行政院所屬各機關因公出國人員出國報告書

赴美日歐參加微光機電系統技術研討會
暨
參訪相關研究機構

出國報告

服務機關：行政院國家科學委員會精密儀器發展中心
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行政院研考會/省（市）研考會
編號欄

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考察行程表

日期	起	至	工作內容	天次
9/17~18 (三)~(四)	台 北	杜賽爾多夫 (德國)	起程	1~2
9/19~20 （五）~(六)	杜賽爾多夫 (德國)		參訪 RAITH 公司	3~4
9/21 （日）	杜賽爾多夫 (德國)	劍橋 (英國)	轉程	5
9/22 25 (一)~(四)	劍橋 (英國)		參加 **MNE' 03** 研討會	6~9
9/26~27 (五)~(六)	劍橋 (英國)	台 北	回程	10~11

摘要

二十世紀後期由於半導體產業及微機電技術興起,製作工藝及元件開發乃至於科學研究皆立足於微米世界上。而接續上個世紀末的微米探索熱潮，本世紀初科學家們再度將目光集中於更精巧且富變化的奈米世界，而有今日奈米科技熱潮的產生。中心長久以來致力於發展微系統類 LIGA 技術，製作並開發相關微元件及製程技術，構築與微米世界溝通的平台。近年來中心則嘗試結合微光學設計與微製程技術，跨入生醫螢光檢測領域，並開發相關的檢測模組。除了生醫微系統技術外，同樣立足於微系統技術的成熟，而逐漸跨入奈/微米工程及檢測的領域中。

為了一窺近年來歐美各國在奈米科技及生醫微系統技術發展的現況,作為中心未來發展方向及策略規劃的參考,特赴英國劍橋參加 2003 年微/奈米工程研討會。此次行程包含：

1. 參訪 Raith 公司

電子束微影系統為製作奈米結構最主要的製程技術之一，Raith 公司長年來發展電子束微影系統，對於相關微影製程技術有長年的經驗，同時亦與歐美各國的研究機構有合作關係。藉由此次參訪，不僅是針對目前中心所建置的 Raith50 電子束微影系統的進階技術開發進行瞭解，更可藉機學習探索目前歐美各國利用電子束微影系統所開發的各種奈米結構之應用。

2. 參加 2003 年微/奈米工程研討會

藉由參加此次研討會，蒐集奈米級微影技術、軟微影技術及生醫微系統技術等領域最新的情報，並考察奈米科技在歐盟各國發展的現況。此外，藉由與與會專家接觸對話，可進一步向各國介紹我國在奈米科技發展，建立未來雙方國際聯繫合作的管道。

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壹、前言

世界上第一部電子束微影系統誕生於西元 1960 年代，發展至今已逾 40 年，傳統的電子束微影系統扮演的是支援積體電路工業的角色，主要的應用市場有三：(1)光罩之製作，如在玻璃上精確定義鉻金屬或 x-ray 光罩之製作等；(2)直寫先進的積體電路原型(prototype)或製作少量的特殊產品，如砷化鎵積體電路(GaAs IC)或波導元件(waveguide)等；(3)輔助積體電路的尺寸限制、量子效應及小尺寸下之物理現象等研究之進行。近幾年來由於奈米科技的蓬勃發展，使得具備製作奈米精度結構的電子束微影系統備受重視。

本中心為配合世界研究潮流與國家科技政策走向，近幾年來亦積極發展包含類 LIGA 微系統加工、奈米表面檢測技術及奈米生醫、微流體等各方面具前瞻性的技術，並於 2002 年底採購建置 Raith 50 電子束微影系統，進一步提升中心在奈米結構製作方面的能力與自主性。配合相關前瞻性研究計畫的進行，如相關光學及生醫方面之應用，未來預計開發包含奈米金屬剝離(lift off)製程、奈米級感應耦合電漿(Inductively Coupled Plasma)矽深蝕刻製程、3D 奈米微影製程及奈米壓模(nanoimprint)等製程能力。

今年度筆者奉派赴德國參訪 RAITH 公司，除與原廠技術人員就目前使用 Raith 50 電子束微影系統遭遇困難處進行密集

討論，亦藉此機會討論更進階功能操作及未來可能應用方向，進一步取得相關資訊並加強本身技術。除參訪德國 RAITH 公司，本次行程亦將赴英國參加 2003 年的微/奈米工程研討會，藉此取得目前歐美各國在微/奈米製程及生物醫學等各方面發展的相關資訊，做為中心目前計畫執行上的參考及未來發展的規劃指標。

貳、出國目的

（一）2003年微/奈米工程研討會

微/奈米工程研討會為微奈米製程技術(尤其是微影方面的相關技術)最重要的研討會，藉由參加本次研討會，一方面蒐集奈米級微影技術、軟微影技術及生醫微系統技術等最新發展，另一方面亦可藉機考察奈米科技在歐盟各國發展的現況。同時與各國專家有機會交流，可進一步向各國介紹我國在奈米科技發展，建立未來雙方國際聯繫合作的管道。

（二）參訪Raith公司

本中心於去年底採購建置該公司的Raith 50電子束微影系統至今已逾半年，除可藉此次機會將這段期間所建立的製程能量與相關人員做相互交流討論外，更重要的是針對中心目前在實際應用上所遭遇的各種問題尋求專業人士的協助與解答。

參、參訪過程

（一）參加 2003 年微/奈米工程研討會

微/奈米工程研討會(Micro and Nano Engineering, 簡稱 MNE)為國際上有關微影技術及奈米結構製程等技術最重要的研討會之一，自 1975 年在英國劍橋開始舉辦以來，今年已是第 29 屆。今年的微/奈米工程研討會於九月二十一至二十四日在創辦地點英國劍橋舉行。本次大會場地設置於 Cavendish Labortary，此實驗室可說是現代科學探索的重鎮，幾項近代科學上重大的發現，如 1897 年 J. J. Thomson 發現了電子、1932 年 Chadwick 發現核子的存在、1953 年 Crick 和 Watson 定義出了 DNA 的結構等。會場同時開放 Cavendish Museum 供與會人士自行參觀，裡面展示了幾項重大發明所使用的儀器設備，以現在的眼光看來未免顯得太過簡陋，然卻愈能提醒參觀者紮根基礎才更能開創新局的觀念。

本次研討會共計約有 220 篇口頭報告及海報張貼論文，此外亦有四場的邀請演講，包含劍橋教授 H. Ahemed 演說"Three decades of micro and nano engineering"，加州柏克萊教授 D. Attwood 介紹極限紫外光(EUV)技術目前發展現況，來自澳洲量子計算技術中心的學者 T. M. Buehler 等人介紹量子計算元件發展現況及未來趨勢，及日本學者 Shinji Matsui 介紹奈米科技在日本的發展現況和經費投入分配等。本次研討會內容相當豐富，包含的主題有

(1) 奈米元件(nanodevices)

主要探討奈米級的電子元件之設計、製作及測試等，主要元件有單電子電晶體、量子點元件及以奈米碳管(carbon nano tube)為基礎的感測器或電子電路。

(2) 圖案轉移(pattern transfer)

探討利用不同蝕刻技術，如 ICP 或濕蝕刻技術製作奈米結構。或是在不同基材上的製程，如矽化鍺(SiGe)。此外，亦有學者發表利用特殊的沈積技術來製作奈米元件。

(3) 生醫微機電系統或實驗室晶片(BioMEMS, Lab-on-a-chip)

包含生醫晶片的製作及設計、檢測技術及化學或生醫感測器之設計製作等。亦有學者提出新的微流體元件設計，如閥門製作及控制或混合器(mixer)等。

(4) 奈米級工程技術(nanoscale engineering)

包含各種奈米結構製作技術，如高能量離子束、X-ray 加工技術、奈米接觸式印刷術(nanocontact printing)及利用原子力顯微鏡(AFM)操控的製作技術等。

(5) 光微影術(photon lithography)

主題包含波長 157nm 的極限紫外光微影技術、模擬的最佳化設計、透鏡像差消除技術及無光罩(maskless)光微影技術等。

(6) 阻劑(resist)

各種新型阻劑的開發及解析度檢驗，或現有阻劑最佳化參數的實驗結果。

(7) 電子束及離子束微影技術(electron & ion beam lithography)

利用電子束微影技術(EBL)或聚焦離子束(FIB)在不同材料上製作微/奈米結構。除了相關應用元計，亦有電子束行為模型等模擬成果發表。

(8) 軟微影技術(soft lithography)

軟微影技術包含步進快閃壓模技術(step & flash nanoimprint)、奈米壓模、奈米印刷及熱壓射出(hot embossing)等技術。本次議題亦包含大面積製程均勻性、對準精度及模仁製作等實用性問題之探討。

(9) 微系統及其製程(microsystem & their fabrication)

所發表的論文包含光子能隙(photonic bandgap)濾波器、三維光子晶體、塑膠雷射(plastic laser)、可調變光衰減器等微機電元件之製作。

(10) 光罩技術(mask technology)

內容包含極限紫外光光罩之製作，及相關金屬鍍膜技術等。

(11) 檢驗、測試及修正(inspection, testing and modification)

發表各項檢測技術及新開發的設備等。

本次研討會投稿論文中，以歐盟各國投稿篇數佔居第一位，除了地緣關係外，亦顯示奈米科技在歐盟各國發展的相當迅速且漸趨成熟。而在亞洲地區方面，以日本的論文數目位居第一，其理由應與奈米級微影及相關製程設備在日本已相當成熟有關。而台灣近年來在產、官、學界積極投入奈米科技的情況下，亦逐漸開花結果，本次研討會台灣亦有 8 篇論文發表，位居亞洲第二，高於鄰近韓國的 4 篇。唯較可惜的是，在台灣所發表 8 篇論文中，僅有 1 篇獲選為口頭報告，其餘皆為海報張貼，因此相較下缺乏與在場專家學者直接對談交流機會，或藉機把台灣的研發成果及能量介紹給歐美各國。

此次研討會內容相當豐富，特別是有關電子及離子束微影及生醫微機電系統等領域，與本中心目前積極投入的計畫有直接相關，可直接與世界上執行此類計畫之專家切磋討論，除瞭解世界研發現況並同時建立國際交流管道。以下茲將幾篇精華論文作一簡單報告，原論文稿件詳見於附件 A 中。

本中心目前積極開發生醫用途的微全分析系統(micro total analysis system, μTAS)，因此對於微流體相關元件的掌控及生物檢體的檢測方式顯得相當重要。在微流體控制元件方面，法國學者提出利用軟性材料如 PDMS 直接製作微流道及閥門，利用氣壓方式控制閥門可導引流體流動，並使流體中的分子作混合的動作，相關的設計及製程可作為中心未來在設計類似微流體晶片時之參考。在檢測技術方面，瑞士學者利用介電泳的方式，配合指狀電極陣列以調整頻率的方式，篩選並偵測附著在電極上的分子；德國研究人員則是利用平行電容板的方式，當生物分子附著於電容板上時會改變系統的阻抗，可藉由量測阻抗改變來判定分子濃度。另一組瑞士學者則是利用 AFM 探針在基板表面上局部區域產生電荷，由於蛋白質分子在溶液中亦帶有電性，而可選擇性地沈積在基板上，藉由標定螢光分子來檢測蛋白質濃度。

除了生醫微系統外，奈米軟微影技術及成果在本次研討會中亦備受各界關注。其中美國研究團隊發表的翻轉奈米壓模技術，可將奈米圖案印製在非平坦表面上，且可達成三維奈米圖案的印製，與會人士均表達高度興趣；日本學者提出一新的模仁設計，即在石英模仁上多加一道金屬遮蔽層，可避免壓模曝光後殘餘阻劑(residual resist)的問題，然目前只進行到模擬階段，未來應注意是否有新的實驗數據出爐；其他相關論文焦點多落在奈米壓模結果的均勻度及高精度模仁的製備上，亦是中心未來發展奈米壓模

製程時必須深入考量的問題。

在研討會進行的同時也有為期三天的廠商展覽，包含製程設備廠商如 Alcatel、 SUSS MicroTec、EV Group、Lecia Microsystem Lithography；電/離子束設備廠商如 Raith、JEOL；奈米壓模設備廠商如 Molecular Imprints 和 Obducat ；軟體設計廠商 Munror 及書籍出版商 Elsevier 等。筆者同時也蒐集有關 FIB 與 奈米壓模等廠商資料，供中心未來執行及規劃核心奈米製程技術之參考。相關文件詳附於附件 B 中。

（二）參訪德國 RAITH 公司

德國 RAITH 公司創立於 1980 年，主力團隊來自劍橋儀器公司(Cambridge Instrument)，基本發展方向為開發與二次電子顯微鏡(Second Electron Microscope)系統相關的各種特殊應用。為了實現此一構想並順利切進電子束微影系統的市場，RAITH 公司從 1985 年起陸續開發了各種相關模組，其中包含大工作行程且高精度的雷射干涉式定位平台(laser interferometer stage)、單一軟體操作平台(one software platform)及三維微影計算轉換程式等。由於相關技術的實用性及市場定位策略的成功，RAITH 公司已成為目前世界上以二次電子顯微鏡系統為基礎的電子束微影系統(SEM based E-beam Lithography)及缺陷檢驗(Defect Review)的市場領先者。

Raith 總公司位於德國多特蒙 (Dortmund) 工業園區內，筆者於九月十九及二十日至 Raith 公司進行參訪行程，此行除拜會該公司總經理 Dr. Ralf Jede 外，並藉機與各部門工程師們就中心所建置的 Raith 50 EBL 系統使用情形與應用開發等方面，作充分的意見與資訊交流。期間與應用工程人員討論目前在實際應用上所遭遇的問題，獲得不少回應及提示；由製程開發人員展示新一代電子束微影系統 Raith 200A 及 DP 系列，其新增加之晶片自動載入後的水平調整功能及全防震桌的設計，對於製程均勻性有很大的幫助，可作為中心未來進行大面積直寫之參考。此外，新系統亦包含低加速電壓影像模式，可檢測如生物檢體等一般較難用 SEM 觀察之試片；業務人員亦介紹其聚焦離子束系統開發現況，針對市場定位及競爭優勢進行說明，其相較於一般商品化系統最主要的突破為離子束直徑可小至數個 nm。此外筆者亦藉此機會提出系統維護標準程序(maintain SOP)建立及直寫速度提昇等建議，獲得該部門主管許諾將進行問題彙整及檢討；在化工人員的陪同下參觀其精巧且管理良好的無塵室，除獲得不少新型阻劑資訊外，相關實驗技巧如實驗時如何維持顯影液的恆溫及試片標示項目和方式等，令筆者獲益不少。有關 Raith 公司相關文件，謹詳附於附件 C 中。

肆、達成之任務

(一) 觀察奈米科技在歐盟之發展現況，供國內參考

本次研討會舉辦地點在英國劍橋，發表論文數目最多的亦屬歐盟各國。藉由參加本次研討會，可看出歐盟各國在奈米科技領域上的發展相當寬廣且迅速，其所發表之論文在各個領域呈均勻分佈。除了藉由文章發表外，與會期間藉由與各地專家相互交流，亦可增進對其發展現況之了解。相關訊息的蒐羅，可作為國內及中心在研發走向上之參考。

(二) 考察英、德兩國之民間企業在奈米科技中如何扮演關鍵角色

在本次研討會中，可看出在歐洲各國及日本，皆存在著民間企業與學術研究界互相合作的模式。如在目前最熱門的奈米壓模領域，由於此屬一先進科技，相關製程設備尚未達可量產的地步。因此民間公司通常會提供開發中的機台給某個大學或研究室進行一些較為細節的研究(如參數調整及均勻性等)同時驗證機台性能以回饋給民間公司，彼此合作可加速研究之進展及培植產業形成。此一模式相信可供國內做為參考，在台灣地小且資源有限的情況下，產學界互相合作才能奠定良好基礎，加速研究進程。

(三) 建立國際聯繫合作管道

藉由參與本屆微/奈米工程研討會及至德國參訪 Raith 公司，一方面藉由當面接觸交流，加強彼此了解；另一方面也藉此機會邀請國外專家學者參訪台灣，建立彼此未來如有機會合作時的聯繫管道。

(四) 介紹我國奈米科技的發展

本次研討會期間，在各場次間的休息時間及中午的用餐時間，有多次機會與各國的學者專家交談，亦藉此機會介紹我國目前奈米科技發展的情形，及中心目前既有的技術和未來發展的方向，提升外國學者專家之興趣，強化未來合作之契機。

伍、心得與建議

（一）本研究室生醫及奈米技術發展之建議

目前奈米技術研究室發展的幾個主軸：生醫檢測系統、微/奈米光學及微/奈米製程技術平台等，皆與國際上研究趨勢及熱潮相符合。然而藉由本次出國考察歐洲各國發展現況，發現到國外研究團隊多以彼此合作競爭的方式進行先期型的尖端研究，對於相較而言資源較為貧乏的台灣而言，若想在科學研究乃至技術方面超越世界水準，合作便成為必經的途徑。往後的研究開發，若能以奈米技術研究室近幾年來所奠基的技術能量為基礎，尋求學、業界共同參與應用開發及提供若干協助，藉由互相交流回饋而激盪出更新的概念，建立團隊合作的模式。如在生醫檢測系統開發過程中，若能與國內醫學單位密切合作，相信能大大縮減在相關領域摸索的時間，且能更貼切的知道應用端的需求，為中心所發展的生醫檢測系統尋求更強而有力的展現載具。

（二）對近年研發方向與成果感想

近年中心研究方向由微系統技術持續深入開發奈米製程技術，且一方面亦結合過去中心在光學設計模擬方面的長才，藉由開發生醫光學檢測平台而逐漸的跨入生醫應用領域。這樣的發展途徑，可說是伴隨著世界研發潮流而持續前進，過去中心在微系

統類 LIGA 製程方面開發的成果，不僅在國內獨占鰲頭，亦可與國外知名的研究機構分庭抗禮。若能立足於這樣優良的基礎，趁目前奈米科技正在起飛發展的階段時，捉住適當的方向切入，或能晉身國內外的研究最尖端之列。

（三）感謝

感謝主任及組長給予筆者此次出國參訪的機會，同時亦要感謝研究室的同仁們在筆者出國期間所給予的相關協助及分擔工作，一併藉此機會表達感謝之意。

附件 A

MNE 論文摘要

Tuesday 23 September 2003

BioMEMS, lab-on-a-chip 1 **Room 1A (West)**

Session Chair:

14:00
BM_01
Concept of a biochemical microassay platform based on dielectrophoresis-controlled adhesive immobilization of functionalized beans on a chip
J. Auerswald[1], V. Linder[2], H.F. Knapp[1]
[1]CSEM S.A., Alpnach, Switzerland
[2]Current Address: Harvard University, Department of Chemistry and Chemical Biology, Cambridge, MA

14:20
BM_02
Development of impedance biosensor arrays for analytical measurements
A. Malavé, M. Tewes, I. Stoyanov, E. Quandt, M. Löhndorf
Center of advanced european studies and research (caesar), Bonn, Germany

14:40
BM_03
Nanoelectrochemical transducers for (bio-)chemical sensor applications fabricated by nanoimprint lithography
M. Beck, P. Carlberg, F. Persson, M. Graczyk, I. Maximov, T.G.I. Ling, L. Montelius
Division of Solid State Physics & The Nanometer Consortium, Lund University, Sweden

15:00
BM_04
Biological lithography: DNA microarrays fabrication and DNA synthesis model
C. Kim, M. Li, A. Lowe, K. Richmond, M. Rodesch, M. Patel, N. Venkataramaiah, J. Kaysen, F. Cerrina
Center for Nanotechnology and ECE Department, University of Wisconsin, Madison, WI

15:20
BM_05
Selective protein deposition via local surface charges
N. Naujoks, A. Stemmer
Nanotechnology Group, Swiss Federal Institute of Technology Zurich, Zurich, Switzerland

15:40
BM_06
NIL structured surfaces for biological applications
P. Carlberg[1], R. Bunk[1], F. Johansson[1], I. Maximov[1], M. Kanje[2], A. Månsson[3], L. Montelius[1]
[1]Department of Solid State Physics & The Nanometer Consortium, Lund University, Sweden
[2]Department of Cell and Organism Biology, Lund University, Sweden
[3]Department of Chemistry and Biomedical Sciences, University of Kalmar, Sweden

Concept of a Biochemical Microassay Platform Based on Dielectrophoresis-Controlled Adhesive Immobilization of Functionalized Beads on a Chip

Janko Auerswald[1], Vincent Linder[2] and Helmut F. Knapp[1]
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Microfluidic lab-on-a-chip systems targeting at biological, chemical and medical diagnostic applications offer competitive advantages such as less consumption of expensive reagents, small sample volumes, the controlled microhandling of tiny objects like cells or molecules and less turn-around time (point-of-care devices). One frequently observed disadvantage is that they are too expensive for applications requiring disposable equipment, e.g. in medical diagnostics. Besides packaging and system integration, the sensor chips represent a major cost issue. Typical on-chip biochemical sensors, for example, use probe molecules immobilized on the chip surface to detect analyte molecules suspended in a solution exploiting a specific biochemical reaction (lock-and-key-principle). The immobilization of the probe molecules on the chip surface is often a rather complicated and expensive process.

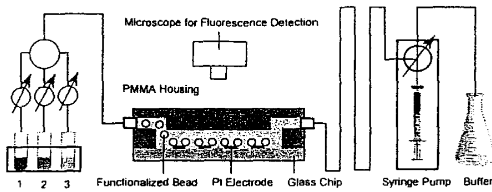
A possible solution is the use of functionalized beads. Here, the probe molecules are coated in large scale production, i.e. cost-efficiently, onto microbeads outside the microfluidic system. Many different bead types with a large variety of molecular coatings are available on the market making bead-based systems versatile with respect to the analyte molecules to be detected. The trapping of the beads at the detection sites inside the microfluidic system can be accomplished using mechanical barriers[1], magnetic fields[2] or vortices generated by an electroosmotic flow (EOF) and a pressure-driven counterflow[3]. In the microassay platform proposed here, dielectrophoresis-controlled adhesion is used to immobilize the beads. This mechanism requires microelectrodes which are easier and more reliable to integrate into a microfluidic system than mechanical barriers, magnetic field generating contraptions or a high-voltage supply for EOF. It is also able to distinguish between different bead types based on their dielectric properties. Compared to the immobilization by DEP alone, after DEP-controlled adhesion the beads stick permanently to the electrodes of the disposable chip allowing to turn the DEP voltage off and to use analyte solutions with physiological (i.e. high) conductivities without problems such as Joule heating or undesired electrochemical effects.

In our conference contribution, we present the concept (animation) and the qualitative experimental proof of principle using biotin-coated beads immobilized by DEP-controlled adhesion on platinum electrodes to detect fluorescently labeled streptavidin molecules (fig. 1 and 2). Further, we show quantitative results for surface passivations with polyelectrolyte multilayer (PEM) and fluoropolymer coatings produced by plasma-enhanced chemical vapor deposition (PE-CVD, fig.3). These coatings reduced the uncontrolled adhesion of beads to the chip surface. We discuss the advantages and disadvantages of both coating materials and show that both passivations have no negative effect on the DEP-controlled adhesion.

References:

[1]L'Hostis E et al., Sensors and Actuators B **64**, 156-162 (2000).
[2]Fan et al., Analytical Chemistry **71**, 4851-4859 (1999).
[3]Lettieri G-L et al., Proc. µTAS 2002, Nara Japan (Eds: Baba Y, Shoji S, v.d.Berg A), Kluwer, 630-2.

FIGURES:



介电泳 DEP_ controlled adhesion

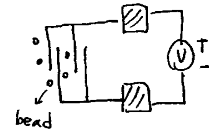
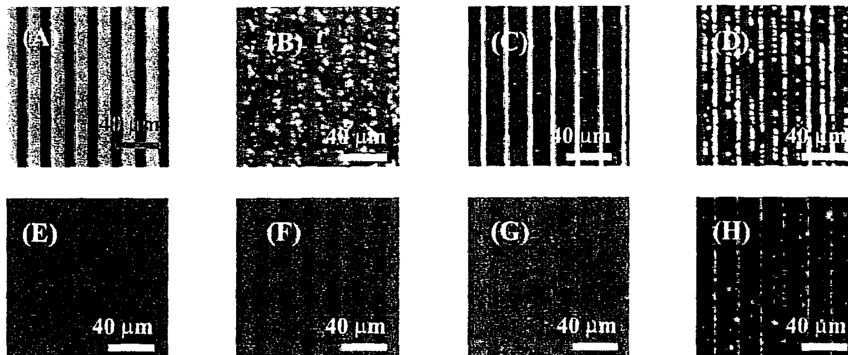


Figure 1: Experimental setup (1-bead suspension, 2-analyte solution, 3-buffer).



利用不同频率 分離or料取不同 size的 bead

Figure 2: *Qualitative proof of principle.* ***A)*** *Dark field (DF) image of the 10 µm wide interdigitated electrodes (black strips).* ***B)*** *DF: Filling with suspension of biotin-coated beads of 2 µm in diameter.* ***C)*** *DF: DEP at 10 kHz.* ***D)*** *DF: DEP at 100 kHz.* ***E)*** *Fluorescence (FL) image before filling with analyte solution.* ***F)*** *FL: Immediately after filling with analyte solution containing fluorescently labeled streptavidin molecules. Electrodes appear bright.* ***G)*** *FL: After 20 min of incubation, beads became fluorescent from bound labeled streptavidin. Strong fluorescent background from excess analyte molecules still in solution.* ***H)*** *FL: After flushing away excess analyte solution, fluorescent beads are clearly visible in front of a dark background indicating successful binding of labeled streptavidin. Scale bars: 40 µm.*

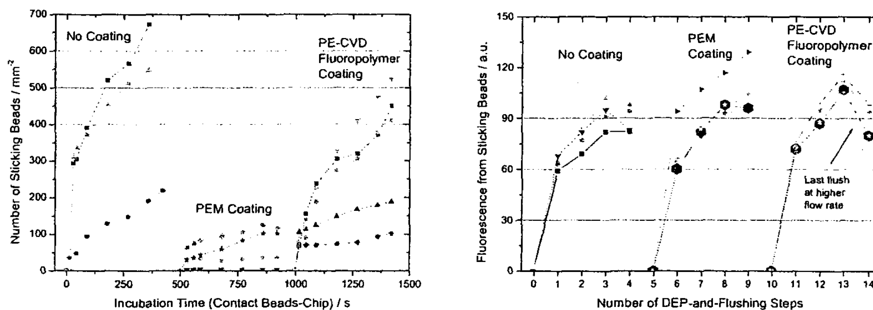


Figure 3: *Influence of PEM and PE-CVD fluoropolymer coatings on the adhesion of 2 µm fluorescent PS beads without DEP (left) and after several consecutive DEP and flushing steps (right); 3-5 data sets per experiment. The PEM coating reduces uncontrolled adhesion of beads to the chip without DEP (left). The coatings have no negative effect on the DEP-controlled adhesion of the beads at the electrodes (right). The number of beads sticking without DEP was determined by counting. With DEP, the fluorescence signal of the numerous sticking beads was measured and compared.*

BM 02

Development of Impedance Biosensor arrays for Analytical Measurements

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Goal of this work is the development of high selective and sensitive biosensor arrays for quantitative measurements. In our approach we utilize micro- and nanofabrication technologies to develop novel impedance biosensors in a batch process.

Two different sensor chip designs have been tested, one consists of a 12 x 12 array of sensor cells. The individual sensor cells are of approx. 200 micrometer width, and comprises two electrodes and with a gap of 90 – 130 nm. While the lower electrode has been deposited on a fused-silica substrate, the upper electrode is supported by pillars (Fig. 1). In this configuration every single sensor cell forms a capacitor, which impedance depends on the filling factor and the dielectric constant of the medium between both microelectrodes.

The solution to be analysed is guided to the sensor cell by a micro fluidic device. Diffusion holes in the upper microelectrode enables a fast response time of the sensor array (Fig. 2). Molecules and ions present in the buffer solution induce also changes in the impedance of the device but this contribution becomes negligible at the measurement frequencies well above 100 MHz. In this frequency region the ions cannot follow the alternating electrical field and therefore the change in impedance is due to the attached bio molecules.

Significant variation of the sensor cell impedance has been observed even at these high frequencies if bio-molecules being immobilized onto the electrode surfaces.
In the case of a replacement of water as a solvent through typical bio-molecules a variation of the relative dielectric constant of the medium ε_r from about 88 to less than 5 have been measured. Further decreasing the gap between the two microelectrodes can increase the change of impedance effect. Figure 3 shows the simultaneous measurement of 5 sensor elements for increasing concentrations of a detergent Triton-x with a molecule length of 8 nm. Between the injections of a higher detergent concentration the sensor cells have been rinsed with Ethanol. This detergent forms monolayer on both electrodes, a complete coverage is obtained at a concentration of 4×10^{-5}. Therefore the sensor signals are not further increased at higher concentration levels. This point of concentration is correlated to the so-called critical micelle concentration (CMC).

Further studies will focus on the detection of selective linked proteins to acceptor molecules that are attached to the Au electrodes via a thiole binding.

BM 03

Nanoelectrochemical transducers for (bio-) chemical sensor applications fabricated by nanoimprint lithography

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Nanometer structured transducers for commercial use in pharmaceutical, medical or (bio-) chemical analysis have so far been hardly accessible since they could not be produced by parallel lithography techniques at reasonable costs. We introduce here a method on how to fabricate nanometer structured interdigitated array electrodes including interconnections and bondpads in the micrometer range in a single imprint step on 2-inch wafer scale. The method enables the mass production for those devices at lowest costs with nanoimprint lithography [1] opening a new field for the commercial use of nanometer structured sensor systems.
Interdigitated array electrodes (IDA's) have been studied and employed as transducers in different kinds of sensors since several years [2]. Aoki et al. performed theoretical calculations on interdigitated array electrodes for electrochmical applications and compared the results with experimental data [3,4,5]. When reducing the spacing between the electrode fingers down to a couple of micrometers or below an electrochemical effect known as redox cycling can be observed when applying potentials e.g. 100 mV above and below the formal potential of a redox couple to each half electrode of the IDA. When the electrode distance approaches the diffusion layer thickness one can observe current amplification through continuous cycling of a redox species between the two finger electrodes. The effect increases with decreasing electrode distance making it possible to build new, highly sensitive electrochemical sensors by manufacturing those electrodes in the nm-range [2].
Imprint of the whole transducer device was possible by omitting resist flow problems, known for large features in the tens of μm-range [6], by implementation of mesh-structured bond pads, large enough to accomodate the displaced resist during the imprint process.
Gold electrodes obtained after imprint and lift-off are illustrated in fig.1. An example for the redox cycling performance of an IDA electrode manufactured with NIL is given in fig.2. The linear current-concentration dependence of both parts of the electrode proves the suitability for concentration sensor applications with redox cycling.

References

BM 04

Biological Lithography: DNA MicroArrays Fabrication and DNA Synthesis Model

C. Kim, M. Li, A. Lowe, K. Richmond, M. Rodesch, M. Patel, N. Venkataramaiah, J. Kaysen and F. Cerrina [1]

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The quality of DNA MicroArray relies on a fabrication process involving the formation of a patterned image. While the aerial image from maskless exposure system [1] does not differ from normal lithographic imaging, the formation of the DNA strands at the glass surface follows a process considerably different. The deprotection process is linear with the exposure dose and thus does not benefit from the non-linearity typical of photoresist materials. Since excess of 72-160 (18mers-40mers) exposures are often involved, the issue of contrast and chemical yield become critical. Interestingly, the quality of the DNA MicroArrays fabricated with lithographic techniques is much better than what would be expected on the basis of simple step-wise yield calculations, and the reason is at the moment unclear.

Hence we have developed a DNA synthesis model that takes into account the light intensity distribution (including flare) as well as chemical synthesis yield. With the model, the amounts and the sequences of all oligonucleotide species which may be grown on a chip will be traced, including wild type (good) and mutant sequences, lengthened and shortened oligomers, capped oligomers, and unreacted sites. The model will be experimentally verified using a fluorescence microscope of $0.1\mu m$'s resolution. In this experiment, image locking technique has been developed and used to prevent image drift with time and temperature. Further, we have studied on the effects of active pixel spacing, inclusion of sensitizer, buffer and quencher, which may play a role in better final yield and purity. Simulation shows that the presence of these effects greatly enhances the quality of the DNA chip. We will present a detailed discussion of the image formation process, and of the total yield variation as a function of optical contrast and chemical synthesis yield.

The model takes into account various factors, from the accurate image formation to the effect of quenchers and buffers on the chemical reactions. We will present a comprehensive discussion of these effects, and provide guidelines to process optimization. It is also important for certain applications to track the sequences that are non-ideal. The computation of these "errors" is computationally challenging because of the combinatorial nature of the process. We will describe our approach and compare the model to the results of gel electrophoresis experiments.

This work is supported by DARPA grant number DAAD 19-02-2-0026.

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[1] S. Singh-Gasson, R. D. Green, Y. Yue, C. Nelson, F. Blattner, M. R. Sussman, and F. Cerrina, Nature Biotechnology, Vol. 17,974(1999).

[1] Corresponding author: cerrina@nanotech.wisc.edu

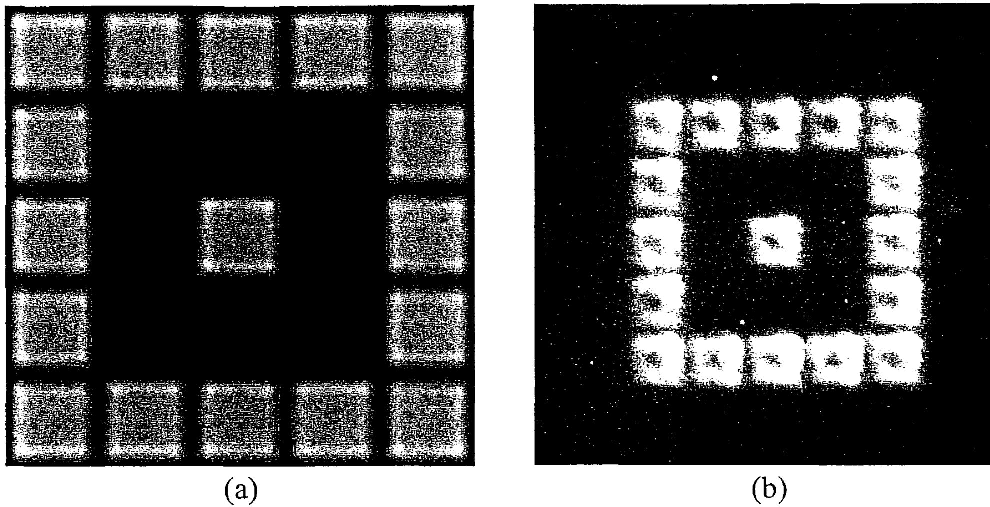
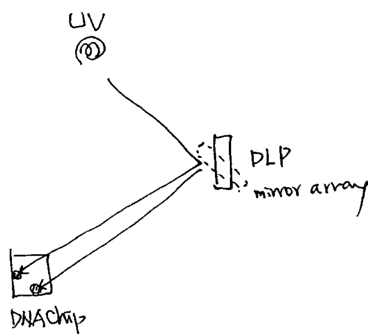


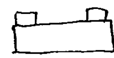
Figure 1: (a) Aerial Image: Calculated by Optolith (Silvaco). Each square is $16 \times 16 \mu m^2$. $NA = 0.08$, $\sigma = 0.5$, $\lambda = 365nm$. Notice the gradual transition of light intensity at edges, which will induce nucleotides of errors in repetitive synthesis steps. (b) Fluorescence image of a single layer DNA chip: Acquired by Nikon Eclipse E800 Microscope (50X). Photodeprotection: 70 seconds. Chemical coupling: 180 seconds. Cy-3 phosphoramidite is attached to single T-base. Center hole of each pixel is formed by a post of micromirror.

※ 利用類似 DLP 的 micromirror array 將 UV 光作 scan 定义 chip 上不同的 DNA 鹼基

※ scatter light 会造成 defect



※ 传統 Litho. DNA



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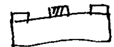

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⋮

2

Selective Protein Deposition via Local Surface Charges

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We recently presented a Xerography-like process for the localized deposition of biomolecules on solid surfaces with sub-µm resolution [1]. Based on electrostatic forces this process may serve as a general tool for positioning chemical receptors or immobilizing enzymes. As all the reaction steps are carried out either in a liquid environment or under normal ambient conditions, there is no need for cost-intensive cleanroom equipment or masks. Arbitrary protein patterns are generated by a process combining the serial lithographic characteristics of an atomic force microscope (AFM) with parallel deposition techniques based on electrostatic fields. Here, we report on applying this method to the fabrication of multi-layered protein structures using the avidin-biotin reaction.

