

國立交通大學

加速器光源科技與應用碩士學位學程

碩士論文

游離輻射對具有不同厚度之鉛氧化物
金氧半元件影響之研究

A Study on the Effect of Ionizing Radiation on MOS
Devices with Various Hf-based Dielectric Thickness

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中華民國一〇一年十一月

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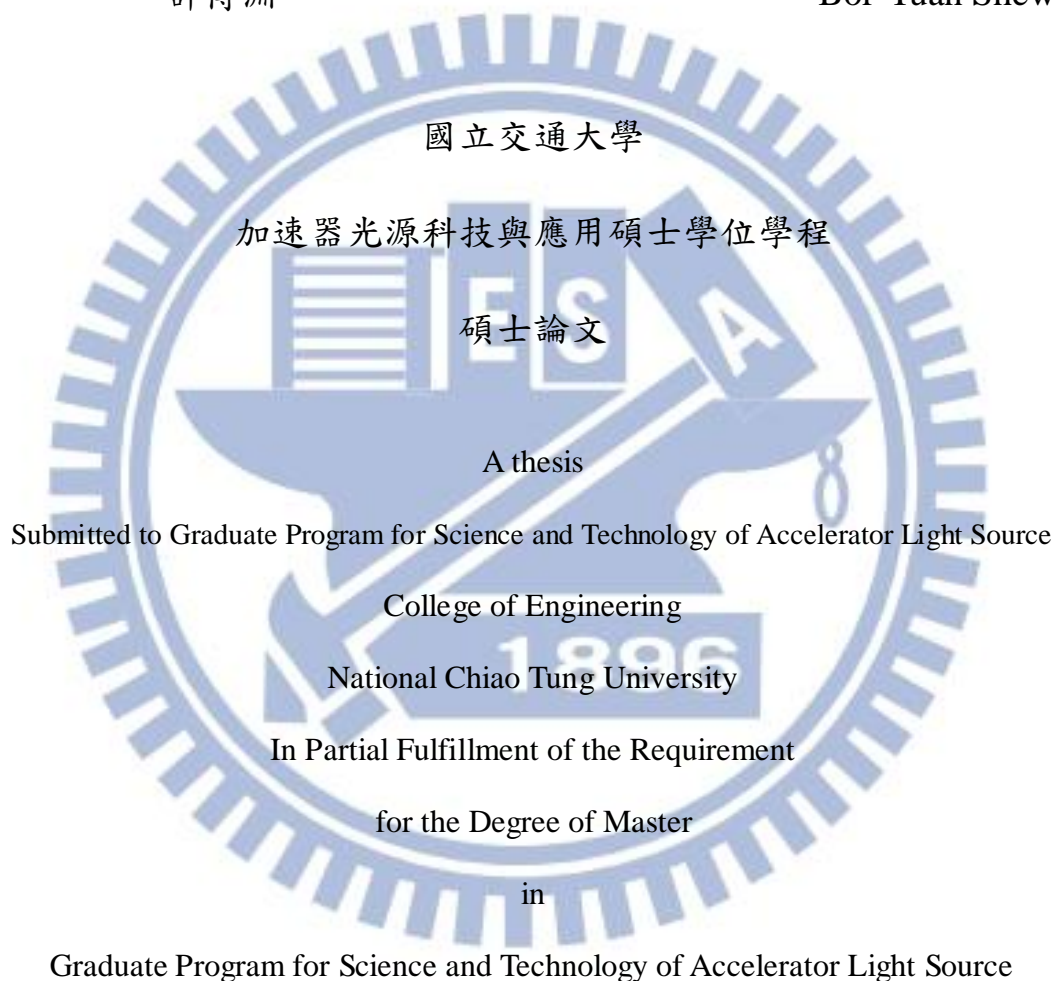
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摘要

