國立成功大學

機械工程學系

聲光電暨奈微米結構實驗室

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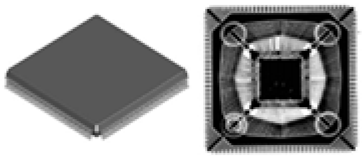
聲 聲波感測元件與材料之非破壞檢測 Acoustic Sensing Device and Non-destructive Evaluation

隨著工業的蓬勃發展，各式製程、產線陸續被開發出來。然而，為了確保產品的品質，對產品缺陷之快速、非破壞性的檢測有其必要性，從半導體晶片、金屬靶材、玻璃面版、封裝IC之缺陷裂紋的檢測到鍍層材料之機械性質量測，超音波一直是最為廣泛應用的選擇。本實驗室專精於超音波檢測方法，透過各式超音波換能器的設計與製作，並建立各式的量測整合系統，可對各式的產品作測試，也因此可達到對各式產線之快速、非破壞性檢測的需求。

Ultrasonic engineering are widely used in a variety of industry applications for the defect nondestructive evaluation and material property measurement. For different measurement requirements, such as the defect detection of silicon wafer, metal target material, LCD glass plate, electronic package IC and the coating material property measurement, we design and fabricate various ultrasound transducers with operating frequency from few MHz up to more than 100 MHz and can integrate with different measurement systems.

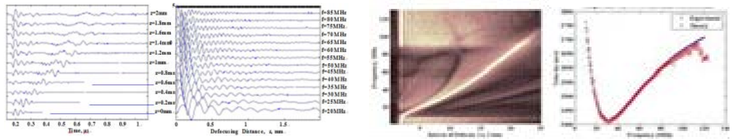
Ultrasound Focusing Transducers

Package IC C-scan Detection



Laboratory-Made PVDF and PZT Hydrophones

Coating Material Property Measurement

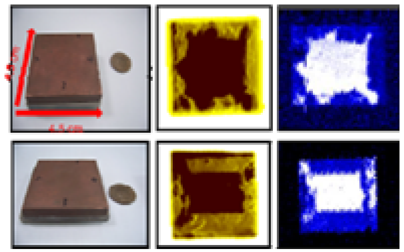


聲 半導體靶材缺陷之超音波影像 Target Material Ultrasound Image Defect Inspection

應用於薄膜濺鍍的大型靶材是許多產業的重要上游材料，包括半導體、平面顯示、與光電產業在內，都需要依賴濺鍍靶材與濺鍍技術產生大面積的薄膜鍍層，包括金屬與非金屬材質的薄膜鍍層。傳統的濺鍍靶材是平面式的，由靶材本體與支撐背板二者構成。隨著時間演進，近年更出現一種圓筒狀的旋轉靶材，因為使用效率優於平面式靶材，因此其重要性更逐步凌駕傳統的平板靶材之上，檢測需求也因此衍生。對靶材檢測的目的有二：(一)找出靶材本體的內部缺陷、與(二)焊合層的完整性，二者都對後續的薄膜濺鍍製程與薄膜的品質有重大的影響。本研究室針對平面式與旋轉式靶材的檢測需求開發其缺陷掃描系統。

