

行政院國家科學委員會專題研究計畫 期中進度報告

具次波長空間解析度之振動檢測用顯微型近場光學干涉儀 系統的設計與研發(2/3) 期中進度報告(精簡版)

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摘要

近場光學顯微鏡對於現今奈米尺度量測上有高空間解析的能力，是分析次波長微結構不可或缺的工具。因其空間解析度受限於光纖探針的尺寸，為近場光學顯微鏡中關鍵部份，本計劃達到用雷射融拉奈米尺度探針，並能精密黏著於石音叉，完成探針自製能力。為了提升近場光學顯微鏡的能力，利用干涉儀的方式來獲得近場光學的相位，亦完成了初步的驗證。

關鍵字: 近場光學顯微鏡、近場光學、干涉儀、相位、外差式干涉

Abstract

Near-field scanning optical microscope (NSOM) has advantages such as high spatial resolution, which makes it a powerful tool for nano-scale measurement and subwavelength structure analysis. As the spatial resolution is restricted by the diameter of fiber tip, which is critical for NSOM, this project has completed nano-scale fiber tip technique implementation by using laser pulling. This newly developed technique fiber tip was shown to be effective by sticking them onto the tuning fork precisely to verify the overall system performance. In order to further enhance the NSOM resolution and metrology capability, we have integrated interferometer with NSOM to retrieve phase information for near-field optics. The preliminary experimental results obtained verified the theoretical predictions reasonably well.

Keywords: Near-field scanning optical microscope, near-field optics, interferometer, phase, heterodyne interference

1.前言

顯微技術，在量測材料表面細微結構佔有舉足輕重的地位。其中，電子顯微鏡自西元 1938 年第一部商用電子顯微鏡-穿遂式電子顯微鏡TEM(transmission electron microscope)問世，至今其解析力已可達數個埃(Å)之原子等級；另一種為研究物體表面結構及成分的分析利器為電子顯微鏡-掃描式電子顯微鏡SEM (scanning electron microscope)，其橫向解析度亦可達幾個nm等級，在材料領域及半導體研發上有廣泛的使用。儘管已有如此高倍率、高解析度的電子顯微鏡可供人們使用，但由於電子顯微鏡的購置與維護成本過高、操作手續繁複，以及為了避免電子束散射無法於電磁透鏡聚焦，必須維持在高度真空(10^{-4} torr~ 10^{-10} torr)的環境操作等限制，再加上電磁透鏡的像差，高能電子束對試片的破壞，與電子束所造成的電荷累積(charging effect)等等不利因素，造成此電子顯微技術無法完全取代傳統光學顯微鏡的功能。而傳統之光學顯微鏡(optical microscope, OM)雖然受限於光學繞射極限的限制，但是經由與其他技術的結合，如共焦術、光子穿遂顯微術、干涉術，使得其量測的能力包括橫向、縱向解析度、以及解析相位能力等都得以提升，應用也隨之多樣化。而其解析度受制於光學繞射極限的缺點，也在近場光學顯微鏡的發明後得到了改善。隨著近場光學顯微鏡的發展，衍生出了許多附加的功能，主要是光學特性的量測，包括材料折射率變化的量測，反射率、穿透率的量測，磁性或應力造成光學特性變化的量測，螢光光譜、拉曼光譜的量測……等。然而原先使得遠場光學顯微鏡改善的技術(如共焦術、光子穿遂顯微術、干涉術等)卻沒有充分地與近場光學技術結合，因此本計畫於研究過程中主要嘗試結合近場光學術(near field microscopy)、光子穿遂顯微術(photon tunneling microscopy)、及干涉術(interferometry)等三大技術，藉由對前項技術做更詳細的討論後，提出創新整合架構來嘗試建構全新的量測系統，以求能進一步利用光學顯微系統來實現奈米結構微小振動的量測需求。

