

藉由密度控制以提高真空微電子用之奈米碳管 之場發射特性

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摘要

利用熱化學氣相沉積系統伴隨乙烯與氫氣混合環境於鍍鐵矽基板下可成長出高密度奈米碳管。由真空量測中可以發現奈米碳管具有優異的場發射特性。奈米碳管在高密度成長下場發射特性呈現衰退現象，然而由於鈦覆蓋層(Ti capping layer)使奈米碳管的密度由 $10^{10}/\text{cm}^2$ 減少至 $10^8/\text{cm}^2$ ，進而改善場遮蔽效應(screening effect)影響。在第二章中，我們提出利用覆蓋層使碳管密度減少而降低起始電壓，且由於管壁缺陷的增加進而提高場發射電流。另一方面，由於碳管與矽基板間的附著性較差，在高電場操作下，碳管易於被拔起而無場發射現象。利用覆蓋層也可使附著性增加，使在高電場操作下達到高電流密度($30 \text{ mA}/\text{cm}^2$)，進而實現長效穩定場發射電流。由觀測螢光板光源中可以證實，利用覆蓋層在奈米碳管成長中於長時間操作下，可以達到均勻且穩定的電流。本論文對於奈米碳管在覆蓋層效應下提出兩種成長機制：(1)覆蓋層原子在高溫下會因為內聚力移動使鐵催化金屬暴露在碳源氣體中，進而遵循氣相—液相—固相(VLS)成長機制；(2)假設催化金屬在覆蓋層原子移動後無法直接與碳源氣體分子接觸，碳源分子仍可利用高溫穿越覆蓋層原子而擴散進入催化金屬中，進而析出奈米碳管。

在第三章中，我們提出奈米碳管應用於側向場發射元件。利用氮化矽絕緣層結構有利於在真空下封裝且可以避免奈米碳管與電極間的短路產生。氮化矽層不僅可在碳管成長中當作硬遮蔽層，而且提供較佳的物理強度。應用此結構可成功避免短路現象進而改善場發射電性。此外，配合高密度氫電漿後處理可以切斷無秩序的奈米碳管且可使碳管頂部催化金屬被移除。由上述方法製造出側向場發射元件，其起始電壓在電極與碳管間距 $1\mu\text{m}$ 下可低於 2 Volt，且場發射電流密度在 10 Volt 時可達到 0.4 A/cm^2 。



Improvement of the Field Emission Characteristics of the Carbon Nanotubes via the Density Control for Vacuum Microelectronics Applications

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Abstract

High density of carbon nanotubes (CNTs) array was synthesized via thermal chemical vapor deposition on iron-coated silicon substrates with an acetylene and hydrogen mixture. The fabricated CNTs emission arrays showed excellent field emission properties. However, the field emission properties of the high density CNTs degraded because of the screening effect of the electric field. The density of CNT decreases from $10^{10}/\text{cm}^2$ to $10^8/\text{cm}^2$. In chapter 2, by means of capping layer method, the turn-on voltage decreases with the modification of the screening effect while the emission current density increases with the increasing of defects.

At high electric field, some of the aligned CNTs were pulled off due to the weak adhesion between the CNTs and the substrate. Capping layer can improve the adhesion problem and the current density can attain to 30 mA/cm². Furthermore, long-term stability of the emission current at high operating voltage can be realized. The photographs of the light emitted by the phosphor screen clearly show a homogeneous field emission current with capping layer. Here, we suppose two mechanisms to synthesize CNTs with capping layer. First, when Ti atoms assemble together like liquid, the Fe may be exposed and follow the vapor-liquid-solid (VLS) growth model. Second, the Fe may not be exposed but the carbon atoms still can diffuse through the thin Ti capping layer and extract the carbon graphite.

In chapter 3, a lateral field emission device which is based on carbon nanotubes is proposed. In order to avoid the short circuit between the CNT emitters and electrode, a nitride-insulated structure was used in lateral field emission device. The nitride layer not only was used as hard mask for CNT synthesizing but also had superior mechanical strength. It successfully avoided the short circuit problem between the electrode and emitters, and therefore, improved the field emission characteristics. Furthermore, argon plasma-post-treatment was introduced on the lateral device to cut off the disordered CNTs and remove the catalyst on the tip of CNTs. The turn-on voltage was 2 V with 1 μm interelectrode gap, and the emission current density is as high as 0.4 A/cm at 10 volt.

誌 謝

研究所兩年使我獲益良多，不僅在課業學術研究方面有所收獲，更使我了解到待人處世的道理，與團隊合作的重要。一路走來要感謝的人太多，若沒有你們就沒有今天這本論文的完成與現在的我。首先要感謝我的父母—張國欽先生與魏桂容女士，始終給我最大的鼓勵，陪我度過人生低潮分享成功的喜悅，謝謝你們給我滿滿的愛。其次要感謝我的指導教授鄭晃忠博士，老師謙恭溫和的待人處世以及對於研究的諄諄教誨增廣了我的視野，也讓我能夠順利的拿到碩士學位。

感謝我的實驗夥伴莊宗穎同學，無論在實驗上或是生活上彼此分享心得，豐富了我的研究生生涯。感謝賴瑞霖學長亦師亦友的教導，為這本論文貢獻眾多心力，並給與生活上的協助。感謝王文彬學長於實驗上的幫忙，一起分享做實驗的苦悶。感謝阮全平學長、林高照學長對於學術方面的指導與實驗方向上的建議。感謝陳柏廷學長一起分享生活中的大小事，聽聽我的牢騷。

再來要感謝實驗室的大家:郭育如同學、江可玉同學、廖大傳同學認識你們的這兩年大家相處融洽，也祝你們有很好的前程。感謝許鈞凱學弟與邵翰忠學弟對於實驗上面的協助，分擔實驗上的辛勞。陳旭信學弟、魏瑛君學妹、傅珍貴學長、李東林同學以及其它學弟妹有你們使實驗室就像一個大家庭互相陪伴合作。

另外，要感謝交通大學奈米中心和國家奈米元件實驗室提供完善的實驗設備，並在實驗設備維護上給予最大的支持與配合，使研究得以順利完成。

最後要感謝實驗室以外的朋友，奈米中心裡的王丁勇學長、楊慶榮學長、鄭兆欽同學、莊志偉同學、林天佑同學謝謝你們這兩年的陪伴。感謝蕭厚元同學與陳志恂同學帶給我許多快樂的回憶。感謝楊士芳同學幫我做最後的校稿。還有許多幫助我的朋友們，謝謝你們一路給我的關心與指導。

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FIGURE CAPTIONS

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(Ref. Carbon Nanotubes Science And Applications, M. Meyyappan page 205)

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