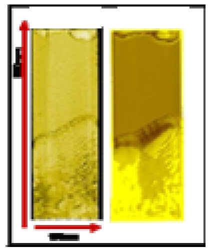
人工銲合缺陷靶材檢測比較

商用系統 開發系統



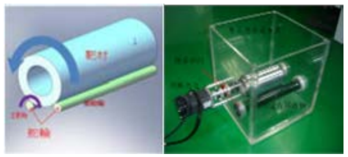
Nb_2O_5 靶材檢測比較

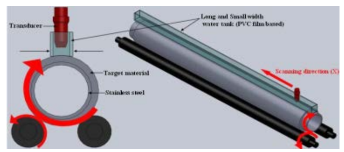
開發系統 商用系統



旋轉靶材測試機構

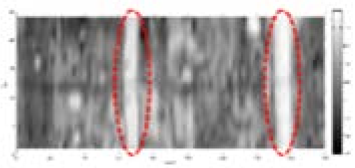
非浸水式靶材缺陷檢測





靶材掃描系統

旋轉靶材掃描結果



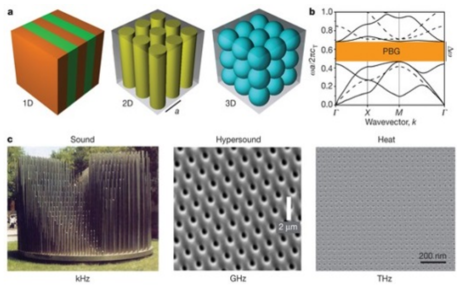
聲子晶體結構中的波傳效應

聲 Wave propagation in Phononic crystal structure

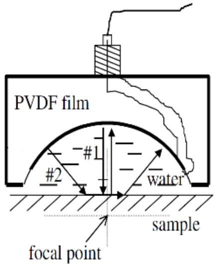
聲子晶體(PC)是由兩種材料(背景材料以及填充材料)組成的結構，填充材料週期性地排列於背景材料中。由於結構中材料分布的週期性，使得聲子晶體具有許多特別的波傳現象，諸如能隙、負折射、自我準直等。本研究使用線聚焦 PVDF 壓電換能器配合 V(f,z)方法，量測含有聲子晶體結構的薄板，其結果顯示原本連續的色散曲線在某些頻段出現了不連續斷階，此即因波無法通過結構而產生的能隙現象。未來將利用此量測系統觀察更多聲子晶體的波傳特性。

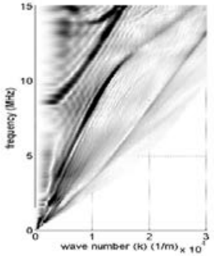
Phononic crystal (PC) is a kind of structure, which is made of two materials (inclusions and matrix), the inclusions are periodically embedded into the matrix material. The periodicity of the material arrangement leads to some interesting phenomenon of wave propagation, such as band gap, negative refraction, self-collimation and so on. In this study, we use the linefocusing PVDF transducer and V(f,z) method to measure the thin slab with phononic crystals.It can be seen in the results that discontinuity appears at some frequency ranges of the dispersion curves, which means the waves cannot pass through the structure, and is so-calledband gap phenomenon. We will use this measuring system to further investigate more properties of phononic crystals.

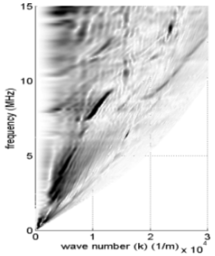
Phononic crystal **PVDF transducer**



Measuring process **without PC** **with PC**







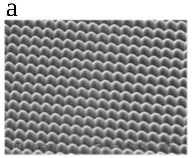
準分子雷射微細加工

光 Excimer Laser Micro Machining

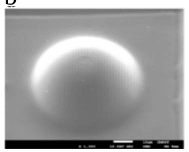
本實驗室的準分子雷射微加工系統由三部分建構而成，分別為雷射光源，光學透鏡系統和精密控制位移伺服平台。其加工方法和特點分為三個部分。一、雙軸拖拉法，可加工大面積且周期性微透鏡陣列，二、旋轉加工法，適合加工微噴嘴和微擴散器，三、孔洞面積法，乃利用光罩透光率分佈不同而製作出所期望的結構。利用雙軸拖拉法加工大面積微透鏡陣列，搭配平行紫外光和位移平台，將紫外光光束聚焦進行黃光微影製成。

Excimer laser micro machining system in our lab includes three components are laser source, optical lens system and precise controlled moving stages. In our research can be divided into three approaches and features. First is Laser Dragging Process which is good at machining big area and periodic micro-lens array. Second is Laser Rotating Process which feature is fabricating nozzles and diffusers. Third is Hole Area Modulation based on the different spatial distribution of projected laser energy intensity to fabricate design surface profile. Using the Laser Dragging Process to get micro-lens array. With the parallel UV light source and precise controlled moving stage, focus the UV light into a spot size and do lithography on photoresist.

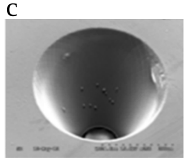
a



b



c



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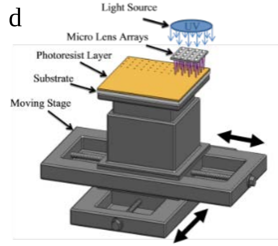
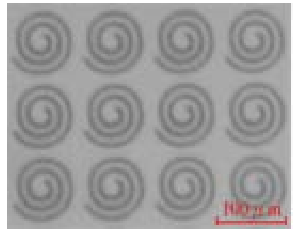


e



(a)fabrication micro-lens array by excimer laser dragging method. (b) fabrication of micro-lens by hole area modulation. (c) micro-structure of nozzles and diffusers. (d)beam pen lithography system. (e)microstructure of photoresist