本計畫的原始概念乃奠基於計劃主持人所領導之研究團隊過去多年持續研究多功光學顯微鏡的基本構想，延續其理念建構一套結構剛性佳且穩定性高的基礎顯微鏡架構，開發多項功能以求同時能承載多種不同功能的量測系統；本研究團隊已開發完成之共焦光學顯微鏡與光子穿隧顯微鏡，即是以一傳統的反射式光學顯微鏡為基礎，將共焦光學顯微鏡之光路系統架構於其中，同時也以同一顯微鏡基礎，利用光子穿隧效應接近近場光學顯微術的架構，研製了光子穿隧顯微鏡，提供了一套擁有雙重功能的顯微鏡系統。通常一套共焦光學顯微鏡或光子穿隧顯微鏡，大概都需要新台幣四、五百萬的等級，此外在半導體廠用於檢測薄膜厚度的橢偏儀，亦是需要花費數百萬之譜，因此，想要同時擁有數種不同的精密量測設備，所需預算必定相當可觀，所以本計畫書延續前述基本理念，試圖推廣

研發一個一機多功能的研究平台，持續研究開發新式光學量測技術，並將其整合至已開發完成之顯微系統架構中。

2.研究目的

在奈米科技蓬勃發展的今日，許多傳統的物理化學特性的基本理論都重新被拿出來檢驗，然而實驗驗證的步調卻相對的緩慢，主要因為缺乏合適的量測設備。舉例而言，奈米碳管的振動和聲子晶體振動的量測至今仍缺乏合適的方法及設備，也因此阻礙了奈米研究的推展。如前所述，在所有顯微技術中，光學顯微相關技術具有最廣之適用範疇。因此本計劃於審視現行全球適用於微機電及奈米系統之光學量測系統後，認定現行應用光學顯微技術於微機電及奈米系統之所有架構中，具有以下幾個最主要之缺憾：(1) 對於高頻振動的量測受到限制；(2) 無法同時量測微小待測物橫向及縱向都具奈米等級的動態移動；(3) 無法同時針對遠場及近場進行多點即時動態量測，同時維持系統量測精度於奈米等級。

本計畫第二年度的目標在於結合掃描式近場光學顯微術(Near-field Scanning Optical Microscopy, NSOM) 與Heterodyne Interferometer的干涉技術來取出近場光學的相位(phase)和振幅(amplitude)的資訊。然而，要進行近場光學顯微術的實驗架構，就必須面對NSOM光纖探針的大量消耗以及是否探針適用於本計畫之實驗的問題，所以決定著手於NSOM光纖探針的自行研製。另一方面，為了使之後Heterodyn干涉儀能與NSOM順利結合搭配，亦同時進行架設近場干涉儀的整體架構，以利將來能與近場Heterodyne 干涉儀順利接軌。在奈米尺度下的次波長結構因為小於波長的繞射特性造成光場漸逝波比例較高，只能在近場下觀察，但一般都是取得光場的強度，對於相位資訊則在觀察中失去，唯有藉由干涉將相位取出才更能了解近場光的資訊，完整解釋次波長結構下的光學特性。而要取得近場光學資訊便得配合近場光學顯微鏡(NSOM)的使用，因此進行近場光學探針的研製，提供進行大量近場光學顯微鏡之量測的探針需求。

3.文獻探討

近場干涉儀用於研究近場光學訊號上有解析度提升的效果，近來瑞士研究群利用近場干涉儀於平面波導傳輸模態的觀察與光子晶體波傳，因為相位提供了另一種解析資訊，尤其是漸逝場(evanescent wave)的量測，因為其非傳播性造成不易觀察，但在近場光纖的擾動下能將非傳播場轉換成可傳遞波取得漸逝場的訊號。近場干涉利用 Mach-Zehnder 的架構，使用同調性高的光源以光纖作為光路，其原理公式如下(3.1)，原本訊號光中就有隨空間位置變化的相位資訊 ϕ_s 與固定架構中的相位 β_s ，其帶有所要量測樣本的資訊。光源分出一道參考光，其單純只

有固定相位 β_r ，並不隨空間改變，將兩者合在一起形成干涉，不同位置的相位會產生相對應的亮暗條紋，藉此推算彼此間相對相位。

$$\begin{aligned} E_s(x, y) &= A_s(x, y) \exp[i(\omega_0 t + \phi_s(x, y) + \beta_s)] \\ E_r &= A_r \exp[i(\omega_0 t + \beta_r)] \\ I &\propto A_s^2 + A_r^2 + 2A_s A_r \cos(\phi_s(x, y) + \beta_s - \beta_r) \end{aligned} \quad (3.1)$$

