行政院國家科學委員會專題研究計畫 期末報告

製程技術世代轉換之整合規劃模式-以 DRAM 產業為例(第 2 年)

計 畫 類 別 ： 個別型
計 畫 編 號 ： NSC 100-2628-E-216-002-MY2
執 行 期 間 ： 101 年 08 月 01 日至 102 年 07 月 31 日
執 行 單 位 ： 中華大學工業管理學系

計畫主持人： 杜瑩美

計畫參與人員： 碩士班研究生-兼任助理人員：張哲豪
碩士班研究生-兼任助理人員：王昭宜
博士班研究生-兼任助理人員：盧俊偉

報 告 附 件 ： 出席國際會議研究心得報告及發表論文

公 開 資 訊 ： 本計畫可公開查詢

中 華 民 國 102 年 10 月 17 日

中文摘要： 自二十世紀後期以來，來由於產品生命週期急遽縮短，連帶造成產品世代以及製程技術也產生快速的變革。因此，企業必須經常性的導入新的技術與設備，以達到符合市場需求以及降低製造成本的目標。然而在面對製程技術世代轉換的問題時，DRAM 廠向來只憑藉過去的經驗來規劃技術轉換的時機、時程與過程，但由於每次的狀況不同，所以經常遭遇到許多的困難。

因此，本計畫將提出一套製程技術世代轉換之整合規劃模式以協助 DRAM 廠順利的轉換製程技術。此模式將從製程技術轉換時程規劃以及轉換期間的生產規劃與管控兩大問題著手。第一年透過資料收集以進行技術演進藍圖的建立以及產能擴充成本時間函數的推導，並且分析未來新世代產能對單位製造成本的影響。第二年則以生產規劃與管控為主，吾人以限制機台作為規劃標的，將上階層規劃之新技術世代投料時程，轉化成為決策時段內之新、舊產品投料組合，再以 X-Factor 觀念進行生產系統內新、舊世代在製品於後製程之預排動作。而現場管控模式則區分為即時管控與預測管控二部分。即時管控部分是以即時 WIP 狀態作為判斷因子以決定是否需要即時處理與重新規劃；而在預測管控方法中，可透過比對往後某一時間區段內之預測產能負荷與當初所規劃之產能曲線之偏離程度以決定是否修正或重新進行規劃。

中文關鍵詞： 製程技術世代轉換、DRAM、X-Factor、生產規劃與管控

英文摘要： Over the past decade, product and process technology migrations have been due to short product life cycle. Under this circumstance, companies have to develop more advanced technology and purchase sophisticated tools to meet the market demand and reduce manufacturing cost as well. When process technology migration occurred, DRAM manufacturers always used the past experiences to handle the migration. However, the challenge is totally different to the past that causes the manufacturers have to suffer many unexpected difficulties.

In this work, an integrated model for technology migration is proposed. There are two major issues regarding the technology migration, the time schedule of technology migration and production planning & control during the migration period. Regarding to the time schedule setting, a time-cost function of

capacity expansion should be developed.
Simultaneously, the relationship between the capacity of new technology generation and its unit manufacturing cost should be analyzed.
Based on the above information, a wafer release schedule of new technology under the minimal capacity cost can be defined. In the second year, a production planning and control model will be developed. The production planning will focus on CCR (Capacity Constraint Resources) to define the complete wafer release schedule and apply X-factor to schedule the production processes during the migration period. There are two control mechanisms to control and monitor the migration which are real time control and predicting control module. In the real time control module, WIP status is the important factor to decide to trigger rescheduling module or not. Besides, a foresee function will be performed by predicting control module which will trigger the rescheduling module by the bias between loading and capacity curves. The solution of the issues of technology migration is proposed. It represents an efficient and effective migration will be performed during the technology migration period. We expect this model can be applied to the other industries with same situation.

英文關鍵詞： Technology migration, DRAM, X-factor, Production planning and control

行政院國家科學委員會補助專題研究計畫 □期中進度報告 ■期末報告

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計畫主持人：杜瑩美 中華大學 工業管理學系
共同主持人：
計畫參與人員：盧俊偉 中華大學 科技管理博士學位學程
王昭宜 中華大學 工業管理學系
張哲豪 中華大學 工業管理學系

本計畫除繳交成果報告外，另含下列出國報告，共 3 份：
□移地研究心得報告
■出席國際學術會議心得報告
□國際合作研究計畫國外研究報告

處理方式：除列管計畫及下列情形者外，得立即公開查詢
□涉及專利或其他智慧財產權，□一年□二年後可公開查詢

中　華　民　國　102 年　10　月　5　日

目 錄

中文摘要

自二十世紀後期以來，來由於產品生命週期急遽縮短，連帶造成產品世代以及製程技術也產生快速的變革。因此，企業必須經常性的導入新的技術與設備，以達到符合市場需求以及降低製造成本的目標。然而在面對製程技術世代轉換的問題時，DRAM 廠向來只憑藉過去的經驗來規劃技術轉換的時機、時程與過程，但由於每次的狀況不同，所以經常遭遇到許多的困難。

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In this work, an integrated model for technology migration is proposed. There are two major issues regarding the technology migration, the time schedule of technology migration and production planning & control during the migration period. Regarding to the time schedule setting, a time-cost function of capacity expansion should be developed. Simultaneously, the relationship between the capacity of new technology generation and its unit manufacturing cost should be analyzed.

Based on the above information, a wafer release schedule of new technology under the minimal capacity cost can be defined. In the second year, a production planning and control model will be developed. The production planning will focus on CCR (Capacity Constraint Resources) to define the complete wafer release schedule and apply X-factor to schedule the production processes during the migration period. There are two control mechanisms to control and monitor the migration which are real time control and predicting control module. In the real time control module, WIP status is the important factor to decide to trigger rescheduling module or not. Besides, a foresee function will be performed by predicting control module which will trigger the rescheduling module by the bias between loading and capacity curves. The solution of the issues of technology migration is proposed. It represents an efficient and effective migration will be performed during the technology migration period. We expect this model can be applied to the other industries with same situation.

Keywords: Technology migration, DRAM, X-factor, Production planning and control

報告內容

一、 前言

近年來由於產品生命週期急遽縮短，連帶使得產品世代以及製程技術產生快速的變革，Hastings(1994)過去曾經提到，當一項新技術或科技被引入市場時，企業的現有之競爭優勢將會立即受到損害。因此，企業必須持續性的導入新的技術與設備，以達到符合市場需求以及降低製造成本的目標。在大多數產業屬於資本與技術密集的今日，企業在新製程或技術的導入以及新世代設備的產能規劃過程中將會面臨更多複雜的難題。在需求不確定以及生產技術快速變革兩者因素間交互影響之下，管理者經常需要面臨到底該在何時導入先進製程技術的難題，一方面要考慮未來需求的成長幅度是否符合預估，另一方面還需考慮新製程技術的更新速度是否能使企業維持競爭優勢。然而，新世代製程技術對企業所帶來的影響卻往往被掩蓋在市場不確定性當中(Rosenberg, 1982)，因而使得這方面的相關研究顯得相當不足。

當新的製程技術被發展問世時，代表產業中存在著一種成本更低、更為有效率的作業模式(Cainarca, 1989)，此時，管理者必須審慎思考新製程技術導入的問題，一方面必需擔心未來需求能否支撐引進新製程所必需的龐大資本支出，另一方面又必需考慮若不引進新製程是否會喪失企業競爭優勢。DRAM 產業即是一個很好的例子，由於產業型態使然，增加產量以及降低單位成本一直是DRAM 製造廠賴以維生的關鍵競爭優勢，因此，當12 吋晶圓製造技術成熟以來，產業內重要企業無不投入巨大資本資出設立12 吋晶圓廠。然而，由於半導體製造產業屬高度資本及技術密集的產業，致使這些企業所必需面臨的壓力將較其他產業大上許多，圖1 所顯示為1994 至2003 年間，半導體製造商的資本投資與股東投資報酬率(return of equity, ROE)之間的關係。從圖1 中吾人可發現，半導體產業近年來廠商在資本上的大量投資與景氣循環的快速變遷，而此結果造成半導體產業的投資報酬率甚至不如一些已發展成熟的傳統產業(Liang and Chou, 2003)。

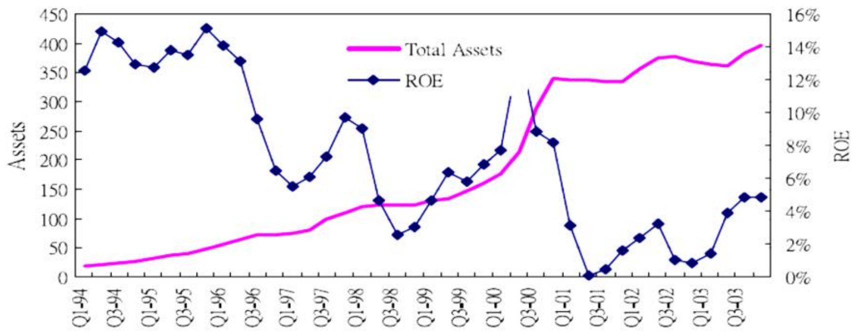

圖 1 半導體製造產業總資本投資與 ROE 趨勢 (Chou et al., 2007)

除了晶圓面積之外，製程技術世代(線寬)亦是影響半導體製造產業作業成本及競爭優勢的重要指標。近年來全球消費性電子產業無不以輕、薄、短、小為產品的主要發展目標，因而造就了 IC 製程技術的蓬勃發展，先進技術的演進已從十年前 0.18 微米一路進步到今日的 65 奈米、40 奈米，甚至 28 奈米已計畫投產(TSMC Technology Roadmap)。因此，為維持企業競爭優勢，半導體製造商必須不斷將其製程技術世代往前推升，藉以維持競爭優勢。然而，先進製程技術所帶來的收益往往不如當初所投入的資本支出(TSMC 2010Q2 營運績效報告)。對產業龍頭企業而言，或許有能力進行如此龐大的投資以維持其領導地位，但是，對規模較小的廠商而言，管理者對於新科技的引進就必須更加審慎考慮。再者，根據研究指出，IC 製造技術的生命週期，通常不會超過三年(Chou et al. 2007)，因此，半導體製造廠商必須不斷的面臨以下問題：倘若投資新技術世代，未來市場需求是否如預期成長？倘若放棄新技術世

代，既有技術世代是否會快速的被淘汰？其中，結構較為偏向整合式製造((Integrated Device Manufacturing, IDM)的 DRAM 產業，對於降低平均製造成本的依賴程度更甚於一般半導體代工廠(Foundry)，因此，DRAM 產業面對製程技術世代轉換難題的機會及頻率也高出 Foundry 廠許多，圖 2 所顯示為未來 15 年半導體製造技術演進之預估(International Technology Roadmap for Semiconductors: 2010 Updates)。從圖 2 吾人可以發現，DRAM 技術演進速度高出 Logic IC 製造業，其製程技術世代轉換的管理複雜程度也將提升不少。

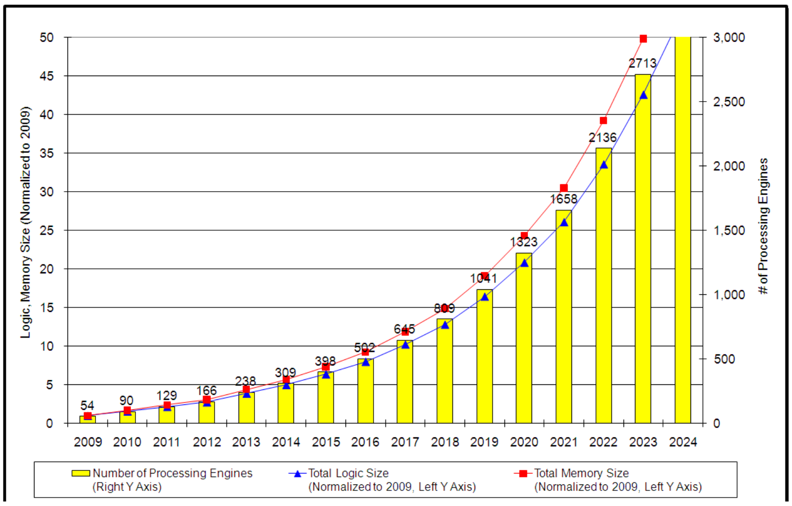

圖 2 International Technology Roadmap for Semiconductor: 2010 Updates

從策略制訂乃至作業管理的層面來看，製程技術世代轉換問題可分成二大面向來觀察，分別為製程技術轉換時程規劃以及轉換期間的生產規劃二個角度。製程技術轉換時程包括轉換時間點制定以及轉換速率，其規劃過程必需同時考慮市場需求波動、技術成熟度以及資金取得；而在轉換期間的生產規劃上，管理者必需根據上階層所制訂之轉換時程決定新世代產能的取得（包含先進機台取得及既有機台調整）、新技術世代產品的投料控制（新、舊產品轉換節奏）、以及現場派工，而這些決策的制訂必需同時考量產能取得前置時間、技術轉換對現場之影響、以及系統績效衡量。從上述分析結果吾人可得知，晶圓製造產業在需求高度不確定、技術世代更替快速的複雜環境之下，製程技術世代的轉換將會是一項充滿挑戰的複雜問題，而DRAM 產業在單位製造成本的龐大壓力下，其技術轉換管理問題的複雜度將更勝Foundry 產業。

綜觀上述問題分析，半導體製程技術轉換問題的核心為生產系統組態轉換時機以及系統轉換下之生產規劃，其目的為：在系統受到影響程度最小的前提下，使技術轉換過程順利完成，並維持企業之競爭優勢。雖然過去已有許多學者針對半導體製造產業提出各類的生產規劃模式，而且大都以等候網路、數學規劃或者平均數分析進行各機器群組所需機台數及投料之估算(Iwata et al., 2003; Walid and Gharbi, 2002; Chou and You, 2001)。然而，這些研究卻未將系統所面臨的不確定性以及設備投資風險納入考量，在半導體製造這樣具有高度需求不確定以及投資風險的產業中，如此的規劃結果必然有所不足。

關於在具有需求或技術不確定性環境下之生產規劃相關研究方面，有許多學者分別討論這兩項影響因子下的規劃手法。針對需求不確定的相關文獻大都以線性規劃模式並將未來需求變化趨勢塑模成為若干個具有不同發生機率的需求情境(scenario)求算最佳化生產策略(Swaminathan, 2000; Hood et al., 2003; Chou et al., 2007)。然而，上述這些相關研究卻未在『情境』發生機率的計算與制訂上多加著墨。利用情境所計算出之規劃結果不外乎是利用各種情境發生機率所估算出之所需產能加權期望值或是以發生機率最高之情境作為產能計算目標，無論是何種計算方法，從統計的角度來看，發生偏移的機率都相當高。除了利用上述所提及之較為主觀的計算方式外，Driver and Goffinet (1998) 提出在需求不確

定的情況下，利用擴充產能以降低單位生產成本，再利用低價提高市場佔有率以穩定需求面的手法。這是一種反向思考的作為，並且與DRAM 產業的作法極為類似。Cakanyıldırım and Roundy (2002)則提出一套利用多項式時間擴張係數演算法(Polynomial time Expansion Algorithm)進行需求不確定下之機台產能或廠房建設的規劃問題，此研究作者並選擇瓶頸產能擴充法則(bottleneck policy）作為產能擴充策略，意即：永遠只針對瓶頸機台進行產能擴充，並且只淘汰使用率最低的機台。Ryan(2004)則同時考慮了需求成長及增設產能所需前置時間提出一套產能擴充策略，作者利用產能水準警示(意即：產能利用率達到某一水準)配合產能設置前置時間，求算出最佳產能增設時點；作者並且認為，需求不確定性與產能設置前置時間具有正向交互影響關係，若市場需求不確定越高，則產能設置前置時間將越長，且規劃活動將更加困難。然而，上述這些研究卻未考量新製程技術導入時對系統的影響。新技術設備導入初期使用率或許不高，但其成長速度將會遠大於其他機台，若缺乏考量此因素，新世代產能擴充的速度將遠不及新世代產品浸蝕系統的速度。

在新技術世代導入影響相關研究方面，Chand and Sethi (1982)考慮新機台提升製程穩定性以進行新世代產能置換的規劃問題，但本研究卻未考量新科技技術對其他因子所造成的影響，也未針對產能替換所必需的前置時間加以考慮。Cohen and Halperin (1986)則提出了新技術導入的時間點決策方法，作者利用新設備價格變化以及其對成本的影響求出最佳的技術世代”完全替換”時機。Rajagopalan 等學者(1998)綜合上述二篇研究，提出了一套在技術演進影響下之產能規劃手法，此研究利用線性規劃模式進行在製造技術突破下之產能擴充(expansion)或是替換(replacement)的決策，並加入時間軸的概念。作者以最大化利潤作為目標，並考慮了新設備取得成本將隨時間改變（新技術出現越久，其購置成本越低），以及新設備的導入將降低製造成本作為考量因子，計算新設備至入的最佳數量及時間點。而Pak等學者(2004)則是首度提出同時考慮需求不確定及新技術更替影響下之產能規劃手法，針對當產能出現缺口時之產能規劃模式進行討論，並考量新技術的出現對產能取得成本所造成的影響，最後，利用市場需求的變化針對產能規劃結果進行敏感度分析，以確認市場需求改變對規劃結果所造成的影響。

以系統模擬為基礎的生產規劃（Simulation Based Production Planning）則是另一個常被用在高度不確定性環境下的規劃手法(Mula et al., 2006)，其優勢為可以將環境中具有不確定性之因子以隨機變數的型態塑模於環境之中，並觀察這些不確定性因子的變化對系統所造成的影響，進而求出在這些不確定性因子影響下之最佳決策。Hung and Leachman(1996)提出了一套利用分散式系統模擬以及線性規劃的手法，建立自動化的生產規劃模式。作者首先以投料、製造流程、機台穩定度等參數作為輸入項目，並以系統模擬技巧取得系統表現，再以模擬結果進行線性規劃以求出最佳解。Monch and Habenicht(2003)則是利用系統模擬做為工具，發展出一套應用於批量工作站的派工演算法。此篇研究首先分析爐管加工區常見之派工法則，再以系統模擬評估各項法則之績效表現，最後觀察系統環境改變時各項法則績效的變化，進而找出在系統環境參數變化下之派工法則選擇邏輯。過去研究指出，以系統模擬為基礎的規劃手法在模式涵蓋度夠廣、執行次數夠多以及模式解析度夠高的前提之下，可找出最佳或近似最佳解。然而，如半導體製造這般製程極其複雜且不確定因子繁多的產業中，利用系統模擬進行規劃將是一件耗時、耗力且高成本的任務(Uzsoy et al., 1992)。面對多目標的系統模擬的環境，系統模擬雖可考量因子的不確定性並將其加以表現，然而，所花費的時間與資源成本也將相對的提高。

製程技術世代轉換問題除上階層轉換策略規劃之外，現場作業管理亦是一個複雜且困難的議題。現場作業規劃與管理必需承接上階層規劃結果，並以其制訂之產品世代轉換節奏及產能轉換排程作為基礎進行生產活動。然而，上階層之策略規劃難以考量現場複雜且高變動性之環境；再者，上階層之決策依據是以需求及技術世代演進的預測或推估結果作為基礎，於現場執行階段必然會有變化及偏移的產生，此時，現場管理的調整及因應將會變成影響轉換成敗的關鍵。

一般而言，在現場規劃與管理方面可以分為兩個方向：投料控制與現場監控。在於投料策略方面一般可概分為兩大類：開放式迴圈（Open-loop）與封閉式迴（Closed-loop）。所謂開放式迴圈即是不管