無光罩式斜掃描曝光系統

光 Mask-less Dot Scanning Lithography System

本實驗室運用數位光源處理技術(DLP)建立無光罩式光點陣列斜掃描曝光系統並探討其微影製程的性能；此系統主要由準分子雷射製作出系統的核心元件微透鏡/空間濾波器陣列(MLSFA)、自行建構的點陣列斜掃描演算法及光投影系統而建構成。點陣列斜掃描法係利用 MLSFA 將數位光學影像轉換成光點陣列並沿著一個軸向拖拉掃描來完成大面積圖案化曝光。無實體光罩非常合適傳統黃光微影的相關產業，有助減少研發的時間與成本，且在少量多樣化發展上擁有相當大的優勢。目前最小線寬可達 5 μm 並透過任意傾斜角度來調整線寬解析度到 0.3 μm。

The Mask-less Dot Scanning Lithography system is based on digital light processing, DLP, technique to advance a novel lithography method for time-saving and cost-down rather than the conventional lithography method. The construction of system has three core subjects, fabrication of Microlens/ Spatial Filter Array (MLSFA) by Excimer laser micromachining, programming the algorithm of dot array scanning, and composing the optical projection system. The main idea of this study is using the MLSFA to transform digital light image into light dot pattern and yawing angle, dragging one way. The major advantage of mask-less is appropriate for manufacturer saving time and cost in development. In addition, it is suitable to produce in small amount of diversity. In recently, the minimum line width is around 5 μm, and the resolution of line width would be around 0.3 μm by yawing angle.

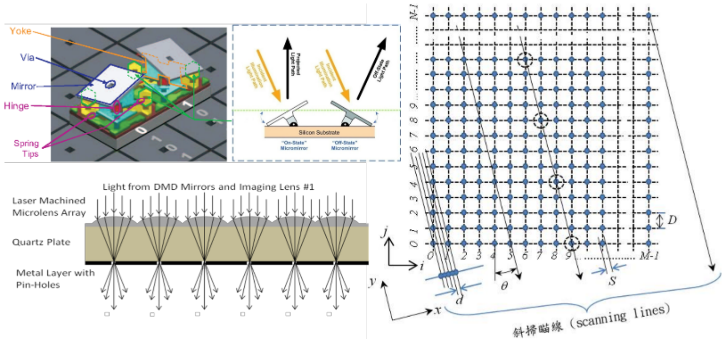


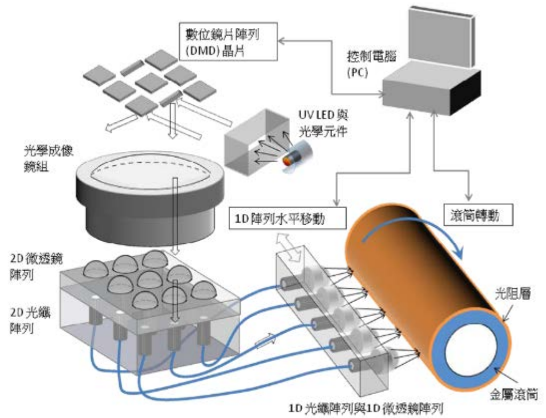
Fig. (a) DLP technique and action (b) Fabrication of MLSFA by Excimer laser machining. (c) Illustration of dot scanning method

無光罩式外滾筒微影製成技術

光 Mask-less Outer Cylindrical Photolithography

光源部分如下圖，有三項硬體:UV-LED 光學元件、數位鏡片陣列與光學成像鏡組；三者構成一完整的「數位光學投影」系統。另外利用光纖陣列，其左端接收來自數位光學投影系統的 UV 光，且排列成二維陣列，右端為出光面，且排列成一維陣列，透過雷射拖曳加工法在兩端加工特定形貌微透鏡陣列。撰寫程式控制數位鏡片陣列每一個畫素的亮暗，並搭配雙軸位移平台和旋轉伺服馬達，在金屬滾筒上完成非週期性結構，達到無光罩式微影製程技術。

The light source is show as follow figure. The Digital Light Process(DLP) include three device, UV-LED optical components□Digital Micro-mirror Device(DMD) and projection lens. Using the fiber array, which the purpose of the left hand side(LHD) is to collect the UV light from DLP, and arrange the LHD as 2D array. In the right hand side(RHS) of the fiber array is to focus the UV light to do the lithography on the roller, and arrange the RHS as 1D array. Using the Laser Dragging Process to manufacture the design surface profile micro-lens on the both side. Control each pixel of the DMD□2-axis stages and servomotor to manufacture aperiodic structure on the metal roller to achieve the mask-less lithography technique.