以本實驗室開發之近場光學頭量測為例，其為具有長焦距的次波長結構，涵蓋近場與遠場特性，使用近場光學顯微鏡做不同高度的掃描，從表面幾十奈米到微米之內，將近場光學頭的聚焦特性描繪出。對於近場光學頭從近場過渡到遠場的傳撥現象可更完整解釋，推算其光轉換函數(Optical Transfer Function, OTF)，先前只能藉由光強分佈來分析調變轉換函數(Modulation Transfer Function, MTF)，在取得像位資訊下對於近場光學元件的研究上對於設計與判別奈米光學元件將有莫大助益。甚至在不同材料下所造成相位影響，也有機會對次波長尺度下的材料特性與近場之間的影響做分析。

4.研究方法

本計劃第二年度主要執行目標為建立NSOM光纖探針自製的能力以及實際進行架設近場干涉儀的整體架構，底下將詳細介紹各部份之研究方法。

4.1 NSOM 光纖探針之研製

在於觀察次波長結構的光學特性反應中，近場光學顯微鏡是一個相當有力的工具，因為其具有高解析度的優勢。因一般光學顯微鏡會受到光學繞射極限的限制，使得在觀察奈米尺度或次波長結構遭遇鑑別度不夠的問題，也就是無法識別距離小於 $1/2$ 波長結構下樣本，且關於消逝波(evanescent wave)會成指數衰減的光場也是無法在遠場觀測到。因此，要能完整反應樣本的光學特性，就必須在近場的範圍內進行光學訊號的偵測。

在 NSOM 的應用上，光纖探針扮演其中很重要的角色，一具探針的 Q 值、敏感度、針頭的收光效率等，皆會影響整體實驗結果的精度，故著手發展 NSOM 光纖探針的自行研製能力，製作出適合本計劃實驗特性的光纖探針，同時亦將探針應用於本計劃的干涉儀鎖向放大器上，做訊號調變之用，是本期計畫之重點。

根據光纖探針的架構分析，設計了流程如下（表 4.1）：

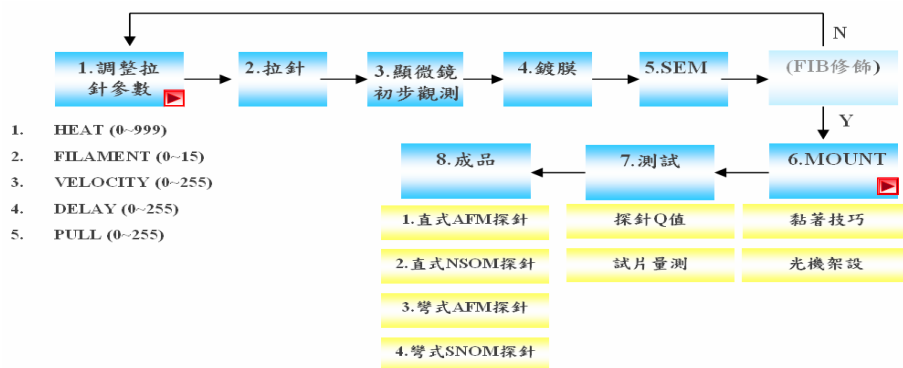


表 4.1 自製光纖探針流程圖

1. 調整拉針參數：設定拉針機（圖 4.1）之五項參數（HEAT、FILAMENT、VELOCITY、DELAY、PULL），研究不同參數對光纖造成之不同影響，以及不同規格光纖所適合之不同參數。
2. 拉針：將光纖夾上拉針機（P-2000 Laser Based Micropipette Puller）進行拉針。拉針機之CO₂雷射會經由一反射鏡聚焦於光纖上（圖 4.2），並隨光纖夾具的兩端施力，將光纖漸縮拉成針狀以至自動斷裂，行成探針。