The process scheme is shown in Figure 1: The AFM is used for charging the sample surface locally (Fig. 1A) by applying voltage pulses to a conductive tip. As sample, we use a silicon wafer coated with a thin electret layer, usually PMMA (poly(methyl metacrylate)), having excellent charge storage properties [2]. The first layer of proteins is then deposited onto the sample via the electrostatic field generated by the charge pattern. To this end, the sample is immersed into a water-in-oil emulsion, consisting of aqueous-phase droplets containing biotin-modified immunoglobulin G (IgG) in a phosphate buffered saline (PBS) solution and an insulating perfluoroalkane liquid to prevent the sample from discharging (Fig. 1B). The droplets are attracted to the charge patterns by Coulomb- and polarization forces. Prior to further modification, the sample is rinsed to remove excess molecules that are not tightly bound to the surface. Afterwards, the sample is immersed into an aqueous buffer solution of avidin to build up the second layer of proteins via the avidin-biotin reaction (Fig. 1C). For better visualization of the results the avidin is labeled with a fluorescence marker (FITC).

As shown in Fig. 2e the emulsion-based method can be used to create arbitrary patterns of biomolecules on electret surfaces with a sub-µm resolution. Pattern definition is kept even after immersion into aqueous buffer solution. Fig. 2B,C demonstrate the ability of the deposited IgG-biotin-molecules to specifically bind the avidin, as fluorescence can only be detected on the predetermined patterns.

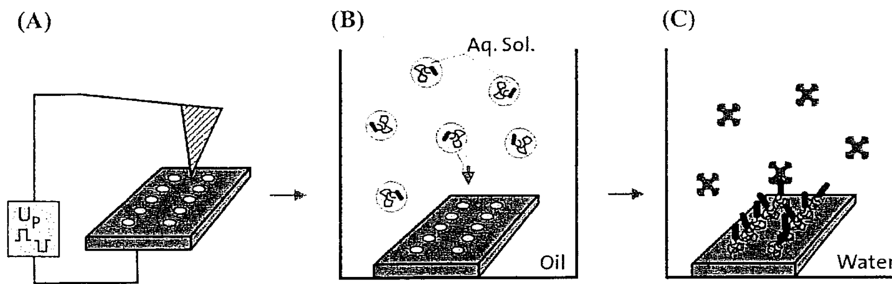


Figure 1. Process scheme: (A) Generation of local surface charges in the sample using a conductive AFM-tip. (B) Immersion into a water-in-oil emulsion consisting of an aqueous phase with the first type of proteins, and a perfluoroalkane liquid as oil phase. (C) Reaction of the protein bound to the sample surface with a second biomolecule in aqueous solution.

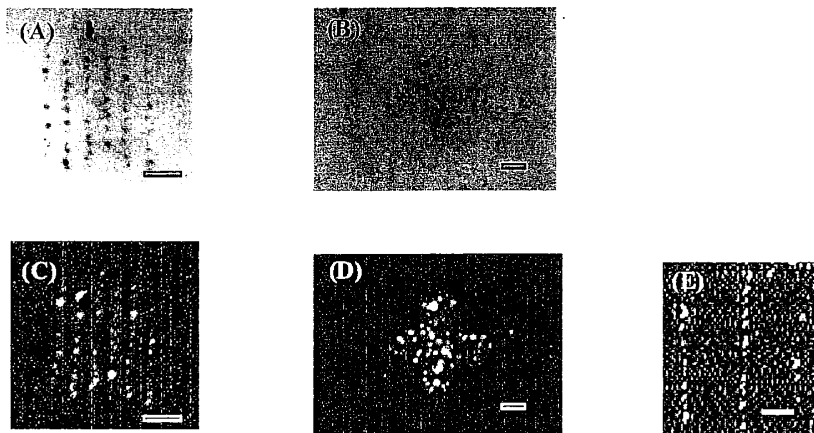
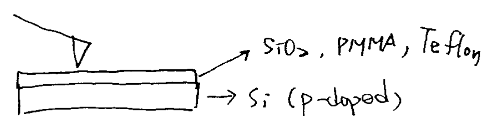


Figure 2. Biotin-modified IgG deposited onto PMMA and reacted with FITC-labeled avidin. (A,B) Reflected light microscopy images of a line pattern and a cross, respectively, 400x. (C,D) Fluorescence microscopy image of the same patterns, 400x. (E) AFM amplitude image, zoom into the line pattern in (A) (arbitrary units). Scale bars: 10 μm (A-D), 5μm (E).

※利用AFM做 charge writing 的動作
以達成 selective protein deposition 的目的



BM 06

NIL Structured Surfaces for Biological Applications

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2 Dep. of Cell and Organism Biology, Lund University, Sweden.
3 Dep. of Chemistry and Biomedical Sciences, University of Kalmar, Sweden.
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Nanoimprint is *the* next generation lithography that has, in recent years, developed to the level were it can be used as a tool for making nanometer structures. This cost-efficient, high throughput method opens new doors for interdisciplinary nanoscale research. In this paper we present a status report on how implementation of nanoimprint lithography (NIL) has advanced our cross over research between solid state physics and biology.

Contact guidance nerve growth experiments have so far primarily been done on micrometer-structured surfaces. Due to the necessity of large area structures and large number of samples for statistical analysis, nanometer scale experiments have up to now not been feasible. Structures that go into the nanometer size range are known to have an impact on the interaction between cells and surfaces so this area warrant further studies in this area.

We have made a NIL stamp, by EBL, with 17 areas (200µm by 200µm) of different line width (100nm to 400nm) and spacing (100nm to 1600nm) covering a total 3.3mmx0.45mm (fig. 1a). The exposure time was 4 hours. This stamp has been imprinted, in PMMA on Silicon wafers, and consequently used in experiments to investigate how axonal outgrowth is affected by the nanopatterns (fig. 1b). The results were examined by immunocytochemistry for neurofilaments and scanning electron microscope. For pattern larger than 100nm most axons displayed contact guidance.

A research field that starts at the nanometer level is guidance of motor proteins. Definition of nanometer sized patterns (fig. 2b) in bilayer resist, PMMA on top of mrL 6000.1, can be used to bind heavy meromyosin molecules preferentially to the mrL, in a way that it supports actin filament motility propelled by ATP-consumption (fig. 2a). The actin movement has a measured velocity of about 3-4µm/s and displays a rectifying motion along the mrL-lines.

The obvious merit of NIL is the ability to create nanometer structures over large areas at a high speed, enabling fabrication of a large number of samples. This makes it possible to perform biological experiments on the nanometer scale in accordance with the statistical demands for standard biological procedures.

Tuesday 23 September 2003

BioMEMS, lab-on-a-chip 2 **Room 1A (West)**

Session Chair: F. Cerrina

16:20 BM_07 **NANOJET as tool for 3-D preparation of the internal structure of the biological cells**
O. Rabinovych[1], R. Pedrak[1], I.W. Rangelow[1], H. Ruehling[2], M. Maniak[2]
[1]Institute of Microstructure Technologies and Analytics "IMA", University of Kassel, Kassel, Germany
[2]Cell Biology and CINSaT, University of Kassel, Kassel, Germany

16:40 BM_08 **Fabrication of chemical sensors based on Si/polymer bimorphs**
S. Chatzandroulis, E. Tegou, D. Goustouridis, S. Polymenakos, D. Tsoukalas
NCSR "Demokritos", Institute of Microelectronics, Athens, Greece

17:00 BM_09 **Fabrication of microfluidic devices for eukariotic cell manipulation**
V. Studer, R. Jameson, E. Pellereau, A. Pépin, Y. Chen
Laboratoire de Photonique et de Nanostructures, CNRS, Marcoussis, France

17:20 BM_10 **Novel actuation and testing of a microperistaltic pump**
B. Husband, M. Bu, V. Apostolopoulos, T. Melvin, A. Evans
Department of Electronics and Computer Science, University of Southampton, Southampton, UK

17:40 BM_11 **Thermopneumatic-actuated PDMS microvalve**
J.-H. Kim, Y.-S. Kim
Department of Electrical Engineering, Myongji University, Kyunggi-do, Korea

BM 07

NANOJET as tool for 3D–preparation of the internal structure of the biological cells

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The knowledge of the internal structure of the biological objects (BO) plays a central role in the understanding of it functional properties. Usually, to recognize the shape and the internal structure of the BO, the various microscopy methods, such as light microscopy and scanning electron microscopy (SEM)are used. The last method *only* describes the *outer surface* of the BO and does not give any information about the internal structure of the BO. From another side, the resolution of the light microscopy strongly depends on the light wave length. Therefore, light microscopy does not allow to resolve *internal* structure of the BO more than $\lambda/2$ apart (for green light this corresponds 265 nm).

The aim of this work is to use the Nanonozzle Plasma Jet Microfabrication Technology (NANOJET) in order to obtain the information about internal structure of the BO. The NANOJET produces reactive species (free radicals) streaming out of a nanometer sized aperture at the end of a hollow AFM tip in order to induce localized etching or deposition of material. The technology provides an active scanning probe, combining an AFM sensor with a high resolution downstream plasma etching device into one versatile tool for micro- and nanostructuring (see Fig. 1). The radicals are created from mixture of a gases (SF_6 and O_2) in a microwave plasma generator, based on a cavity, powered by an EMS microtron 200 microwave generator (100 W at 2.45 GHz). More details of the NANOJET method are presented in Ref. [1]. Using NANOJET method, we are concentrating our attention on recognizing on the internal structure of *amoebae*.

The method of the preparation of the cells consists two general steps. First the cellular structure is preserved by chemical fixation,then water in the cells is gradually exchanged by ethanol. Subsequently ethanol is exchanged for CO_2. Finally CO_2 is replaced by air by the so-called *critical–point–drying*method. [2].

The preliminary results of our investigations is demonstrated on Fig. 2. Process parameters are 1 sccm flow rate SF_6 and 50 sccm O_2, respectively, at a plasma pressure of 2.2 mbars. Etching time is 5 minutes.The obtained results show that the NANOJET allows to remove the outer layer (plasmamembrane) of the cell without damaging the internal structures of the cell. We are clearly able to see the spherical– and tubulare *organelles* of the cell.

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Fabrication of Chemical Sensors based on Si/polymer bimorphs

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Abstract

The fabrication and first results of a capacitive type chemical sensor based on a silicon/polymer bimorph structure is described. Upon exposure to analytes the polymer covering the thin silicon membrane swells inducing a deflection on the membrane which is measured as a capacitance change between membrane and substrate. Five different polymer layers [poly-hydroxy-ethyl-methacrylate (PHEMA), poly-methyl-methacrylate (PMMA), poly-vinyl-acetate (PVAc), epoxy-novolac (EPN) and poly-dimethylsiloxane (PDMS)] are examined. Exposure to water, methanol and ethanol vapors is used to evaluate performance.

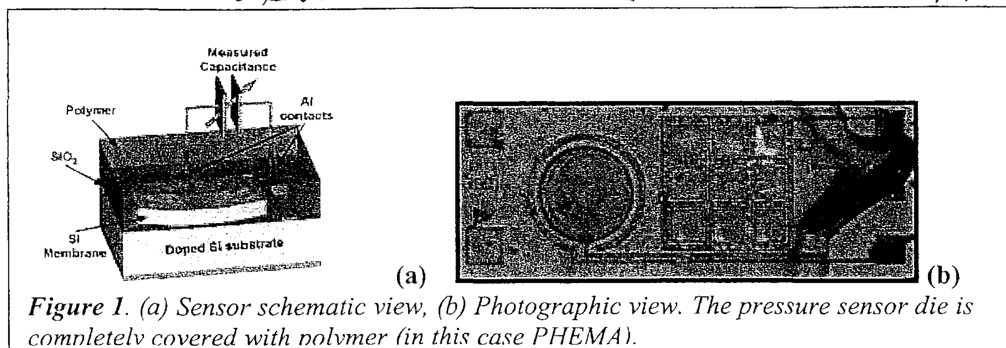
To construct the silicon/polymer bimorph, the thin silicon membrane which constitutes the diaphragm of a capacitive pressure sensor is covered with one of the selected chemical sensing layers. These sensors are fabricated with an already presented technique [1], and are characterized by the their thin single crystal silicon diaphragm (typically less than 4um) and small diaphragm to substrate spacing (<1um). Solutions of PHEMA (4% w/w), PMMA (5% w/w), PVAc (5% w/w), EPN (41% w/w) and PDMS (3% w/w) were subsequently applied over the sensor membrane using a micropipette and post-apply baked to insure solvent evaporation (figure 1). Sensitivities to relative humidity of 29fF/%RH for PHEMA covered devices to 4.5fF/%RH for PDMS are reported. Devices covered with PHEMA, PVAc and PMMA also exhibit strong response upon exposure to methanol and ethanol atmospheres. Differences in sensitivities between these layers may be exploited in constructing an effective chemical discriminating array [2-4].

In order to characterize the devices, and evaluate the performance of each polymer layer, exposure to volatile organic compounds (methanol and ethanol) and humidity was used. Testing was performed in a chamber were relative humidity and temperature are controlled to within ?0.1% and ?0.1°C, respectively. The response versus relative humidity for the five polymer layers is depicted in figure 2. On the same plot the pressure necessary to obtain same response is also shown. For volatile compound testing, methanol and ethanol vapors are introduced in the test setup via a dry nitrogen flux going through a bubbler with the respective compound. The atmosphere is interchanged between dry nitrogen and the volatile compound mix. Figure 3 depicts the maximal capacitance change between the two states. In all cases the response to methanol is higher than for ethanol. This is attributed to the longer chain length of

※ 應用：① food processing
② environmental monitoring

※ CMP & Bonding for Si - memberane

※ 是了做 biosensor 在 Si memberane 上加一層 polymer



(a) (b)

Figure 1. (a) Sensor schematic view, (b) Photographic view. The pressure sensor die is completely covered with polymer (in this case PHEMA).

※將 pressure sensor 轉換成 bio sensor <電容式>
※測試不同 polymer member 的性能表現

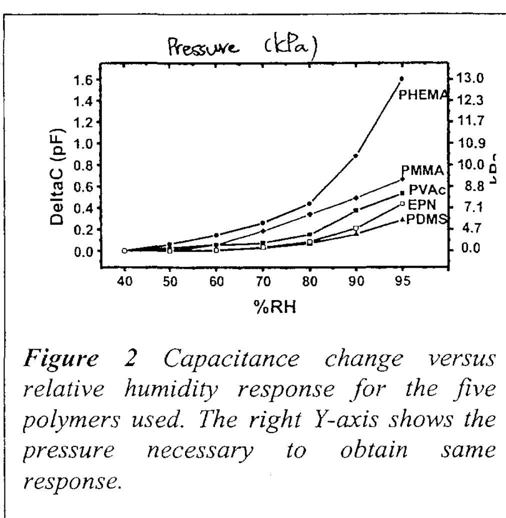


Figure 2 Capacitance change versus relative humidity response for the five polymers used. The right Y-axis shows the pressure necessary to obtain same response.

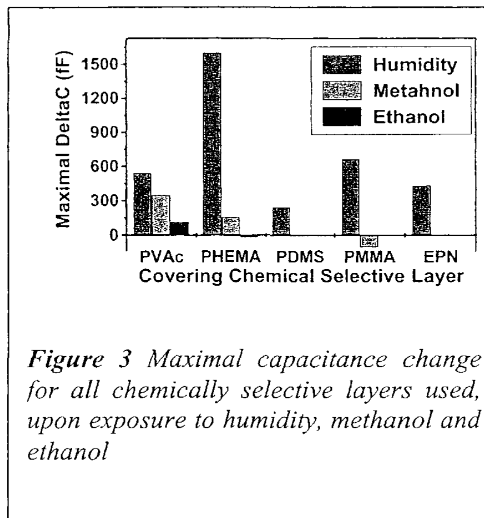
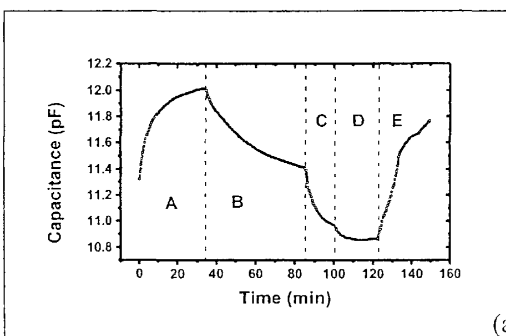
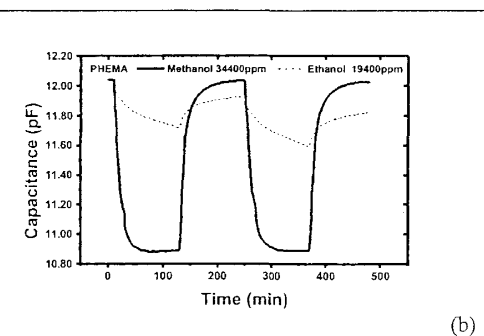


Figure 3 Maximal capacitance change for all chemically selective layers used, upon exposure to humidity, methanol and ethanol

不同分子(溶液)測試





(a) (b)

Figure 4 Response of a four membrane sensor covered with PHEMA. (a) In region A dry nitrogen is fed in the chamber. Then methanol is added at concentrations of 8700, 19275 and 29000 ppm before exposing the sensor to dry nitrgen again. (b) same device is exposed to certain concetrations of methanol and ethanol

(a) PHEMA - methanol (b) PHEMA - methanol - ethanol

Fabrication of microfluidic devices for eukariotic cell manipulation

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Manipulation of single cells is of particular importance in biological and biomedical studies [1]. One of the challenges is to provide solutions for easy and fast cell handling allowing further biochemical assays. Ultra fast sorting of fluorescently tagged rare cells is a key issue for cancer cell analysis.

In this work, we study the feasibility of realising microfluidic devices and we will test the performance of the fabricated devices by using micro-beads of two different colours, with diameters comparable to eukariotic cells (10 μm).