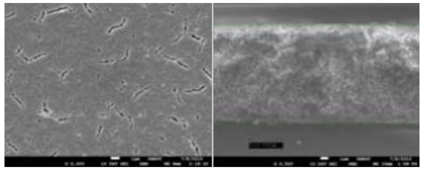
壓電膜製作技術

電 Technique of Fabricating Piezoelectric Film

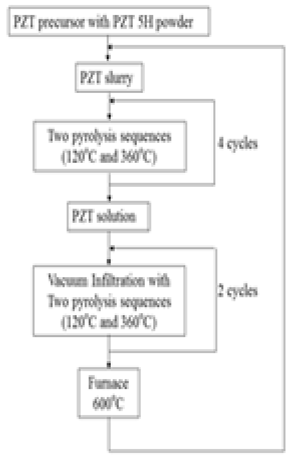
本實驗室透過改良式溶膠凝膠法針對 1~20 μm 膜厚的 PZT 壓電陶瓷膜進行材料的開發，使其具備高品質且穩定的性能。目前透過改良式溶膠凝膠法可以得到膜厚範圍介於 2.4μm ~ 12.8μm 的壓電厚膜。當膜厚為 12.8μm 時，在最大電場 625kV/cm 的狀況下，殘餘極化向量為 24.48μC/cm_2，而矯頑電場為 122.72 kV/cm。

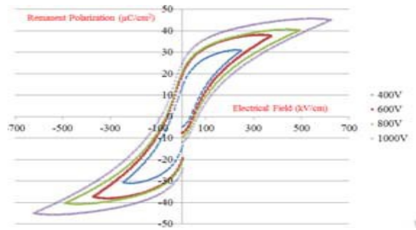
We focus on the development of high-quality and stable PZT thick film around 1 to 20 μm in thickness by modified sol-gel method. Films with a thickness in the range from 2.4μm to 12.8μm can be obtained by the improved sol-gel method. When the thickness of the film is 12.8μm, the maximum remanent polarization is 24.48μC/cm and the coercive field is 122.72 kV/cm at the maximum electric field, 625kV/cm.

★Thick film

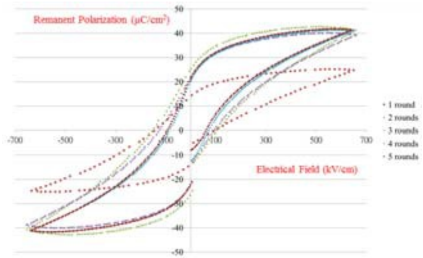


SEM image, five rounds coatings





P-E curve, five rounds coatings



P-E curve, different rounds coatings

NANO 軟性光罩微影技術

Soft Photo-mask Lithography

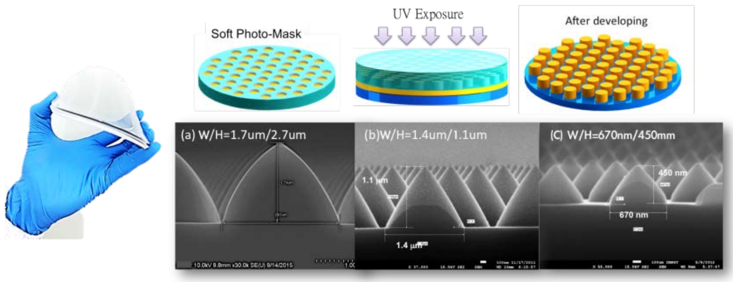
軟性光□微影製程技術運用於圖案畫藍寶石基板製造

Soft Phot-mask Lithography for Patterned Sapphire Substrate Manufacturing

軟性光罩微影製程是以黃光微影製程技術的概念結合奈米壓印的特點（包括：大面積、可撓性的黏附、一次性的曝光製程、小線寬等優點）而延伸出的另一項新技術術，此技術克服奈米壓印中 UV 膠蝕刻選擇比、殘留層均勻度、壓印產率等問題。本研究之軟性光罩微影技術，目前主要應用為4 吋與 6 吋的圖案畫藍寶石基板製作，可完成週期 3um、2um 以及 1um 的圖案畫藍寶石基板，後續產品應用如中介層、透明導電膜、太陽能等應用。

The new method of soft photo-mask lithography (SPL) is based on photolithography Process combined with characteristics of nanoimprinting lithography. The SPL can resolve the problems of nanoimprinding, including etching selectivity, uniformity of residule layer, throughtput, and so on.