圖 4.1 P-2000 Micropipette Puller

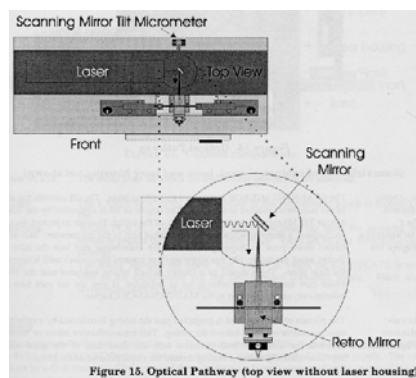


圖 4.2 拉針機架構

3. 顯微鏡初步觀察：透過百倍的光學顯微鏡觀察光纖的針尖部分之針形，初步判斷並確認上述拉針步驟是否成功，成功者繼續進行鍍膜，並做更高解析之確認。
4. 鍍膜：將光纖以 45° 的傾斜角度旋轉（圖 4.3）進行濺鍍，使之均勻的濺鍍上金屬。此步驟可防止光纖針頭在針尖以外部份因拉針過程使原始鍍膜破損而造成的漏光，另外金屬鍍膜亦有助於利用掃描式電子顯微鏡（SEM）對於針尖進行更進一步的觀察。
5. SEM 觀察：利用掃描式電子顯微鏡作高解析度的觀察，確認光纖針頭於上述步驟中是否有有所破損，倘無則完成一完整的光纖針頭，可進行後續步驟。
6. MOUNT：設計直式及彎式探針 Holder，將光纖針頭與震盪音叉黏接於探針座之上，並焊接兩端電極，完成一光纖探針。
7. 探針測試：完成之探針正式架上近場光學顯微儀（NSOM）平台進行測試。確認其 Q 值（Quality Factor）大小後，進行標準試片之樣本掃描，透過掃描出之結果比對，了解此一光纖探針成功與否。
8. 成品：完成之光纖探針可正式使用於 NSOM 上，進行近場光學訊號的量測應用。

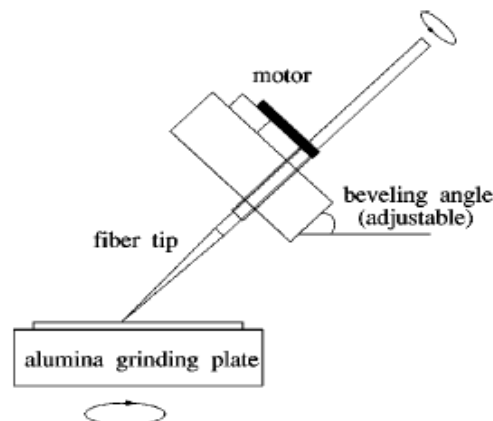


圖 4.3 45° 角傾斜濺鍍示意圖

4.2 近場干涉儀之架設

4.2.1 實驗架構

在干涉架構中，需要有一道參考光引入，形成干涉。如下圖 4.4 所示，光源使用較為穩定的紅光氦氖(He-Ne)氣體雷射，波長為 632.8nm ，其具有頻寬窄、同調長度長、模態單純與線性偏極態的特性，適合用於干涉儀所需的穩定光源。

雷射出口端用二分之一波板(Half waveplate, HP)來改變雷射偏極態方向，接著用濾波器濾波，將聚焦光通過為孔洞(pinhole)阻擋高頻雜散光，增加雷射光輸出的穩定度。這裏使用偏極態分光鏡(Polarization Beam Splitter, PBS)來分光，由旋轉前端的二分之一波板來調整 P 光與 S 光之間的比例，一道為參考光，使用物鏡將光導入光纖，另一道入射進 Olympus 倒立式顯微鏡(Inverted Microscope, IX71)，用於打入試片，進入顯微鏡之前再用二分之一波板調整入射光的偏極態方向，以滿足不同結構所需的 TE 或 TM 波觀察。近場光學顯微鏡為架設在倒立式顯微鏡上的精密移動掃描平台(Nananocs, MultiView2000)，光纖黏著在石英晶體(tuning forks)上，由於距離的力回饋控制距離，約再幾十奈米的高度。此處使用收光模式(collection mode)，光纖末端漸縮至奈米等級，表面有鍍膜，由於收光孔洞約百奈米，因此解析度比傳統光學顯微鏡來的高。用光纖耦合器(2x2 coupler)將近場光纖探針所量測的訊號與參考光耦合在一起形成干涉，由光電倍增管(Photo Multiplier Tube, PerkinElmer MP942)將微弱光訊號放大。