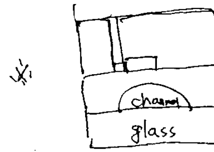
Multilayer soft lithography was used for the fabrication of micro channels, valves and pumps [2]. Figure 1 shows the design and the realisation of a two-level isolation scheme. The solution is injected from the entrance of the 300μm width channel (blue line). Once the target bead is identified, the two valves (red line) of the wide channel are closed and the peristaltic pump located along the 50 μm wide channel is activated which allows precise displacement of all beads presented in the close circuit. Finally, when the target bead is located in the region of the collection channel, the related valve is opened and the target bead is extracted from the sorting loop.

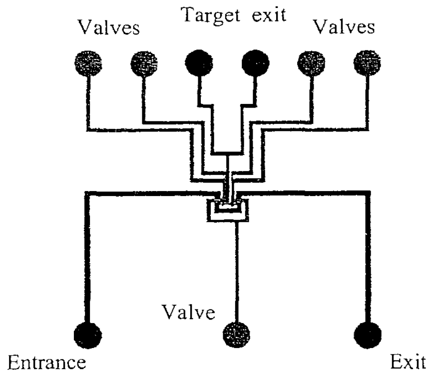
Microfluidic valves and pumps are pneumatically actuated by computer controlled electro-magnetic valves through an home-made electronic and pressure interface. Figure 2 shows a microfluidic device placed on the stage of an inversed optical microscope (left) and the control box with pressure lines for micro-valving.

To evaluate the performance of the fabricated device, a mixture of 10 μm diameter fluorescent red and green latex beads with a red/green ratio of 100/1 was injected. Bead motion was monitored with a digital CCD camera by fluorescent detection. Manual control of bead motion was achieved by actuating appropriate valves. A computing algorithm was also developed for automatic detection and sorting. Figure 3 shows a super-imposed image

※ Multilayer Soft Litho <PDMS>

※ soft micro-valve





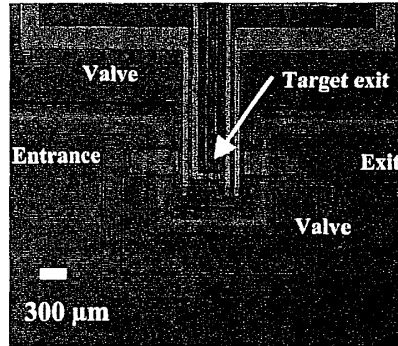
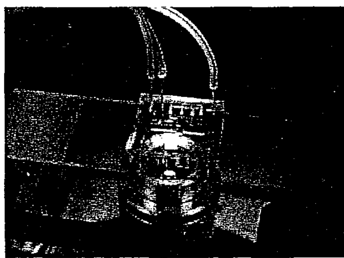
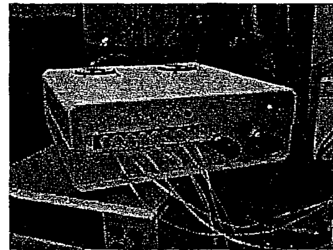


Figure 1. Schematic representation (left) and microphotograph of a fabricated microfluidic device (b) for eukariote cell manipulation. One the left, the blue lines are channels for particle circulation and the red ones are for valve activation.





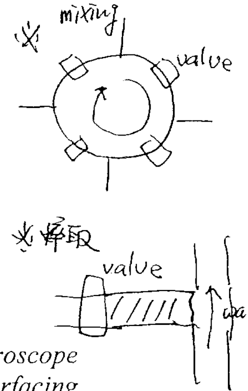


Figure 2. Fabricated microfluidic device on the stage of an inversed optical microscope (left) and home made control box for the pressure regulation and the computer interfacing (right).

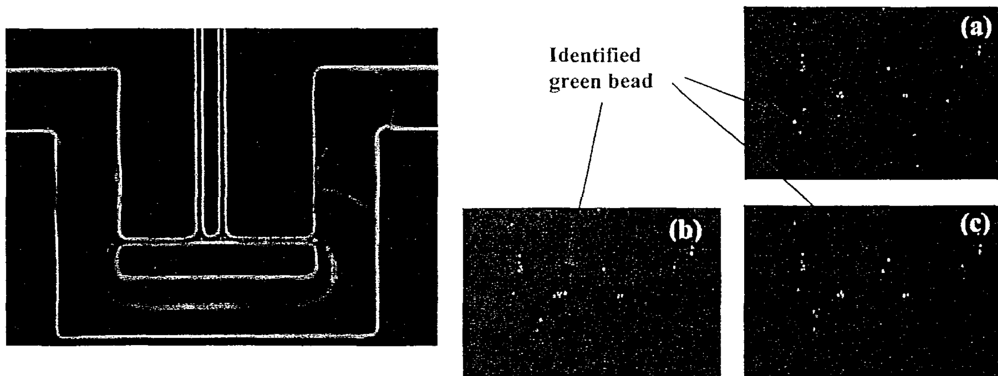


Figure 3. Super-imposed images of a single particle motion inside the close circuit (left) and three selected flash shots of a recorded film, indicating three positions of a green bead during automatic sorting.

Novel actuation and testing of a microperistaltic pump

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Silicon micropumps are an important component of many micro Total Analysis Systems (μTAS) (1). Most of these fluidic systems are designed such that a continuous fluid stream is pumped through the channels. For these systems 'relatively large' volumes of liquid are processed but are problematic due to the formation of bubbles that prevent pumping. The fabrication of bubble tolerant micropumps is possible, as established previously in our group. (2). We have decided to take a different approach for processing samples within μTAS devices – here we present the design of, and our preliminary studies on, a three stage microfabricated peristaltic pump (3) to be used for the transport of a 1ul droplet of fluid containing biomaterial back and forth between reaction cavities for processing. The concept of this system is novel, and once complete will offer the opportunity for multi-stage processing of extremely small volumes of bioanalytes. Here we report the design, operation and testing of a three stage micro peristaltic pump for μTAS devices, which as a first step is to be used for the polymerase chain reaction (PCR).

Our microfabricated silicon-Pyrex microperistaltic pump, incorporated as part of the PCR device, is illustrated in Figure 1. The three-stage pump is actuated by PZT ceramic discs, which are glued to a 200μm thick glass diaphragm located above narrow channels etched into the silicon wafer below. The actuation sequence of the PZT elements is illustrated in Figure 2. The air pressure changes, created by the pump, are used to move a droplet of water located within the reaction chambers integrated within the device. Electrical actuation of the micropump has been achieved using both sequencer and driver circuits. The pump has been designed to be actuated at +/- 100 volts. One of the three driver circuits, used to actuate each of the PZT ceramic discs in the pump by providing a voltage step, is illustrated in Figure 3. Because this circuit, which provides an inverted output of +/-100volts, does not work at low frequencies another driving circuit has been developed with photovoltaic transistors. The microperistatic pump, actuated using these circuits, has been shown to pump a 1μl droplet back and forth between the reaction chambers. The testing and pump optimisation using a Michelson Interferometer that has been constructed, to image the whole diaphragm, will be presented. The advantage of this interferometric method is that the whole pump chamber can be imaged, thus enabling the relationship for voltage actuation with membrane displacement to be established. The optimal phase relationship for actuation of the three pumps is thus obtained.

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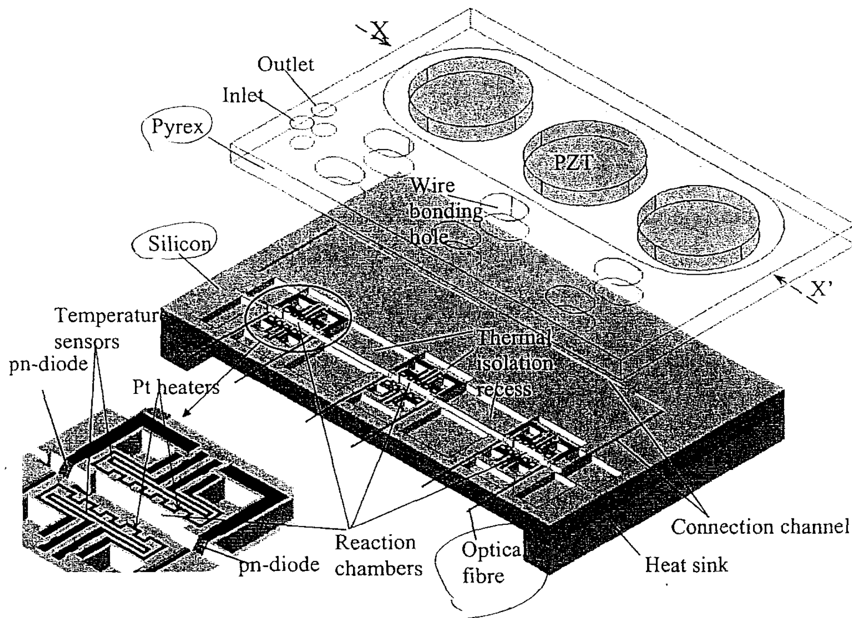


Figure 1 PCR Device

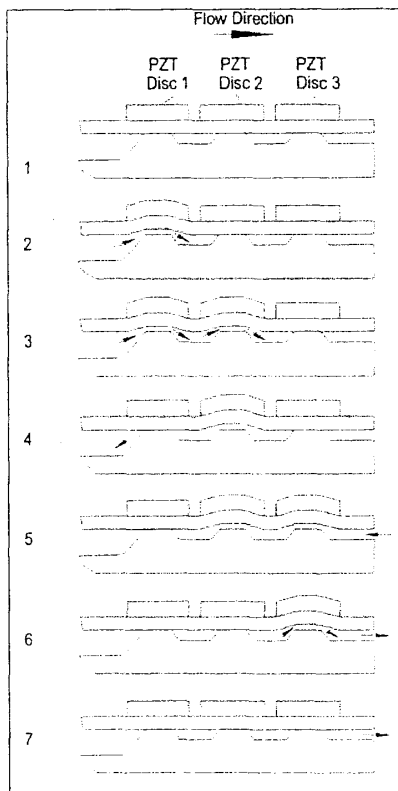


Figure 2 Pump Sequence

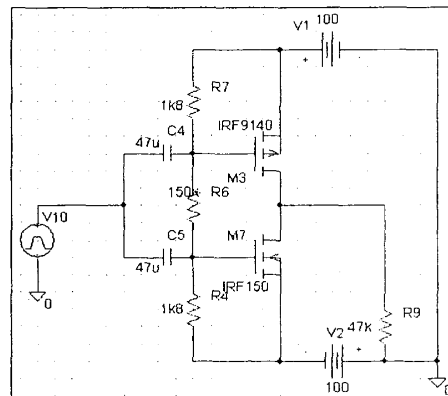
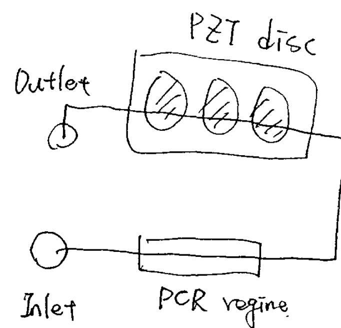
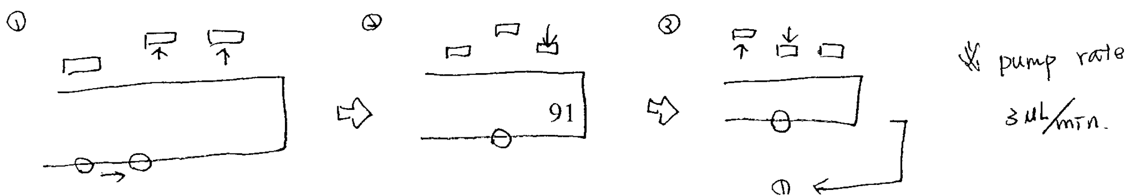
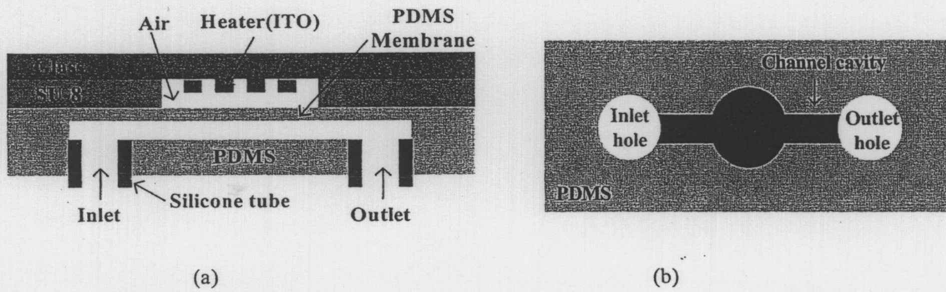


Figure 3 Driver Circuit





※ disposable PDMS-based microvalves



(a) (b)

Fig. 1 The proposed structure of the microvalve. (a) A cross-sectional view of the microvalve, (b) A cavity of PDMS replica of the microvalve.

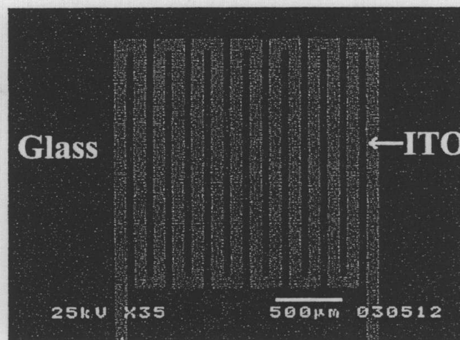


Fig. 2 SEM image of the ITO heater.

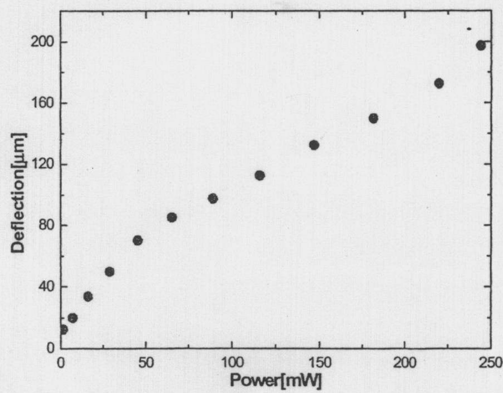


Fig. 3 PDMS membrane deflection of a microvalve as a function of applied heater power.

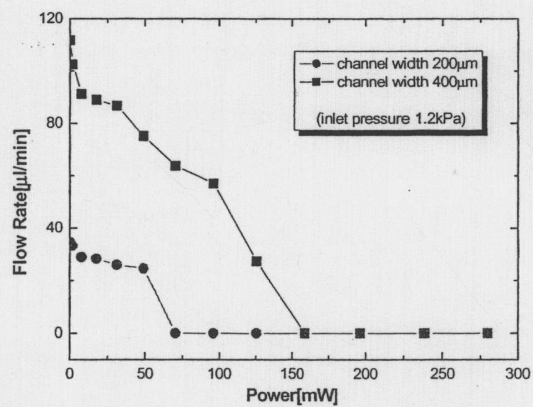


Fig. 4 Flow rate of a microvalve versus applied heater power.

SL 05

Study on a newly proposed hybrid nano imprint lithography

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Nano imprint lithography (NIL) is promising technology for fabrication of integrated micro and nano systems with low cost. In the NIL process, there have been proposed two types of imprinting. One is a thermal NIL[1] and the other is a photo curing NIL[2]. In both methods, residual resist is remained after the process. This is one of the fatal problems for NIL because additional dry etching process is required to remove the residual layer.

To overcome the problem, a hybrid NIL is newly proposed using metal shade and negative photo resist[3,4]. Figure 1 shows the process flow of the hybrid NIL. A transparency mold with metal shade at the top portion of the pattern is prepared as shown in Fig 1 (a). Then, a negative photo resist is deformed by a thermal NIL (Fig.1 (b)). Holding the transparency mold, the negative resist is exposed like a photo curing NIL as shown in Fig.2 (c). In this process, the resist underneath the metal shade is not irradiated. After removing the mold (Fig.1 (d)), the resist is developed as shown in Fig.1 (e). At this time, the residual resist underneath the shade is selectively developed by the developer. As a result, a residual resist is removed.

In this hybrid NIL, the optical diffraction through the metal shade is considerable. The optical intensity distribution is calculated by solving Maxwell's equations using FDTD (Finite Difference Time Domain) method.

Figure 2 shows the optical intensity distribution for various pattern sizes in conventional photo curing NIL without shade metal. The wave length of the irradiated light is 320nm and the residual resist thickness is 100nm. The line sizes are 80nm, 160nm and 320nm. The light propagates through the mold and irradiates the residual resist. In cases that the line width is larger than$\lambda/2$, the residual resist underneath the shade is not sufficiently exposed, which means that the resist could be removed by the resist development process.

On the other hand, the irradiated light can not propagate into the residual layer when the line width is around $\lambda/4$. In this case, the resist is unexposed and the residual layer remains. This means that the propped hybrid NIL is effective over$\lambda/2$ in feature size of the pattern, where the residual layer would be removed at the development process.

Also, the dependency on the residual thickness will be discussed.

Acknowledgements
A part of this work is supported by New Energy and Industrial Technology Development Organization (NEDO).

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4) X. Cheng, et al., Abstract of EIPBN, **10A4** (Tampa,2003).

