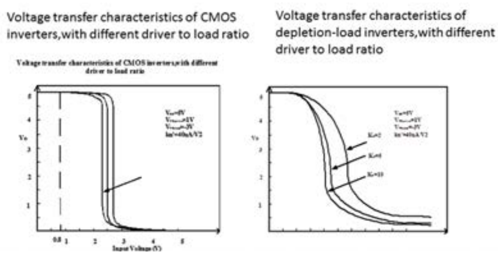

Fig.3 / CMOS 與 Depletion NMOS 的切換比較