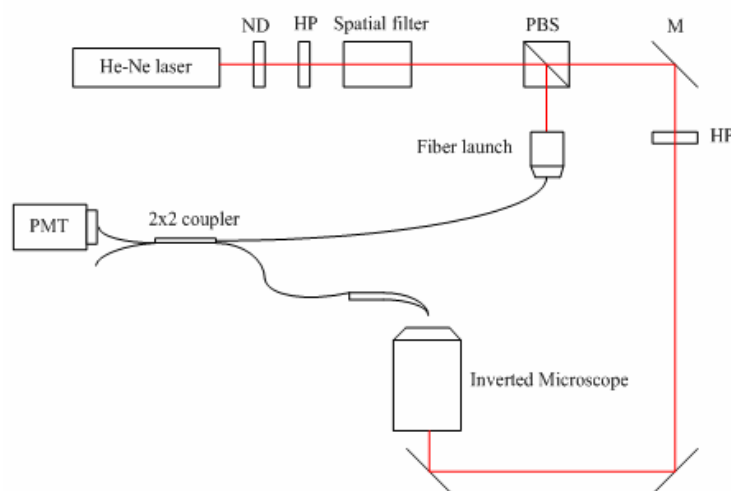


圖 4.4 干涉架構圖

4.2.2 實驗細部調整

干涉需要的條件為 1. 頻率相同 2. 偏極態 3. 可見度(visibility)。這些要求，是為了使干涉效果明顯與穩定。光源同調長度要長，其頻率寬帶才小，較不會有頻率漂移所造成相位的變化，He-Ne 氣體雷射是相當好的選擇，其模態跳躍(mode hop)的干擾情形較雷射二極體好，減低回光影響模態。使用穩頻雷射(Spectra Physics 所生產的 Frequency and Intensity Stabilized He-Ne Laser)回饋控制雷射共振腔長度恆定對於頻率的穩定更佳。整體光纖光路採用單模光纖(single mode fiber)，只允許單一模態通過，避免不同的高階光相位不同造成干涉時相位的混亂。偏極態方面，光纖在彎曲下對於偏極態可能造成解偏極態，特別是近場微控

平台上的彎式光纖根據其他人研究的確造成偏極態的改變，但量測中偏極態不會隨時間變化，是處於靜態的，在此條件下克服偏極態影響可以於參考光那一道中加入偏極態控制器(General Photonics PLC003)，施加壓力造成光纖的雙折射效應(Birefringence)改變參考光的偏極態，調成讓干涉對比明顯即代表參考光與訊號光的偏極態近乎相同。可見度為 $\frac{I_{\max}-I_{\min}}{I_{\max}+I_{\min}}$ ，盡可能讓訊號光與參考光的強度相同，因訊號光的強度恆定所以一開始先掃描一次看訊號光最強為多少，調整雷射出口第一個二分之一波板，調整參考光強度使其與最強訊號光差不多，即可使可見度提高。

5.結果與討論

5.1 光纖探針研製

針對光纖探針自製成果，以下分為三個部份討論之：參數設置與拉針針形觀察、針座設計；光纖黏著平台設計；光纖探針測試。

5.1.1 參數設置與拉針針形觀察

拉針機台共有五個可供配置參數，HEAT (Laser 能量大小)、FILAMENT (Laser 聚焦光點大小)、VELOCITY (光纖熱熔拉動達該速度後即停止加熱)、PULL (拉力大小)、DELAY (加熱停止後施力延續之時間)，而本次實驗測試影響較大的關鍵參數 HEAT 與 PULL，在五組拉針實驗中觀察參數對拉出光纖的影響，從得到的結果得知若 HEAT 或 PULL 值愈大，則 Taper Length 愈長且 Tip Diameter 愈小。如表 5.1。

Num	Taper Length	Tip diameter	Heat	Pull
1A			300	150
1B			300	150
2A	(<500 μ m)	(<150nm)	300	150
2B	384 μ m	120nm	300	150
3A	(<600 μ m)	(<120nm)	400	150
3B	428 μ m	90nm	400	150
4A	1241 μ m	(<100nm)	500	150
4B	1535 μ m	~80nm	500	150
5A	429 μ m	70nm	300	200
5B	655 μ m	(~70nm)	300	200