• just Simulation FDTD TE+TM

• resolution determined by ① λ ② thickness

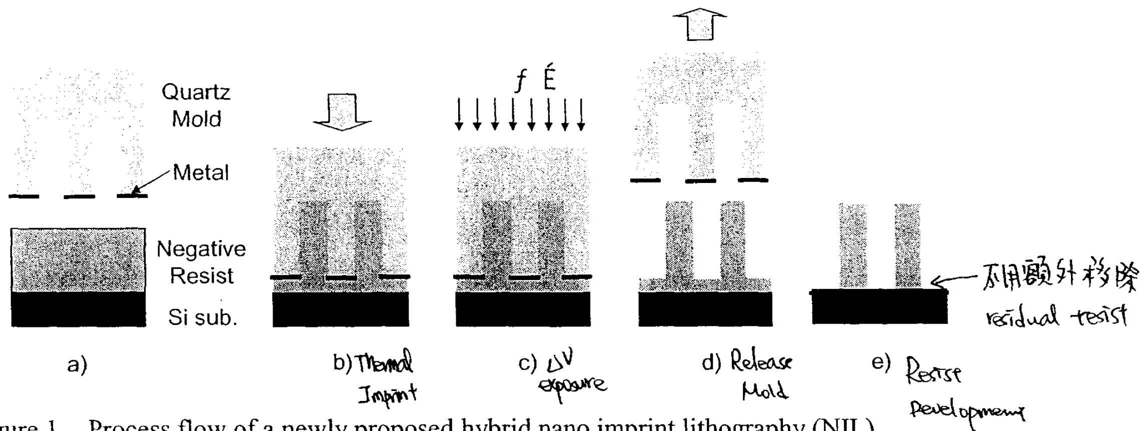
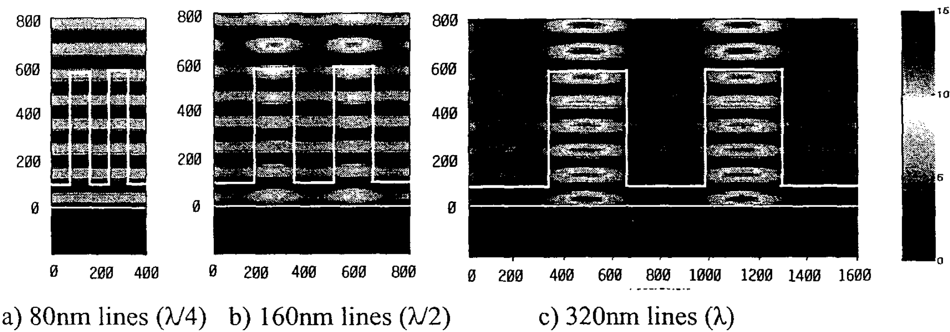
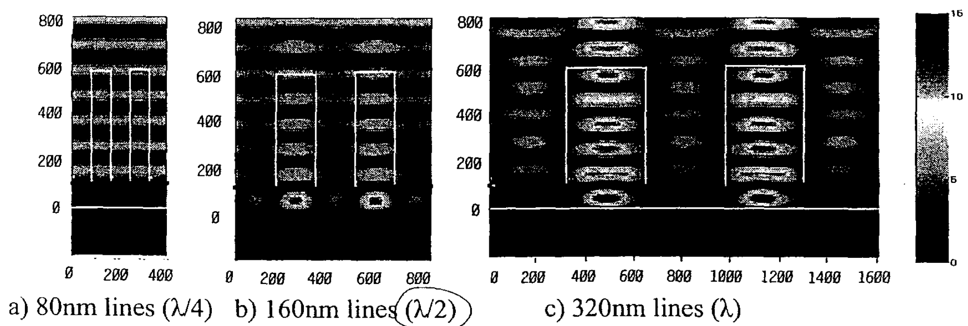


Figure 1. Process flow of a newly proposed hybrid nano imprint lithography (NIL).



a) 80nm lines (λ/4) b) 160nm lines (λ/2) c) 320nm lines (λ)

Figure 2. Optical intensity distribution for various pattern sizes in conventional photo curing NIL without metal shade. The irradiated light propagates the mold and exposes residual resist. (λ=320nm, The line width are 80, 160 and 320nm)



a) 80nm lines (λ/4) b) 160nm lines (λ/2) c) 320nm lines (λ)

↳可試的 resolution limit

Figure 3. Optical intensity distribution for various pattern sizes in newly proposed hybrid NIL with metal shade. The irradiated light is blocked by the metal shade and does not expose residual resist. However, the light does not propagate at $L<\lambda/4$. (λ =320nm, The line width are 80, 160 and 320nm)

Reversal Nanoimprinting Technology for 3-Dimensional Patterning

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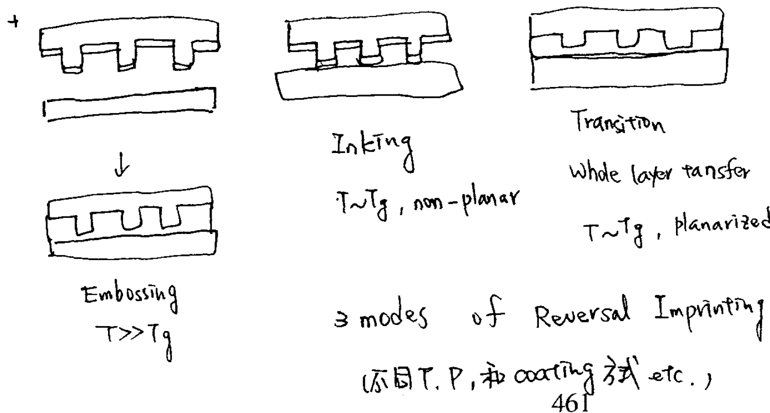
Reversal imprinting is developed to form 3-dimensional nanostructures. Using this technology, multiple layer 3-dimensional polymer structures, channels, cavities, conformal coating, as well as patterning inside trenches have been demonstrated.

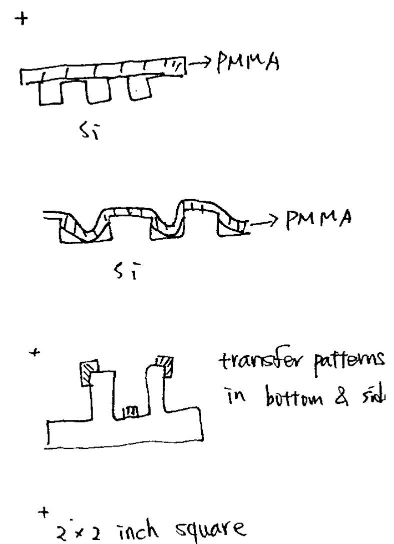
For reversal imprinting, a polymer film is spin-coated onto a mold and then transferred to a substrate by imprinting. Depending on the applications, the mold and the substrate can have patterned microstructures or they can be flat without any patterns. The characteristics of the imprinted nanostructures depend on the polymer material properties, imprinting conditions, and pattern dimensions on the substrate. Three distinctive patterning modes are obtained, including 'continuous film transfer over microstructures', 'film transfer to both trenches and protrusions', and 'film transfer to protrusions only'. The mold can be a hard mold made of Si or a flexible mode made of polydimethylsiloxane (PDMS). With a flexible mold, the PDMS can deform elastically around features on the substrate and produce patterns along the sidewalls and at the trench bottoms. Using this reversal imprinting technology, 3-dimensional nanostructures, nanochannels, and nanopatterning inside trenches have been achieved. These unique patterning capabilities are difficult to accomplished using conventional patterning techniques. In addition, reversal imprinting has the advantages of simplicity, versatility, and high resolution.

+ Reversal Nano imprint : ① 3D imprint
② 可印製在非平面上
③ 各种 ~~matter~~ material : PMMA, Al, ceramic, Au

+ Polyimide mold , SiC mold

+ J.VAC. SCI. TECHNOL B 16, 1145 (1998)





+ 2×2 inch square

(不同T, P, 和 coating 方式 etc.)

SL 01

High-Precision Overlay Alignment in Step and Flash Imprint Lithography

Philip Schumaker[†], Ian McMackin, Tom Rafferty, Jin Choi, Pankaj Lad,
S.V. Sreenivasan[‡], Michael Watts, Norman Schumaker

Molecular Imprints, Inc.
1807C W. Braker Lane
Austin, Texas 78758, U.S.A.

The Step and Flash™ Imprint Lithography (S-FIL™) process is a step and repeat nano-replication technique based on UV curable low viscosity liquids. Investigation by this group and others has shown that the resolution of replication by imprint lithography is limited only by the size of the structures that can be created on the template (mold). This article will discuss overlay alignment accuracy that can be obtained using the S-FIL process.

The S-FIL process has several key features that makes it particularly suited for high-precision overlay alignment: (i) The process is practiced at room temperature; (ii) Imprinting involves very low applied pressure (< 0.5 psi); (iii) The template-substrate interface is filled with a low viscosity liquid film that provides damping and allows for lubricated *in-situ* alignment measurements and corrections; and (iv) Step and repeat processing allows use of templates that are much smaller than the substrates thereby leading to lower distortion during pattern generation of the template.

This presentation will discuss results from a through-the-template (TTT), field-to-field step and repeat overlay alignment experiments on 200 mm wafers. The current alignment capability with respect to x, y, θ, and magnification will be presented. Two kinds of alignment techniques will be discussed: (i) Proximity alignment wherein the alignment is performed with an air gap of a few microns followed by open-loop imprinting; and (ii) *In-situ* lubricated alignment wherein the alignment metrology and corrections are made immediately prior to UV curing. Various aspects of the system design including TTT optics, XY stage characteristics, and template-substrate target acquisition will be discussed.

Molecular Imprints, Inc. (MII) has developed the Imprio™ 100, which is the first commercial step and repeat imprint lithography system with field-to-field alignment (Figure 1). Full wafer step and repeat printing performance is shown in Figure 2. The current status of overlay alignment accuracy is presented in Figure 3.

Keywords: Step and Flash Imprint Lithography, Step and Repeat Through-The-Template Alignment Proximity Alignment, In-Situ Lubricated Alignment

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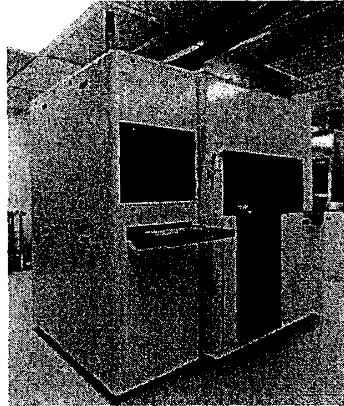


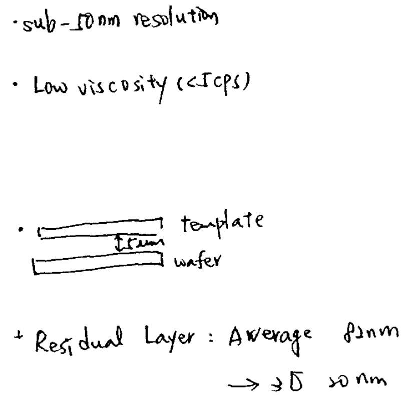
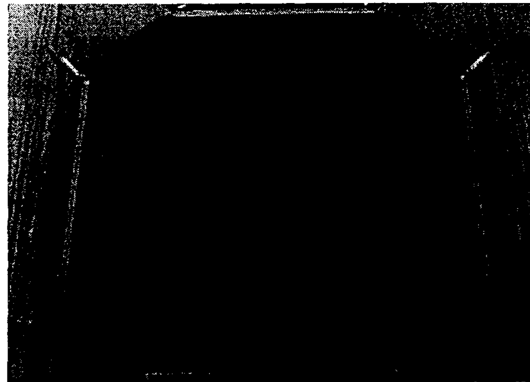


Figure 1: Imprio™ 100 from Molecular Imprints, Inc. is a step and repeat imprint lithography system with field-to-field alignment



+ 250 nm 3σ alignment in x, y

+ Automated Alignment

+ Time for full wafer ~ 1hr

Figure 2: Full 200 mm step and repeat wafer coverage with lithographically useful residual layer thickness (variation of <20 nm, 3σ) and field edge control compatible with < 500 μm kerf.

X-mean (nm)	Y-mean (nm)	3σ, X (nm)	3σ, Y (nm)	θ (μrad)
-12	20	252	225	6.32

Figure 3: Full wafer overlay alignment accuracy based on three alignment error measurements per field on the wafer.

Reproducibility and homogeneity in step & repeat UV-nanoimprint lithography

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** Raith, GmbH, Hauert 18, D-44227 Dortmund, Germany*

In recent years, nanoimprint lithography (NIL) has emerged as a promising low-cost technique for the fabrication of nanostructures with a potential for high throughput [1,2,3]. In our UV-NIL approach a transparent quartz mold is pressed softly into a low viscosity UV-curable liquid resist, which has been spin-coated onto a substrate. Pressures in the range of 100mbar to 1bar are sufficient to displace the resist into the cavities of the mold relief structures. After exposure with ultraviolet radiation through the quartz mold, the mold is separated from the substrate, leaving behind a replica of the mold relief structure.

A detailed study of the step & repeat process on silicon substrates has been performed. An imprint tool was developed by the Raith GmbH which features a movable wafer stage for 4"-wafers, allowing the high precision, vertical and lateral positioning necessary for a step & repeat imprint technique. The movement speeds of the wafer stage and the hold time before exposure currently allow process times of 40 seconds per single imprint. The molds used for the step & repeat experiments have a size of 1x1 cm^2 with structures ranging from 4μm wide lines & spaces down to 50nm test structures. Sticking problems are avoided by the use of an anti-adhesion layer on the mold surface and additives in the resist which lower the surface energy at the resist-mold interface [4]. An example of a 4" silicon wafer printed in step & repeat mode using a 1x1cm^2 mold with 4μm lines and spaces is shown in figure 1. More than 1000 imprints (30 4"-wafers with 37 imprints each) with the same mold have been performed without any cleaning of the mold. During these 1000 imprints no degradation of the mold could be observed. The high number of consecutive imprints demonstrates the high asymmetry between the detachment from the mold and the adhesion to the substrate achieved, an essential issue concerning reproducibility.

One of the major issues in step & repeat imprint lithography is the homogeneity of the imprints. To evaluate the homogeneity, the residual resist thickness is measured on a series of samples as a function of imprint pressure and thickness of the initial film. In figure 2 the residual resist thickness is plotted together with the height of the printed resist structures for 12 samples out of 37 printed on one wafer. The imprint force for these imprints was 30N and the initial film thickness of the spin coated resist layer was 220nm. On each of the 12 samples measurements are performed in 9 locations arranged in a grid-like manner to obtain an overview of the uniformity of the residual resist thickness across one sample and from sample to sample. The graph demonstrates the uniformity of the residual resist thickness which is necessary for a reliable pattern transfer of the printed structures.

We will present technical details of the imprint tool developed by the Raith GmbH, along with a detailed analysis of the imprint process.

References

[1] S.Y. Chou, P.R. Krauss, P.J. Rennstromm, J. Vac. Sci. Technol. B 14 (1996) 4129-4133.
[2] M. Colburn et al., Proc. SPIE 3676 (1999) 379-389.
[3] M. Bender et al. Microelectron. Eng. 53 (2000) 233.
[4] M. Bender et al. Microelectron. Eng. 61-62 (2002) 407.

+ two major concerns
· sticking defects
· non-uniform residual resist thickness

+ total time per imprint : 3 sec

mold ↕200 um
substrate

+ Resist : ino®flex (NI+)
(inomat GmbH) ~350nm

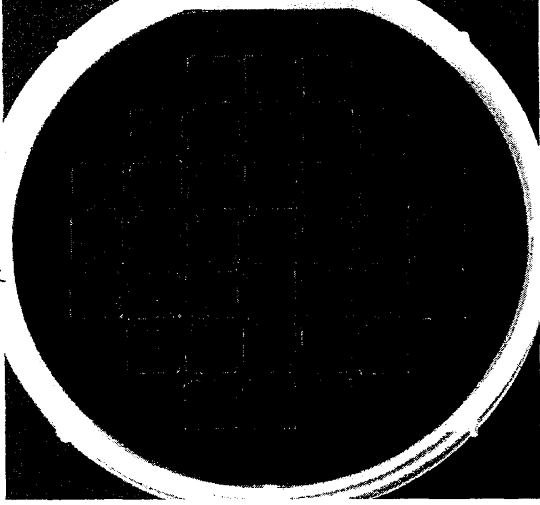


figure 1: Fully printed 4"-silicon wafer with 37 fields printed using a 1x1cm² mold with 4µm lines and spaces as test structures. The initial film thickness was 340nm; the height of the printed structures was 280nm.

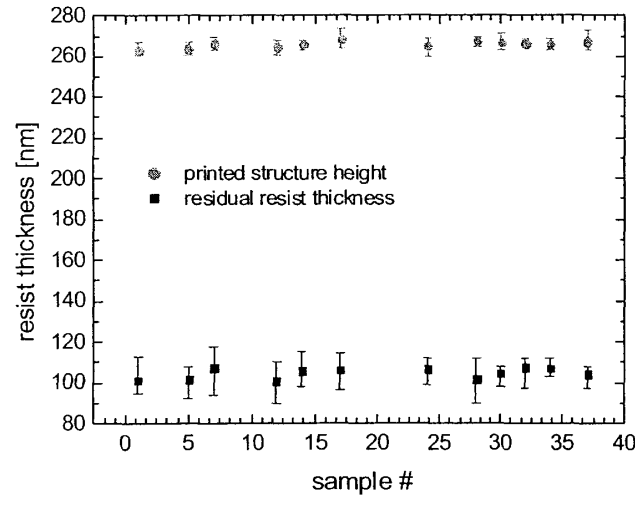


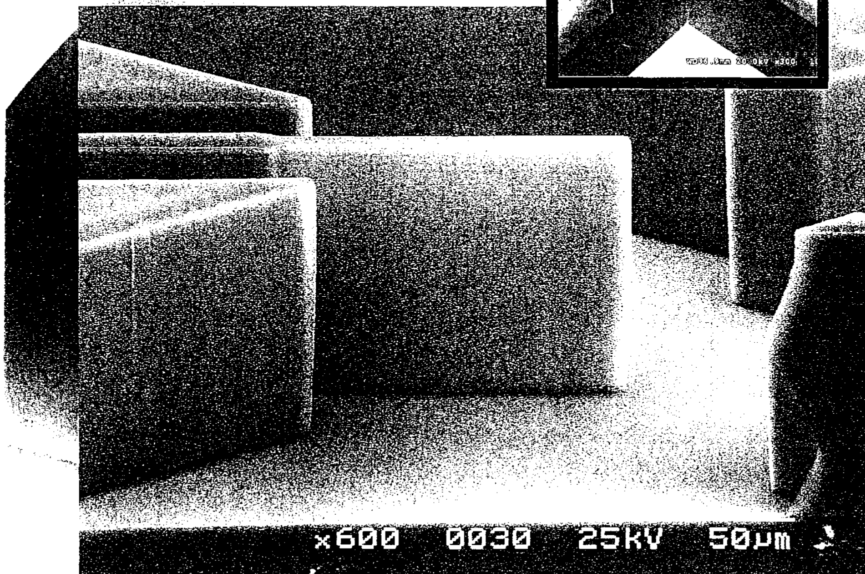
Figure 2: Measurement of residual resist thickness and structure height for 12 of 37 samples on one printed wafer with an initial film thickness of 220nm. On each of the samples measurements were performed in 9 locations arranged in a grid-like manner.