In our experiment , both 4 and 6 inch patterned sapphire substrates (PSSs) with miro and nanometer feature size are successfully achieved. Other possible applications of SPL are interposer, metal mash, and solar energy devises



Soft Photo-mask and Micro/Nano PSS

平面奈米壓印

NANO

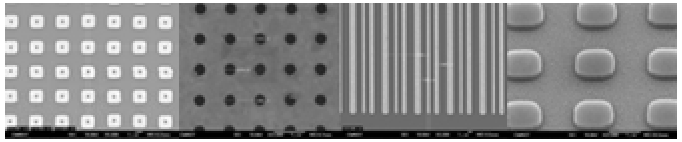
Flat Nano-Imprinting

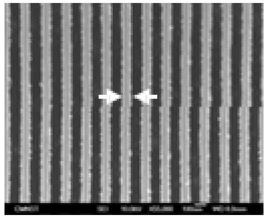
金屬接觸轉印微影製程

Metal Contact Printing Photolithography Technology

金屬接觸轉印微影技術是一種創新混合型技術，具有低成本、高成功率的奈微米圖 形轉印，主要特點在於克服傳統奈米壓印技術上光阻殘餘層 所衍生的壓印失敗問題，同時經由自行設計的壓印系統能夠 均勻完整的轉印 6” wafer 大小的金屬圖形，最小線寬達到 60 nm。

Metal contact printing photolithography (MCPP) technology is a micro-/nano-patterns transfer method which has the characteristics of low cost and high success rate. It can directly transfer a patterned thin metal film from a mold to a substrate and overcome the problem of the conventional nanoimprint technology, when the residual layer is too thick. In our lab, we can complete transfer the metallic patterns to a substrate. The transfer area size has achieved 6” wafer and the smallest feature size is line-width of 60 nm.



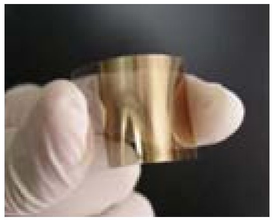


完成最小線寬 **60** 奈米轉印

The smallest feature size of 60 nm has been successfully patterned into PET films.

製作大面積可撓式光學元件

Large-Area Flexible Optical Devices Fabrication



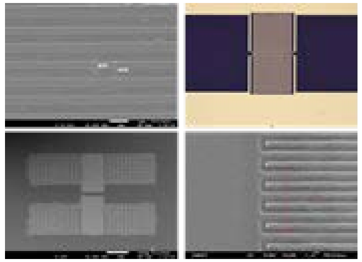
平面奈米壓印

NANO

Flat Nano-Imprinting

製作表面聲波元件

Surface Acoustic Wave (SAW) Devices Fabrication

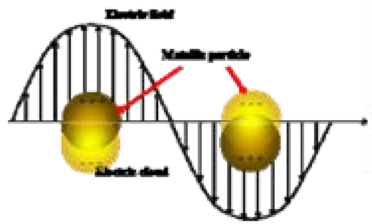


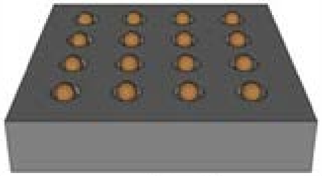
以金屬接觸轉印微影技術完成最小線寬 500 奈米之表面聲波元件

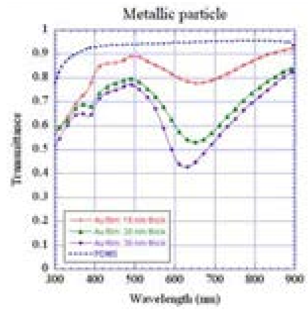
500 nm line width SAW device fabrication by Metal Contact printing photolithography

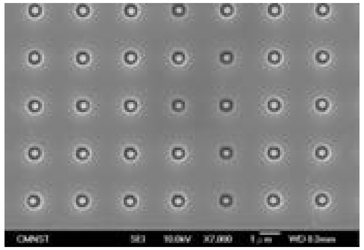
製作陣列式金屬奈米粒子應用於局域性表面電漿共振效應

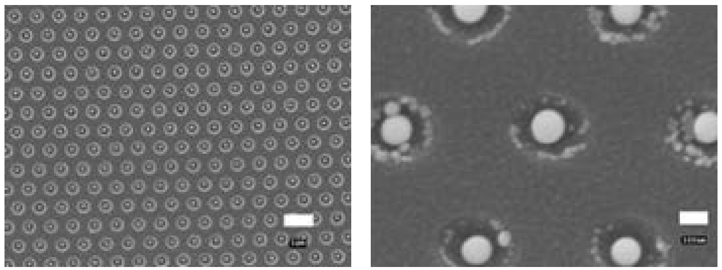
Array nanoparticles fabrication for localized surface plasmon resonance (LSPR)