表 5.1 五組相異拉針參數結果比較表。由此表可得知若 HEAT 或 PULL 值愈大，則 Taper Length 愈長且 Tip Diameter 愈小。

5.1.2 針座設計、光纖黏著平台設計

近場光學探針之配置分為三大部份。分別為光纖探針頭、震盪音叉以及探針座。光纖探針頭可利用光纖配合拉針機台拉製而成，如前述步驟。而震盪音叉採用 32kHz 石英晶體振盪器中拆取之震盪音叉。探針座部分則模仿原廠樣式自行繪製 CAD 圖形以加工製作（圖 5.1），使之可配合原廠機台使用。此外具備光纖探針頭、震盪音叉及探針座三者後，必須將三者黏合焊接，方可成為完整之近場光纖探針。於是先將音叉與探針座黏合焊接完成後，細部的光纖與音叉黏合則仰賴自行設計之光纖黏著平台（圖 5.2），調整 XYZ 三軸與 Θ 角度，將光纖針頭突出於音叉約 0.5mm，並配合 UV 膠在照射 UV 光約二十分鐘後，可黏合固定完成（圖 5.3）。

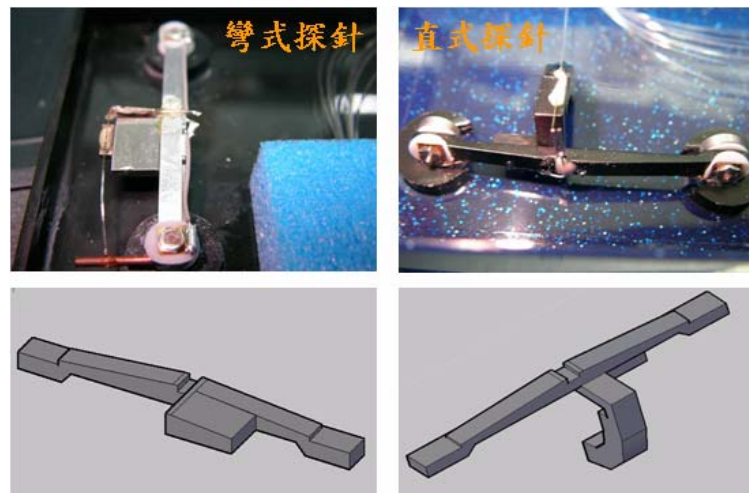


圖 5.1 左右分別為彎式和直式探針以及探針座 CAD 圖

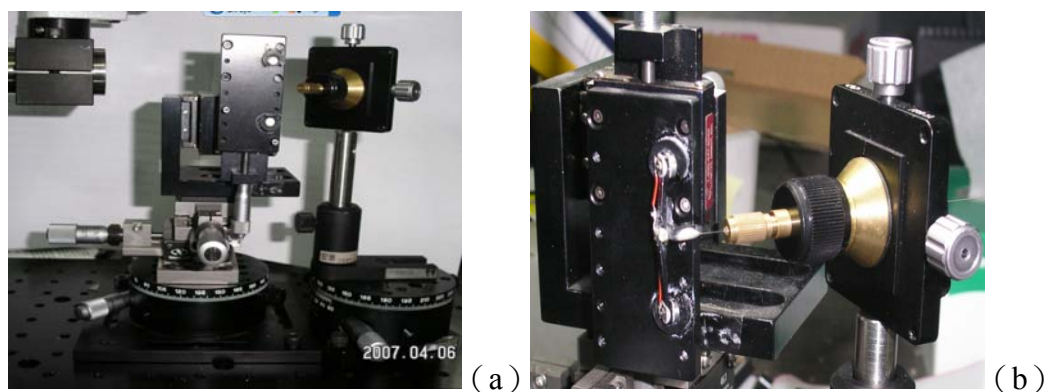


圖 5.2 光纖黏著平台 (a) 多軸平台整體架構 (b) 光纖座由兩端強力磁鐵吸附固定，音叉與光纖則於多維平台上調整正確相對位置後，進行 UV 膠黏合步驟。

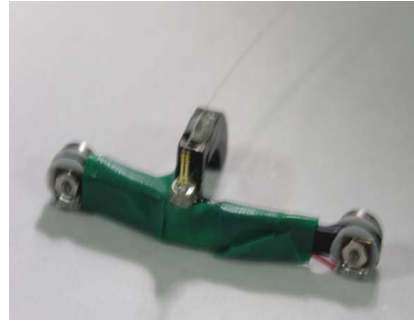
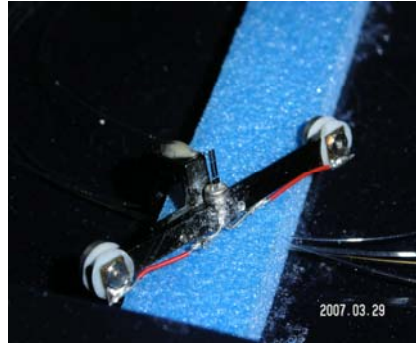