生產環境的狀態如何（如機台的狀態，WIP 量等），而一定的法則來進行投料，如單一法（Uniform）。而封閉式迴圈之投料策略則是以工廠中的某些資訊，例如WIP 量、重要機台之負荷…等為指標，以作為是否繼續投料之依據。一般而言，因為封閉式迴圈之投料策略會依現場動態性的改變而有所調整，所以在整體績效的表現上比開放式迴圈之投料策略為佳(Miller 1990)。在封閉式迴圈之投料策略較有名的有Glassey et al.(1988a, b)提出避免饑餓法，即是利用安全存量的觀念作為投料之基準。其主要的目的在於盡量提高瓶頸機台的使用率，同時也希望能夠降低在製品的存量。Wein (1988)提出的 ”工作負荷調整法” 係以目前系統內對限制資源工作站之總工作負荷(或稱實質存貨;W),來作為投料決策之依據。若此工作負荷小於設定值，則進行投料作業。Lou (1989a,b)所提出來的雙界法。這種方法是針對每個機台訂定簡單的控制法則，以實際存貨水準與計劃存貨水準之差距，及實際累積生產與累積需求之差異程度來作為投料的依據，並利用存貨水準的差值、產品的權重以及層級的權重三者的乘數來決定投料的優先順序。另一較為有名的投料策略是Spearman et al.(1989, 1992)所提出的常數在製品量投料法(CONWIP)。CONWIP 是一種介於 JIT 與推式系統(push system)間之一種生產控制型態。此外，過去也有許多學者針對半導體製造現場管理進行探討，Hungand Chang (2002)提出一套修正的最小寬鬆時間法則與最小剩餘加工時間法則，期望能達到縮短生產時間的目標；Bowman (2002)則是以JIT 為基礎，提出一套投料控制法則，避免瓶頸機台閒置以達成最大產出；Louw and Page (2004)則是利用等候網路模型，計算半導體晶圓廠在以TOC 為基礎之管控法則下，緩衝時間大小之制訂法則。

然而，上述研究卻未針對生產系統轉換過程中之現場管理深入探討，事實上，探討此問題的相關研究也十分稀少。在生產系統轉換過程中，生產線上的產品組合會較穩定時期複雜且多變、產能組態也將隨著時間變化，在投料、產能都不穩定的情形下，過去學者所提出的管理手法幾乎都無法適用。而從過去半導體製造管理經驗也可得知，當系統中存在超過三個世代以上的產品，管理將會變得非常困難，系統績效也將變的難以維持，因此，找出一個在變動系統下的現場管理模式，不只解決製程技術世代轉換問題，對於產品世代複雜的Foundry 產也將有極大的助益。

二、 研究目的

Chou 等學者(2007)曾經說明，如同半導體這類產能設置週期時間繁長、資本投資龐大的產業，若將各類管理活動分開獨立進行規劃，將無法獲得一個有效的解決方法。因此，對於製程技術世代轉換的問題吾人必需整合並提出一套涵蓋上階層轉換策略規劃及現場製造管理的決策模式。針對上階層轉換策略制訂，本研究選擇以技術演進藍圖(Technology Roadmap)作為轉換時機選擇的決策依據，而在轉換時程的制訂上，本研究將市場需求不確定性、技術演進變化及產能取得前直時間偏移等不確定因子以隨機變數的型態建置於模式之中，藉以求得最佳的轉換時間表。

而在現場製造管理上，本研究進一步將之細分為生產規劃與現場管控二部分。在生產規劃中，吾人以限制機台(Capacity Constraint Resources, CCR）作為規劃標的，將上階層規劃之新技術世代投料時程，利用新、舊世代產品佔用限制機台產能之大小，將其轉化成為決策時段內之新、舊產品投料組合，並再以X-Factor觀念進行生產系統內新、舊世代在製品於後製程之預排動作。而現場管控模式之主要目的為，當製造系統發生足以影響技術轉換成敗之偏移時，能夠即時發出警示，並利用修正規劃結果或重新規劃以克服系統偏移所造成之影響。本研究所提出之現場管控模式可區分為即時管控與預測管控二部分。由於系統內之在製品存量足以表徵系統目前所發生的狀況，因此，吾人在各生產區段之主要機台(Key Machine)設置在製品存量之上、下警示線，並監視其在製品存量，當在製品存量高或低過警示線時，吾人即可察覺系統所發生的狀況，並加以即時處理；而在預測管控方法中，可透過比對往後某一時間區段內之實際產能負荷與當初所規劃之產能曲線，藉由其偏離程度，吾人可得知目前之產能狀況是否可負荷當初所排定之結果，若偏移程度過大，則必需修正或重新進行規劃。

新世代製程技術的導入，半導體製造產業所面臨問題已非要或不要，而是該如何進行；對於DRAM

產業而言，新世代製程的導入成效更是攸關企業存亡的關鍵。此一影響深遠且重大的決策問題，過去卻鮮少有研究觸及。本研究期望透過一個從上到下的整合式決策模式，為半導體製造產業，特別是DRAM製造業，提供一個決策制訂乃至於作業的管理的準則。

三、 研究方法

本研究之主要目的為：在半導體製造產業製程技術世代轉換的問題中，考量需求與技術不確定因素，提出一套整合策略與現場管控之決策模式。如同先前所言，製程技術世代的轉換，對DRAM產業而言是維持企業競爭優勢的關鍵所在，再者，市場需求量短期來看或許會有所增減，但就長期而言，市場需求大多呈現向上成長的趨勢(Ryan, 2004)。回顧過去整體半導體製造產業的發展歷程，即使在市場需求萎縮的時期，廠商大都還是選擇繼續將其製程技術世代往前推升，因此，技術世代轉換的決策制訂，關鍵因素將會是產業內的技術演進藍圖；然而，市場需求的波動卻會影響企業推升技術世代的速度，進而影響製產能設置的策略，以及造現場生產規劃的結果。

就前述研究背景所言，過去的先進製程轉換策略或產能規劃模式都將未來需求變化視為最重要之不確定因素，但需求變化的預測是一項困難且準確度不高規劃行為，將此預測結果作為策略規劃中最重要的因子，將會使投資風險大為提高。此外，技術世代轉換對於企業而言是一種中、長程的規劃活動，而如同前面所言，若將時間軸拉長，市場需求將會呈現較為穩定的成長趨勢，而此成長趨勢除受了大環境的經濟因素影響而偏移之外，最重要的偏移原因將來自於新科技或技術的突破性發展(Rajagopalan et al., 1998)。因此，本研究將以未來技術藍圖的發展作為技術世代轉換策略的主要考量因子，輔以針對市場需求變化趨勢與科技發展時程產生偏移進行技術世代轉換速率的調整，以滿足企業維持競爭力並兼顧市場波動的目標。

本研究將製程技術世代轉換規劃模式依據其決策層級區分為轉換評估模式及現場轉換管理模式二大部分，分別詳述如下：

(一) 技術世代轉換評估模式

在新技術世代轉換策略制訂的過程中，經吾人分析整理，決策制訂的困難點有以下三點：

1. 技術生命週期急遽縮短

現今各產業大多必須面臨產品生命週期縮短的問題，連帶使得新技術世代的機台或製程在短時間內變的過時。在此影響之下，新機器設備或技術的購置成本及其剩餘價值將隨時間有極大的差異。在新科技技術出現初期其購置成本將會高出許多，企業也因此必須面臨更大的投資風險，但也可能比對手更早取得競爭優勢；倘若等到技術普及再行導入，其資本投資金額及風險將會小的許多，但如果下一世代的技術快速的被提出，將使此項投資決策顯得極為愚蠢(Rajagopalan et al., 1998)。

2. 新技術或設備導入前置時間過長

在半導體製造產業中，機台設置前置時間皆相當冗長，即便是現存技術世代的機台，其前置時間也需要三個月至一年之久(Swaminathan, 2000)。若是新世代機台設備的導入，由於還必須經過機台參數調整及產品良率驗證的步驟,機台設置前置時間甚至極有可能超過一年。因此，新世代產能的擴充計畫常常需要在新科技與技術前景尚未明朗時就必須做出決策，增加其困難度。

3. 新技術世代對市場的影響程度難以預估

在快速變遷的市場中，管理者必須經常面對如何使系統有辦法因應市場需求的困難問題(Ubois, 1993)，因此，每當有新的技術或設備推出時，企業必須審慎考慮其對當前企業價值之損害，以及新技術導入對企業競爭優勢之助益。因此，企業在新技術導入的決策上，通常會受對未來市場的擔憂以及對此項技術重要性的看法所影響。然而，現今市場對新科技之接受度以

及其重要性以不如以往那樣容易判定，新製程技術世代的導入對企業的助益將變得難以預測，技術世代轉換規劃當然也變的極為困難。

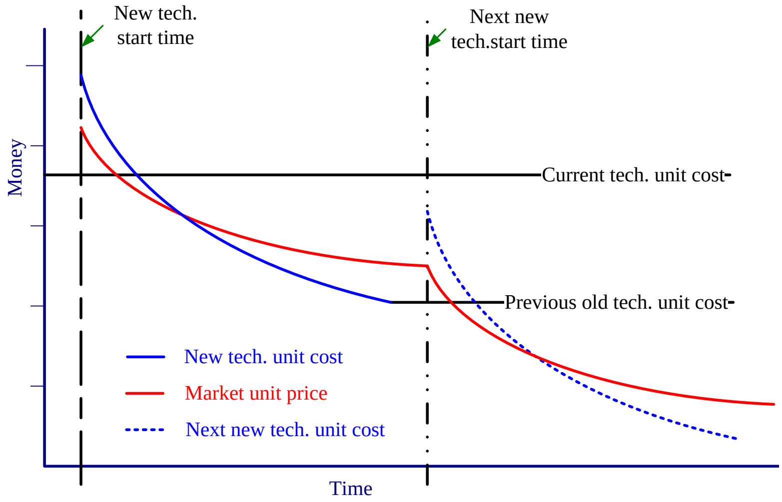

圖 3. 每單位容量之 DRAM 成本與售價關係圖

承如背景與目的中所述 DRAM 產業在種種環境因素下，對於在新製程轉換需求的決策上可說是相當難以取捨，尤其業界正面臨所謂大者恆大的態勢下，如沒有果斷以及有效的轉換勢必影響公司未來的存亡。有新製程技術的問世，此時表示著產業現有環境中存在著比當前製程成本更低的技術，這對於追求單位製造成本最低化之 DRAM 產業而言，無疑是企業永續發展與存活的一項挑戰。從文獻的收集與整理，吾人發現 DRAM 產業的單位容量製造價格與市場售價有著如圖 2 之現象。在現有技術之情況下，由於機台成本的攤提以及產品良率穩定等因素下，其 DRAM 之單位容量製造成本大致會趨於一平穩之狀態，而 DRAM 之單位容量市場價格方面的變化則會因企業的經營策略、新產品或新製程技術的問世而有逐漸下降之態勢，而此部分的變化趨勢除從市場的歷史資料整理取得，也可從 DRAM 的技術演進藍圖 (Technology Roadmap)中分析獲取之。然而對於新製程技術的導入上其單位容量製造費用變化，由於初期機台成本昂貴以及新技術初期製程不穩定而導致單位容量製造費用相較於現行成熟技術高，但隨著產品良率的提升與機台成本折舊攤提，其單位容量製造費用將比現行技術來的較低，所以新製程技術之單位製造成本也將呈現如學習率曲線之走勢，如此可知新技術的導入決策時點將發生在圖 2 新技術出現時點與下一世代技術出現時點之間。

由於新技術的轉換主要目的是期望為公司帶來更多的利潤，本研究之總利潤計算方式以新技術決定開始轉換後至下一世代技術出現前之間所發生之總收益，扣除在相同時間範圍下所花費之總成本，因此在以最大化公司利潤之條件情況下，決定最佳之技術轉換開始時段實為本研究之目標，而最佳之技術轉換開始時段之研究考量範圍，是以其新製程技術之出現時點與下一世代製程技術出現時點之間為其範圍，吾人稱此為新製程技術之生命週期時間，其範圍將被分隔為 n 個時間區段，以利後續模式之建構分析與探討，其時間區段之長短可由管理者自行設定之。總利潤函數如下所示且後續將就各部份進行介紹。

$$TP(t) = \sum_{i=t}^{n} Q_i \times P_i - \sum_{i=t}^{n} (FC_i + VC_i)$$

Where

$TP(t)$：t時間區段開始進行製程轉換時之總利潤

Q_i：第i時間區段下之總良品數

P_i：第i時間區段之平均市場單位售價

FC_i：第i時間區段產能設置成本

VC_i：第i時間區段之變動成本

t：新製程技術開始轉換時間區段

1. 總收益函數

供需平衡為本研究之環境假設條件，收益部分皆來自於產品的銷售，而其影響因子取決於產品數量與市場價格之變化，因此新製程技術之生命週期時間內之總收益函數將透過此兩項因子進行建構。

1.1. 產品數量函數

在產品數量方面由於產品不良率為其主要之影響來源，而從過去的經驗與資料中得知，產品不良率之變化與製造進步函數效果相似，皆會隨著時間與累積產量的增加而有所進步，因其產品不良率下降之原因大致可分為以下三方面：

(1) 操作次數增加，使作業員在單位時間內發生之錯誤機率因學習率而下降。
(2) 部門間合作默契的提升，使得生產排程更為流暢，造成產品損害機率下降。
(3) 經驗的累積，使管理者能迅速找到現場問題點，使傷害擴大導致良率下降。

因此本研究在新製程技術生命週期時間內之產品數量函數，將透過製造進步函數之概念建構之。

1.2. 市場價格曲線

此部分市場售價之變化從過去之文獻與資料分析得知，其市場價格會隨著廠商不良率下降與以及時間之增加而有所下降，而其表現在新製程技術生命週期時間內之變化曲線呈現猶如指數函數之趨勢(圖二紅線所示)，因此本階段藉由利用指數函數與期望值之概念進行公式建構，其可對所需之時間區段計算出其時間區段下之平均市場價格，而此函數之相關參數可由管理者依其經驗判斷與歷史資料進行整理並修正與設定，以符合企業本身對於市場走向之觀點與看法。

2. 總成本函數

在成本的計算上一般而言管理者會將其分為固定成本與變動成本兩部分，而在新製程技術之生命週期時間內，本研究將其所需之總成本計算方面分述如下兩點，一為新世代產能取得成本，另一點則是新世代製程技術之變動成本，其詳細之說明如下：

2.1. 新世代產能取得成本時間函數

新技術的導入勢必造成新機台的購置成本與舊機台處理成本問題之產生，由於技術的演進可從技術演進藍圖中分析得知，因此機台設備或製程技術的置入成本、剩餘價值與時間點之間所形成之函數關係也較容易取得，而此部分之固定成本以折舊攤提之角度計算至新製程技術之生命週期時間內之每一決策時間區段中，使得新技術導入之機台成本端能與時間相互連結且更貼近現實環境狀況。

2.2. 計算新世代製程技術之變動成本

新世代製程技術的導入將有助於單位生產成本的下降，然而在單位成本計算過程中，變動成本會隨著現場人員與機台之配合度成熟以及製程良率的提高而有所下降，而此部分的概念如同學習率曲線函數一般，因此吾人利用此一概念建構變動成本曲線，而使製造管理成本隨時間推移逐漸下降之現象，得以納入新技術製造變動成本中。

在上述各因素需求之考量下，本研究透過數學模式建構新製程技術轉換決策模式，藉由製程轉換期間收益與成本之變化情況，求得最佳導入時點使新製程技術轉換之利潤最大化，讓管理者能透過此模式得到適合本身的製程轉換時點。其細部之邏輯計算過程歸納整理如下列所示：

Step1. 計算當前製程技術之總收益

由於當前技術市場價格已趨於穩定，則價格在此視為不隨時間變化之定值。而後須計算當前製程技術生產之產量，累加至導入新製程技術前期。所得之生產量需與需求函數進行最小化比較，求出實際產出量。並將實際產出量與價格相乘求得前一世代製程技術之收益。

Step2. 建立產品市場單位售價

管理者由經驗判斷製程技術價格之轉換速率後，利用 Sigmoid 函數，即可得出在各個i時間區段平均價格之 Sigmoid 函數值。將所得到之趨勢正規化還原，而市場價格之還原範圍管理者可由過去的市場資料來進行判斷。

Step3. 計算學習率下產品生產量

由於新製程技術初期，作業人員對於技術參數設定或者是未知的問題點都尚未熟悉。所以，工廠所投入之生產量並非百分之百產出，而產量隨作業人員操作之次數逐漸上升至穩定，不良率隨時間而逐漸減少。所得之生產量亦須與需求函數進行最小化比較後，再計算收益。

Step4. 計算新舊製程總收益

利用 Step1.與 Step3.所得之收益加總，即可得出各區間之新舊製程技術之總營業收益。

Step5. 計算舊式代技術機台數

利用IC片顆粒上之總容量，使新舊製程產能相除，推算出企業應導入多少台新製程技術機台。

Step6. 計算各時段機台價格下降值

機台價格隨著時間區段呈現等差趨勢，利用等差之觀點給定在每個時間區段，機台價格有一個固定價格跌幅，以平均折舊之概念攤提機台購入時初始價格與機台最終之殘餘價格之差。得出每個時間購入機台之價格。

Step7. 計算在各時間區段之產能設置成本

由 Step6.與 Step7.求得在某特定時間區段所購入之新製程技術機台價格與需購入之

新製程技術機台數目之乘積，取得此時間區段之產能設置成本。

Step8. 計算特定時間區段之變動成本

計算特定時間區段新製程技術開始轉換之變動成本，其成本隨時間之推移有一學習曲線之變化趨勢。

Step9. 計算前一製程技術機台移出所得之收益

利用機台價格之公式回推目前舊製程技術機台價值，得到舊製程機台售價再與售出機台術相乘，得到舊製程技術移出之機台收益。

Step10. 新舊製程技術之總利益

由上述步驟得總利潤由舊世代技術機台之產能收益與新製程技術之產能收益扣除新製程技術所引發之產能取得成本與變動管理成本後，加上舊製程技術機台剩餘之價值。企業可得出最佳利潤時點，進而決定應在何時點進行新製程技術之導入。

上述詳細之研究結果已整理於吾人所指導之碩士生畢業論文(王昭宜, 2013)，且部分研究內容也已整理並發表於國際學術研討會 2012 EBM (International Conference on Engineering and Business Management)與 2013 ICEIS (International Conference on Enterprise Information Systems)中，其刊登之文章如附錄一與附錄二所示。

(二) 現場技術世代轉換模式

吾人認為，對於製程技術世代轉換的過程中，現場的實際製程轉換是承襲上層規劃的結果加以執行。然而上層的規劃畢竟難以考量到現場複雜而變動的狀況，因此在執行階段也必須要有一套完整的計畫與管控的機制，否則在為期數個月的轉換過程將造成企業不少的損失。各項規劃模式與管控機制分述如下：

1. 新舊製程技術之生產規劃

誠如從上述所言，現場的製程轉換將依循上層規劃的結果加以執行。因此在本階段將以上階段所規劃出來之新製程技術投料時程當作目標加以規劃新舊製程技術之投料計畫與機台之調機排程。由於上階段所規劃出來之新製程技術投料時程是屬於漸進式增加投料的方式，因此我們將轉換時期依不同的新製程投料量劃分為若干時期，且依時期來規劃其生產排程。此外，此生產排程採用 X-Factor 的觀念，將工廠中所有在製品往後製程安排加工。其詳細的步驟詳述如下：

Step 1：訂定時間單位，例如：天、3 小時…等。

Step 2：投料計畫設定

在上階層的規劃中只有提供新製程的投料計畫，所以在本階段必須計算出同一時期舊製程的投料計畫，如此才有完整的整廠投料計畫。晶圓廠在新舊製程轉換中雖然有增添一些新製程所需之機台，但僅止於原有機台無法加工之部分。所以基本上整體產能並不會增加，甚至有可能因新製程的複雜度增加而使總產出下降。而此一步驟則評估新舊製程在限制機台的產能差異以定義舊製程的投料數量。由於新製程的加入，舊製程的投料量勢必減少。而減少的數量則可經由新舊製程在限制機台的產能耗損比例求得。其計算過程考量如下：

1. 定義產能限制機台群（Capacity Constraint Resources, CCR）

   在此一步驟管理者可以定義產能限制機台的標準，亦即設定一個機台使用率標準。當機台使用率大於此一數值時則為產能限制機台。
2. 計算新舊製程產品在各個限制機台生產所需之產能耗損比率
3. 計算舊製程產品的減投量
4. 新舊製程皆以均勻分佈投料

Step 3：以現場目前的在製品狀態（數量＋位置）以及投料計畫，利用 X-Factor 的觀念預排轉換期間之生產排程，並計算 Key Machine 在各時間單位的產能需求。