附件 B

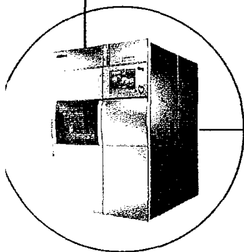
MNE 參展廠商資料

Extra Smooth Mirror *for* **OPTICAL SWITCH**

AMS 200 "I-Speeder"
The Advanced Deep Plasma Etching Tool



SOI Etch with
VERY LOW ROUGHNESS *(18 nm)*
all along 70 μm deep vertical beams



Application: Telecom

Product: Optical Switch

Wafer size: 100 mm

Feature width: 4 μm

Etch depth: 70 μm

Feature shape: Beams

Etch time: 20 min

Mask: SiO_2

Etch rate: 3.5 μm/min

Mask selectivity: >200:1

Roughness: 18 nm

Profile angle: 90 degrees

Undercut: 0.1 μm

Aspect ratio: 18:1

Process regime: Room Temp.

Substrate: SOI

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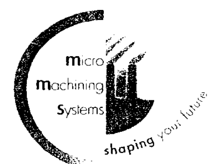
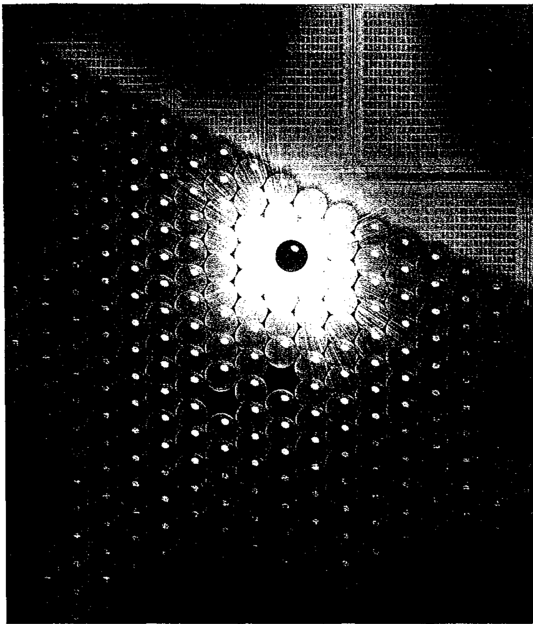
Dept. Micro Machining Systems mms-sales@an.cit.alcatel.fr www.alcatelvacuum.com





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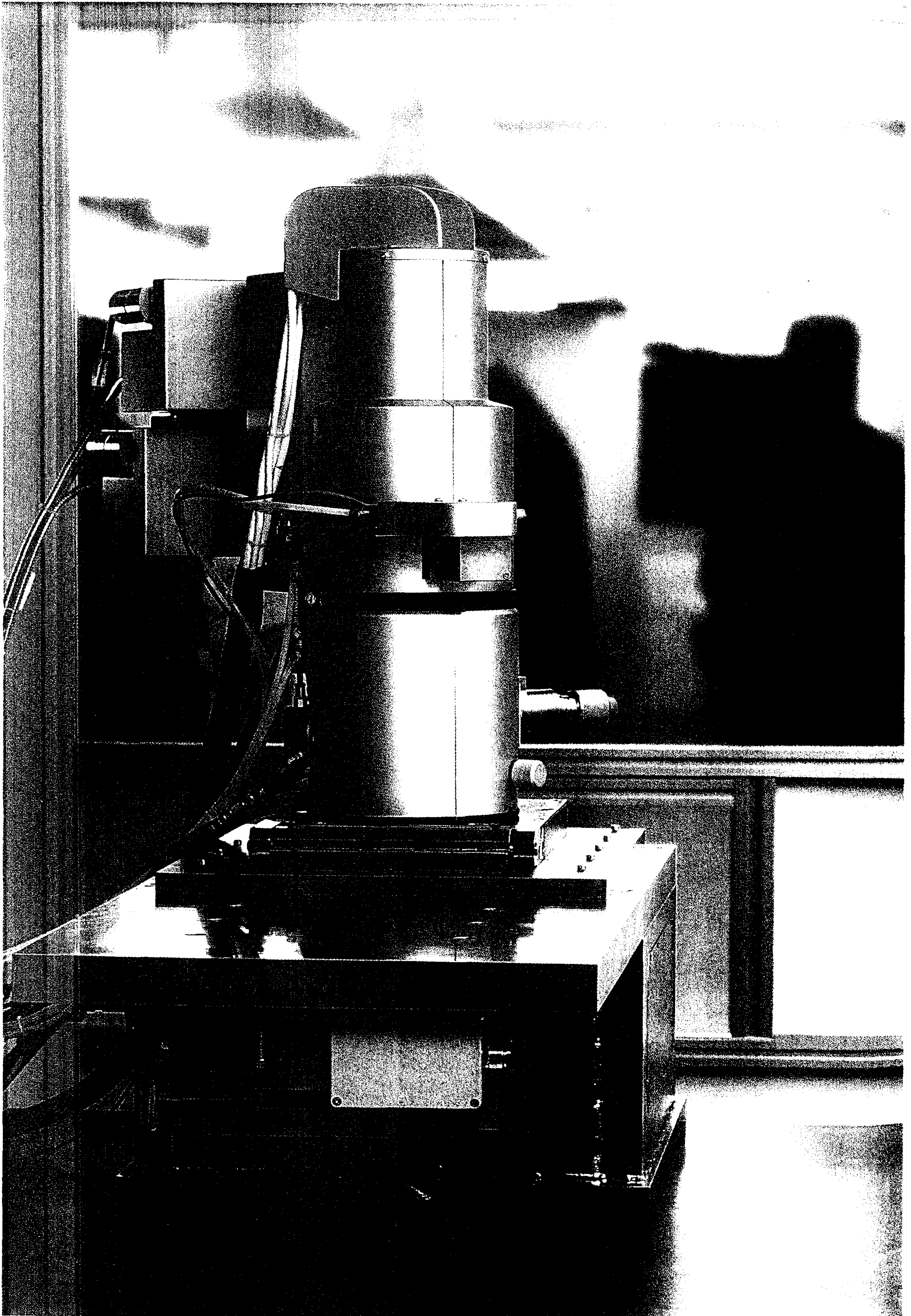


Outstanding E-beam Lithographic Capabilities

– Improved Performance

General information

The design and know-how in Obducat's Electron Beam Recorders (EBR) are based on a 30-year history of successful development, manufacturing and supply of electron beam based analytical tools. By combining Obducat CamScan's E-beam experience with Obducat's extensive knowledge of mastering processes, we can provide e-beam based mastering equipment dedicated to produce micro- and nano structures.

The process for e-beam lithography is similar to the standard laser beam photo resist process. Standard equipment for substrate preparation including cleaning, drying, resist spinning, and baking can be used. The process is less risk prone and allows a larger process window than the standard laser beam process. As an example the development time is less critical because the process time is just a few minutes rather than a few seconds. Resist contrast is higher and edge roughness smaller than resists for UV lithography.

The EBR-200 electron beam recorders from Obducat are intended for sub micron lithographic applications such as optical- and magnetic mastering. The general system design is focused on satisfying the advanced demands set by ever accelerating industry roadmaps.

With a sub-100nm minimum feature spot size, our direct-write systems lithographic capability will support a number of existing and future pattern needs for the optical media and magnetic media industries.

Obducat offers two different electron beam recorders:

- the EBR-200 LaB_6 with a Lantanium Hexaboride filament electron optics column
- the EBR-200 TFE with a Thermal Field Emission filament

Both systems are based on the EBR-200 platform.

EBR-200 LaB_6

The EBR-200 LaB_6

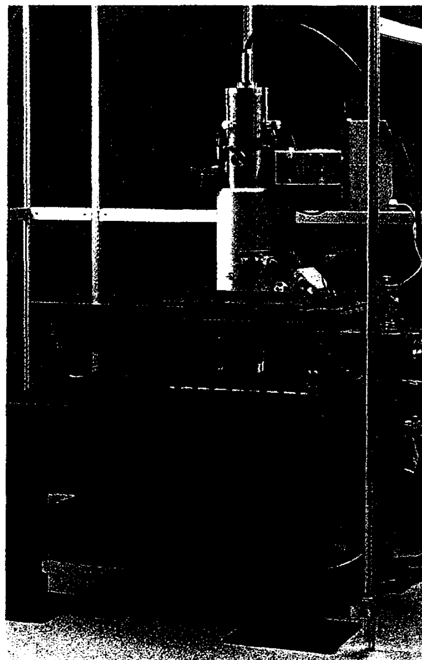
The Obducat EBR-200 LaB_6 is a high performance lithography tool suitable for R&D applications. The LaB_6 filament electron optics column produces a Gaussian beam spot. This together with a high-speed beam blanker, the high performance linear stage and the high accuracy rotation spindle gives a lithographic tool designated to cover rotation substrates with spiral or concentric patterns at high exposure speeds.

Electron Optic System

The advanced electron optics has a number of outstanding characteristics. A Lantanium Hexaboride cathode of high brightness delivers a high current density with a high current stability. To improve stability and minimize interference from the surrounding environment all the lenses are of electro magnetic type. The acceleration voltage is variable up to 40 kV to allow recording of structure sizes from CD (700 nm) via DVD (350 nm) down to as small as 50 nm. To further improve the flexibility and accuracy we have incorporated a closed loop current control feedback and a dynamic auto focusing system to handle higher exposure speeds and non-flat substrates.

Software Interface

The user interface is designed with the R&D personnel's needs in focus and is a Windows™ based computer control interface. Many parameters are logged continuously and to a great extent, relevant system parameters are entered and controlled. In addition the system provides a wide range of manual control facilities. There is a complete set of scanning electronmicroscope possibilities giving the opportunity to use the Obducat EBR-200 LaB_6 as an orthogonal SEM instrument with high resolution.



The EBR-200 LaB_6, electron beam recorder, for R&D purposes.

EBR-200 LaB_6 Technical Specifications

System Dimensions (L x W x H)	
EBR Plint & Chamber	135 x 125 x 205 cm
EBR Control Station	175 x 100 x 120 cm
EBR Control Rack	80 x 80 x 235 cm

General	
Vibration isolation table	Self-leveling gas suspension
Main frame	Rigid base plate for low natural frequency

Electron Optics	
Electron gun / Filament type	Lantanium Hexaboride (LaB_6) with Mechanical and Magnetic Alignment
Cathode life	Typically > 2,000 hrs
Beam current density	Typically > 10 A / cm² @ 30 kV
Acceleration voltage	Max 40 kV
Gun EHT unit	Gun bias is feedback controlled for stability
Condenser lenses	Two electromagnetic lenses operated as a doublet lens
Objective lens	One electromagnetic low aberration final probe forming lens
Stigmator	Octupole, electromagnetic
Beam blanker	Electrostatic blanking plates conjugate to writing plane Bandwidth up to 30 MHz. (tr / tf < 6 ns)
Dynamic focus	Iron free coil, ± 100 µm range
Beam current drift	< ± 1% / hr with activated beam current feedback system
Beam defining apertures	4 selectable by aperture changer mechanism

Linear Stage	
Maximal travel	100 mm
Drive unit	Brush less 3-phase linear motor
Bearing	Cross roller bearing
Straightness	< 5 µm / 50 mm
Measuring system	Integrated laser scale, resolution < 1 nm
Position repeatability	± 10 incr
Dynamic position error	< ± 6 incr
Speed range high resolution	2.5 – 250 µm / s
Speed range low resolution	Up to 5 mm / s

Rotation Spindle	
Axial rotational error	< 0.05 µm
Radial rotational error	< 0.05 µm
Radial async. rotation error	< 0.015 µm ptp (0- < 5 nm)

Facility Requirements	
Voltage # 1	400VAC, 3 phase
Frequency	50 Hz
Power	8 kW
Compressed Air	7 bars, 5 m³/ hr
Cooling Water	1 l / min

EBR-200TFE

The EBR-200 TFE

For industrial production of master stamps Obducat offers the EBR-200 TFE electron beam recorder. Its superior performance sets new standards for both today's and tomorrow's needs in magnetic- and optical disc mastering. Typical applications include master recording for pre-recorded and recordable optical discs, magneto-optical discs, and patterned magnetic media mastering.

The EBR-200 TFE can handle specialized media types and future formats. The TFE filament produces a sub-10nm Gaussian beam spot. This together with the high-speed beam blanker, and the precision linear stage and rotation spindle of the EBR-200 platform makes it possible to cover rotating substrates with spiral or concentric patterns at very high exposure speeds in an industrial production environment.

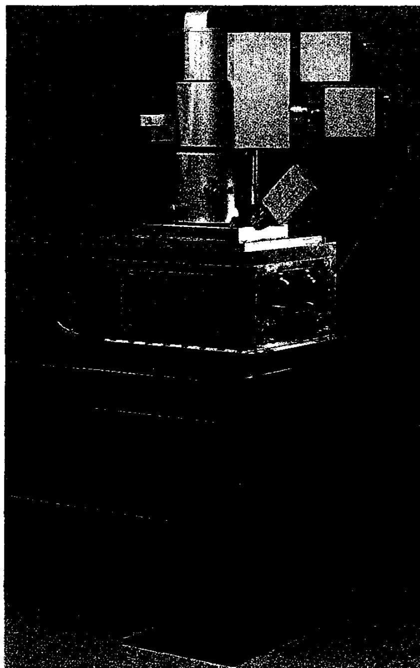
Electron Optic System

The advanced electron optics has a number of outstanding characteristics. A Thermal Field Emission cathode of extremely high brightness delivers a high current density with an exclusively high current stability, typically better than ± 0.5% per hour long term stability.

To improve stability and minimize interference from the surrounding environment all the lenses are of electro magnetic type. The acceleration voltage is variable up to 25 kV to allow recording of structure sizes from DVD (350 nm) via HD-DVD down to as small as 10nm. To further improve the flexibility and accuracy we have incorporated a closed loop current control feedback and a dynamic auto focusing system to handle higher exposure speeds and non-flat substrates.

Software Interface

The EBR-200 TFE has a Windows™ based computer control interface. Many parameters are logged continuously and to a great extent relevant system parameters are input and controlled. In addition the system provides a wide range of manual control facilities. There is a complete set of scanning electronmicroscope possibilities giving the opportunity to use the EBR-200 TFE as an orthogonal SEM instrument with superb resolution.



Obducat's EBR-200 TFE is suitable for industrial production of nano-scale structures.

EBR-200 TFE Technical Specifications

System Dimensions (L x W x H)	
EBR Plint & Chamber	135 x 125 x 170 cm
EBR Control Station	175 x 100 x 120 cm
EBR Control Rack	80 x 80 x 235 cm

General	
Vibration isolation table	Self-leveling gas suspension
Main frame	Rigid base plate for low natural frequency

Electron Optics	
Electron gun / Filament type	Thermal Field Emission (ZrO / C) X / Y Tilt / Shift Magnetic Alignment
Cathode life	Typically 10,000 hrs +
Beam spot size	Down to 10 nm
Beam current density	Typically >1000A / cm^2
Acceleration voltage	25 kV
Gun EHT unit	EHT unit includes Suppressor, Extractor, Lens and Filament supplies
Condenser lenses	Integrated E / S Lens in Electron Gun and Magnetic Condenser Lens
Objective lens	One electromagnetic low aberration final probe forming lens
Stigmator	Two Octupole Stigmators. To correct both lens and source astigmatism
Beam blanker	Electrostatic blanking plates conjugate to writing plane. Bandwidth up to 30 MHz (tr / tf < 6 ns)
Dynamic focus	Iron free coil, ± 100 µm range
Beam current drift	< ± 0.5% / hr without additional stabilizing
Beam defining apertures	4 selectable by aperture changer mechanism

Linear Stage	
Maximal travel	100 mm
Drive unit	Brush less 3-phase linear motor
Bearing	Cross roller bearing
Straightness	< 5 µm / 50 mm
Measuring system	Integrated laser scale, resolution < 1 nm
Position repeatability	± 10 incr
Dynamic position error	< ± 6 incr
Speed range high resolution	2.5 – 250 µm / s
Speed range low resolution	Up to 5 mm / s

Rotation Spindle	
Axial rotational error	< 0.05 µm
Radial rotational error	< 0.05 µm
Radial async. rotation error	< 0.015 µm ptp (0- < 5 nm)

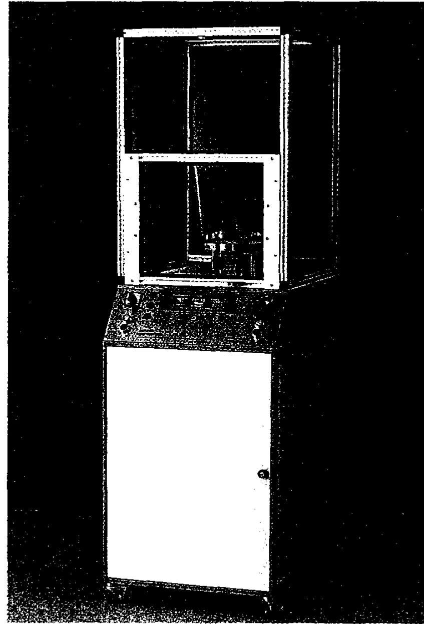
Facility Requirements	
Voltage # 1	400 VAC, 3 phase
Frequency	50 Hz
Power	8 kW
Compressed Air	7 bars, 5 m^3 / hr
Cooling Water	1 l / min

NIL 2.5"

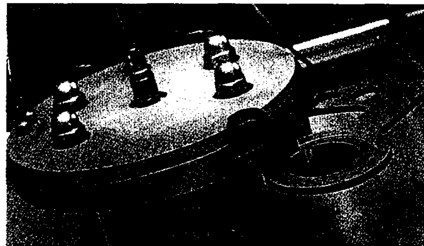
In our line of nano imprint lithography equipment, the laboratory version allows imprinting on any stamp- and substrate size up to 2.5-inch (65 mm) in diameter. It has a basic degree of automation, where the most important automated control functions are supported. As an option, the equipment can be upgraded with a user-friendly softwear interface for operation control and process log.

The equipment is optimized for research and small-series structure replication on for example Si, GaAs and InP substrates, as well as on polymers, ceramics, and metal substrates.