奈米壓印

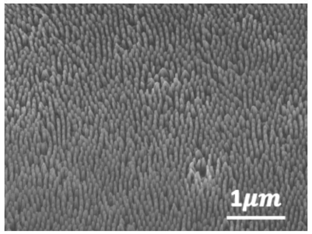
NANO

Nano-Imprinting

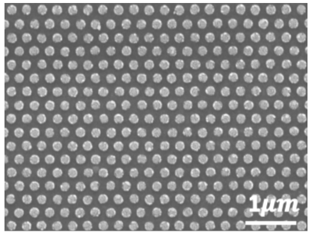
本實驗室透過奈米壓印製程結合金屬轉印技術，於基板

上佈值奈米金屬點，成功於可撓式基板上產生侷域性表面電漿共振效應(LSPR)，可用於製作曲面貼覆性質的感測元件，或更進一步地輔以蝕刻技術製作週期性微奈米結構，改善基板的光學特性，應用在節能玻璃上以減少熱輻射傳遞、於藍寶石基板上製作抗反射結構，大幅提升光穿透效率。目前研究方面也將由平面奈米壓印轉向於曲面壓印，致力於將微奈米圖形轉移至曲面透鏡上。

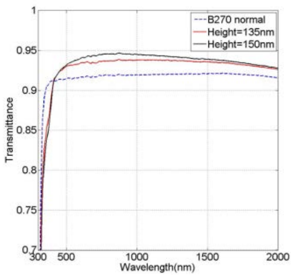
The fabrication of nanoparticles array by nano-imprinting and Metal contact printing photolithography enhance Localized surface plasmon resonance on flexible substrate for making surface-contacted sensor, furthermore, we fabricate periodic nanostructure with etching process to improving optical property. This application such like energy-saving glass, which decreasing heat radiation, or antireflection structure on sapphire in order to the significant enhancement of light extraction efficiency. In future work, our research will focus on the nano-patterned tranfer from flat to curved surface.



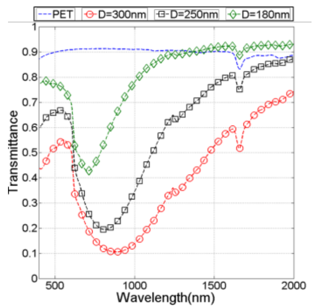
a. Moth-eyes structure



b. Nanoparticles array



c. Transmittance spectrum



d. LSPR spectrum

奈米壓印

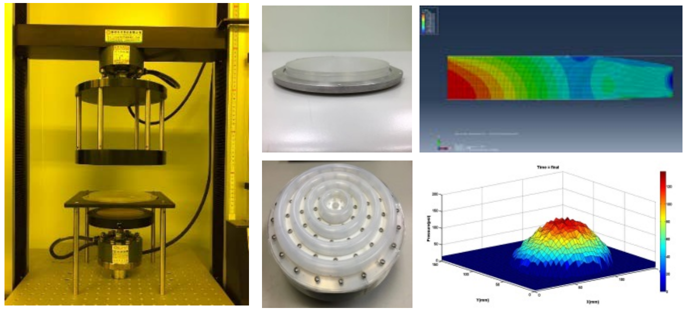
NANO

Nano-Imprinting

精準力學控制之奈米壓印

Nano-Imprinting System with Precision Contact Force and Deformation Control

此為本計畫之核心，將提出二種機台設計，並分別搭配不同的撓性模仁，進行 UV-NIL 的實驗測試。第一種設計採用具厚度變化的 PDMS 模仁，以彈性變形的方式控制接觸壓力的分布與變化，進而控制阻劑膠的擴散與流動，得到更佳的壓印結果。第二種設計採用”數位、環形、與陣列式的致動機構”，以多個、可以單控制施力的驅動器，個別地對撓性模仁施加壓力，透過撓性模仁的力學特性與可撓曲變形特性，建立所希望的介面接觸壓力分佈與阻劑膠的擴散流動方式，最後得到所希望的壓印結果。



In this project we will design, construct, and experimentally test new types of imprinting systems with emphasis on precise control on the distribution of mold/substrate contact pressure and the flowing of resist layer during an imprinting process. The first imprinting mechanism uses a PDMS mold with a varying thickness. By displacement and deformation controls, one can then established a certain type of contact pressure. The second imprinting system use a new type of composite flexible mold, and a digital and arrayed actuating system which can individually apply loading forces on the mold. In conjunction with the mold’s elastic characteristics, these digitally loaded forces can be transformed into a controllable contact pressure distribution between mold and substrate.