Step 4：排定調機排程

某些機台由於新舊製程的轉換需要將機台停機調整，而其停機調整的安排必須以不影響新舊製程為前提。因此吾人將以需調整機台之產能曲線及產能需求曲線之差異加以排定其調機計畫。

Step5：當新製程投料率改變時即進入新階段的排程。此時必須以過去的歷史資料重新計算各機台的 X-Factor，再回到 Step2 開始新階段的排程。

2. 技術世代轉換之現場管控模式

晶圓製造可謂是現今最複雜的產業之一，生產步驟多再加上生產製程中充滿著諸如機台當機、加工時間變異、維修保養(Preventive Maintenance, PM)等不確定因素。因此，即使將生產計畫規劃得完美無缺，計畫也常常趕不上變化。在此狀況下，一套完備的現場管控模式是相當重要的。

在現場管控模式中最重要的是找到足以影響排程與生產結果的因子且加以管控，如此才能確保計畫目標的達成。一般而言，在現場管控系統中可以分為即時管控及預測管控模式。所謂即時管控模式即以即時性資料判斷現場狀況與計畫的偏離程度，再以偏離程度的大小作為是否啟動重新規劃機制的判斷。而預測管控模式則是在一段時間後（例如：每三個小時或每天）以現場即時資料往後排程以預估未來依計畫執行時之產能負荷狀況，並判斷此未來狀況與計畫之產能曲線偏離程度以決定是否修正計畫。以下則對此兩種管控模式加以詳細說明。

(1) 即時管控模式：

a. 生產週期時間之控制：

對目前 DRAM 產業的競爭力而言，降低生產成本是一個重要的議題。另外在工廠端對於生產週期時間的控制與產品的良率(Yield)是息息相關的，在 Meyerdorf and Yang(1997)的研究中提到，產品在生產線上的生產週期時間過長會有兩項較嚴重的影響，第一、潛在於製程或設備的問題延後發現。第二、晶圓會受到微粒(Particle)或化學氧化(Oxidize)的影響，造成良率的下降。因此為了讓生產線的在製品降至最低又能確保產出不受影響，生產週期時間(Cycle Time, C/T)的掌控就顯得格外重要。

生產週期時間(C/T)簡單的定義就是加工時間(Process time)加等候時間(Queue Time)， 如下式所示。

$$CT_t = \sum_{i=1}^{n} PT_i + QT_i$$

Where

CT_t :理論生產週期時間

n :總加工步驟

PT_i :第 i 站的加工時間

QT_i:第 i 站的等待時間

然而本研究將針對上述之生產週期時間定義進行延伸，發展出下列三種生產週期時間指標，使得在現場管控應用上面臨不同情況下能更為適切:

(a) 產出的生產週期時間(Output Cycle Time)指標:

此指標為產品產出的日期減去該產品投料之日期，因此 Output Cycle Time 即是該產品的實際生產週期時間，如下式所示。

$$CT_o = F - I - B$$

Where

CT_o:產出的生產週期時間

F :產品的產出時間

I :產品的投入時間

B: WIP 因工程實驗的停滯時間

(b) 產線內的生產週期時間(In Line Cycle Time)指標:

所謂的 In Line Cycle Time，是將每一道工程站點之該日平均 Cycle Time 加總後的資料，因為 In Line Cycle Time 是前一天工廠的作業實績，所以已經是接近即時的生產週期時間資料，如下所示。

$$CT_I = \sum_{i=1}^{n} (PT_i + TT_i + QT_i)$$

Where

CT_I:In Line Cycle Time

n :總加工步驟

PT_i:第 I 站的加工時間

(c) 週轉率生產週期時間(Turn Rate Cycle Time ; TR Cycle Time)指標:

所謂的 Turn Rate Cycle Time，是根據每一道製程的週轉率(Turn Rate, TR)來預估整段生產流程可以做到的生產週期時間，這是一個屬於未來式的生產指標。週轉率(Turn Rate)的定義如下。

$$TR = \frac{\text{Move}}{WIP}$$

而週轉率生產週期時間(TR Cycle Time)的定義則如下所示。

$$TR\ Cycle\ Time\ = \frac{Process_{step}}{TR} = \frac{WIP \times Process_{step}}{Move}$$

吾人將上述三種生產週期時間指標之說明與觀察指標彙整如下表 1 所示。雖然工廠端可以利用各種生產週期時間指標來監控生產線的績效，但為避免工廠管理者陷入追求生產週期時間績效的迷失，故仍須與其他管控模式互相搭配，才能讓產品的生產週期時間達到較佳的監控效果。

生產週時間期指標	型式	生產週時間期指標說明	觀察指標
Output C/T	過去式	由已產出的產品計算由投入到產出的平均時間	1.實際的生產週期時間指標 2.觀察派工系統是否有偏差
In Line C/T	現在式	每一道工程碼的該日平均C/T加總	1.各工作站的工作時間是否異常 2.該工作站WIP的等候時間是否異常 3.該工作站的傳送時間是否異常
TR C/T	未來式	根據每一道工程碼的TR速度預估整段Flow可以做到的C/T	1.該工作站的Move數量是否異常 2.該工作站的WIP數量是否異常

表 1　各種生產週期時間指標應用說明

b.　在製品數量之控制：

一般而言，WIP 狀態是現場的即時資料中足以反映目前生產活動正常順暢與否的主要資訊。機台前的 WIP 量過多顯示可能機台的產能不足或是派工出了問題;而 WIP 量過少則可能是前面機台或派工出了問題。這些狀況都會使計畫難以達成，因此在即時管控模式中可以 WIP 狀態作為判斷是否啟動重新規劃機制之訊號。在此我們將採用 TOC 理論中的暫存區管理的觀念，對每個主要機台（Key Machine）設定兩個警戒線：LL（Low Limit）以及 HL（High Limit）。當 WIP 量低於 LL 或高於 HL 時則啟動重新規劃機制。而 LL 與 HL 的設定則以 GI/G/m 等候理論中平均等候線長度再加上管理者對於工廠管理能力的評斷參數。

(2)　預測管控模式：

a.　產能負荷偏離度之控制

如前述所言，預測管控模式則是在一段時間後以現場即時資料往後排程以預估未來依計畫執行時每個單位時間內之產能負荷狀況，並判斷此未來狀況與計畫之產能曲線偏離程度以決定是否修正計畫。由於預測有個非常重要的特性是：預測會隨時間越遠而降低其準確度。因此假設未來的產能曲線有一定的可靠度，但現場存在著許多的不確定性，所以依目前現場狀況資料往後排程所得到之單位時間的機台產能負荷曲線可能會隨著時間延長而使其準確度下降。因此在比較產能負荷與產能曲線之偏離度時，吾人將時間因素加入偏離容忍度的考量中，且設定偏離容忍度(DT, Deviation Tolerance)。當產能負荷高於產能曲線且偏離度高於 DT;或產能負荷低於產能曲線且偏離度大於 DT 時，則啟動重新規劃機制。

b. 生產節奏之控制：

在 DRAM 產業新/舊製程世代交替時，控制生產節奏最重要之因素為投料節奏的控制。為避免落入追求局部性及暫時性的最佳化，因此必須以系統資源瓶頸當作生產節奏控制的起始點來控制投料，並且要以瓶頸負荷導向及投料時間為連續性來設定投料策略，依據沙姓學者(2000)投料法則的分類架構中得知，DRAM 產業新/舊製程世代交替時，利用工作負荷法(WR)做為控制生產節奏的策略，除了可以避免瓶頸機台達到最大的負荷狀況，亦能監控 Cycle Time，其生產節奏之控制步驟概述如下:

Step 1. 計算計畫投入系統內之 WIP 且未過系統資源瓶頸之總工作負荷值：

此步驟是將新產品的計畫日投片量乘以自 Wafer Release 至系統資源瓶頸機台站點的 Cycle Time 再乘以該站點的加工時間，最後將系統資源瓶頸機台各工作站點的負荷值加總後計算出該資源瓶頸之計畫總工作負荷值。

$$S_{CCRm} = \sum_{i=1}^{n} (P \times CT_{mi} \times PT_{mi})$$

Where

S_{CCRm}：瓶頸機台 m 之計畫總工作負荷值

P：每日計畫投入的批量

CT_{mi}：Wafer Release 至瓶頸機台 m 之第 i 站的標準生產週期時間

PT_{mi}：產品在瓶頸機台 m 之第 i 站點的加工時間

n：產品在瓶頸機台 m 之總站點數

Step 2. 計算實際投入系統內之 WIP 且未過系統資源瓶頸之總工作負荷值:

實際上，產線內的 WIP 並不會像步驟一那樣穩定地依照 Cycle Time 來流動，經常會受到機台或製程上的問題影響到 WIP 的流動，故此步驟是將已投入產線內且未過系統資源瓶頸機台站點的實際 WIP 加總後再乘以該站點的加工時間，最後將系統資源瓶頸機台各工作站點的負荷值加總後計算出該系統資源瓶頸機台的實際總工作負荷值。

$$A_{CCRm} = \sum_{i=1}^{n} (A_{mi} \times PT_{mi})$$

Where

A_{CCRm}: 實際 WIP 需使用瓶頸機台 m 之總工作負荷值

A_{mi}: 尚未過瓶頸機台 m 之第 i 站點的實際批量數

Step 3. 判斷是否要執行投料控制:

利用 S_{CCRm} 及 A_{CCRm} 的比值來判斷當日是否要依照表定計劃來投料，如 3.11 公式所示。當系統瓶頸機台的工作負荷值 $WR_m > 1$ 時則建議系統停止投料，用以控制生產節奏並可避免 Cycle Time 變長。待工作負荷 $WR_m \leq 1$ 時則視當天系

統資源瓶頸機台的 WIP 狀況來決定投料策略，若非瓶頸機台仍能充分供應瓶頸機台 WIP 時不必急著投料，若預期系統資源瓶頸機台會斷料時再恢復投料。

$$WR_m = A_{CCRm} / S_{CCRm}$$

Where

WRm :瓶頸機台 m 之計畫工作負荷與實際工作負荷之比值

3. 技術世代轉換之即時反應模式

在現場管控模式中，不管是即時管控或預測管控模式都僅止於提出警示訊息，對於系統並沒有提供該有的反應及行動。因此必須再設定一個模組提供系統警事後的訊號判讀與反應指示。在預測管控模式中警示來源為產能偏離需求，因此計畫難以執行。在這種情形下唯一的行動只有重新規劃，因此可以利用先前的規劃步驟以目前的狀態再規劃一次。如果是即時管控模式中 WIP 狀態偏離的警示則需判斷導致 WIP 偏離的主因。一般而言，WIP 狀態偏離可能造成的原因有機台的統計波動以及產能偏離。若因此統計波動而引起，則可藉由派工法則來加以調整;但如果是產能偏離，例如此時該有 3 台機台投入生產，但目前僅有 2 台，此種狀況則為產能偏離，則必須重新調整計畫，亦即可以利用先前的規劃步驟以目前的狀態再重新規劃一次

上述階段之研究相關結果已彙整於吾人與李榮貴教授所共同指導之碩士生畢業論文裡(許敦皓, 2012)，且其研究內容也亦發表於國際學術研討會 2012 ICINCO (9th International Conference on Informatics in Control, Automation and Robotics)與 Advanced Materials Research 期刊論文中，其刊登之文章如附錄三與附錄四所示。

四、 結果與討論

半導體產業屬於高資產、技術密集高且競爭相當激烈的產業，而對於台灣DRAM產業環境而言更是嚴峻。由於台灣DRAM產業面臨著幾個主要問題：缺乏核心技術、以產值為導向的管理思維、欠缺製程轉換技術，各家廠商可以解決的方法就是仰賴國外技術母廠引進製程技術支援，提升製程轉換能力，透過新技術的產能提升達到降低製造生產成本的目標。然而，在引進新技術動輒數百億的產業中，若管理者無法判斷應該在何時導入新技術可以為企業帶來最大利潤，則龐大的機台折舊費用與其他成本，可能會影響企業的存亡。有鑑於此，本研究提出一套新製程技術轉換時機點決策模式。在需求環境不確定下以技術演進藍圖為基底，透過新製程轉換相關決策因子的考量，以最大化企業利潤為目標決策出較佳之轉換時點。其中利潤概念之考量為收益與成本之差額，收益因子包含市場價格、良品產出量與舊技術機台汰換所得之利益，而成本方面主要為新技術機台之購入成本與變動成本。另一方面對於現場製程轉換之管控上，本研究亦從新舊製程技術之生產規劃階段、技術世代轉換之現場管控階段以及對於技術世代轉換之現場即時反應階段，利用TOC與CCR之相關概念分別對各階段提出相關決策管控模式，提供管理者在現場執行轉換時所可能面臨到問題時，能有一套有系統且邏輯性之管控流程，進而使管理者對於製程世代轉換上能更為順遂。

前幾年的金融海嘯震驚了全世界，也帶給台灣半導體產業不少的衝擊，在半導體產業之中，唯有不斷的提升製程能力與生產之績效，方能在瞬息萬變的市場中佔有一席之地，因此如何建立與訂立一個可以快速因應市場變動且容易管控之廠區規模，亦或是發展一可含納多個製程技術之建廠管控思維，實為後續相關研究可以進行探討之方向。

就本質而論，本計畫之研究成果同時具有實務及學術價值。在實務方面，本計畫成果可提供半導

體產業上，不論是DRAM製造商或是其他類型之晶圓廠，對於製程世代轉換決策之制定與轉換實行時現場之管控能有一系統化之憑藉；在學術上，本研究發展出以最大化製程世代轉換利潤為依據之轉換決策概念，亦延伸CCR限制理論於DRAM製程世代轉換現場管控之應用，除此之外本研究亦已將相關研究成果發表於國際學術研討會以及國際學術期刊之中。

本研究之研究成果分述如下：

1. 透過研究所提出之製程技術世代轉換整合規劃模式，可使得經常必須面臨技術世代轉換之DRAM 製造廠，在面臨製程技術轉換時能更有效率且更為順利。
2. 藉由此決策模式使企業在轉換時依然能夠維持一定之競爭力與獲利水準，避免半導體產業面臨技術轉換時相關不確定性因素所導致之公司損害
3. 經由所發展之整合規劃管理流程，提供擁有在多變環境與高投資風險之其他類似產業因應技術世代轉變時能有一個完整解決架構參考

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附 錄 一

The Model to Determine Optimal Timing of Capacity Replacement for Manufacturing Technology Upgrades

The Model to Determine Optimal Timing of Capacity Replacement for Manufacturing Technology Upgrades

Chao-I WANG, Ying-Mei TU

Dept. of Industrial Management, Chung Hua University, Hsinchu City, Chinese Taipei, 300

Email: kinki_true@hotmail.com, amytu@chu.edu.tw

Abstract: Over the past decade, product and process technology migrations have been due to short product life cycle. Under this circumstance, companies have to develop more advanced technology and purchase sophisticated tools to meet the market demand and reduce manufacturing cost as well. When process technology migration occurred, DRAM manufacturers always used the past experiences to handle the migration. However, the challenge is totally different to the past that causes the manufacturers have to suffer many unexpected difficulties.In this work, an integrated model for technology migration is proposed. Regarding to the time schedule setting, a time-cost function of capacity expansion should be developed. Based on the above information, a wafer release schedule of new technology under the minimal install cost can be defined.

Keywords: Technology migration; DRAM; Capacity expansion; install cost

製程技術升級下之產能替換最佳時點決策模式

王昭宜，杜瑩美

中華大學工業管理學系, 新竹市, 中華台北, 300

Email: kinki_true@hotmail.com, amytu@chu.edu.tw

摘　要：自二十世紀後期，產品的生命週期急遽縮短，連帶造成產品世代以及製程技術快速的變革。因此，企業必須經常導入新的世代技術與設備，以符合市場需求以及降低製造成本。然而在面對製程技術世代轉換時，Dynamic Random Access Memory (DRAM) 產業向來只憑藉著過去經驗來規劃轉換時機，但由於每次轉換技術時，所遭遇之情況大不相同，所以經常會遇到許多決策上的困難。為了因應此困難點，本研究將提出一製程技術世代轉換之決策模式以協助 DRAM 產業順利的轉換製程技術。主要透過產能擴充成本時間函數的推導，並且分析未來新世代技術對設置成本的影響，藉以解決半導體製造產業中技術世代轉換策略制定的複雜問題。

關鍵詞：製程技術世代轉換；DRAM；產能擴充；設置成本

1 引言

在需求不確定以及生產技術快速變革的交互影響之下，管理者經常需要面臨到底應該在何時導入先進製程技術的難題，一方面要考慮未來需求的成長幅度是否符合預估，另一方面還需考慮新製程技術的更新速度是否能使企業維持競爭優勢。然而，新世代製程技術對企業所帶來的影響卻往往被掩蓋在市場不確定性當中[1]，因而使得這方面的相關研究顯得相當不足。

當新的製程技術被發展問世時，代表產業中存在著一種成本更低、更為有效率的作業模式[2]，此時，管理者必須審慎思考新製程技術導入的問題，一方面必須擔心未來需求能否支撐引進新製程所必須支付的龐大資本，另一方面又必須考慮若不引進新製程是否會喪失企業競爭優勢。DRAM 產業即是一個很好的例子，由於產業型態使然，增加產量以及降低單位成本一直是 DRAM 製造廠賴以維生的關鍵競爭優勢。

除了晶圓面積之外，製程技術世代(線寬)亦是影響半導體製造產業作業成本及競爭優勢的重要指標。近年來全球消費性電子產業無不以輕、薄、短、小為產品的主要發展目標 因而造就了 IC 製程技術的蓬勃發展，先進技術的演進已從十年前 0.18 微米一路進步到今日的 65 奈米、40 奈米，甚至 28 奈米已計畫投產(TSMC Technology Roadmap)。因此，為維持企業競爭優勢，半導體製造商必須不斷將其製程技術世代往前推升，藉以維持競爭優勢。然而，先進製程技術所帶來的收益往往不如當初所投入的資本支出(TSMC2010Q2 營運績效報告)。對產業龍頭企業而

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言，或許有能力進行如此龐大的投資以維持其領導地位，但對於規模較小的企業而言，管理者對於新科技的引進就必須更加審慎考慮。再者，根據研究指出，IC 製造技術的生命週期，通常不會超過三年[3]。

本文中製程技術世代轉換問題主要探討技術轉換時間點，其規劃過程必須同時考慮市場需求波動、技術成熟度以及資金取得，晶圓製造產業在需求高度不確定、技術世代更替快速的複雜環境之下，製程技術世代的轉換將會是一項充滿挑戰的複雜問題。主要目的為在系統受到影響程度最小的前提下，使技術轉換過程順利完成，並維持企業之競爭優勢。

在新技術世代導入影響相關研究方面，[4]考慮新機台提升製程穩定性以進行新世代產能置換的規劃問題，但本研究卻未考量新科技技術對其他因子所造成的影響，也未針對產能替換所必須的前置時間加以考慮。[5]則提出了新技術導入的時間點決策方法，作者利用新設備價格變化以及其對成本的影響求出最佳的技術世代”完全替換”時機。[6]綜合上述二篇研究，提出了一套在技術演進影響下之產能規劃手法，此研究利用線性規劃模式進行在製造技術突破下之產能擴充(Expansion)或是替換(Replacement)的決策，並加入時間軸的概念。作者以最大化利潤作為目標，並考慮了新設備取得成本將隨時間改變（新技術出現越久，其購置成本越低），以及新設備的導入將降低製造成本作為考量因子，計算新設備至入的最佳數量及時間點。而[7]則是首度提出同時考慮需求不確定及新技術更替影響下之產能規劃手法，針對當產能出現缺口時之產能規劃模式進行討論，並考量新技術的出現對產能取得成本所造成的影響，最後，利用市場需求的變化針對產能規劃結果進行敏感度分析，以確認市場需求改變對規劃結果所造成的影響。

2 研究目的

對於新世代製程技術的導入，半導體製造產業所面臨的問題已非要或不要，而是該如何進行；對於DRAM產業而言，新世代製程的導入成效更是攸關企業存亡的關鍵。此一影響深遠且重大的決策問題，過去卻鮮少有研究觸及。本研究期望為半導體製造產業，特別是DRAM製造業，提供一個決策制訂的準則。