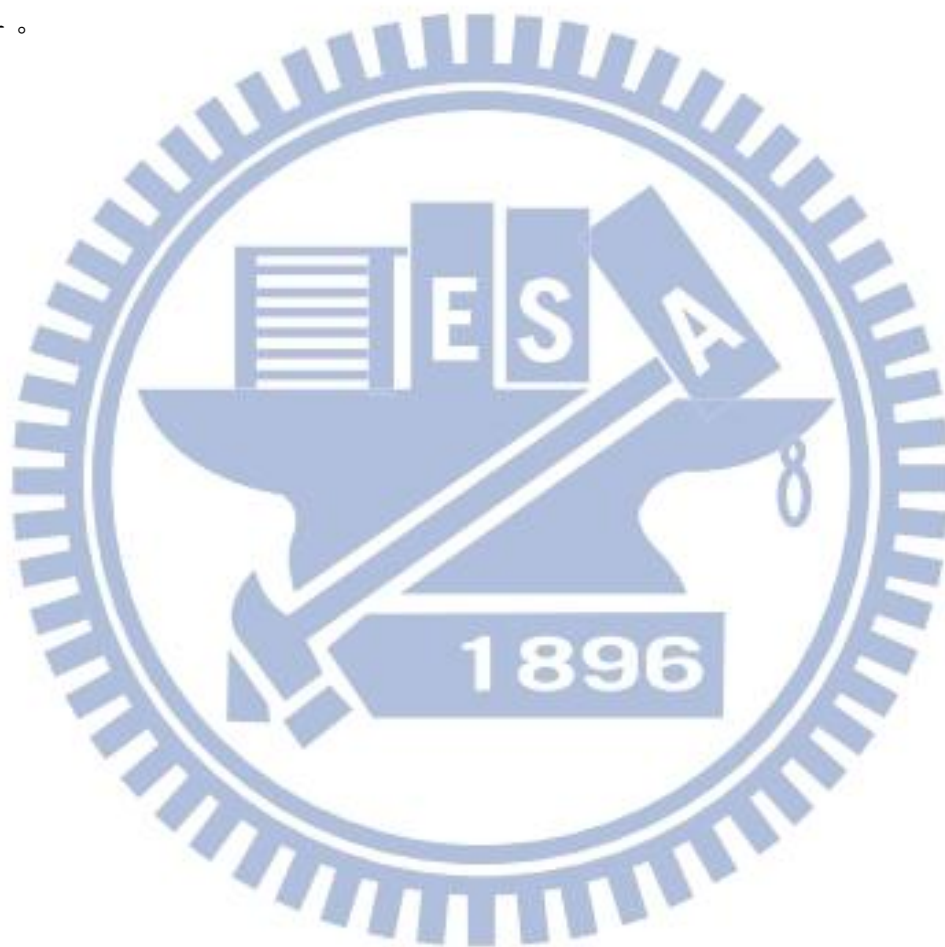
極紫外光微影技術很有可能成為下一個世代主要的微影技術，如果未來極紫外光微影技術被工業界所採用，在曝光過程中，極紫外光對元件所造成的輻射損傷勢必無可避免，且必須謹慎的評估。本論文主要探討極紫外光輻射對於不同介電層厚度的金屬閘極/高介電常數介電層金氧半電容器的影響；另外，我們也利用先進的N型金氧半場效電晶體來驗證極紫外光輻射對電晶體的影響。

經過極紫外光照射之後，金氧半電容器的電性產生了許多明顯的變化，包括電容-電壓曲線飄移和變形，以及遲滯現象劣化。這些電性的變化表示經過極紫外光照射之後，介電層中、邊界以及介電層和矽基板間介面的缺陷以及被捕捉的電荷增加。在各種不同介電層厚度的電容器中，擁有最薄介電層厚度的電容器提供最佳的抗輻射能力，且輻射損傷程度會隨著介電層厚度增加而增加。極紫外光對先進N型金氧半場效電晶體的影響與電容器相似，但不同的是，極紫外光對場氧化層的影響是不可以忽略的，因為其具有足夠的厚度。經過極紫外光照射之後，在場氧化層和矽基板間的介面態會增加，且成為電子-電洞對的激發和復合中心，造成電晶體在關閉下的漏電流上升。另外，本論文也利用臨界電壓對正偏壓以及溫度的不穩定性，來探討N型電晶體經過極紫外光照射前後的可靠度。

在照射完極紫外光之後，我們也持續監控電容器和電晶體的電性變化。當電容器以及電晶體擺放在室溫下一段時間之後，都會有自我回復現象發生。然而，

自我回復並無法完全修復輻射損傷；因此，我們嘗試使用較高溫度退火來修復輻射損傷，幾乎所有被游離輻射照射過的元件在經過高溫退火之後都回復到照射之前的狀態。

最後，在實際應用上，半導體元件還有許多接觸不同輻射環境的可能，不僅止在極紫外光曝光過程中。本論文除了極紫外光，同時也探討一萬電子伏特的X射線對元件的輻射損傷影響。我們發現材料的吸收特性也是影響輻射損傷的重要因素。



A Study on the Effect of Ionizing Radiation on MOS Devices with Various Hf-based Dielectric Thickness