滾輪壓印

ROLLER

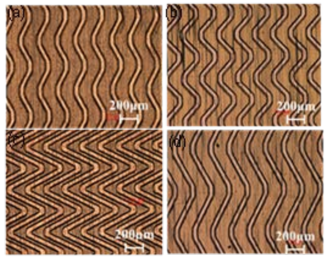
Nano-Imprinting

曲面光筆直寫應用於無縫滾筒模仁製作技術

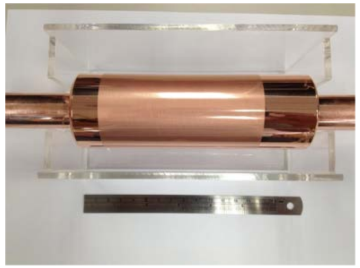
Fabrication of Seamless Roller Molds with Wave Microstructure by Curved Surface Beam Pen Lithography

本實驗以創新的方法利用準分子雷射加工具有高聚光效果之微透鏡陣列之光罩，藉由微透鏡陣列聚光的特性進行曲面光筆直寫微影製程，完成具有微米尺寸波浪結構的無縫滾筒模仁。其無縫滾筒模仁可經由 UV 滾印製程完整的轉移至 PET 基板，完成微米尺寸波浪結構的複製。

This investigation presents an innovative method for directly fabricating roller mold with wave microstructure based on beam pen lithography. The major steps in the fabrication process include the pneumatic air-flow coating of a thin PR layer, a continuous UV exposure by x-axis stage move and mask with microlens arrays. chemical etching and electro-polishing to improved surface roughness. In this work, we have successfully fabricated the different wave microstructure on the surface of metal roller which is the seamless roller mold.



Patterned PR layer

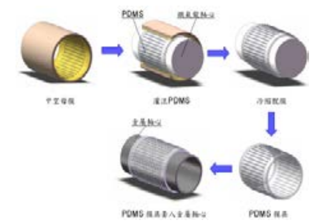

Roller mold

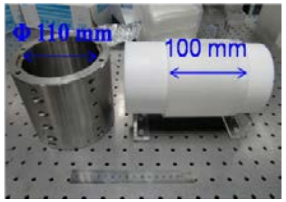
內滾筒微影製程技術

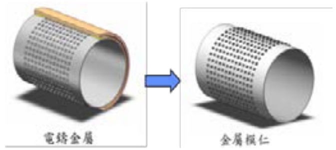
Inner cylindrical Photolithography

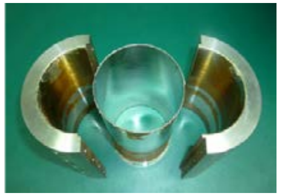
本實驗以創新的想法利用傳統的微影製程製作無縫的中空滾筒模仁，首先以一氣旋塗佈的方式在內滾輪表面塗佈光阻，接著以軟性光罩進行曲面步階式旋轉曝光。最後，可分別由 PDMS 澆鑄的方式或微電鑄的方式完成中空滾筒模仁。

This investigation a innovative approach for fabricating seamless hollow roller molds based on conventional photolithography. First of all, a mothod for spread coating of thin photo-layer on the hollow roller internal surface is developed. Secondly, a step -and-rotate UV-exposure system is construced for transforning patterns defined by photo-mask to the coated PR layer. Based on these two developments, seamless roller molds with fine and complicated surface features are obtained from either molding process (PDMS mold) or electroforming processes.



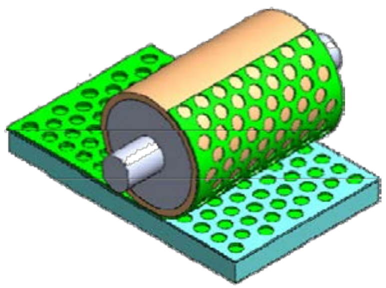






另一研究為結合金屬轉印技術與曲面黃光微影製程成功地製作次微米圖形結構於金屬滾筒上,首先,實驗中採用氣環式光阻塗佈系統將光阻薄膜均勻且平滑塗佈於滾筒上,而在金屬轉印技術層面上,本實驗室開發一套金屬轉印機構系統,將具有金屬微結構的平面模仁,利用該系統將金屬微結構轉移至曲面滾筒上當成曝光遮罩，之後運用 UV 準直曝光燈源並且搭配精密旋轉機構平台,完成滾筒曲面黃光微影製程加工，將光罩圖形定義於金屬滾筒上，最後使用蒸鍍金屬滾筒的方式完成圖形轉移，達到次微米滾筒模具之製作。