因此，本研究之主要目的為在需求不確定下之新製程技術的產能擴充或替換策略，以及新世代產品或服務所需產能的導入策略二大部分。在新製程技術的產能規劃手法方面，吾人發現，就台灣的IC製造產業而言，技術演進歷程尚稱具有高度預測性。因此，針對此一部份吾人可以透過產業所公布的技術發展藍圖(Technology Roadmap)作為依據，利用產能成本時間序列以及生產成本函數進行規劃求解。

3 產能規劃模式

本研究之主要目的為：在半導體製造產業製程技術世代轉換的問題中，考量需求與技術不確定因素，提出一套整合策略與決策模式。如同先前所言，製程技術世代的轉換，對 DRAM 產業而言是維持企業競爭優勢的關鍵所在，再者，市場需求量短期來看或許會有所增減，但就長期而言，市場需求大多呈現向上成長的趨勢[8]。回顧過去整體半導體製造產業的發展歷程，即使在市場需求萎縮的時期，企業大都還是選擇繼續將其製程技術世代往前推升，因此，技術世代轉換的決策制訂，關鍵因素將會是產業內的技術演進藍圖；然而，市場需求的波動卻會影響企業推升技術世代的速度，進而影響製程產能設置的策略。

就前述研究背景所言，過去的先進製程轉換策略或產能規劃模式都將未來需求變化視為最重要之不確定因素，但需求變化的預測是一項困難且準確度不高規劃之行為，將此預測結果作為策略規劃中最重要的因子，將會使其投資風險大為提高。此外，技術世代轉換對於企業而言是一種中、長程的規劃活動，而如同前面所言，若將時間軸拉長，市場需求將會呈現較為穩定的成長趨勢，而此成長趨勢除了受大環境的經濟因素影響而偏移之外，最重要的偏移原因將來自於新科技或技術的突破性發展[6]。因此，本研究將以未來技術藍圖的發展作為技術世代轉換策略的主要考量因子，輔以針對市場需求變化趨勢與科技發展時程產生偏移進行技術世代轉換速率的調整，以滿足企業維持競爭力並兼顧市場波動的目標。

3.1 制定技術轉換開始時點

在半導體製造產業中，相較於市場需求的劇烈波動，技術發展歷程可算是呈現較為穩定成長的趨勢。例如，早在 1965 年即提出的摩爾定律(每顆 IC 可容納之電晶體數量約每 12 個月將增加一倍，1975 年修正為 18 個月、1997 年修正為 24 個月)，時至今日仍然適用，圖 1 所示的資料為 1971 至 2008 每顆 IC 尚可容納之電晶體數量，可以發現其關係準確地吻合摩爾定律的預

測，台積電董事長張忠謀甚至大膽預測，摩爾定律在未來 10 至 15 年將仍然適用。

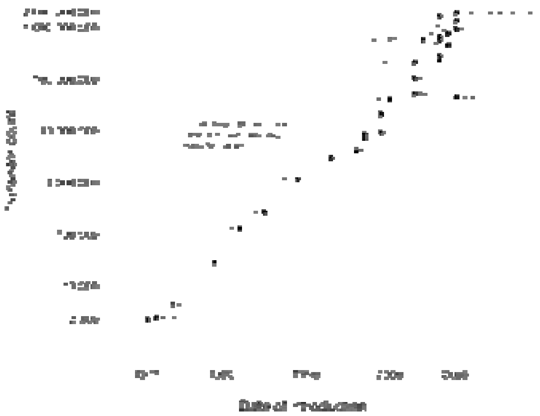

Figure 1.CPU Transistor Counts 1971-2008&Moore's Law
圖 1.1971 至 2008 每顆 IC 可容納之電晶體數量

由於技術的演進呈現穩定的發展，因此，吾人只需分析企業所制訂之技術演進藍圖(Technology Roadmap)，即可得知企業必須在何時開始進行技術世代轉換，才能在技術演進藍圖所規劃的時間點完成技術世代轉換。

3.2 新世代產能取得成本時間函數

由於技術的演進呈現穩定的發展，則機台設備或製程技術的設置成本以及舊有機台剩餘價值與時間點之間也將呈現較為穩定的關係。因此，可將產能設置成本簡單如下表示：

$$FC_t = \sum_i (x_{i,t,s} \times p_{i,t} - y_{i,r,t} \times p_{i,t}) \quad (1)$$

$$p_{i,t} = g_i - P_i(t) \quad (2)$$

其中，

$x_{i,t,s}$： 於 t 時間點購入並於 s 時間點完成設置之第 i 技術世代機台($s>t$)

$y_{i,r,t}$： 於 r 時間點計畫移出並於 t 時間點完成移出之 i 技術世代機台($t>r$)

$p_{i,t}$： 第 i 技術世代機台於時間點 t 之市場價格

FC_t： 時間點 t 之資本支出

g_i： 第 i 技術世代機台於問世時之初始價格

$P_i(t)$： 第 i 技術世代機台市場價格下降之時間函數

3.3 新世代製程技術變動管理成本

購入新技術製程或新機台設備後，伴隨而來著為因應製程或機台變動，而改變管理方式所應付出之成本，而變動管理成本會隨時間推移而下降，在時間點 t 進行購入後，將時間點 t 至下一新技術機台決策時間點 z 分隔為 n 個 j 時間段，而各個間隔之變動管理成本則會隨時間推移，而使成本逐漸下降。A 為常數，簡單表示如下：

$$VM_{tz} = \sum_{j=1}^{n} c_{tj}\, e^{Aj} \quad (3)$$

其中，

C_{tj}： 於 t 時間點購入並於 j 時間點之變動管理成本

VM_{tz}： 於 t 時間點購入並於 z 時間點完成變動之總變動管理成本

3.4 最佳設置成本

當新製程技術或新機台設備購入時，管理者會思考新製程技術或新機台設備是否足以支持企業優勢，直至下一個新製程技術或新機台設備問世，於是這段區間所發生之成本,如下表示：

$$TC_{tz} = \min[FC_t + VM_{tz}] \quad (4)$$

其中，

TC_{tz}： 於 t 時間點購入於 z 時間點進入下一個新製程技術決策區間之總成本

4 結論與建議

本研究針對高科技產業，特別是 DRAM 產業，科技演進快速以及需求高度不確定的環境下之產能擴充策略。本研究以未來技術藍圖作為未來設備取得成本時間函數之基礎，提出一數學規劃模式求出各決策時點之最佳設置成本，期望能以此模式找出最佳之產能擴充策略。

對於未來後續之研究，本研究建議可以加入決策時點之機會成本，由於有利益的背後亦表示著損失某些利益，若能加入機會成本則可使購入新製程技術或新設備機台之成本更加明確，進而得到最佳設置時間點。

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附 錄 二

Technology Migration Determination Model For DRAM Industry

Technology Migration Determination Model For DRAM Industry

Ying-Mei Tu[1] and Chao-I Wang[1]
[1] *Department of Industrial Management, Chung Hua University, HsinChu City, Taiwan,300*
amytu@chu.edu.tw, kinki@hotmail.com

Keywords: *Technology migration, DRAM, Technology roadmap, Learning curve.*

Abstract: Due to short life cycle of DRAM industry over the past decade, the product generation and technology migration have to be quickly enhanced. When technology migration occurred, DRAM companies always used the past experiences to proceed with process changes. However, the issues are totally different particularly in the best practice of technology migration that caused the companies suffered many uncertainties. In this work, a model to determine the timing of technology migration is proposed. The model is based on technology roadmap to set the timing of migration under maximum profit condition. A stable growth trend is assumed for market demand to decide the revenue. Furthermore, the time-cost function of new generational equipment and the theory of learning curve are introduced as the factors to determine the manufacturing cost and profit. Consequentially, the best timing is determined with maximum profit.

1 INTRODUCTION

DRAM industry is a capital intensive, high-tech industry with complex processes and technology migration for DRAM manufacturers has been a very challenging aspect and more time consuming. Since there is no any physical capacity expansion over the past 5 years in Taiwan, all DRAM manufacturers were relying more than ever on technology migration to increase supply and reduce cost. Furthermore, product generation and technology had been quickly enhanced due to short product life cycle. When new technology emerges, it reveals that a lower cost and more effective operation model emerged [Cainarca, 1989]. Simultaneously, it also means the current competitive advantages of the company will be jeopardized [Hastings, 1994]. Under this circumstance, manufactures have to launch new technology and retrofit generational equipment to meet the market demand and reduce manufacturing cost. Chou *et al.* pointed out the technology life cycle of semiconductor manufacturing usually won't be over three years and the time of technology generational transition should take about nine months. Therefore, the semiconductor manufacturers always face the dilemma between capacity expansion and new technology migration. Generally, the major competition factor of DRAM industry is the manufacturing cost. That is why the frequency of technology migration is higher than foundries.

There are many researches regarding to the influence of new technology introducing. Chand and Sethi based on the enhancement of process stability by the new generational equipment to plan the replacement of new generation capacity. However, the impacts on the other factors and the lead time of replacement were not taken into account. Cohen and Halperin proposed a method to determine the timing of technology migration which was based on the price changes of new equipment as well as its impact on the cost to find the best timing for migration. Rajagopalan *et al.* combined the above two studies and proposed a capacity planning model under the impact of technology evolution. The linear programming was applied and the concept of timeline was added to the decision of capacity expansion or replacement decisions. Pak *et al.* proposed a methodology of capacity planning which focused on the capacity shortage to plan the capacity requirement and the influence from cost of new technology capacity was taken into account. Furthermore, the sensitivity analysis was applied to determine how sensitive of this plan in the changes of market demand. Chien and Zheng proposed a mini–max regret strategy for capacity planning under demand uncertainty to improve capacity utilization and capital effectiveness in semiconductor manufacturing. Seta *et al*. studied optimal investment in technologies characterized by the learning curve. They emphasized that if the learning process is slow, firms invest relatively late and on a larger scale. If the curve is steep, firms invest earlier and on a smaller scale. It is obvious that most of these researches focused on the market demand to decide the timing of technology migration. However, the market demand is full of uncertainties and hard to handle. Therefore, there will be great difficulty in the practical applications.

The purpose of this work is to propose a model to determine the timing of technology migration. The model is based on technology roadmap to set the timing of migration under maximum profit condition. A stable growth trend is assumed for market demand to decide the revenue. Furthermore, the time-cost function of new generational equipment and the theory of learning curve are introduced as the factors to determine the manufacturing cost and profit. Consequentially, the best timing is determined with maximum profit.

2 TECHNOLOGY MIGRATION DETERMINATION MODEL

The purpose of technology migration is to make more profit for the company. Under the assumption of demand stable growth, the best timing of technology migration is the time which can make the maximum profit for the company. Based on the literature review and market survey, the trend of DRAM unit cost and market price is as Fig. 1. Because the equipment depreciation and product yield is stable under the current production status, the production cost of per giga bit DRAM is almost the same. However, the market price will be dropped off due to the business strategy, new product or technology emerged. The trend of market price can be gotten from history data. Regarding to the unit cost produced by new technology, it will be higher than current mature technology due to the higher price of new equipment and lower yield of production in the beginning. However, the yield will be improved after a period of time and the unit cost also can be dropped off and even lower than the product from current technology. Based on the abovephenomena, it shows that the best timing of technology migration will be occurred between the emerged time of new technology and the next generation technology.

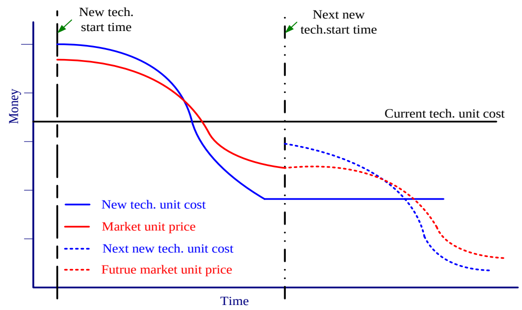

Fig. 1. The relationship between unit cost and unit price of per giga bit DRAM

In order to analyse and establish the model easily, we called the horizon between the emerged time of new technology and the next generation technology as the life cycle of new technology and divided it into n periods. The profit function is established as Eq. 1 and there are three parts, total revenue, total manufacturing cost and the income of equipment disposal, included. The details are described in the follows.

$$TP(t) = (R_{g-1} + R_g) - (\sum_{i=1}^{t-1}(FC_{g-1} + VC_{g-1})$$

$$- \sum_{i=t}^{n}(FC_{g,i} + VC_{g,i})) + I_{g-1,t} (1)$$

Where

$TP(t)$: Total profit which the technology migrated from *t* period

t : The time of technology migration

R_j : Revenue of *j* generation technology

$FC_{g,i}$: Fixed cost of *g* generation technology per period which is migrated at *i* period

FC_{g-1} : Fixed cost of *g-1* generation technology per period

$VC_{g,i}$: Variable cost of *g* generation technology per period which is migrated at *i* period

VC_{g-1} : Variable cost of *g-1* generation technology per period

$I_{g-1,t}$: The income from the deposal of *g-1* generation equipment at *t* period

2.1 The Function of Total Revenue

The environment of supply demand balance is an assumption of this work. Therefore, all products can be sold by market price. The total revenue means the revenue of n periods. If the new technology is migrated at t period, the revenue from current technology will be the revenue from period 1 to period t-1 and the revenue from new technology will be from period t to period n. Down below is the equation of current technology revenue andnew technology revenue.

2.1.1 The Revenue from Current Technology

If the current technology is not eliminated after new technology emerged, the current technology is still under production. Because the current technology is under a stable stage, the market price and production quantity of the company will keep almost the same. Therefore, the revenue from current technology is established as follows.

$$R_{g-1} = \sum_{i=1}^{t-1} \left(P_{g-1} \times Q_{g-1,i}\right) \tag{2}$$

Where

P_{g-1} : The average market price of *g-1* generation technology

$Q_{g-1,i}$: The total quantity of *g-1* generation technology at period *i*

2.1.2 The Revenue from New Technology

The calculation of the revenue from new technology is still formula by the price multiplying the quantity. Due to the new technology belonging to the growing stage, the market price and production quantity of the company will be changed by time. Based on the historical data analysis, the market price can be modelled as a Sigmoid function. The output of Sigmoid function is between 0 and 1. Therefore, the managers should forecast the rate of price change and the saddle point of price curve. Besides, the normalization is used to fit the actual DRAM price. Regarding to the production quantity, due to the unfamiliarity of new technology process, the yield of products will be lower in the beginning. After a period of time, the yield can be improved and products quantity will be increased as well. This concept is similar to the learning curve. Therefore, the concept of learning curve is applied to model the production quantity of new technology. The equation of the revenue from new technology is as follows.

$$R_g = \sum_{i=t}^{n} (P_{g,i} \times Q_{g,i}) \tag{3}$$

$$P_{g,i} = X \times \left(P_{g,Max} - P_{g,Min}\right) + P_{g,Min} \tag{4}$$

$$X = \frac{1}{1 + e^{a(i-T)}} \tag{5}$$

$$Q_i = IQ \times \left(1 - \left(NP_t \times (i - t + 1)^{\frac{log c_1}{log 2}}\right)\right) \tag{6}$$

Where

$P_{g,i}$: The average price of g generation technology at *i* period

$P_{g,Max}$: The maximum price of g generation technology

$P_{g,Min}$: The minimum price of g generation technology

X : The normalization value of Sigmoid function

a : The rate of price change

T : The saddle point of Sigmoid function

Q_i : Production quantity at *i* period

IQ : Release quantity per period

NP_t : The initial failure rate of new technology

c_1 : The learning rate of production failure rate, set by the managers

2.2 The Function of Total Cost

As the characteristics of DRAM industry, the company can get more profit from new generation technology. However, a huge of cost should be paid for new generational equipment behind profit. This cost is called as capacity acquired cost. Therefore, the calculation of production cost can be divided into two part, fixed cost and variable cost. The fixed cost is the cost of equipment for new technology and the depreciation of current equipment. There is no depreciation for the deposal equipment. The variable cost is the expense for the production. The details are as follows.

2.2.1 Fixed Cost of New Technology

Due to the migration to new generational technology, the new generational equipment is required. Generally, the price of new generational equipment will be reduced by time. In this work we assume the price will be linear decreasing. Besides, the required equipment quantity depends on its throughput. Based on these concepts, the fixed cost is formulized as follows.

$$FC_i = (\frac{MP_{g,i} \times x_{g,i}}{m} - RFC_{g-1}) + FC_{g-1} \quad (7)$$

$$MP_{g,i} = MP_{g,0} - D \times (i-1) \quad (8)$$

$$D = \frac{MP_{g,0} - RV_g}{m} \quad (9)$$

$$x_{g,i} = \left\lfloor \frac{C_{g-1} \times x_{g-1}}{C_g} \right\rfloor + 1 \quad (10)$$

$$C_g = MP_g \times CP_g \times ICC_g \quad (11)$$

Where

- $x_{g,i}$: The quantity of generation *g* equipment which purchased at*i* period
- D : The reducing value of equipment per period
- $MP_{g,i}$: The price of generation *g* equipment which purchased at *i* period
- RFC_{g-1} : The fixed cost of generation *g-1* equipment which is disposed at period t
- RV_g : The residual value of generation *g* equipment
- m : Numbers of depreciation period
- C_g : The capacity of generation *g* equipment
- MP_g : The wafer numbers which producing by the generation *g* equipment
- CP_g : The numbers of IC which producing by the generation *g* equipment
- ICC_g : The memory size per die which producing by the generation *g* equipment

2.2.2 Variable Cost of New Technology

Generally, the variable cost of production will decrease as the yield increase. The yield increasing is the result of the mature of co-operating in man-machine and the accumulation of engineer's experiences. Therefore, the variable cost will present same as the concept of manufacturing progress function and it is applied in the formulation of variable cost.

$$VC_{g,i} = C_t (i - t + 1)^{\frac{\log c_2}{\log 2}} \quad (12$$

Where

- C_t : The variable cost which the migration occurred at *t* period
- c_2 : The learning rate of variable cost, set by the managers

2.3 The Income from the Disposal of Equipment

The equipment which cannot process the new generation technology will be disposed. The income from the disposal of equipment is as the following equation.

$$I_{g-1,t} = MP_{g-1,t} \times y_{g-1,t} \quad (13)$$

Where

- $MP_{g-1,t}$: The price of *g-1* generational equipment at *t* period
- $y_{g-1,t}$: The equipment quantity of *g-1* generational equipment

3 NUMERICAL EXAMPLE

Here, a numerical example is illustrated to demonstrate the modelling and determination process of the proposed model. The environment of this example is a 300mm DRAM fab with 30K wafers per month. The major product is DDRII and 1300 chips per wafer. New generation technology is DDRIII and 1800 chips per wafer. The sales quantity is equal to the production quantity under the assumption of strong market demand condition. Besides, the duration of period is one month and all cost, price and revenue are counted by US dollar. The following is the detailed modelling and determination process. Furthermore, t=8 is assumed for all calculation.

3.1 Total Revenue

3.1.1 The Revenue from Current Technology

Assume the price of current technology is \$0.8 per giga bit and production yield is 0.98. Therefore, the revenue from current technology is as follows.

$$R_{g-1} = \sum_{i=1}^{7} (1.2 \times 1300 \times 30K \times 0.98)$$
$$= 45{,}864{,}000 \times 7$$
$$= 321{,}048{,}000$$

3.1.2 The Revenue from New Technology

Regarding to the price of DDRIII, the data from Aug. 2009 to July 2012 is collected to formula the Sigmoid function. Assume the parameters of Sigmoid function T is 16 and a is 0.3. The maximum and minimum price of DDRIII is 2.5 and 1.2. The price of new technology is as follows.

$$X = \frac{1}{1 + e^{0.3\times(8-16)}} = 0.9168$$

$$P_{g,8} = 0.9168 \times (2.5 - 1.2) + 1.2 = 2.3918$$

Due to the improvement of product yield, the production quantity will increase. Assume the product yield is 0.45 in the beginning of migration and c_1 equals to 0.85. The production quantity of period 8 is calculated as follows.

$$Q_{g,8} = 54{,}000K \times \left(1 - \left(0.55 \times (8 - 8 + 1)^{-0.2345}\right)\right) = 23{,}220{,}000$$

$$a_1 = \frac{\log 0.9}{\log 2} = -0.152$$

The revenue from new technology is as follows.

$$R_g = \sum_{i=8}^{36} (P_{g,i} \times Q_{g,i}) = 1{,}504{,}087{,}017$$

3.2 Total Cost

3.2.1 Fixed Cost

Assume the depreciation for equipment is six years. Three sets of g-1 generation should be replaced and their original cost is 0.1 billion. Total equipment cost of old technology excluding the disposals is 2 billion. The parameters of product by new and old technology are as follows.