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Abstract

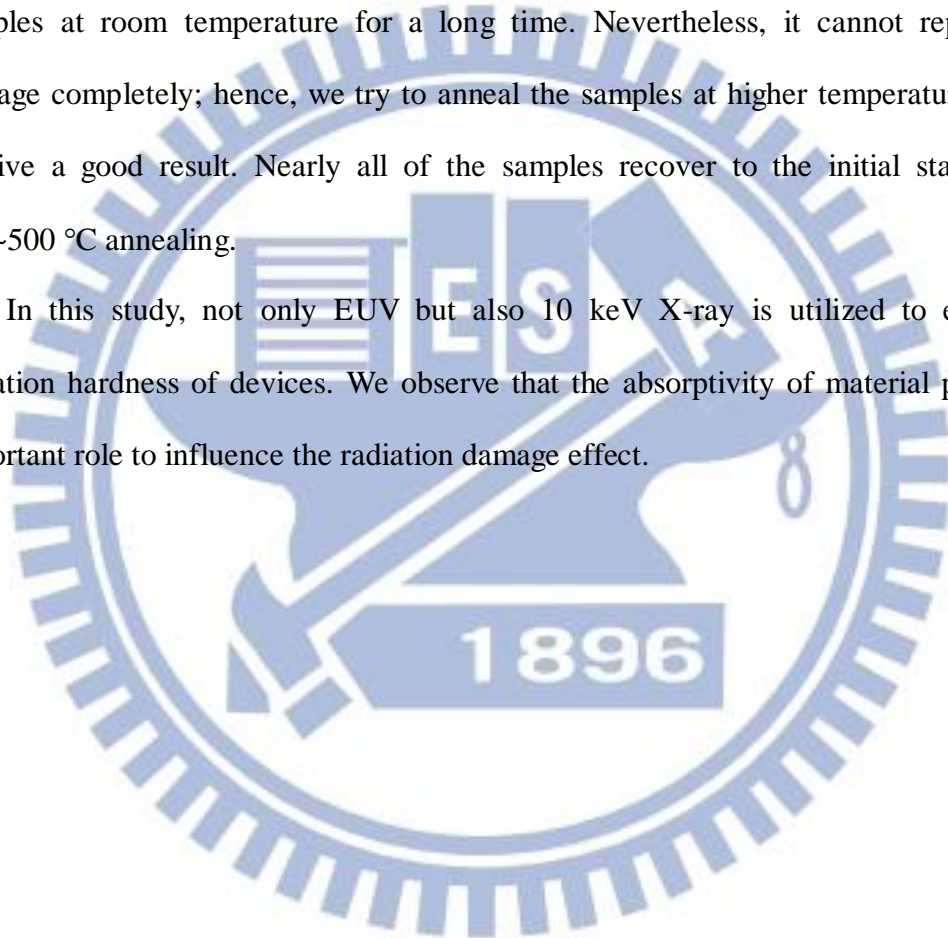
Extreme ultraviolet lithography (EUVL) is a promising technology and is most likely to be the next generation lithography technology in the future. Subsequently, the radiation damage during exposing process is inevitable and should be considered carefully. In this study, EUV irradiation damage effects on the metal gate/high dielectric constant (high-k) dielectric metal-insulator-semiconductor (MIS) capacitors with different dielectric thicknesses are evaluated. Moreover, we also prepare the state-of-the-art n-channel Metal-Oxide-Semiconductor-Field-Effect-Transistor (nMOSFET) in order to demonstrate radiation effect on nMOSFET.

Before and after EUV irradiation, the electrical characteristics of MIS capacitors change distinctly. Capacitance-voltage (C-V) curve shift, C-V curve distortion, and increment of hysteresis are observed. These results indicate that oxide-traps, interface traps, and border traps increase after irradiation as well as the charges trapped by these traps. Among the capacitors with different dielectric thicknesses, the sample with the thinnest dielectric thickness offers the best radiation hardness, and the amount of radiation damage increases with dielectric thickness increasing. The observations on the state-of-the-art nMOSFET are consistent with those on the MIS capacitors. Differently, the radiation effect on field oxide is unignorable because it is much thicker than gate oxide. The increment of interface states after irradiation at the

field oxide/silicon interface act as generation and recombination center, and contribute to high off-state leakage current. Besides, the reliability of nMOSFET is investigated by positive bias temperature instability (PBTI) measurement before and after irradiation.

In the meantime, we continually monitor the recovery property of MIS capacitors and nMOSFET after irradiation. The self-annealing effect is observed after storage the samples at room temperature for a long time. Nevertheless, it cannot repair the damage completely; hence, we try to anneal the samples at higher temperatures, and receive a good result. Nearly all of the samples recover to the initial state after 400~500 °C annealing.

In this study, not only EUV but also 10 keV X-ray is utilized to evaluate radiation hardness of devices. We observe that the absorptivity of material plays an important role to influence the radiation damage effect.



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在能夠寫這篇誌謝的同時，代表碩士班生涯即將進入尾聲，兩年多來在交大的日子，雖算不上備受煎熬，但也歷經許許多多酸甜苦辣。

這篇論文得以完成，首先最要感謝我的指導教授 崔秉鉞老師。老師對於做研究的態度總是一絲不苟，從一開始的實驗規劃，實驗進行，到結果分析與討論終至最後的論文撰寫，老師總是不厭其煩地給予我許多寶貴的建議。在老師的指導下，讓我從當初的懵懂無知到現在稍微具備了些專業知識。此外，老師的熱心公益也令我相當欽佩，跟隨老師參加了三個學期的新光計畫，至今小朋友們圍著我嬉鬧玩耍以及他們天真無邪的笑容仍然深深烙印在我腦海中。再來也要感謝共同指導 許博淵博士幫我們申請光束線時間以及解決在同步輻射中心做實驗時所遇到的瓶頸。

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