The heater of the press provides uniform heating of the substrate in a wide range of temperatures, making it possible to use almost any thermoplastic. Thanks to its increased maximum temperature, the heater can be used for hard baking of resists after and during the imprinting step.



Obducat's 2.5 inch NIL system is developed for R&D purposes.

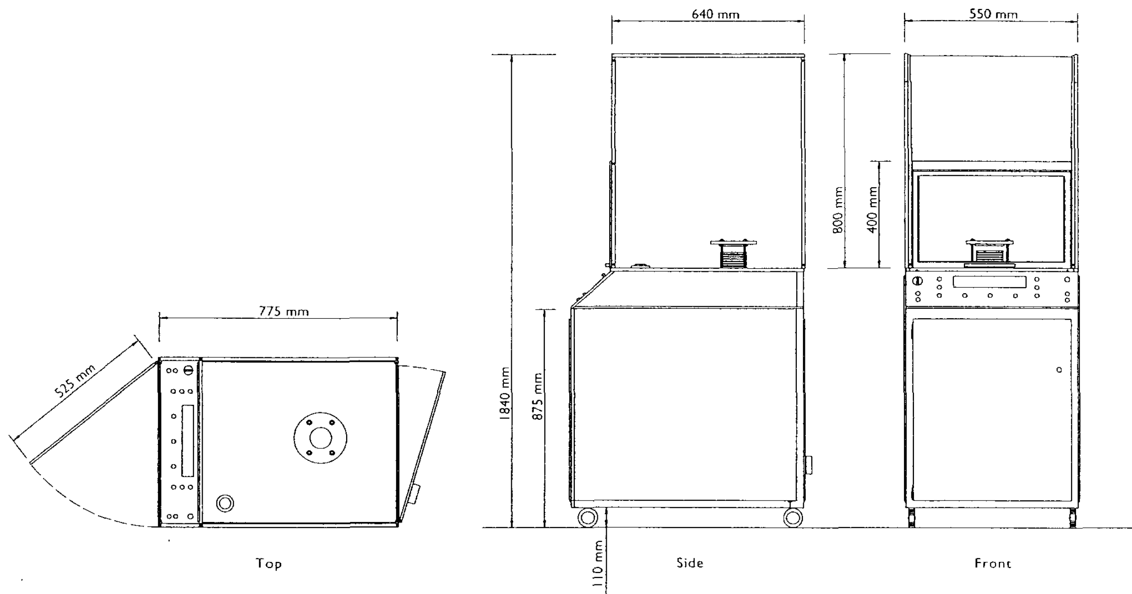


Key Features

- Pressure range: 5 bar – 70 bar
- Temperature up to 250 °C

Key Benefits

- High-quality pattern transfers from stamps to substrates
- Rapid cooling procedure
- High process repeatability
- High process accuracy



NIL 2.5" Technical Specifications

System Scope and Dimensions	
Dimensions (LxWxH)	78 x 56 x 180 cm
Weight	Approx. 200 kg

Product Safety
CE Mark
Interlocked safety cover
Lock out / Tag out disconnect
EMOS

CONFIGURATION
Programmable PLC – Set value Control for Temperature, Pressure vs Time with closed feedback loop to ensure process accuracy
Substrate holder: System will include a user-friendly "tray system" for loading and unloading substrate/stamp material into equipment

Parameter	Specification
Temperature (Minimum)	Ambient Temperature
Temperature (Maximum)	250°C
Temperature Field Uniformity	± 0.5% Temperature Stability over imprinting surface area
Heat-up Ramp	0,5-1 °C / Sec
Cooling	Ambient temperature down to below -10°C or lower
Print uniformity	± 10 nm
Pressure	≤ 70 bar (Minimum inlet gas pressure)
Cleanroom Class	Class 100
Stamper Size	Maximum Ø 65 mm, maximum thickness 1 mm
Imprinting Area	Ø 65 mm
Substrate Size	10 – 65 mm

Facility Requirements	
Voltage #1	230VAC, 1 phase
Frequency	50 / 60 Hz
Power	2.5 kW
Compressed Air	5 – 8 bars, 30 l / min
Room Temperature Range for Normal Operations	18 – 32°C
Relative Humidity	65 %
Cleanroom Class	Class 100

NIL 4" & 6"

For mass replication of micro- and nano size structures, there is an industrial version that allows imprinting on a 4-inch (102 mm) diameter area.

As with the 2.5-inch (65 mm) laboratory version, the industrial version is suitable for imprinting on substrates of a wide range of different materials. Likewise it also come with a heater that provide uniform heating in a broad temperature range, and an increased maximum temperature, that make the heater usable for hard baking of resists after the imprinting step.

For industrial application, the loading of substrates and stamps and their separation after imprint can be fully automated. For simplified operations it is computer controlled, with user-friendly interface software.

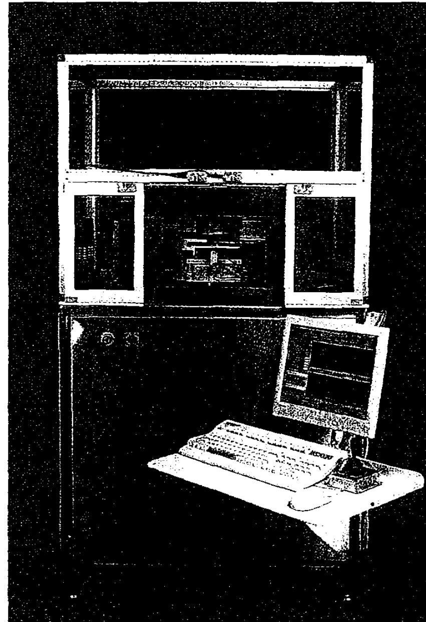
The machine is also available with a 6-inch (152 mm) diameter imprinting area.

Key Features

- Pressure range: 5 bar – 80 bar
- Temperature up to 350 °C
- Fast heating ramp
- Independent temperature control of top and bottom heaters
- Upgradable
- Double side imprinting as option
- Integrated optical or mechanical alignment of stamps and substrates as option
- Auto demolding as option
- Different heating techniques available as option.
- Solid state heater/holder for different substrates as option

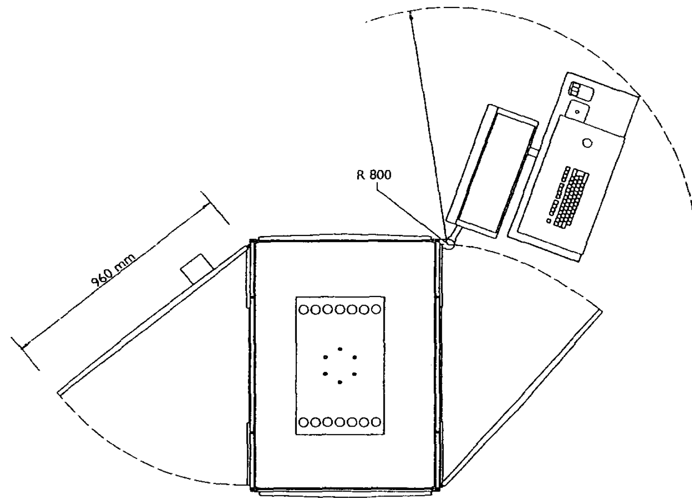
Key Benefits

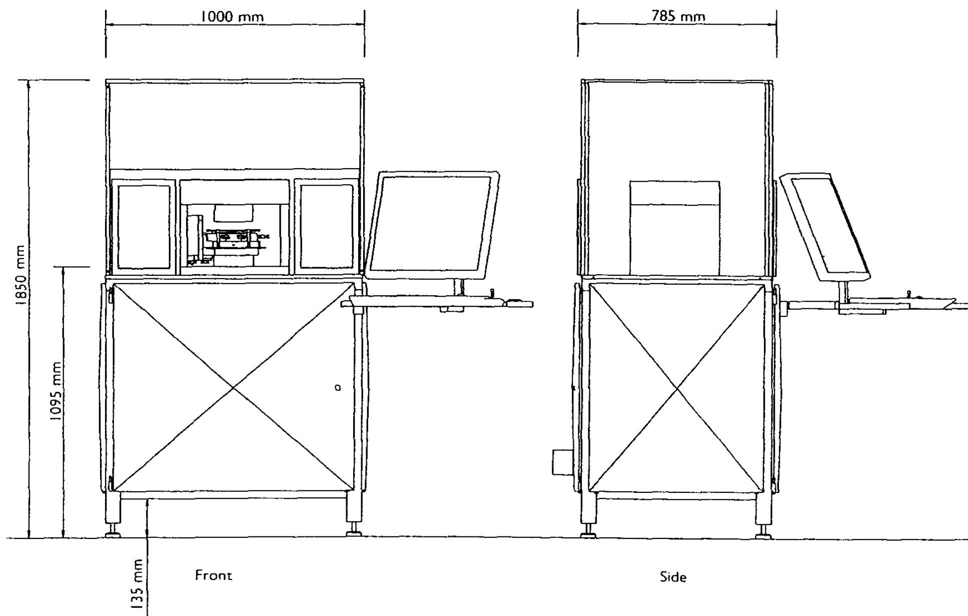
- High-quality pattern transfers from stamps to substrates
- Rapid cooling procedure
- High process repeatability
- High process accuracy



The 4 inch system for Nano Imprint Lithography has been developed for industrial test production, and process optimization purposes.

The system can be upgraded to a 6 inch imprint area.


960 mm
R 800
Top


1000 mm
785 mm
1850 mm
1095 mm
135 mm
Front
Side

NIL 4" Technical Specifications

System Scope and Dimensions	
Dimensions (LxWxH)	100 x 75 x 180 cm
Weight	Approx. 900 kg
PC for machine control	Industrial computer with 15" flat screen display

Product Safety
CE Mark
Interlocked safety cover
Lock out/Tag out disconnect
EMOS

CONFIGURATION

Programmable Recipe Software - Profile Control for Temperature, Pressure VS Time with closed feedback loop to ensure process accuracy

Stamp/substrate alignment: A method will be supplied and any associated equipment required to accurately align stampers at high accuracy (including cameras, microscope, etc.)

Substrate holder: System will include a user-friendly "tray system" for loading and unloading stamp/substrate material into equipment

Manual Stamp/substrate Offload: Material offload process includes a tool that can be operated manually and safely when material is at high temperatures

Parameter	Specification
Temperature (Minimum)	Ambient Temperature
Temperature (Maximum)	350 °C
Temperature Field Uniformity	± 1 % Temperature Stability over imprinting surface area
Heat-up Ramp	2 – 5 °C / Sec. Temperature in top and bottom chuck can be controlled separately
Print uniformity	± 20 nm
Pressure	≤ 80 bar (Minimum 5 bar)
Stamper Size	Ø 130 mm, +4 / -1 mm, Maximum thickness 1 mm
Imprinting Area	102 mm Ø

Optional	
Cooling	-10 °C or lower (External Gas Cooler)
Overlay Alignment Accuracy (X,Y,Theta)	10 % of Alignment mark size (Limitation ± 1 μ m)
Substate Alignment	Relative to Aligned Stamper
Two-Sided Imprinting	Capability available with relative alignment accuracy
UV-Module UV-Module is placed in upper chuck.	Xenon lamp Central wave length: 365 nm Power: 1,375 or 1,8 W / cm2 Pulse rate: 3 pulses / second ON / OFF time: 2μ Second Generated temperature at Substrate: Ultra low Configuration: One Lamp UV-source area: Ø 5,5 inch Exposure area: Ø 6 inch

Facility Requirements	
Voltage #1	400 VAC, 3 phase
Frequency	50 / 60 Hz
Power	10 kW
Compressed Air	5 – 8 bars, 40 l / min
Room Temperature Range for Normal Operations	18 – 32 °C
Relative Humidity	65 %
Cleanroom Class	Class 100

NIL 6" Technical Specifications

System Scope and Dimensions	
Dimensions (LxWxH)	100 x 75 x 180 cm
Weight	Approx. 900 kg
PC for machine control	Industrial computer with 15" flat screen display

Product Safety

CE Mark

Interlocked safety cover

Lock out/Tag out disconnect

EMOS

CONFIGURATION

Programmable Recipe Software - Profile Control for Temperature, Pressure VS Time with closed feedback loop to ensure process accuracy

Stamp/substrate alignment: A method will be supplied and any associated equipment required to accurately align stampers at high accuracy (including cameras, microscope, etc.)

Substrate holder: System will include a user-friendly "tray system" for loading and unloading stamp/substrate material into equipment

Manual Stamp/substrate Offload: Material offload process includes a tool that can be operated manually and safely when material is at high temperatures

Parameter	Specification
Temperature (Minimum)	Ambient Temperature
Temperature (Maximum)	350 °C
Temperature Field Uniformity	± 1 % Temperature Stability over imprinting surface area
Heat-up Ramp	2 – 5 °C / Sec. Temperature in top and bottom chuck can be controlled separately
Print uniformity	± 20 nm
Pressure	≤ 80 bar (Minimum 5 bar)
Stamper Size	Ø 160 mm, +4 / -1 mm. Maximum thickness 1 mm
Imprinting Area	152 mm Ø
Substrate Size	≤ 200 mm Ø. Maximum thickness 1,5 mm.

Optional	
Cooling	-10 °C or lower (External Gascooler)
Overlay Alignment Accuracy (X,Y,Theta)	10 % of Alignment mark size (Limitation ± 1μ m)
Substate Alignment	Relative to Aligned Stamper
Two-Sided Imprinting	Capability available with relative alignment accuracy
UV-Module UV-Module is placed in upper chuck.	Xenon lamp Central wave length: 365 nm Power: 1,375 or 1,8 W / cm2 Pulse rate: 3 pulses / second ON / OFF time: 2μ Second Generated temperature at Substrate: Ultra low Configuration: One Lamp UV-source area: Ø 5,5 inch Exposure area: Ø 6 inch

Facility Requirements	
Voltage # 1	400 VAC, 3 phase
Frequency	50 / 60 Hz
Power	10 kW
Compressed Air	5 – 8 bars, 40 l / min
Room Temperature Range for Normal Operations	18 – 32 °C
Relative Humidity	65 %
Cleanroom Class	Class 100

附件 C

Raith 公司相關資料文件

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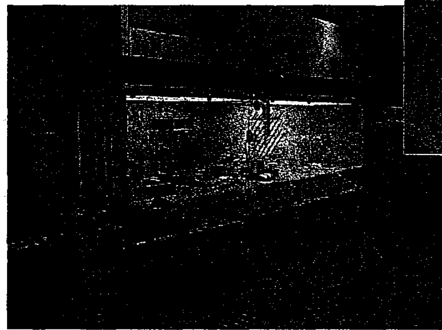
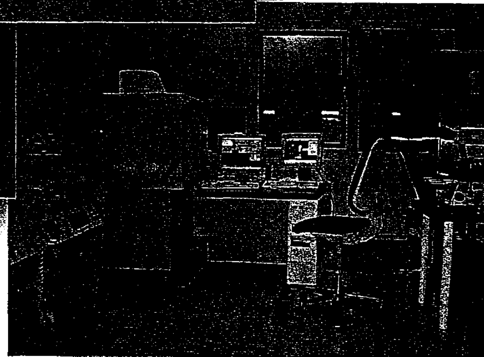
July 2003

Raith strengthens its position as a key enabler in nanotechnology

Since the last newsletter sent out in August 2001, Raith has addressed its main resources on customers' enquiries about its e-beam lithography product range, the RAITH150, RAITH50 and ELPHY. While the global downturn in semiconductor industry did not have a dramatic effect on Raith, the demand for the company's leading edge nanolithography tools grew continuously mainly fuelled by the fivefold worldwide increase in nanoscience and technology funding since 1999.





Raith delivered the RAITH150 and RAITH50 R&D e-beam tools to famous research centres, including Stanford Nanofabrication Facility (SNF), Centre for Nanoscience and Technology Tel Aviv, Samsung Advanced Institute of Technology and the Naval Research Centre.

The well-known ELPHY attachment for SEM and FIB lithography continues to be a powerful product and an excellent complement to the "Turnkey" e-beam tools, the RAITH150 and RAITH50.

Since 2001, number of staff at the headquarters in Germany has been increased continuously - the headcount in January 2003 exceeded fifty employees. In parallel, the customer support and service staff at Raith USA have been doubled - accompanied by a move into an extended office and support centre located in Ronkonkoma, New York.

In collaboration with the Dortmund Centre for Packaging and Interconnection Technology (AVT), Raith established its own clean-room environment equipped with resist processing and e-beam technology. The facility now serves as a customer-training centre, which also allows application support and offers demonstration capabilities to interested parties.

Raith GmbH is actively participating in European and National Research Projects such as "Nano-FIB", which is an initiative for exploring new technologies and application fields for sub-10nm nano-fabrication with focused ion beams. For more details, please refer to the article inside of this newsletter.

Of course, as a company grows, occasional errors are inevitable - but Raith staff are committed to providing both solutions and improvements wherever they become necessary. We are looking forward to trustful cooperation with our existing and prospective customers and partners in the future.

Raith

ww.raith.com

First Korean e-beam lithography users group meeting held at Sung Kyun Kwan University on May 20th, 2003

For the first time a Raith Lithography systems Users Group Meeting was held in Korea. The meeting was hosted by the Technology Innovation Centre of Sung Kyun Kwan University (SKKU), Suwon.

With about thirty-five participants in the modern premises of SKKU, the event was regarded as highly prolific and beneficial.

Beside presentations from Raith staff members, who were also available to answer technical and software-related questions, Prof. Gyu-Tae Kim[1] of Korea University and Dr. Baek Inbok[2], ETRI (formerly at Chung Buk University) presented their scientific results.

[1] *Selective Patterning on a Single Nano Fibre by using an ELPHY*

[2] *Nano-Patterning Using E-Beam Lithography for Fabricating Single-Electron Transistors*

Thanks should be given to the excellent event organisation by the staff members of JinSan Scientific, the local Raith partner in Korea.