ICC_g=1GB, CP_g=1800, MP_g=10000

ICC_{g-1}=1GB, CP_{g-1}=1300, MP_{g-1}=10000

Therefore, C_g and C_{g-1} equals to 18,000,000 and 13,000,000. The new generational equipment quantity can be determined by Eq. 10.

$$x_g = \left\lfloor \frac{13000000 \div 0.98 \times 3}{18000000 \div 0.61} \right\rfloor + 1 = 3$$

Assume the price of new generational equipment is 1 billion per set in the beginning and its residual value is 0.2 billion. Therefore, if the new generational equipment is purchased at period 8, its price is calculated as follows.

$$D = \frac{100{,}000{,}000 - 20{,}000{,}000}{72} = 1{,}111{,}111$$

$$MP_{g,8} = 100{,}000{,}000 - 1{,}111{,}111 \times 7 = \$92{,}222{,}222$$

Based on the assumptions above, the total fixed cost is calculated as follows.

$$FC_{g,8} = \frac{92{,}222{,}222 \times 3}{72} + \frac{2{,}000{,}000{,}000}{72} = 31{,}620{,}370$$

$$\sum_{i=1}^{7} FC_{g-1,i} + \sum_{i=8}^{36} FC_{g,i} = 1{,}121{,}157{,}407$$

3.2.1 Variable Cost

Assume c_2 = 0.82, C_t=10,600,000 and $VC_{g-1,i}$=7,141,000

Then $a_2 = \log 0.82 / \log 2 = -0.377069649$

$$VC_8 = 10{,}600{,}000(8 - 8 + 1)^{-0.377069649} = 10{,}600{,}000$$

$$\sum_{i=8}^{36} VC_{g,i} = 156{,}956{,}539$$

The following is the calculation of total variable cost.

$$VC = \sum_{i=1}^{7} VC_{g-1,i} + \sum_{i=8}^{36} VC_{g,i} = 7{,}141{,}000 \times 7 + 156{,}956{,}539 = 206{,}943{,}539$$

The total cost is fixed cost plus variable cost.

$$\text{Total Cost} = 1{,}121{,}157{,}407 + 206{,}943{,}539 = 1{,}328{,}100{,}946$$

3.3 The Income from the Disposal of Equipment

Assume the disposal equipment has been purchased for 47 months at the time of new technology emerged. Therefore, the total value at the period 8 is as follows.

$$I_{g-1,8} = \left(\frac{\frac{100{,}000{,}000\times 0.8}{72}\times 17 + 100{,}000{,}000\times 0.2}{3}\right)\times 3 = 38{,}888{,}888$$

3.4 Total Profit

Finally the total profit is as follows if the technology migration occurred at period 8.

$$TP(8) = (321{,}048{,}000 + 1{,}504{,}087{,}017) - 1{,}328{,}100{,}946 + 38{,}888{,}888 = 535{,}922{,}959$$

Based on the above calculation, the relationship of total profit vs. the migration time t is shown as Fig. 2.

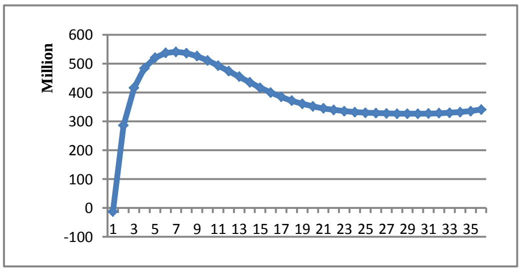

Fig. 2. The relationship between total profit and migration time *t*

The best time for generational transition can be determined as period 7 from Fig. 2.

4 CONCLUSIONS

DRAM industry is a capital intensive, high-tech industry and the product generation has been quickly enhanced. Due to the huge investment for the technology migration, the migration timing is very important for the company. In this work, a model to determine the best timing for the technology migration is established. The maximum profit is the objective to determine the migration time in the model. All revenue and cost of technology migration are considered. We expect this model can be applied in other industries with same situation.

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附 錄 三

Production Planning and Control Model of Technology Migration for DRAM Industry

Production Planning and Control Model of Technology Migration for DRAM Industry

Ying-Mei Tu
Department of Industrial Management, Chung Hua University, Hsin Chu,Taiwan, R.O.C.
amytu@chu.edu.tw

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Abstract: Due to product life cycle has been shortened rapidly, it forces the product generation and technology should be enhanced quickly. When technology generation change occurred, DRAM manufacturers always used the past experiences to handle the change process. However, the issues are totally different and it made the companies suffered many difficulties. In this work, a production planning and control model is developed. The production planning focuses on CCR (Capacity Constraint Resources) to define the complete wafer release schedule and apply X-factor to schedule the production processes during the migration period. Regarding to the shop floor control, there are two control mechanisms to control and monitor the migration process, real time control and predicting control. WIP status is the important factor to decide whether the production planner needs to launch the rescheduling module or not in the real time control portion. Besides, a foresee function is performed by predicting control portion which firing the rescheduling module by the bias between the loading and capacity curves.

1 INTRODUCTION

DRAM industry is a capital intensive, high-tech industry with complex processes. Nevertheless, product generation and technology had been quickly enhanced due to short product life cycle. When new technology emerges, it reveals a lower cost and more effective operation model (Cainarca, 1989). Simultaneously, it also means the current competitive advantages of company will be jeopardized (Hastings, 1994). Under this circumstance, manufactures have to launch new technology and retrofit generation equipment to meet the market demand and reduce manufacturing cost. Chou, Cheng, Yang and Liang (2007) pointed out the technology life cycle of semiconductor manufacturing usually won't be over three years. Therefore, the semiconductor manufacturers always face the dilemma of new technology migration. Generally, the major competition factor of DRAM industry is the manufacturing cost. That is why the frequency of technology migration is higher than foundries.

When migration occurred, DRAM manufactures always used the past experiences to handle the migration. However, the issues are totally different that caused the manufactures suffered many unknown difficulties. Generally, the production planning of technology migration should take the planning result of high-level strategy into account, such as the start time of migration, output target of new technology…etc., to set the migration tempo and capacity switching schedule. Nevertheless, the uncertainties and dynamic factors of shop floor (ex: machine breakdown, schedule delay for new generation equipment or equipment retrofit…etc.) can not be taken into consideration in the high-level strategy. Besides, the high-level decision is based on the prediction of technology roadmap, there will be some changes and biases between the setup of high-level strategy and the execution of technology migration process. In order to guarantee a smooth and successful migration process, a robust and effective production planning and control model of shop floor for technology migration is very important.

Many researches have proposed some methods for production planning and shop floor control of semiconductor manufacturing. Regarding to the production planning, queuing theory, linear programming and mean value analysis are usually applied to estimate the capacity requirement of workstations and wafer release quantity (Iwata, Y., Taji, K. and Tamura, H., 2003; Walid and Gharbi, 2002; Chou and You, 2001). Nevertheless, the system uncertainty and the risk of investment are not taken into account. Besides, many researches focused on release policy (Glassey, C. R. and Resende, M. G. C., 1998a & 1998b; Wein, 1988, Lou, 1989a &1989b; Spearman, M. L., Woodruff, D. L., and Hopp, W. J., 1989&1992; Bowman, 2002; Hung & Leachman, 1996). Either opened-loop or closed loop policy is based on the normal production situation and does not think of the events of products generation changes, equipment retrofit and new equipment move-in. According to the shop floor control, many dispatching rules were developed to fulfil the purpose of higher production performance (Dabbas & Flowler, 2003; Lee & Kim, 2011; Louw & Page, 2004; Hsieh & Hou, 2006; Hung and Chang, 2002; Uzsoy *et al.*, 1992). Nevertheless, the issues of process migration were not considered either in the release policy nor shop floor control rule. In general, the production system will be more complicated during the technology migration period, such as the instability of products mix, the changes of capacity. Therefore, the proposed methods won't be satisfied the requirements. Moreover, the experiences of semiconductor management showed that the production management will be extremely complicated when there are over three generation products produced in the same time. System performance will be difficult to keep in such a circumstance. Hence, an efficient and effective planning and shop floor control model for a varied system can not only solve the technology migration issues but also be applied to the foundry with multiple generation products.

This paper investigates the technology migration of DRAM industry from manufacturing point of view. In this work, a production planning and control model of technology migration was developed. There are two portions in this model including production planning and shop floor control. The production planning focused on CCR to define the complete wafer release schedule and applying X-factor to schedule the production processes and equipment retrofit during the transition period. Regarding to the shop floor control, there are two control mechanisms to control and monitor the migration process, which are real time control and predicting control module.

2 PRODUCTION PLANNING MODULE

As mentioned above that the migration process has to fulfil the target of high-level strategy. The major decision factors of high-level strategy include the fluctuation of future demand, technology development and company financial situation. The complication and variation of production system are difficult to take into account in the strategy level. Therefore, a robust planning and control model not only can help to a successful migration process but also to find out various migration problems in advance. In production planning module, the major target is to transfer the output targets of new generational products to execution plan. The plan includes the wafer release plan of new/old generational products, the release plan of new generational equipment and equipment retrofit plan. Generally, the placement of new/old generational products will be progressed step by step. Hence, the migration period is divided into several time periods for planning. Furthermore, X-factor is applied to the scheduling process. The following is the procedure of production planning.

Step 1. Set up the time unit

It can be defined as a day, three hours…etc.

Step 2. Plan wafer start schedule

In this step, the wafer start schedule of new/old generational products should be planned by referring the output target of new generational products. Generally, top management will hope to keep the total output of factory as before. However, the manufacturing complexity of new generational products may be higher than old one and it will result to the total output decreasing. Therefore, the total output during migration period should be planned in this step. The sub-steps are as follows.

1) *Identify Capacity Constraint Resources (CCR)*
   Generally, the CCR will be only one of equipment in a factory. However, due to the heavy investment of equipment, several workstations are highly utilized. If we assign the equipment with the highest utilization to be the CCR and based on this CCR to make all plans, the issue of bottleneck shifting will be occurred. Hence, multiple CCRs are suggested and can be the equipment with the utilization rate being higher than the predefined value.
2) *Calculate capacity consumption rate of CCRs by new and old generational products*
   Because the new/old generational products will be processed by the same equipment, the

capacity consumption rate should be decided for the calculation of migration plan. The equations are show as follows.

$$CR_M = \frac{C_{O_M}}{C_{N_M}} \quad (1)$$

$$C_{N_M} = \sum_{q=1}^{x} R_{N_q} \sum_{i=1}^{n} PT_{iN_qM} \quad (2)$$

$$C_{O_M} = \sum_{k=1}^{y} R_{O_k} \sum_{j=1}^{m} PT_{jO_kM} \quad (3)$$

$$R_{N_q} = \frac{\lambda_q}{\sum_{k=1}^{x} \lambda_k} \quad (4)$$

$$R_{O_k} = \frac{\lambda_k}{\sum_{l=1}^{y} \lambda_l} \quad (5)$$

Where

CR_M : The capacity consumption rate of new to old generational product in CCR M

C_{N_M} : The average required capacity for the new generation product in CCR M

C_{O_M} : The average required capacity for the old generation product in CCR M

R_{N_q} : The ratio of product q in new generational products

R_{O_k} : The ratio of product k in old generational products

λ_p : Arrival rate of product p

PT_{iN_qM} : The ith processing time of product q in CCR M

PT_{jO_kM} : The jth processing time of product k in CCR M

3) Compute the reducing quantity of old generational products

Based on the capacity consumption rate, the reducing quantity of old generational products can be calculated by the following equation.

$$\Delta Q_O = Q_N \times CR_M \quad (6)$$

Where

ΔQ_O :The reducing quantity of old erational products

Q_N :The required quantity of new erational products

4) Release new and old generational products by uniform distribution

Step 3. Apply X-factor to pre-schedule all production processes

In this step, the concept of X-factor will be applied to schedule all production process including WIP and new release products, and calculate the loading of CCRs in all time periods. The definition of X-factor is as equation (7) and it has to be defined by new/old generational products and equipment. Regarding to the detailed calculation equations of workstations for the wafer fabrication, please refer to Tu, Lu and Chang (2009).

$$X - Factor_m = \frac{CT_{pm}}{RPT_{pm}} \quad (7)$$

Where

CT_{mp} : The cycle time of product p in equipment m

RPT_{mp} : The raw processing time of product p in equipment m

Step 4. Plan equipment retrofit schedule

In order to fulfill the manufacturing requirements of new generational products, some kinds of equipment should be retrofitted. During the equipment refurbishment period, it cannot work and the capacity will lose. Furthermore, it may hurt the factory throughput if the loss belongs to the bottleneck machine. In this step, the equipment loading from schedule result of step 3 has to apply to compare to the provided capacity. The equipment retrofit can be scheduled when the loading is under capacity.

Step 5. Come back to step 2 and recalculate X-factor when the product mix of new/old generational products changed.

3 SHOP FLOOR CONTROL MODULE

Regarding to the shop floor control, there are two control mechanisms to control and monitor the migration process including real time control and predicting control module.

3.1 Real Time Control Module

Generally, WIP status is an important and sufficient information to reflect the production situation. If WIP level in front of workstation is too high, it reveals the capacity of this workstation is insufficient or there is something wrong in dispatching. Contrarily, low WIP level indicates some problems occurred in upstream workstations or wrong dispatching. Both situations cannot achieve the target of plan. In the real time control module, actual WIP level is taken as an indicator to judge the rescheduling mechanism should be launched or not. The buffer management concept of TOC is applied to control CCRs. Besides, the queuing theory and the capability of factory management are used to define the high and low control limits. When WIP level is over these limits, the response module will be triggered. The control limits are defined as the following equations.

$$HL_j = (\lambda_j \times P(W > 0) \times EW_j) \times (1 + \alpha) \quad (8)$$

$$LL_j = (\lambda_j \times P(W > 0) \times EW_j) \times (1 - \alpha) \quad (9)$$

$$P(W > 0) = \eta \times EW_j \quad (10)$$

$$\eta = 2m_j (1 - \rho_j) / (C_{aj}^2 + C_{sj}^2) \quad (11)$$

$$EW_j = \frac{C_{aj}^2 + C_{sj}^2}{2} \times \frac{\tau_j (\rho_j^{\sqrt{2m_j+1}-1})}{m_j (1 - \rho_j)} \quad (12)$$

Where

λ_j : Arrival rate of workstation j

m_j : Parameter of capability of factory management（0~1）

EW_j : Expected waiting time of workstation j

C_{sj} : Number of machines for workstation j

ρ_j : Utilization rate of workstation j

C_{aj}^2 : Squared coefficients of variation (SCV) of inter-arrival time of workstation j

C_{sj}^2 : SCV of service time of workstation j

3.2 Predicting Control Module

As mentioned above, the real time control module is based on current shop floor information to diagnose the plan can be achieved or not. However, current shop floor status is the execution result. If the result is far away from the plan, the most possible action is to revise the plan. It seems behinds manager's expectation. Therefore, a predicting control function is needed in the shop floor control module. In predicting control module, a foresee function will be performed which will trigger the response module when the bias between loading and capacity curves is over the predefined deviation tolerance (DT). The major task of the foresee function is to predict the production situation in the future. The deterministic simulation is applied to this function. Based on the deterministic simulation, the loading curves of CCRs by time can be defined. As to the capacity curves of CCRs, they can be derived from current capacity, the move-in schedule of new generational equipment and equipment retrofit plan. Fig. 3 is an example of equipment capacity curve and loading curve. Besides, as everyone knows that the accuracy of prediction will decrease as the time increasing. Therefore, the time factor should be considered into the bias tolerance. The equation for defining the deviation tolerance is as follows.

$$DT = \beta \times n \times C_n \quad (13)$$

Where

β : Parameter of capacity deviation

n : The time period

C_n : The capacity of period n

4 CONCLUSIONS

Technology migration is imperative for semiconductor manufacturing, particularly for DARM industry. The migration of technology will result in dramatic decreases in manufacturing cost and significantly increases competitive advantage. Nonetheless, how to guarantee a smooth and successful migration is very crucial. Therefore, the solution of the production planning and control of technology migration for DRAM industry is proposed in this work. There are two major modules developed in this model, one is production planning and the other is shop floor control. The production planning module is based on the output plan of new generational products to come out the wafer start schedule of new/old generational products, equipment retrofit schedule and move-in schedule of new generational equipment. The shop floor control module includes three sub-modules, real time control, predicting control and response module. Through the shop floor control module, the execution can be monitored and controlled to meet the plan target.

Regarding to the future works, the response module can be enhanced. An ideal response module should provide the detailed action items instead of direction when the abnormal situation occurred. Therefore, an intelligent system should be set up in this module.

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附 錄 四

Model to Plan and Control the Generational Transition of DRAM Industry

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Model to Plan and Control the Generational Transition of DRAM Industry

Ying-Mei Tu[1, a] and Tun-Hao Hsu[2,b]

[1]Dept. of Industrial Management, Chung Hua University, HsinChu City, Taiwan, 300

[2]Dept. of Industrial Engineering and Management, National Chiao Tung University, HsinChu City, Taiwan, 300

[a]amytu@chu.edu.tw, [b]andy.hsu98@gmail.com

Keywords: DRAM, Generational Transition, TOC, Workload Ratio

Abstract. DRAM industry is not only among the largest manufacturing industries in the world, but also the most competitive. Furthermore, due to DRAM business is characterized by short life cycles, along with highly competition, the manufacturers are forced to migrate to advanced technology quickly. Under this circumstance, the manufacturers have to launch new technology and purchase generational equipment to meet the market demand and reduce manufacturing cost frequently.
This paper investigates the technology generational transition of DRAM industry from manufacturing and planning perspectives. The concept of TOC is applied to schedule the production plan of the new/old products. Regarding to shop floor control, three definitions of cycle time are used to diagnose the production status. Finally, the workload ratio of bottleneck is used for the release decision to adjust the rhythm of production.

Introduction

DRAM industry is a capital-intensive, high-tech industry with complicated manufacturing process. Due to the short product life cycle, product generation and technology had been forced to quickly enhance. When new technology emerges, it reveals a lower cost and more effective operation model [1]. Therefore, manufactures have to launch new technology and retrofit generational equipment to meet the market demand and reduce manufacturing cost. Besides, as the characteristic of DRAM, the objective of production plan is to maximize the shipment. Consequently, "make to stock" is the general production type. The target of production will be guided to maximize the utilization of equiment to increase the total output. It will make more profit for the comany in the uptrend. However, when the supply exceeds the demand or the technology migrates quickly, this production mode will result in some issues, such as the difficulties of production scheduling, a fault of bottleneck identification and cycle time out of control. After the financial crisis in 2008, DRAM industry is coming to the micro-profit era with quick evolution of product generation. Under such a circumstance, DRAM manufacturing company should phase in new generation technology and phase out the current technology rapidly, otherwise, the company will get into plights. Therefore, a planning and control model to expedite the process of technology generational transition with low inventory and cost is very important.

There are many researches about the methods for production planning and shop floor control of semiconductor manufacturing had been proposed. Queuing theory, linear programming and mean value analysis are usually applied to estimate the capacity requirement of workstations and wafer release quantity[2,3]. Nevertheless, system uncertainty and the risk of investment are not taken into account. Besides, many researches focused on release policy [4,5,6]. Either opened-loop or closed loop policy is based on the normal production situation and does not think of the events of products generational transitions, equipment retrofit and new equipment move-in. According to the shop floor control, many dispatching rules were developed to fulfill the purpose of higher production performance [7,8]. Nevertheless, issues of process migration were not considered either in the release policy nor shop floor control rule. In general, the production system will be more complicated during the technology migration period, such as the instability of products mix, the changes of capacity. Therefore, the proposed methods won't be satisfied the requirements. Moreover, the experiences of semiconductor management showed that the production management will be extremely complicated when there are over three generation products produced in the same time. System performance will be difficult to keep in such a circumstance. Hence, an efficient and effective planning and control model for a varied system can not only solve the technology generational transition issues but also be applied to the foundry with multiple generational products.