Metal Contact Transfer Technology



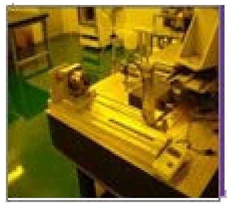
MACHINE

機械設備研發製作

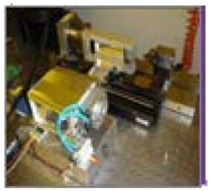
Research And

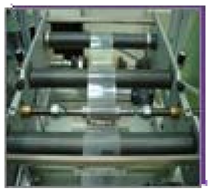
Fabrication of Machines

隨著科技產業蓬勃發展,本研究團隊於科技的推動也不遺餘力，研究主題包含於奈米平壓微影技術、微米滾壓系統開發、超音波探頭設計及雷射加工 3D 微細結構製程，並針對實驗上之需求製作機台及相關配件。研發機台從設計製作、組裝測試、系統整合等皆獨立完成,使得在製程上有相當大的自由度。目前已開發油壓加壓系統之奈米壓印機、滾輪薄膜測試儀等。奈米壓印機最大壓印力可超越當前壓印機可達之壓力,壓印基板可達六吋,秉持符合產業自動化的原則,達到快速、簡單、高效率的生產力，結合技術及人性化的考量。



There are several research subjects such as nano-imprinting lithography, ultrasonic engineering, and excimer laser machining in our lab, and we have ability to research and work out any machines for experimental needs. All parts of making any machine, from designing, fabricating, setting, testing, to integrating, can be completed on our own with great amounts of freedom. Based on the principle of auto mation and the consideration of user-friendly, oil-pressured nano-imprinting machine, thin-film roller coating machine, and so forth, were developed in our lab. Take nano-imprinting machine for example, it can easily get an amazingly imprinting area in size of 6 in. wafer with sufficient pressure in an automatic process; thus both of high throughput and easy process are not just a big dream in the semiconductor industry.





李永春教授　個人簡介

Professor Yung-Chun Lee

學歷(Education)：

- 美國西北大學理論與應用力學博士 (Ph.D., Theoretical & Applied Mechanics, Northwestern University, IL, USA)
- 國立台灣大學應用力學碩士 (MS, Institute of Applied Mechanics, National Taiwan University, Taiwan)
- 國立台灣大學機械工程學士 (BS, Department of Mechanical Engineering, National Taiwan University, Taiwan)

經歷(Experience)：

- 國立成功大學機械系系主任(Chair, Department of Mechanical Engineering)
- 國立成功大學微奈米科技研究中心-行政業務組組長(Group Leader of Administrative for Micro/Nano Science and Technology)
- 博士後研究,美國康乃爾大學工程應用物理系(Post-Doc. in Applied and Engineering Physics, Cornell University, Ithaca, NY, USA)
- 助理教授、副教授、教授、特聘教授，國立成功大學機械系

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- 應力波動學 (Elastic Wave Propagation)
- 超音波工程與非破壞性檢測 (Ultrasound Engineering and Non-destructive Evaluation)
- 聲波感測器 (Acoustic Sensor)
- 高頻電子測試 (High-Speed Electrical Testing)
- 表面聲波元件 (Surface Acoustic Wave Device)
- 準分子雷射微細加工 (Excimer Laser Micromachining)
- 奈米壓印與滾印技術 (Nano-Imprinting and Roller Imprinting)
- 無光罩式黃光微影技術 (Maskless Lithography)
- 軟性光罩式微影技術 (Soft Photomask Lithography)

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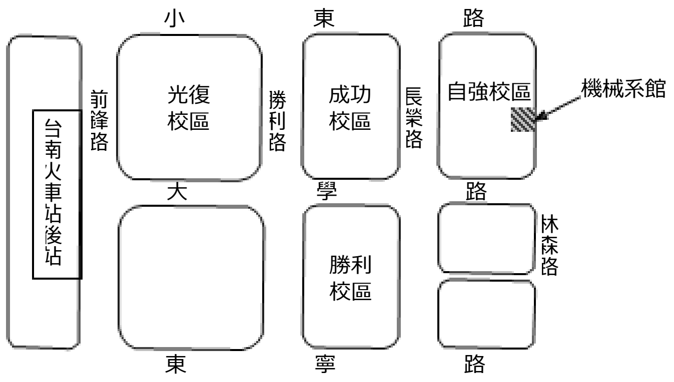
交　通　資　訊



搭乘台鐵至台南站後站下車 大學路直走到底 左方即為自強校區

Take Taiwan railways to Tainan station and go straight down University Rd., the Mechanical Engineering department on Tzu-Chiang campus is on your left.

搭乘高鐵至台南站後站下車，轉乘台鐵至台南站後站下車，大學路 直走到底，左方即為自強校區。

Take Taiwan High Speed Rail to Tainan station and transfer to take Taiwan railways to Tainan station, then go straight down University Rd., the Mechanical Engineering department on Tzu-Chiang campus is on your left.

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