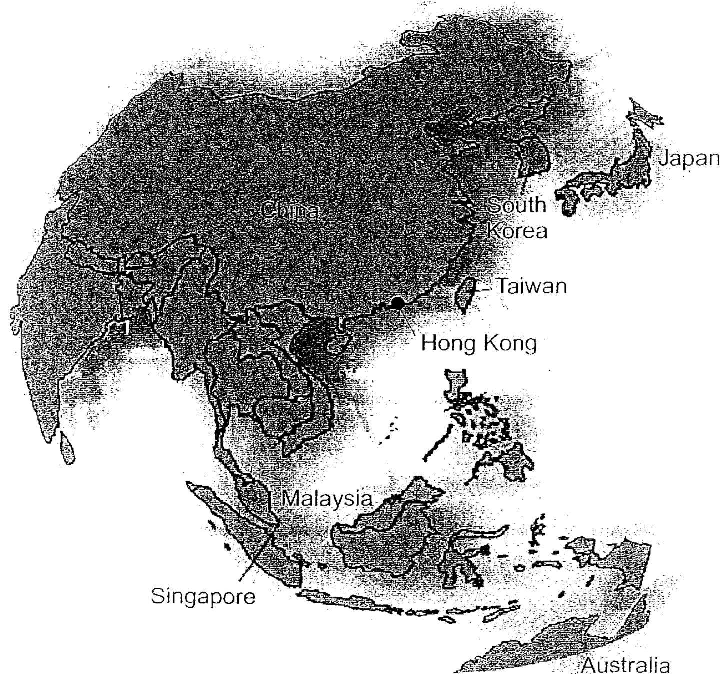
Raith Asia support centre opened in July 2002

Raith is pleased to announce that as of July 2002, there is a direct presence in Asia. The mission of the Raith Asia Support Centre based in Hong Kong is to provide full support for Raith installations throughout Asia.

Raith Asia will closely work together with the sales and service partners of South Korea, China, Japan, Taiwan, Australia, Singapore and Malaysia.

Your main contact for technical support there is Dr. Keith Moulding. He has a profound 15-year background on electron optics and previously worked at the Materials Characterisation and Preparation Facility of the Hong Kong University of Science and Technology.

With an increasing user base, Raith Asia will follow our general expansion strategy.



Raith Asia Service and Support, Ocean Shores,Tower 6, Flat 47G, O-King-Road, Tseung Kwan O, Kowloon, Hong Kong
phone: ++852-2247-1446, fax: ++852-2247-1449, kmmoulding@raithasia.com

New software release 3.0 - for Raith lithography and navigation products

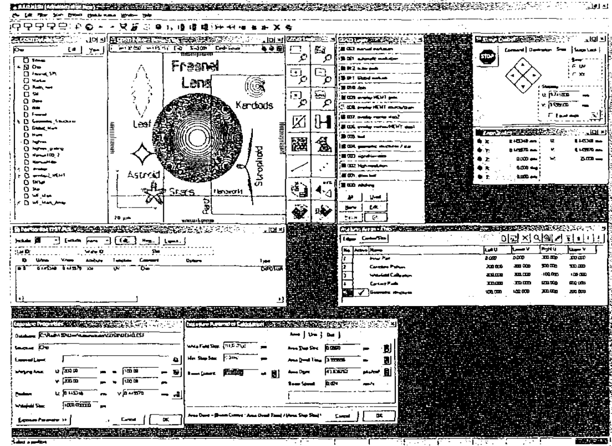
The new release 3.0 accumulates the work of more than fifteen engineering years in continued software development. Following the strategy of a common software platform, it is available for all Raith products now.

One major feature that has been implemented is a unique **Multi-User Environment**, allowing each individual user to configure the entire lithography system for his individual application without affecting any other user's setup. A user can get back to the lithography tool, finding it with exactly the same configuration it was left with, minimising configuration time and potential for errors whenever multiple users have access to an instrument.

The capabilities of the **GDSII layout data-base** have been enhanced significantly, now enabling the handling of file sizes of up to GB range, leaving the limitations of general purpose CAD layout programs for lithography applications far behind.

Various features like "Undo" functionality for the design phase, the definition of multiple working areas within a single file, an intelligent exposure parameter calculator as well as a range of exposure file preprocessing functions, and much more have been implemented. Most of it is the result of many years of close cooperation with the largest research-oriented e-beam customer base.

Moreover, an **open-access Script Engine** has been implemented within the software platform allowing automating many of the routine tasks. All these features will assist in saving valuable time and speed up the whole process flow. Please enquire for more details.

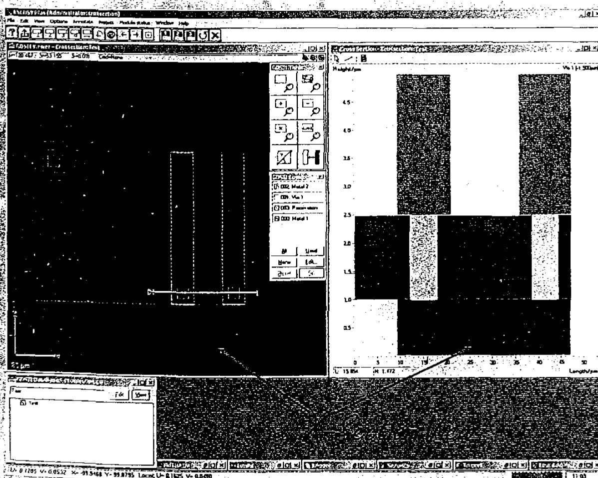


Screenshot of software release version 3.0

ESCOSY *Plus* CAD navigation advances - New features

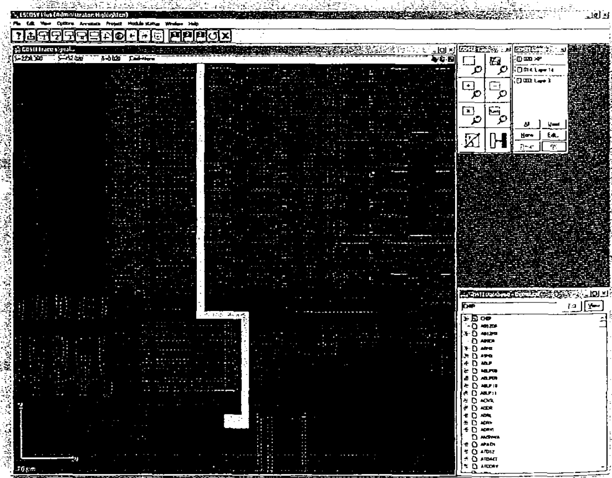
CAD-file data handling of GDSII-files with 1,8 GB successfully tested with ESCOSY Plus at customers' site

Cross section simulation



The user can now select an area and simulate a cross-section. It can easily be avoided to cut at the wrong position and destroy the sample during FIB operation.

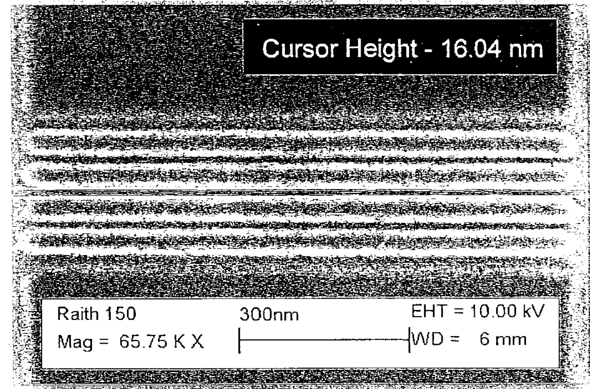
Signal tracing



By clicking on any structure, the signal path can be followed through the entire layout. This feature helps to find the best position for an FIB cut or modification.

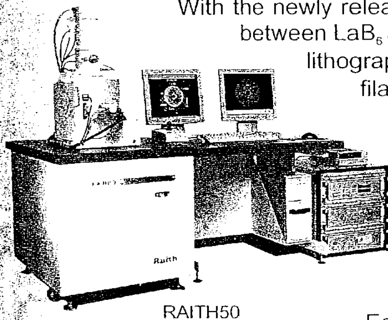
Improved specifications for RAITH150

When offering ELPHY Nanolithography attachments for any SEM or FIB, the level of application and system guarantees are naturally different compared to the Raith Turnkey product range. Offering the complete, factory integrated solution is the key for a high-level system specification. Consequently the technological facilities of Raith at the "AVT" centre were expanded with the goal of having permanent access to reliable and reproducible resist technology. Processes were developed and refined so that Raith can guarantee a minimum line width specification of 20nm for the RAITH150, a TFE-based e-beam tool. Of course today's FE-based electron optics have the potential for sub-20nm features, however when it comes to providing a reliable specification, someone who can offer full control from tool to technology should be sought.



High resolution pattern sub 20nm line width showing

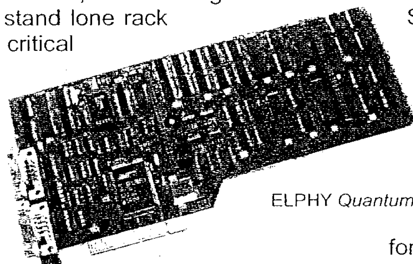
New generation of the RAITH50


RAITH50

With the newly released second generation of the RAITH50, the researcher community now has a choice between LaB_6 and Tungsten filament technology within a dedicated high-grade and affordable e-beam lithography system. Whereas the advanced LaB_6 electron emitter configurations offer long filament lifetime at high current stability, the inexpensive and easy-to-use Tungsten filament technology is the perfect choice for facilities with a high degree of educational and training background. In conjunction with new electron optics, the new electrostatic beam blanker and further refinements in the system integration, a minimum feature size of 50 nm or less is now guaranteed for LaB_6 filament. The drawer mounted laser stage with 2 nm positioning resolution allows a wide range of variation in the working distance. A fast and direct access to the universal sample mount supports extreme flexibility with ease of use. The nm-accurate calibration of any selected write field size at various working distances is a matter of minutes and requires no calibration standard. Easy Multi-User Interface is standard with the new RAITH50.

New Hardware for ELPHY *Quantum* - the evolution is continuing

The Raith success story started in 1986 based on a first custom-made PC board for high performance pattern generation. In 1993 a new PC based hardware was launched to also comply with the need for video grabbing and layer-to-layer mark registration, field calibration, and image acquisition. To improve electronic performance and to improve writing speed issues, Raith designed lithography hardware in a stand lone rack with thermal control of the critical components, extremly stable power supplies and the best available 16 bit DACs. This Digital Signal Processor (DSP) based solution is better known as the **ELPHY *Plus*.**

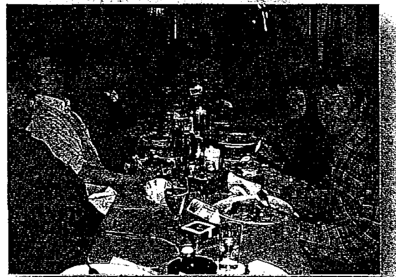

ELPHY *Quantum*

The ELPHY *Plus* hardware is currently in its 4th generation, accumulating all sequential enhancements in critical parameters for lithography, such as linearity, stability, speed and signal-to-noise level of the electronics. Raith highest-speed pattern processors are operating at frequencies of up to 10MHz. Raith exclusively offers these in conjunction with RAITH150 Turnkey e-beam tools tuned to "digest" such a high writing speed by active dynamic scan correction.

Raith offers non-compromised DSP-based pattern generator technology that is still the perfect complement to the state-of-the-art field emission electron optics offered by SEM vendors like JEOL, FEI, Hitachi and LEO.

The ELPHY *Quantum* with its PC-based hardware is a unique entrance level e-beam lithography attachment for SEM and FIB. To comply with the enhanced PC technology, Raith has developed a new DSP-controlled ELPHY *Quantum* electronic based on the PCI-bus system. The PCI-based system is the best technical solution to offer good electronic performance and speed, while keeping an eye on customers' budgets. The technological advances of the last few years have in fact enabled Raith to provide customers with a new generation of ELPHY *Quantum* with much faster mark recognition, higher writing speeds and increased flexibility compared to the previous generation. Please contact Raith for further information.

Raith events 2003



Raith Lithography System Training arranged in March 2003

For the 2nd time, the Raith headquarter in Dortmund has been the pivot point for the annual Raith Lithography System Training.

In addition to users from Europe, Raith had the pleasure to welcome two users from New Zealand. As in previous training programs, Raith could "pick up" new ideas and suggestions by communicating with the users. To customise their products better, Raith is keen to present them in view of gathering direct user feedback.

Raith would therefore like to thank all participants once again for their lively interest and the active exchange of information during the 3-day meeting.

Due to the exceptionally high interest in the Raith customer training course this year, Raith will offer additional training courses.

For detailed information, please see: www.raith.com

Nano2003 - 9th International Workshop on SEM-based E-beam Lithography

This year's Nano2003 international workshop held from March 17th-18th received the same exceptional high response like the Raith customer training.

The 9th workshop, held at the Raith headquarters, proved to be a great success with thirty-seven participants from all over the world attending.

To make that event more than an ordinary workshop, Raith invited not only their own specialists but also five highly qualified speakers from the domain of nanostructuring, who gave a variety of lectures on their own specialised subjects. Raith was very pleased with the very positive feedback confirming the participants' full satisfaction. In addition to the theoretical part, practical demonstrations on Raith systems completed the overall impression and gave the participants a short insight into the high performance of Raith electron beam lithography systems. A program arranged for the evening provided some recreation and social exchange beyond the official occasion.

Invited speakers

James W. Conway, Stanford University, USA
Electron Beam Lithography, a critical enabler towards the Integration of Photonic Device Systems

Johannes Kretz, Infineon Technologies, München, Germany
20nm Electron Beam Lithography for ultimate MOSFET device fabrication

Sven Bauerdick, NMI Natural and Medical Science Institute ,Reutlingen, Germany
Rapid Prototyping of Nanostructures by Electron Beam Induced Deposition

Jacques Gierak, LPN / CNRS Marcoussis, France
Nano- Fabrication with Focused Ion Beams

Britta Hausmanns, University of Duisburg, Germany
Resistance Behavior of Magnetic Nanowires prepared by EBL

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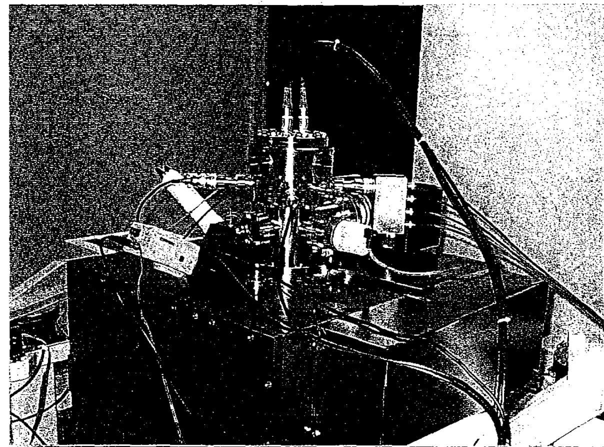
Raith

lanoFIB - Investigating new nano-fabrication processes and instrumentation

lanotechnology aims to carry out new processes at a scale of just a few molecules or even single atoms. The European :ommunity has highlighted this technology field because of its revolutionary potential. Therefore new tools and skills will need) be developed. As part of this, focused ion beam (FIB) technologies will increasingly play an important role in many pplication areas requiring nanometre-sized patterning or precision. Well-known international research groups, Raith and ther small and medium-sized enterprises (SMEs) joined forces to enhance the capabilities of FIB-based nano-fabrication ıstrumentation and processes. This work is partially funded by the EC (R&D project: "NanoFIB", FP5 GROWTH program: ;5RD-CT-2000-00344). The consortium consists of ten research and industrial partners with highly complementary areas of xpertise. In detail the partners are:

- **CNRS LPN Laboratory** (Marcoussis, France, coordinator)
- **Raith GmbH** (Dortmund, Germany)
- **FuG Elektronik GmbH** (Rosenheim, Germany)
- **CNRS-CEMES** (Toulouse, France)
- **Delft University** (Delft, Netherlands)
- **Surrey University** (Surrey, Great Britain)
- **CEA** (Saclay, France),
- **University Duisburg-Essen** (Essen, Germany)
- **Université Paris Sud** (Paris, France)
- **Institute of Scientific Instruments** (Brno, Czech Republic)



Nano-FIB tool at CNRS LPN

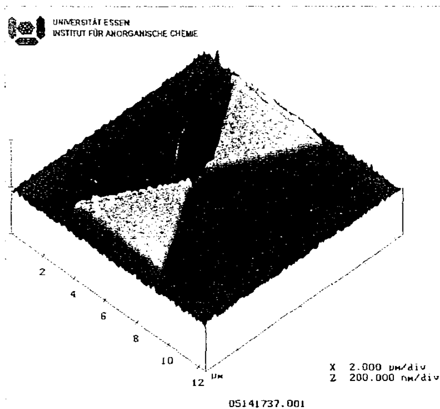
It is well known that, unlike e-beam lithography, ion beams allow direct (i.e. resistless) surface modifications and different patterning approaches. Focused ion beams are already used for milling and etching applications, usually to remove materials and for depositing vapour phase materials on to surfaces. All of these processes are generally associated with high dosed ion operations and limited throughput.

In contrast to these areas, the concept of NanoFIB is to develop new focused ion beam (FIB) instrumentation dedicated for low-dose, high-resolution (sub-10nm) and high-selectivity nano-fabrication work. The consortium is also exploring new highly sensitive ion beam patterning processes, such as (i) fabrication tasks for ultra-high-density magnetic data storage, (ii) patterning of metal nano-clusters, (iii) generation of active III-V semiconductor structures, (iv) localised growth of carbon nano-tubes, (v) polymer film modification for bioscience use, and more. For further information on NanoFIB please visit:

www.cordis.lu/nanotechnology/src/pressroom-pub.htm
www.phantomsnet.com/html/newsletter5.php

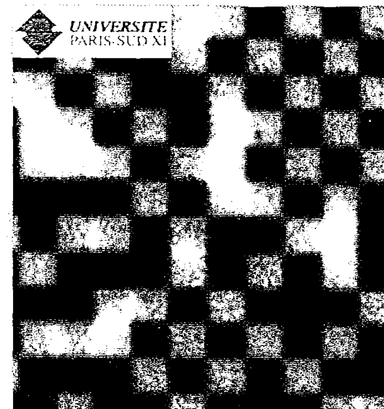
Example applications:

AFM image of a butterfly pattern



minimum features 30nm, Au55 used as "negative resist" for FIB

Magneto optical image of magnetic domain patterns



900nm*900nm squares, domain walls defined by FIB