Production Plan for Generational Transition

Generally, production planning of technology generational transition should consider the planning result of high-level strategy, such as the start time of migration, output target of new technology…etc., to set the migration tempo and capacity switching schedule. Nevertheless, the uncertainties and dynamic factors of shop floor (ex: machine breakdown, schedule delay for new generational equipment…etc.) can't be taken into consideration in the high-level strategy. Besides, the high-level decision is based on the prediction of technology roadmap, there will be some changes between the setup of high-level strategy and the execution of migration process. In order to guarantee a smooth and successful migration process, a robust and effective production planning and control model of shop floor for technology migration is very important.

The five steps of Theory of Constraints (TOC) are applied to make the release plan and capacity plan. The details are as follows.

Step 1. Identify the constraint

Generally, the most expensive equipment will be taken as the capacity constraint resource (CCR) in semiconductor manufacturing. As this aspect, the immersion scanner will be the CCR and taken as the bases to arrange the release plan of new/old products.

Step 2 - Exploit the constraint- calculate the release mix of new/old products

In order to fully utilize the constraint, the release schedule of new/old products should be well planned. There are two kinds of information have to prepare in advance, the release plan of new generational equipment and the cycle time information of new products. The release plan of new generational equipment comes from the planning result of high-level strategy. However, there is no any historical data for the cycle time information of new products. Therefore, X-factor is applied to estimate the cycle time data. The following is the procedure for release schedule.

Step 2.1. Calculate the monthly production quantity of bottleneck for new product

The monthly production quantity of bottleneck machine will be the total available hours to divide by the summation of processing time of new product.

$$CP_M = \frac{D\times H \times EQ \times U \times E}{\sum_{i=1}^{n} PT_i} \times P \tag{1}$$

$$CP_D = \frac{CP_M}{D} \tag{2}$$

In these equations, CP_M means the monthly production quantity of bottleneck machine. D is the days per month; H is hours per day; EQ means the equipment quantity of bottleneck machine; U represents the uptime of bottleneck machine; E is the efficiency of operations; PT_i represents the processing time of the *ith* traveling the bottleneck and there is n times to travel to the bottleneck. Finally, P means the pieces of wafer per lot. The daily release quantity, CP_D, can be easily get from the monthly production quantity dividing by the days per month.

Step 2.2. Decide the monthly production quantity of old product

As mentioned above, the monthly output target will be plan by high level production plan. Therefore, when the monthly production quantity of new product is decided, the quantity of old product can be calculated by total monthly output subtracting the quantity of new product.

Step 2.3. Schedule the release plan of new/old products

The release date of new/old products can be scheduled just offsetting the schedule out date by the cycle time of product.

Step 3 - Subordinate to the constraint.

All workstations should be investigated their workloads of the planning horizon to make sure the feasibility of the schedule in Step 2. In order to calculate the workload, the current WIP and release schedule products within the planning horizon should be pre-scheduled by penetration rate of products. If there is any workstation overloaded, an alternative solution should be proposed.

Step 4 - Elevate the constraint.

In the transition period, the step 1 to 3 should be repeated continuously until the system reaching a point where the bottleneck has been exploited or squeezed to its maximum. At this point, the new equipment is invested, and this as known as "elevation" of the constraint.

Step 5 - Do not let Inertia become the constraint.

Once the constraint has been elevated, the constraint will move to a new point in the system! The system therefore cannot be managed the same way as before and Step 1 must be revisited.

Shop Floor Control System for the Generational Transition Process

There are two modules, cycle time control and production rhythm control, proposing in the shop floor control system to well manage the production process in the transition period.

Cycle Time Control Module

Cycle time is one of the key factors of the competition, especial for semiconductor industry. Meyerdorf &Yang [9] mentioned that there are at least two critical issues caused by long cycle times. First, the long cycle times will lead to the detection of the faults and error in process or equipment protracted. Second, the long cycle times will result in the low yield. Therefore, to well manage the product cycle time is very important for shop floor control. Generally, there are three kinds of definition for cycle time, output cycle time, in line cycle time and turn rate cycle time.

Output cycle time:

The output cycle time is the total time that a product stayed in a fab and can be calculated by the release date subtracting from the output date. Actually, it is a result of production and can be regarded as a past performance index. From this index the managers can realize the production performance and find out the deviation of dispatching system. The output cycle time is calculated by the following equation. Where F means the output date, I is the release date and B represent the days in bank.

$$CT_o = F - I - B \quad (3)$$

In line cycle time:

The in line cycle time is the summation of the daily average cycle time of all workstations which includes the processing time, transportation time and queue time of the workstations. This index is a result of daily operations. Therefore, it can be taken as a present performance index and be reviewed and find out the operation issues in time. The formula is as follows. Where n is the total process steps, PT_i is the processing time of step i, TT_i means the transportation time of step i and QT_i is the queue time of step i.

$$CT_I = \sum_{i=1}^{n}(PT_i + TT_i + QT_i) \quad (4)$$

Turn rate cycle time:

The turn rate cycle time is the product cycle time which is estimated by process turn rate. It is a forecast data and can be regarded as a future performance index. Based on this index, we can judge that if the move quantity and WIP level of workstation still under control. The equation of the index is as follows.

$$CT_{TR} = \frac{n}{TR} = \frac{WIP \times n}{Move} \quad (5)$$

Production Rhythm **Control Module**

The rhythm of production is very important for shop floor control. As everyone knows, bottleneck is the constraint of factory throughput. Based on the concepts of TOC, all non-bottlenecks should subordinate to the bottleneck's needs, ensuring the bottleneck is able to focus on doing only what it is meant to. Therefore, all operations should subordinate the rhythm of the bottleneck to release the wafer to fab. The following is the procedure for wafer release control.

Step 1. Calculate the bottleneck loading from daily plan release

The bottleneck loading comes from the daily release wafer will be the multiplying result of the daily release quantity (*P*), the standard cycle time from the release to *ith* traveling bottleneck *m* (CT_{mi}) and the processing time of bottleneck (PT_{mi}). The equation is as follows.

$$S_{CCRm} = \sum_{i=1}^{n}(P \times CT_{mi} \times PT_{mi}) \quad (6)$$

Step 2. Calculate the bottleneck loading from actual WIP

The bottleneck loading comes from the actual WIP can be calculated by the multiplying of the summation of WIP loading (A_{mi}), and the processing time of bottleneck (PT_{mi}). The WIP is the WIP quantity located at *j* point multiplying by the standard cycle time from *j* to *ith* traveling bottleneck m. The equation is as follows.

$$A_{CCRm} = \sum_{i=1}^{n}(A_{mi} \times PT_{mi}) \quad (7)$$

Step 3. Make a decision of wafer release

The workload ratio (WR) is defined as S_{CCRm} divided by A_{CCRm}. If WR is greater than one, the decision of stop release will be executed, else, follow the original release plan.

Conclusions

Technology generational transition is an important process for DRAM industry. If there is no any special planning and control methodology designed for the transition process, it will suffer many difficulties. In this work, the concept of TOC is applied to schedule the production plan of the new/old products. Regarding to shop floor control, three definitions of cycle time are used to diagnose the production status. Finally, the workload ratio of bottleneck is used for the release decision to adjust the rhythm of production.

Acknowledgements

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行政院國家科學委員會補助國內專家學者出席國際學術會議報告

101 年 8 月 10 日

附件三

報告人姓名	杜瑩美	系所 職稱	工業管理系 教授
會議 時間 地點	自 101 年 7 月 28 日至 101 年 7 月 31 日 Rome, Italy	本校核定 補助字號	NSC 100-2628-E-216-002-MY2
會議 名稱	（中文）第九屆控制、自動化及機器人資訊學國際學術會議 （英文）**The 9th International Conference on Informatics in Control, Automation and Robotics (ICINCO)**		
發表 論文 題目	（中文）DRAM 產業技術移轉之生產與規劃模式 （英文）**Production Planning and Control Model of Technology Migration for DRAM Industry**		

報告內容應包括下列各項：

一、參加會議經過

The 9th International Conference on Informatics in Control, Automation and Robotics (ICINCO) was hold in Rome, Italy. The purpose of this conference is to bring together researchers, engineers and practitioners interested in the application of informatics to Control, Automation and Robotics. Four simultaneous tracks will be held, covering Intelligent Control Systems, Optimization, Robotics, Automation, Signal Processing, Sensors, Systems Modeling and Control, and Industrial Engineering, Production and Management. Informatics applications are pervasive in many areas of Control, Automation and Robotics; This conference intends to emphasize this connection. Besides, there were four keynote speeches and three special sessions. It is really a wonderful conference.

In the conference, I presented the paper entitled "Production Planning and Control Model of Technology Migration for DRAM Industry". The topic is based on the practice point of view to define the complete wafer release schedule and apply X-factor to schedule the production processes during the migration period. Therefore, the topic attracted the attention of attendants. In addition, some other topics about management have been presented and they were all impressed me very much.

二、與會心得

The conference will serve as an important forum for the exchange of ideas and information to promote understanding and cooperation among the engineering and management. There are four special speeches, **"Recent Advances in Physical Human-Robot Interaction", "Resilience of Dynamical Transportation Networks", "Optimization in Design of Automated Machining Systems"** and **"Space Robotics - Guidance, Navigation and Control Challenges"** presented in the conference. They all impressed me very much. Due to this conference was hold in Italy, there were some of authors came from Europe's Universities. It is a good chance to exchange the ideas and teaching experiences from different area. In the finally, I would like to thank the budgets support from National Science Council.

三、考察參觀活動(無是項活動者省略)

None.

四、建議

None.

五、攜回資料名稱及內容

1. Conference Program :
   The 9th International Conference on Informatics in Control, Automation and Robotics (ICINCO 2012)
2. CD of the proceedings.

六、其他

None

Production Planning and Control Model of Technology Migration for DRAM Industry

Ying-Mei Tu
Department of Industrial Management, Chung Hua University, Hsin Chu,Taiwan, R.O.C.
amytu@chu.edu.tw

Keywords: Technology migration, DRAM industry, X-factor, Production planning and control.

Abstract: Due to product life cycle has been shortened rapidly, it forces the product generation and technology should be enhanced quickly. When technology generation change occurred, DRAM manufacturers always used the past experiences to handle the change process. However, the issues are totally different and it made the companies suffered many difficulties. In this work, a production planning and control model is developed. The production planning focuses on CCR (Capacity Constraint Resources) to define the complete wafer release schedule and apply X-factor to schedule the production processes during the migration period. Regarding to the shop floor control, there are two control mechanisms to control and monitor the migration process, real time control and predicting control. WIP status is the important factor to decide whether the production planner needs to launch the rescheduling module or not in the real time control portion. Besides, a foresee function is performed by predicting control portion which firing the rescheduling module by the bias between the loading and capacity curves.

1 INTRODUCTION

DRAM industry is a capital intensive, high-tech industry with complex processes. Nevertheless, product generation and technology had been quickly enhanced due to short product life cycle. When new technology emerges, it reveals a lower cost and more effective operation model (Cainarca, 1989). Simultaneously, it also means the current competitive advantages of company will be jeopardized (Hastings, 1994). Under this circumstance, manufactures have to launch new technology and retrofit generation equipment to meet the market demand and reduce manufacturing cost. Chou, Cheng, Yang and Liang (2007) pointed out the technology life cycle of semiconductor manufacturing usually won’t be over three years. Therefore, the semiconductor manufacturers always face the dilemma of new technology migration. Generally, the major competition factor of DRAM industry is the manufacturing cost. That is why the frequency of technology migration is higher than foundries.

When migration occurred, DRAM manufactures always used the past experiences to handle the migration. However, the issues are totally different that caused the manufactures suffered many unknown difficulties. Generally, the production planning of technology migration should take the planning result of high-level strategy into account, such as the start time of migration, output target of new technology…etc., to set the migration tempo and capacity switching schedule. Nevertheless, the uncertainties and dynamic factors of shop floor (ex: machine breakdown, schedule delay for new generation equipment or equipment retrofit…etc.) can not be taken into consideration in the high-level strategy. Besides, the high-level decision is based on the prediction of technology roadmap, there will be some changes and biases between the setup of high-level strategy and the execution of technology migration process. In order to guarantee a smooth and successful migration process, a robust and effective production planning and control model of shop floor for technology migration is very important.

Many researches have proposed some methods for production planning and shop floor control of semiconductor manufacturing. Regarding to the production planning, queuing theory, linear programming and mean value analysis are usually applied to estimate the capacity requirement of workstations and wafer release quantity (Iwata, Y., Taji, K. and Tamura, H., 2003; Walid and Gharbi, 2002; Chou and You, 2001). Nevertheless, the system uncertainty and the risk of investment are not taken into account. Besides, many researches focused on release policy (Glassey, C. R. and Resende, M. G. C., 1998a & 1998b; Wein, 1988, Lou, 1989a &1989b; Spearman, M. L., Woodruff, D. L., and Hopp, W. J., 1989&1992; Bowman, 2002; Hung & Leachman, 1996). Either opened-loop or closed loop policy is based on the normal production situation and does not think of the events of products generation changes, equipment retrofit and new equipment move-in. According to the shop floor control, many dispatching rules were developed to fulfil the purpose of higher production performance (Dabbas & Flowler, 2003; Lee & Kim, 2011; Louw & Page, 2004; Hsieh & Hou, 2006; Hung and Chang, 2002; Uzsoy *et al.*, 1992). Nevertheless, the issues of process migration were not considered either in the release policy nor shop floor control rule. In general, the production system will be more complicated during the technology migration period, such as the instability of products mix, the changes of capacity. Therefore, the proposed methods won't be satisfied the requirements. Moreover, the experiences of semiconductor management showed that the production management will be extremely complicated when there are over three generation products produced in the same time. System performance will be difficult to keep in such a circumstance. Hence, an efficient and effective planning and shop floor control model for a varied system can not only solve the technology migration issues but also be applied to the foundry with multiple generation products.

This paper investigates the technology migration of DRAM industry from manufacturing point of view. In this work, a production planning and control model of technology migration was developed. There are two portions in this model including production planning and shop floor control. The production planning focused on CCR to define the complete wafer release schedule and applying X-factor to schedule the production processes and equipment retrofit during the transition period. Regarding to the shop floor control, there are two control mechanisms to control and monitor the migration process, which are real time control and predicting control module.

2 PRODUCTION PLANNING MODULE

As mentioned above that the migration process has to fulfil the target of high-level strategy. The major decision factors of high-level strategy include the fluctuation of future demand, technology development and company financial situation. The complication and variation of production system are difficult to take into account in the strategy level. Therefore, a robust planning and control model not only can help to a successful migration process but also to find out various migration problems in advance. In production planning module, the major target is to transfer the output targets of new generational products to execution plan. The plan includes the wafer release plan of new/old generational products, the release plan of new generational equipment and equipment retrofit plan. Generally, the placement of new/old generational products will be progressed step by step. Hence, the migration period is divided into several time periods for planning. Furthermore, X-factor is applied to the scheduling process. The following is the procedure of production planning.

Step 1. Set up the time unit

It can be defined as a day, three hours…etc.

Step 2. Plan wafer start schedule

In this step, the wafer start schedule of new/old generational products should be planned by referring the output target of new generational products. Generally, top management will hope to keep the total output of factory as before. However, the manufacturing complexity of new generational products may be higher than old one and it will result to the total output decreasing. Therefore, the total output during migration period should be planned in this step. The sub-steps are as follows.

1) *Identify Capacity Constraint Resources (CCR)*
   Generally, the CCR will be only one of equipment in a factory. However, due to the heavy investment of equipment, several workstations are highly utilized. If we assign the equipment with the highest utilization to be the CCR and based on this CCR to make all plans, the issue of bottleneck shifting will be occurred. Hence, multiple CCRs are suggested and can be the equipment with the utilization rate being higher than the predefined value.
2) *Calculate capacity consumption rate of CCRs by new and old generational products*
   Because the new/old generational products will be processed by the same equipment, the

capacity consumption rate should be decided for the calculation of migration plan. The equations are show as follows.

$$CR_M = \frac{C_{O_M}}{C_{N_M}} \quad (1)$$

$$C_{N_M} = \sum_{q=1}^{x} R_{N_q} \sum_{i=1}^{n} PT_{iN_qM} \quad (2)$$

$$C_{O_M} = \sum_{k=1}^{y} R_{O_k} \sum_{j=1}^{m} PT_{jO_kM} \quad (3)$$

$$R_{N_q} = \frac{\lambda_q}{\sum_{k=1}^{x} \lambda_k} \quad (4)$$

$$R_{O_k} = \frac{\lambda_k}{\sum_{l=1}^{y} \lambda_l} \quad (5)$$

Where

CR_M : The capacity consumption rate of new to old generational product in CCR M

C_{N_M} : The average required capacity for the new generation product in CCR M

C_{O_M} : The average required capacity for the old generation product in CCR M

R_{N_q} : The ratio of product q in new generational products

R_{O_k} : The ratio of product k in old generational products

λ_p : Arrival rate of product p

PT_{iN_qM} : The ith processing time of product q in CCR M

PT_{jO_kM} : The jth processing time of product k in CCR M

3) Compute the reducing quantity of old generational products

Based on the capacity consumption rate, the reducing quantity of old generational products can be calculated by the following equation.

$$\Delta Q_O = Q_N \times CR_M \quad (6)$$

Where

ΔQ_O : The reducing quantity of old erational products

Q_N : The required quantity of new erational products

4) Release new and old generational products by uniform distribution

Step 3. Apply X-factor to pre-schedule all production processes

In this step, the concept of X-factor will be applied to schedule all production process including WIP and new release products, and calculate the loading of CCRs in all time periods. The definition of X-factor is as equation (7) and it has to be defined by new/old generational products and equipment. Regarding to the detailed calculation equations of workstations for the wafer fabrication, please refer to Tu, Lu and Chang (2009).

$$X - Factor_m = \frac{CT_{pm}}{RPT_{pm}} \quad (7)$$

Where

CT_{mp} : The cycle time of product p in equipment m

RPT_{mp} : The raw processing time of product p in equipment m

Step 4. Plan equipment retrofit schedule

In order to fulfill the manufacturing requirements of new generational products, some kinds of equipment should be retrofitted. During the equipment refurbishment period, it cannot work and the capacity will lose. Furthermore, it may hurt the factory throughput if the loss belongs to the bottleneck machine. In this step, the equipment loading from schedule result of step 3 has to apply to compare to the provided capacity. The equipment retrofit can be scheduled when the loading is under capacity.

Step 5. Come back to step 2 and recalculate X-factor when the product mix of new/old generational products changed.

3 SHOP FLOOR CONTROL MODULE

Regarding to the shop floor control, there are two control mechanisms to control and monitor the migration process including real time control and predicting control module.

3.1 Real Time Control Module

Generally, WIP status is an important and sufficient information to reflect the production situation. If WIP level in front of workstation is too high, it reveals the capacity of this workstation is insufficient or there is something wrong in dispatching. Contrarily, low WIP level indicates some problems occurred in upstream workstations or wrong dispatching. Both situations cannot achieve the target of plan. In the real time control module, actual WIP level is taken as an indicator to judge the rescheduling mechanism should be launched or not. The buffer management concept of TOC is applied to control CCRs. Besides, the queuing theory and the capability of factory management are used to define the high and low control limits. When WIP level is over these limits, the response module will be triggered. The control limits are defined as the following equations.

$$HL_j = (\lambda_j \times P(W > 0) \times EW_j) \times (1 + \alpha) \quad (8)$$

$$LL_j = (\lambda_j \times P(W > 0) \times EW_j) \times (1 - \alpha) \quad (9)$$

$$P(W > 0) = \eta \times EW_j \quad (10)$$

$$\eta = 2m_j(1 - \rho_j)/(C_{aj}^2 + C_{sj}^2) \quad (11)$$

$$EW_j = \frac{C_{aj}^2 + C_{sj}^2}{2} \times \frac{\tau_j(\rho_j^{\sqrt{2m_j+1}-1})}{m_j(1-\rho_j)} \quad (12)$$

Where

λ_j: Arrival rate of workstation j

m_j: Parameter of capability of factory management (0~1)

EW_j: Expected waiting time of workstation j

C_{sj}: Number of machines for workstation j

ρ_j: Utilization rate of workstation j

C_{aj}^2: Squared coefficients of variation (SCV) of inter-arrival time of workstation j

C_{sj}^2: SCV of service time of workstation j

3.2 Predicting Control Module

As mentioned above, the real time control module is based on current shop floor information to diagnose the plan can be achieved or not. However, current shop floor status is the execution result. If the result is far away from the plan, the most possible action is to revise the plan. It seems behinds manager's expectation. Therefore, a predicting control function is needed in the shop floor control module. In predicting control module, a foresee function will be performed which will trigger the response module when the bias between loading and capacity curves is over the predefined deviation tolerance (DT). The major task of the foresee function is to predict the production situation in the future. The deterministic simulation is applied to this function. Based on the deterministic simulation, the loading curves of CCRs by time can be defined. As to the capacity curves of CCRs, they can be derived from current capacity, the move-in schedule of new generational equipment and equipment retrofit plan. Fig. 3 is an example of equipment capacity curve and loading curve. Besides, as everyone knows that the accuracy of prediction will decrease as the time increasing. Therefore, the time factor should be considered into the bias tolerance. The equation for defining the deviation tolerance is as follows.

$$DT = \beta \times n \times C_n \quad (13)$$

Where

β: Parameter of capacity deviation

n: The time period

C_n: The capacity of period n

4 CONCLUSIONS

Technology migration is imperative for semiconductor manufacturing, particularly for DARM industry. The migration of technology will result in dramatic decreases in manufacturing cost and significantly increases competitive advantage. Nonetheless, how to guarantee a smooth and successful migration is very crucial. Therefore, the solution of the production planning and control of technology migration for DRAM industry is proposed in this work. There are two major modules developed in this model, one is production planning and the other is shop floor control. The production planning module is based on the output plan of new generational products to come out the wafer start schedule of new/old generational products, equipment retrofit schedule and move-in schedule of new generational equipment. The shop floor control module includes three sub-modules, real time control, predicting control and response module. Through the shop floor control module, the execution can be monitored and controlled to meet the plan target.

Regarding to the future works, the response module can be enhanced. An ideal response module should provide the detailed action items instead of direction when the abnormal situation occurred. Therefore, an intelligent system should be set up in this module.

ACKNOWLEDGEMENTS

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行政院國家科學委員會補助國內專家學者出席國際學術會議報告

102 年 4 月 10 日

附件三

報告人姓名	杜瑩美	系所 職稱	工業管理系 教授
時間 會議 地點	自 102 年 3 月 30 日至 102 年 3 月 31 日 中國 大連	本校核定 補助字號	
會議 名稱	（中文）第四屆製造科學與工程國際學術會議 （英文）the 4th International Conference on Manufacturing Science and Engineering		
發表 論文 題目	（中文） **DRAM 產業製程技術世代轉換之規劃與管控模式** （英文）Model to Plan and Control the Generational Transition of DRAM Industry		

報告內容應包括下列各項：

一、參加會議經過

The 4th International Conference on Manufacturing Science and Engineering was held in Dalian, China. It is the premier forum for the presentation of new advances and research results in the fields of manufacturing science and engineering including advanced manufacturing technology, new materials and advanced materials, new materials and advanced materials, and manufacturing systems and automation**.** The conference will bring together leading researchers, engineers and scientists in the domain of interest from around the world.

In the conference, I presented the paper entitled "Model to Plan and Control the Generational Transition of DRAM Industry". It is based on the practice point of view to develop a model to plan and control the production activities during the technology migration period for DRAM industry. Therefore, this topic attracted the attention of attendants. In addition, some other topics about management have been presented and they were all impressed me very much.

二、與會心得

The conference will serve as an important forum for the exchange of ideas and information to promote understanding and cooperation among the manufacturing science and engineering. Due to this conference was hold in China, there were some of authors came from China's Universities. It is a good chance to exchange the ideas and teaching experiences between Taiwan and mainland China. Besides, the conference arranged a plenary talk for a whole day to present and discuss some better topics. It is a way to make a large discussion for a special topic. In the finally, I would like to thank the budgets support from National Science Council and Chung Hua University.

三、考察參觀活動(無是項活動者省略)

There was one activity been taken during this trip. I visited TSMC China Company Limited. The major purpose of this visiting is to take a look on the e-track system. It is a simple system performs as an AMHS (Automatic Material Handling System). Actually, AMHS is well established in TSMC fabs in Taiwan. It is a complicated system with high invested cost. In other word, the company should not only invest more money but also hire some experts to let this system perform well. However, TSMC China fab creates a good performance just by a simple tool and good management skill. As everyone knows that TSMC owns high technology, well-organized system and good management skill. However, I realized a good management skill can be over the other two factors. Although both Taiwan and mainland China are all Chinese, the cultures are totally different. How to well apply the management skills to get good performance is well be done in this fab. It impressed me very much and provided more evidences for me to tell the students the importance of management skills.

四、建議

The 4th International Conference on Manufacturing Science and Engineering was a large conference and over 100 papers were presented in this conference. As we know that international conference is a good way not only to get new ideas quickly but also to face to face discuss with the authors. Therefore, I suggested that National Science Council and school should encourage and support the teachers and graduate students to attend these conferences. Besides, due to Chung Hua University is a sponsor of this conference, to follow for the future conference hold in Taiwan is very worth and important.

五、攜回資料名稱及內容

1. Conference Program :

    The 4th International Conference on Manufacturing Science and Engineering

六、其他

None

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Model to Plan and Control the Generational Transition of DRAM Industry

Ying-Mei Tu[1, a] and Tun-Hao Hsu[2,b]

[1]Dept. of Industrial Management, Chung Hua University, HsinChu City, Taiwan, 300

[2]Dept. of Industrial Engineering and Management, National Chiao Tung University, HsinChu City, Taiwan, 300

[a]amytu@chu.edu.tw, [b]andy.hsu98@gmail.com

Keywords: DRAM, Generational Transition, TOC, Workload Ratio

Abstract. DRAM industry is not only among the largest manufacturing industries in the world, but also the most competitive. Furthermore, due to DRAM business is characterized by short life cycles, along with highly competition, the manufacturers are forced to migrate to advanced technology quickly. Under this circumstance, the manufacturers have to launch new technology and purchase generational equipment to meet the market demand and reduce manufacturing cost frequently.
This paper investigates the technology generational transition of DRAM industry from manufacturing and planning perspectives. The concept of TOC is applied to schedule the production plan of the new/old products. Regarding to shop floor control, three definitions of cycle time are used to diagnose the production status. Finally, the workload ratio of bottleneck is used for the release decision to adjust the rhythm of production.

Introduction

DRAM industry is a capital-intensive, high-tech industry with complicated manufacturing process. Due to the short product life cycle, product generation and technology had been forced to quickly enhance. When new technology emerges, it reveals a lower cost and more effective operation model [1]. Therefore, manufactures have to launch new technology and retrofit generational equipment to meet the market demand and reduce manufacturing cost. Besides, as the characteristic of DRAM, the objective of production plan is to maximize the shipment. Consequently, “make to stock” is the general production type. The target of production will be guided to maximize the utilization of equiment to increase the total output. It will make more profit for the comany in the uptrend. However, when the supply exceeds the demand or the technology migrates quickly, this production mode will result in some issues, such as the difficulties of production scheduling, a fault of bottleneck identification and cycle time out of control. After the financial crisis in 2008, DRAM industry is coming to the micro-profit era with quick evolution of product generation. Under such a circumstance, DRAM manufacturing company should phase in new generation technology and phase out the current technology rapidly, otherwise, the company will get into plights. Therefore, a planning and control model to expedite the process of technology generational transition with low inventory and cost is very important.

There are many researches about the methods for production planning and shop floor control of semiconductor manufacturing had been proposed. Queuing theory, linear programming and mean value analysis are usually applied to estimate the capacity requirement of workstations and wafer release quantity[2,3]. Nevertheless, system uncertainty and the risk of investment are not taken into account. Besides, many researches focused on release policy [4,5,6]. Either opened-loop or closed loop policy is based on the normal production situation and does not think of the events of products generational transitions, equipment retrofit and new equipment move-in. According to the shop floor control, many dispatching rules were developed to fulfill the purpose of higher production performance [7,8]. Nevertheless, issues of process migration were not considered either in the release policy nor shop floor control rule. In general, the production system will be more complicated during the technology migration period, such as the instability of products mix, the changes of capacity. Therefore, the proposed methods won’t be satisfied the requirements. Moreover, the experiences of semiconductor management showed that the production management will be extremely complicated when there are over three generation products produced in the same time. System performance will be difficult to keep in such a circumstance. Hence, an efficient and effective planning and control model for a varied system can not only solve the technology generational transition issues but also be applied to the foundry with multiple generational products.

Production Plan for Generational Transition

Generally, production planning of technology generational transition should consider the planning result of high-level strategy, such as the start time of migration, output target of new technology…etc., to set the migration tempo and capacity switching schedule. Nevertheless, the uncertainties and dynamic factors of shop floor (ex: machine breakdown, schedule delay for new generational equipment…etc.) can't be taken into consideration in the high-level strategy. Besides, the high-level decision is based on the prediction of technology roadmap, there will be some changes between the setup of high-level strategy and the execution of migration process. In order to guarantee a smooth and successful migration process, a robust and effective production planning and control model of shop floor for technology migration is very important.

The five steps of Theory of Constraints (TOC) are applied to make the release plan and capacity plan. The details are as follows.

Step 1. Identify the constraint

Generally, the most expensive equipment will be taken as the capacity constraint resource (CCR) in semiconductor manufacturing. As this aspect, the immersion scanner will be the CCR and taken as the bases to arrange the release plan of new/old products.

Step 2 - Exploit the constraint- calculate the release mix of new/old products

In order to fully utilize the constraint, the release schedule of new/old products should be well planned. There are two kinds of information have to prepare in advance, the release plan of new generational equipment and the cycle time information of new products. The release plan of new generational equipment comes from the planning result of high-level strategy. However, there is no any historical data for the cycle time information of new products. Therefore, X-factor is applied to estimate the cycle time data. The following is the procedure for release schedule.

Step 2.1. Calculate the monthly production quantity of bottleneck for new product

The monthly production quantity of bottleneck machine will be the total available hours to divide by the summation of processing time of new product.

$$CP_M = \frac{D\times H \times EQ \times U \times E}{\sum_{i=1}^{n} PT_i} \times P \tag{1}$$

$$CP_D = \frac{CP_M}{D} \tag{2}$$

In these equations, CP_M means the monthly production quantity of bottleneck machine. D is the days per month; H is hours per day; EQ means the equipment quantity of bottleneck machine; U represents the uptime of bottleneck machine; E is the efficiency of operations; PT_i represents the processing time of the *ith* traveling the bottleneck and there is n times to travel to the bottleneck. Finally, P means the pieces of wafer per lot. The daily release quantity, CP_D, can be easily get from the monthly production quantity dividing by the days per month.

Step 2.2. Decide the monthly production quantity of old product

As mentioned above, the monthly output target will be plan by high level production plan. Therefore, when the monthly production quantity of new product is decided, the quantity of old product can be calculated by total monthly output subtracting the quantity of new product.

Step 2.3. Schedule the release plan of new/old products

The release date of new/old products can be scheduled just offsetting the schedule out date by the cycle time of product.

Step 3 - Subordinate to the constraint.

All workstations should be investigated their workloads of the planning horizon to make sure the feasibility of the schedule in Step 2. In order to calculate the workload, the current WIP and release schedule products within the planning horizon should be pre-scheduled by penetration rate of products. If there is any workstation overloaded, an alternative solution should be proposed.

Step 4 - Elevate the constraint.

In the transition period, the step 1 to 3 should be repeated continuously until the system reaching a point where the bottleneck has been exploited or squeezed to its maximum. At this point, the new equipment is invested, and this as known as "elevation" of the constraint.

Step 5 - Do not let Inertia become the constraint.

Once the constraint has been elevated, the constraint will move to a new point in the system! The system therefore cannot be managed the same way as before and Step 1 must be revisited.

Shop Floor Control System for the Generational Transition Process

There are two modules, cycle time control and production rhythm control, proposing in the shop floor control system to well manage the production process in the transition period.

Cycle Time Control Module

Cycle time is one of the key factors of the competition, especial for semiconductor industry. Meyerdorf &Yang [9] mentioned that there are at least two critical issues caused by long cycle times. First, the long cycle times will lead to the detection of the faults and error in process or equipment protracted. Second, the long cycle times will result in the low yield. Therefore, to well manage the product cycle time is very important for shop floor control. Generally, there are three kinds of definition for cycle time, output cycle time, in line cycle time and turn rate cycle time.

Output cycle time:

The output cycle time is the total time that a product stayed in a fab and can be calculated by the release date subtracting from the output date. Actually, it is a result of production and can be regarded as a past performance index. From this index the managers can realize the production performance and find out the deviation of dispatching system. The output cycle time is calculated by the following equation. Where F means the output date, I is the release date and B represent the days in bank.

$$CT_o = F - I - B \tag{3}$$

In line cycle time:

The in line cycle time is the summation of the daily average cycle time of all workstations which includes the processing time, transportation time and queue time of the workstations. This index is a result of daily operations. Therefore, it can be taken as a present performance index and be reviewed and find out the operation issues in time. The formula is as follows. Where n is the total process steps, PT_i is the processing time of step i, TT_i means the transportation time of step i and QT_i is the queue time of step i.

$$CT_I = \sum_{i=1}^{n}(PT_i + TT_i + QT_i) \tag{4}$$

Turn rate cycle time:

The turn rate cycle time is the product cycle time which is estimated by process turn rate. It is a forecast data and can be regarded as a future performance index. Based on this index, we can judge that if the move quantity and WIP level of workstation still under control. The equation of the index is as follows.

$$CT_{TR} = \frac{n}{TR} = \frac{WIP \times n}{Move} \tag{5}$$

Production Rhythm **Control Module**

The rhythm of production is very important for shop floor control. As everyone knows, bottleneck is the constraint of factory throughput. Based on the concepts of TOC, all non-bottlenecks should subordinate to the bottleneck's needs, ensuring the bottleneck is able to focus on doing only what it is meant to. Therefore, all operations should subordinate the rhythm of the bottleneck to release the wafer to fab. The following is the procedure for wafer release control.

Step 1. Calculate the bottleneck loading from daily plan release

The bottleneck loading comes from the daily release wafer will be the multiplying result of the daily release quantity (*P*), the standard cycle time from the release to *ith* traveling bottleneck *m* (CT_{mi}) and the processing time of bottleneck (PT_{mi}). The equation is as follows.

$$S_{CCRm} = \sum_{i=1}^{n}(P \times CT_{mi} \times PT_{mi}) \quad (6)$$

Step 2. Calculate the bottleneck loading from actual WIP

The bottleneck loading comes from the actual WIP can be calculated by the multiplying of the summation of WIP loading (A_{mi}), and the processing time of bottleneck (PT_{mi}). The WIP is the WIP quantity located at *j* point multiplying by the standard cycle time from *j* to *ith* traveling bottleneck m. The equation is as follows.

$$A_{CCRm} = \sum_{i=1}^{n}(A_{mi} \times PT_{mi}) \quad (7)$$

Step 3. Make a decision of wafer release

The workload ratio (WR) is defined as S_{CCRm} divided by A_{CCRm}. If WR is greater than one, the decision of stop release will be executed, else, follow the original release plan.

Conclusions

Technology generational transition is an important process for DRAM industry. If there is no any special planning and control methodology designed for the transition process, it will suffer many difficulties. In this work, the concept of TOC is applied to schedule the production plan of the new/old products. Regarding to shop floor control, three definitions of cycle time are used to diagnose the production status. Finally, the workload ratio of bottleneck is used for the release decision to adjust the rhythm of production.

Acknowledgements

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行政院國家科學委員會補助國內專家學者出席國際學術會議報告

102 年 7 月 15 日

附件三

報告人姓名	杜瑩美	系所 職稱	工業管理系 教授
會議 時間 地點	自 102 年 7 月 4 日至 102 年 7 月 7 日 Angers, France	本校核定 補助字號	
會議 名稱	(中文)第十五屆企業資訊系統國際學術會議 (英文) 15th International Conference on Enterprise Information Systems (ICEIS)		
發表 論文 題目	(中文)DRAM 產業製程技術世代轉換決策模式 (英文) Technology Migration Determination Model For DRAM Industry		

報告內容應包括下列各項：

一、參加會議經過

The 15th International Conference on Enterprise Information Systems (ICEIS) was held in Angers, France. The purpose of this conference is to bring together researchers, engineers and practitioners interested in the advances and business applications of information systems. Six simultaneous tracks were held, covering different aspects of Enterprise Information Systems Applications, including Enterprise Database Technology, Systems Integration, Artificial Intelligence, Decision Support Systems, Information Systems Analysis and Specification, Internet Computing, Electronic Commerce, Human Factors and Enterprise Architecture.

In the conference, I presented the paper entitled "Technology Migration Determination Model For DRAM Industry". It is based on the practice point of view to develop a model to determine the best timing of the technology migration of DRAM industry. Therefore, this topic attracted the attention of attendants. In addition, some other topics about IT system development and application have been presented and they were all impressed me very much.

二、與會心得

The conference will serve as an important forum for the exchange of ideas and information to promote understanding and cooperation among the business applications of information systems. The Conference provided a service called "My Program" to give the attendants the possibility to create their own conference program, i.e. the sequence of sessions that you plan to attend. Therefore, the attendants can print-to-pdf the papers and read before the conference. Due to "My Program" service, the discussion about the presentation was very hot even the poster presentation. I think it is not only a good service for the attendants but also for the conference sponsor to host all conference activities. Besides, the conference arranged four keynote speeches: "Agile Model Driven Development", "Semantic and Social (Intra) Webs", "Multi-Perspective Enterprise Modeling as a Foundation of Method Engineering" and "Self-Referential Enterprise Systems and Architecture-based Services Innovation". In the first speech, The keynote proposes agile model-driven development using executable models based on existing standards and tools. He discussed various kinds of models, executable modeling, and how that can be applied in an agile manner. This speech impressed me very much. Finally, I would like to thank the budgets support from National Science Council and Chung Hua University.

三、考察參觀活動(無是項活動者省略)

None.

四、建議

The 15th International Conference on Enterprise Information Systems (ICEIS) was a large conference and over 180 papers were presented in this conference. I received so much information regarding the conference progress and local information before I arrived. It is the first time I feel so warm in a stranger place. There are many procedures regarding the conference holding is worth to learn.

Besides, as we know that the prices of all things are going up including flight fee, local transportation, and accommodation. Therefore, if the conference is taken place out of Asia, the supporting fund is not enough usually. I suggested that National Science Council can base on the conference to decide the amount of supporting fund.

五、攜回資料名稱及內容

1. Conference Program :
   15th International Conference on Enterprise Information Systems (ICEIS)

六、其他

None

Technology Migration Determination Model For DRAM Industry

Ying-Mei Tu[1] and Chao-I Wang[1]
[1] *Department of Industrial Management, Chung Hua University, HsinChu City, Taiwan,300*
amytu@chu.edu.tw, kinki@hotmail.com

Keywords: *Technology migration, DRAM, Technology roadmap, Learning curve.*

Abstract: Due to short life cycle of DRAM industry over the past decade, the product generation and technology migration have to be quickly enhanced. When technology migration occurred, DRAM companies always used the past experiences to proceed with process changes. However, the issues are totally different particularly in the best practice of technology migration that caused the companies suffered many uncertainties. In this work, a model to determine the timing of technology migration is proposed. The model is based on technology roadmap to set the timing of migration under maximum profit condition. A stable growth trend is assumed for market demand to decide the revenue. Furthermore, the time-cost function of new generational equipment and the theory of learning curve are introduced as the factors to determine the manufacturing cost and profit. Consequentially, the best timing is determined with maximum profit.

1 INTRODUCTION

DRAM industry is a capital intensive, high-tech industry with complex processes and technology migration for DRAM manufacturers has been a very challenging aspect and more time consuming. Since there is no any physical capacity expansion over the past 5 years in Taiwan, all DRAM manufacturers were relying more than ever on technology migration to increase supply and reduce cost. Furthermore, product generation and technology had been quickly enhanced due to short product life cycle. When new technology emerges, it reveals that a lower cost and more effective operation model emerged [Cainarca, 1989]. Simultaneously, it also means the current competitive advantages of the company will be jeopardized [Hastings, 1994]. Under this circumstance, manufactures have to launch new technology and retrofit generational equipment to meet the market demand and reduce manufacturing cost. Chou *et al.* pointed out the technology life cycle of semiconductor manufacturing usually won't be over three years and the time of technology generational transition should take about nine months. Therefore, the semiconductor manufacturers always face the dilemma between capacity expansion and new technology migration. Generally, the major competition factor of DRAM industry is the manufacturing cost. That is why the frequency of technology migration is higher than foundries.

There are many researches regarding to the influence of new technology introducing. Chand and Sethi based on the enhancement of process stability by the new generational equipment to plan the replacement of new generation capacity. However, the impacts on the other factors and the lead time of replacement were not taken into account. Cohen and Halperin proposed a method to determine the timing of technology migration which was based on the price changes of new equipment as well as its impact on the cost to find the best timing for migration. Rajagopalan *et al.* combined the above two studies and proposed a capacity planning model under the impact of technology evolution. The linear programming was applied and the concept of timeline was added to the decision of capacity expansion or replacement decisions. Pak *et al.* proposed a methodology of capacity planning which focused on the capacity shortage to plan the capacity requirement and the influence from cost of new technology capacity was taken into account. Furthermore, the sensitivity analysis was applied to determine how sensitive of this plan in the changes of market demand. Chien and Zheng proposed a mini–max regret strategy for capacity planning under demand uncertainty to improve capacity utilization and capital effectiveness in semiconductor manufacturing. Seta *et al*. studied optimal investment in technologies characterized by the learning curve. They emphasized that if the learning process is slow, firms invest relatively late and on a larger scale. If the curve is steep, firms invest earlier and on a smaller scale. It is obvious that most of these researches focused on the market demand to decide the timing of technology migration. However, the market demand is full of uncertainties and hard to handle. Therefore, there will be great difficulty in the practical applications.

The purpose of this work is to propose a model to determine the timing of technology migration. The model is based on technology roadmap to set the timing of migration under maximum profit condition. A stable growth trend is assumed for market demand to decide the revenue. Furthermore, the time-cost function of new generational equipment and the theory of learning curve are introduced as the factors to determine the manufacturing cost and profit. Consequentially, the best timing is determined with maximum profit.

2 TECHNOLOGY MIGRATION DETERMINATION MODEL

The purpose of technology migration is to make more profit for the company. Under the assumption of demand stable growth, the best timing of technology migration is the time which can make the maximum profit for the company. Based on the literature review and market survey, the trend of DRAM unit cost and market price is as Fig. 1. Because the equipment depreciation and product yield is stable under the current production status, the production cost of per giga bit DRAM is almost the same. However, the market price will be dropped off due to the business strategy, new product or technology emerged. The trend of market price can be gotten from history data. Regarding to the unit cost produced by new technology, it will be higher than current mature technology due to the higher price of new equipment and lower yield of production in the beginning. However, the yield will be improved after a period of time and the unit cost also can be dropped off and even lower than the product from current technology. Based on the abovephenomena, it shows that the best timing of technology migration will be occurred between the emerged time of new technology and the next generation technology.

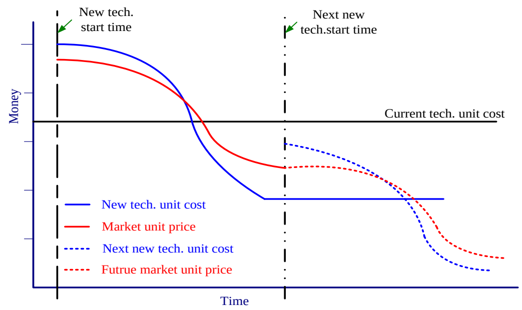

Fig. 1. The relationship between unit cost and unit price of per giga bit DRAM

In order to analyse and establish the model easily, we called the horizon between the emerged time of new technology and the next generation technology as the life cycle of new technology and divided it into n periods. The profit function is established as Eq. 1 and there are three parts, total revenue, total manufacturing cost and the income of equipment disposal, included. The details are described in the follows.

$$TP(t) = (R_{g-1} + R_g) - (\sum_{i=1}^{t-1} (FC_{g-1} + VC_{g-1}) - \sum_{i=t}^{n} (FC_{g,i} + VC_{g,i})) + I_{g-1,t} \quad (1)$$

Where

$TP(t)$: Total profit which the technology migrated from *t* period

t : The time of technology migration

R_j : Revenue of *j* generation technology

$FC_{g,i}$: Fixed cost of *g* generation technology per period which is migrated at *i* period

FC_{g-1} : Fixed cost of *g-1* generation technology per period

$VC_{g,i}$: Variable cost of *g* generation technology per period which is migrated at *i* period

VC_{g-1} : Variable cost of *g-1* generation technology per period

$I_{g-1,t}$: The income from the deposal of *g-1* generation equipment at *t* period

2.1 The Function of Total Revenue

The environment of supply demand balance is an assumption of this work. Therefore, all products can be sold by market price. The total revenue means the revenue of n periods. If the new technology is migrated at t period, the revenue from current technology will be the revenue from period 1 to period t-1 and the revenue from new technology will be from period t to period n. Down below is the equation of current technology revenue andnew technology revenue.

2.1.1 The Revenue from Current Technology

If the current technology is not eliminated after new technology emerged, the current technology is still under production. Because the current technology is under a stable stage, the market price and production quantity of the company will keep almost the same. Therefore, the revenue from current technology is established as follows.

$$R_{g-1} = \sum_{i=1}^{t-1} \left(P_{g-1} \times Q_{g-1,i}\right) \tag{2}$$

Where

P_{g-1} : The average market price of *g-1* generation technology

$Q_{g-1,i}$: The total quantity of *g-1* generation technology at period *i*

2.1.2 The Revenue from New Technology

The calculation of the revenue from new technology is still formula by the price multiplying the quantity. Due to the new technology belonging to the growing stage, the market price and production quantity of the company will be changed by time. Based on the historical data analysis, the market price can be modelled as a Sigmoid function. The output of Sigmoid function is between 0 and 1. Therefore, the managers should forecast the rate of price change and the saddle point of price curve. Besides, the normalization is used to fit the actual DRAM price. Regarding to the production quantity, due to the unfamiliarity of new technology process, the yield of products will be lower in the beginning. After a period of time, the yield can be improved and products quantity will be increased as well. This concept is similar to the learning curve. Therefore, the concept of learning curve is applied to model the production quantity of new technology. The equation of the revenue from new technology is as follows.

$$R_g = \sum_{i=t}^{n} \left(P_{g,i} \times Q_{g,i}\right) \tag{3}$$

$$P_{g,i} = X \times \left(P_{g,Max} - P_{g,Min}\right) + P_{g,Min} \tag{4}$$

$$X = \frac{1}{1 + e^{a(i-T)}} \tag{5}$$

$$Q_i = IQ \times \left(1 - \left(NP_t \times (i - t + 1)^{\frac{log c_1}{log 2}}\right)\right) \tag{6}$$

Where

$P_{g,i}$: The average price of g generation technology at *i* period

$P_{g,Max}$: The maximum price of g generation technology

$P_{g,Min}$: The minimum price of g generation technology

X : The normalization value of Sigmoid function

a : The rate of price change

T : The saddle point of Sigmoid function

Q_i : Production quantity at *i* period

IQ : Release quantity per period

NP_t : The initial failure rate of new technology

c_1 : The learning rate of production failure rate, set by the managers

2.2 The Function of Total Cost

As the characteristics of DRAM industry, the company can get more profit from new generation technology. However, a huge of cost should be paid for new generational equipment behind profit. This cost is called as capacity acquired cost. Therefore, the calculation of production cost can be divided into two part, fixed cost and variable cost. The fixed cost is the cost of equipment for new technology and the depreciation of current equipment. There is no depreciation for the deposal equipment. The variable cost is the expense for the production. The details are as follows.

2.2.1 Fixed Cost of New Technology

Due to the migration to new generational technology, the new generational equipment is required. Generally, the price of new generational equipment will be reduced by time. In this work we assume the price will be linear decreasing. Besides, the required equipment quantity depends on its throughput. Based on these concepts, the fixed cost is formulized as follows.

$$FC_i = (\frac{MP_{g,i} \times x_{g,i}}{m} - RFC_{g-1}) + FC_{g-1} \tag{7}$$

$$MP_{g,i} = MP_{g,0} - D \times (i-1) \tag{8}$$

$$D = \frac{MP_{g,0} - RV_g}{m} \tag{9}$$

$$x_{g,i} = \left\lfloor \frac{C_{g-1} \times x_{g-1}}{C_g} \right\rfloor + 1 \tag{10}$$

$$C_g = MP_g \times CP_g \times ICC_g \tag{11}$$

Where

- $x_{g,i}$: The quantity of generation *g* equipment which purchased at*i* period
- D : The reducing value of equipment per period
- $MP_{g,i}$: The price of generation *g* equipment which purchased at *i* period
- RFC_{g-1} : The fixed cost of generation *g-1* equipment which is disposed at period t
- RV_g : The residual value of generation *g* equipment
- m : Numbers of depreciation period
- C_g : The capacity of generation *g* equipment
- MP_g : The wafer numbers which producing by the generation *g* equipment
- CP_g : The numbers of IC which producing by the generation *g* equipment
- ICC_g : The memory size per die which producing by the generation *g* equipment

2.2.2 Variable Cost of New Technology

Generally, the variable cost of production will decrease as the yield increase. The yield increasing is the result of the mature of co-operating in man-machine and the accumulation of engineer's experiences. Therefore, the variable cost will present same as the concept of manufacturing progress function and it is applied in the formulation of variable cost.

$$\mathrm{VC_{g,i}} = \mathrm{C_t}(\mathrm{i} - \mathrm{t} + 1)^{\frac{\log c_2}{\log 2}} \quad (12$$

Where

- C_t : The variable cost which the migration occurred at *t* period
- c_2 : The learning rate of variable cost, set by the managers

2.3 The Income from the Disposal of Equipment

The equipment which cannot process the new generation technology will be disposed. The income from the disposal of equipment is as the following equation.

$$I_{g-1,t} = MP_{g-1,t} \times y_{g-1,t} \tag{13}$$

Where

- $MP_{g-1,t}$: The price of *g-1* generational equipment at *t* period
- $y_{g-1,t}$: The equipment quantity of *g-1* generational equipment

3 NUMERICAL EXAMPLE

Here, a numerical example is illustrated to demonstrate the modelling and determination process of the proposed model. The environment of this example is a 300mm DRAM fab with 30K wafers per month. The major product is DDRII and 1300 chips per wafer. New generation technology is DDRIII and 1800 chips per wafer. The sales quantity is equal to the production quantity under the assumption of strong market demand condition. Besides, the duration of period is one month and all cost, price and revenue are counted by US dollar. The following is the detailed modelling and determination process. Furthermore, t=8 is assumed for all calculation.

3.1 Total Revenue

3.1.1 The Revenue from Current Technology

Assume the price of current technology is \$0.8 per giga bit and production yield is 0.98. Therefore, the revenue from current technology is as follows.

$$R_{g-1} = \sum_{i=1}^{7} (1.2 \times 1300 \times 30K \times 0.98)$$
$$= 45{,}864{,}000 \times 7$$
$$= 321{,}048{,}000$$

3.1.2 The Revenue from New Technology

Regarding to the price of DDRIII, the data from Aug. 2009 to July 2012 is collected to formula the Sigmoid function. Assume the parameters of Sigmoid function T is 16 and a is 0.3. The maximum and minimum price of DDRIII is 2.5 and 1.2. The price of new technology is as follows.

$$X = \frac{1}{1 + e^{0.3\times(8-16)}} = 0.9168$$

$$P_{g,8} = 0.9168 \times (2.5 - 1.2) + 1.2 = 2.3918$$

Due to the improvement of product yield, the production quantity will increase. Assume the product yield is 0.45 in the beginning of migration and c_1 equals to 0.85. The production quantity of period 8 is calculated as follows.

$$Q_{g,8} = 54{,}000K \times \left(1 - \left(0.55 \times (8 - 8 + 1)^{-0.2345}\right)\right) = 23{,}220{,}000$$

$$a_1 = \frac{\log 0.9}{\log 2} = -0.152$$

The revenue from new technology is as follows.

$$R_g = \sum_{i=8}^{36} (P_{g,i} \times Q_{g,i}) = 1{,}504{,}087{,}017$$

3.2 Total Cost

3.2.1 Fixed Cost

Assume the depreciation for equipment is six years. Three sets of g-1 generation should be replaced and their original cost is 0.1 billion. Total equipment cost of old technology excluding the disposals is 2 billion. The parameters of product by new and old technology are as follows.

ICC_g=1GB, CP_g=1800, MP_g=10000

ICC_{g-1}=1GB, CP_{g-1}=1300, MP_{g-1}=10000

Therefore, C_g and C_{g-1} equals to 18,000,000 and 13,000,000. The new generational equipment quantity can be determined by Eq. 10.

$$x_g = \left\lfloor \frac{13000000 \div 0.98 \times 3}{18000000 \div 0.61} \right\rfloor + 1 = 3$$

Assume the price of new generational equipment is 1 billion per set in the beginning and its residual value is 0.2 billion. Therefore, if the new generational equipment is purchased at period 8, its price is calculated as follows.

$$D = \frac{100{,}000{,}000 - 20{,}000{,}000}{72} = 1{,}111{,}111$$

$$MP_{g,8} = 100{,}000{,}000 - 1{,}111{,}111 \times 7$$
$$= \$92{,}222{,}222$$

Based on the assumptions above, the total fixed cost is calculated as follows.

$$FC_{g,8} = \frac{92{,}222{,}222 \times 3}{72} + \frac{2{,}000{,}000{,}000}{72}$$
$$= 31{,}620{,}370$$
$$\sum_{i=1}^{7} FC_{g-1,i} + \sum_{i=8}^{36} FC_{g,i}$$
$$= 1{,}121{,}157{,}407$$

3.2.1 Variable Cost

Assume c_2 = 0.82, C_t=10,600,000 and $VC_{g-1,i}$=7,141,000

Then $a_2 = \log 0.82 / \log 2 = -0.377069649$

$$VC_8 = 10{,}600{,}000(8 - 8 + 1)^{-0.377069649}$$
$$= 10{,}600{,}000$$
$$\sum_{i=8}^{36} VC_{g,i} = 156{,}956{,}539$$

The following is the calculation of total variable cost.

$$VC = \sum_{i=1}^{7} VC_{g-1,i} + \sum_{i=8}^{36} VC_{g,i}$$
$$= 7{,}141{,}000 \times 7 + 156{,}956{,}539$$
$$= 206{,}943{,}539$$

The total cost is fixed cost plus variable cost.

$$\text{Total Cost} = 1{,}121{,}157{,}407 + 206{,}943{,}539 = 1{,}328{,}100{,}946$$

3.3The Income from the Disposal of Equipment

Assume the disposal equipment has been purchased for 47 months at the time of new technology emerged. Therefore, the total value at the period 8 is as follows.

$$I_{g-1,8} = \left(\frac{\frac{100{,}000{,}000 \times 0.8}{72} \times 17 + 100{,}000{,}000 \times 0.2}{3}\right) \times 3 = 38{,}888{,}888$$

3.4Total Profit

Finally the total profit is as follows if the technology migration occurred at period 8.

$$\begin{aligned} TP(8) = (321{,}048{,}000 + 1{,}504{,}087{,}017) \\ - 1{,}328{,}100{,}946 + 38{,}888{,}888 \\ = 535{,}922{,}959 \end{aligned}$$

Based on the above calculation, the relationship of total profit vs. the migration time t is shown as Fig. 2.

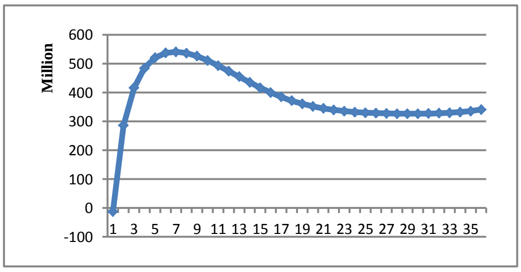

Fig. 2. The relationship between total profit and migration time *t*

The best time for generational transition can be determined as period 7 from Fig. 2.

4 CONCLUSIONS

DRAM industry is a capital intensive, high-tech industry and the product generation has been quickly enhanced. Due to the huge investment for the technology migration, the migration timing is very important for the company. In this work, a model to determine the best timing for the technology migration is established. The maximum profit is the objective to determine the migration time in the model. All revenue and cost of technology migration are considered. We expect this model can be applied in other industries with same situation.

ACKNOWLEDGEMENTS

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國科會補助計畫衍生研發成果推廣資料表

日期:2013/10/17

國科會補助計畫	計畫名稱: 製程技術世代轉換之整合規劃模式-以DRAM產業為例
	計畫主持人: 杜瑩美
	計畫編號: 100-2628-E-216-002-MY2　　　學門領域: 生產系統規劃與管制

無研發成果推廣資料

100 年度專題研究計畫研究成果彙整表

計畫主持人：杜瑩美			計畫編號：100-2628-E-216-002-MY2				
計畫名稱：製程技術世代轉換之整合規劃模式-以 DRAM 產業為例							
成果項目			量化			單位	備註（質化說明：如數個計畫共同成果、成果列為該期刊之封面故事...等）
			實際已達成數（被接受或已發表）	預期總達成數(含實際已達成數)	本計畫實際貢獻百分比		
國內	論文著作	期刊論文	0	0	100%	篇	
		研究報告/技術報告	0	0	100%		
		研討會論文	0	0	100%		
		專書	0	0	100%		
	專利	申請中件數	0	0	100%	件	
		已獲得件數	0	0	100%		
	技術移轉	件數	0	0	100%	件	
		權利金	0	0	100%	千元	
	參與計畫人力（本國籍）	碩士生	0	0	100%	人次	
		博士生	0	0	100%		
		博士後研究員	0	0	100%		
		專任助理	0	0	100%		
國外	論文著作	期刊論文	0	0	100%	篇	
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國科會補助專題研究計畫成果報告自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估 ■達成目標 □未達成目標（請說明，以 100 字為限） 　　□實驗失敗 　　□因故實驗中斷 　　□其他原因 說明：
2. 研究成果在學術期刊發表或申請專利等情形： 論文：□已發表 □未發表之文稿 ■撰寫中 □無 專利：□已獲得 □申請中 ■無 技轉：□已技轉 □洽談中 ■無 其他：（以 100 字為限）
3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）（以 500 字為限） 就本質而論，本計畫之研究成果同時具有實務及學術價值。在實務方面，本計畫成果可提供半導體產業上，不論是 DRAM 製造商或是其他類型之晶圓廠，對於製程世代轉換決策之制定與轉換實行時現場之管控能有一系統化之憑藉；在學術上，本研究發展出以最大化製程世代轉換利潤為依據之轉換決策概念，亦延伸 CCR 限制理論於 DRAM 製程世代轉換現場管控之應用，除此之外本研究亦已將相關研究成果發表於國際學術研討會以及國際學術期刊之中。 本研究之研究成果分述如下： 1. 透過研究所提出之製程技術世代轉換整合規劃模式，可使得經常必須面臨技術世代轉換之 DRAM 製造廠，在面臨製程技術轉換時能更有效率且更為順利。 2. 藉由此決策模式使企業在轉換時依然能夠維持一定之競爭力與獲利水準，避免半導體產業面臨技術轉換時相關不確定性因素所導致之公司損害 3. 經由所發展之整合規劃管理流程，提供擁有在多變環境與高投資風險之其他類似產業因應技術世代轉變時能有一個完整解決架構參考 　前幾年的金融海嘯震驚了全世界，也帶給台灣半導體產業不少的衝擊，在半導體產業之中，唯有不斷的提升製程能力與生產之績效，方能在瞬息萬變的市場中佔有一席之地，因此如何建立與訂立一個可以快速因應市場變動且容易管控之廠區規模，亦或是發展一可含納多個製程技術之建廠管控思維，實為後續相關研究可以進行探討之方向。