圖 5.3 完成黏合之自製探針。可見光纖針尖黏著於音叉前端之探針整體架構。

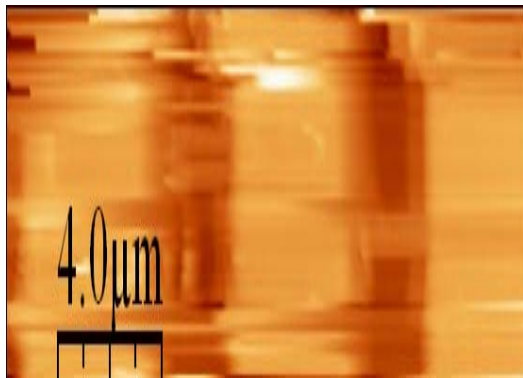
光纖探針測試：製作完成之光纖探針接著進行測試。

5.1.3 光纖探針測試

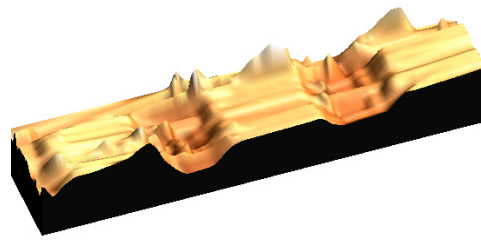
製作完成之光纖探針接著進行測試，測試的項目為探針 Q 值大小確認（共振頻率靈敏度）與實際掃描 sample 的測試（探針與機台整合度）。自製探針的 Q 值部份（Quality Factor：約為共振波形之中心頻率與半高寬的比值，值愈大則震盪音叉對頻率變動之感應愈靈敏，愈有利於本處之使用）約為 156.5，雖與原廠探針（ Q 值約為 504.3）相較下自製探針 Q 值較低，不過推測應已足夠應用於一般需求下，是以繼續進行下一部份測試—使用自製之探針進行周期 $8\mu\text{m}$ 樣本（圖 5.4）的表面訊號量測，而量測結果的 2D 或 3D 圖形皆與樣本週期吻合（圖 5.5），且由圖 5.5(c)可看出代表來與回兩次掃描的藍色紅色兩線圖形大約一致，又一週期約由下方座標 $-6\mu\text{m}$ 至 $2\mu\text{m}$ 處，符合樣本週期 $8\mu\text{m}$ 。由此可知本自製探針已成功與 NSOM 系統完成整合，雖然仍有可精進之處，但整體探針製作與接合流程獲得了證實是確定可行的。



圖 5.4 AFM 訊號量測之樣本，結構週期 $8\mu\text{m}$ 。



(a)



(b)



(c)

圖 5.5 AFM 訊號量測結果: (a) 2D 圖形掃描結果、(b) 3D 圖形掃描結果、(c) 掃描探針軌跡圖形。

5.2 近場干涉儀架設

近場光學顯微鏡為以光纖為主體製作的探針，所以要在近場光學顯微鏡架構上達到干涉的目的，是以光纖干涉儀為主體來完成，以便結合原本的光纖探針。為提高干涉的穩定與訊號的訊雜比，分別從降低光的損失以及使用鎖相放大器來討論。

5.2.1 降低光的損失

光纖干涉的架構是相當敏感的，要提高量測的可性度，需要拉高訊雜比(S/N ratio)，避免散粒雜訊(shot noise)的限制，最後光偵測器所收得的光子數要多比較不會受到雜訊的影響。首先就是要先避免訊號光的損失，在實驗架構中可能的損失如下。

1. 近場光纖探針的直徑小，收光面積更是平方倍的縮小，所以最後可收的光的強度相當微弱，除非以物鏡聚焦增加單位面積的光強度才能大幅提升接收的光子數，但也不可以太強，因尖端細小形成加熱溫度可能高達 400 多度造成表面鍍膜剝落。這邊使用的光纖採用彎式探針，因為不會擋住上方視野，可以達到精準定位光纖到次波長結構上，但也因為彎曲特性而造成光損失嚴重，只能在彎曲地方鍍膜盡量降低光的逸散。
2. 中間將光纖導到耦合器時需要接合，這時候接合的損失也要盡可能減少，使用毛細管(capillary)式的機械接合(Splice)，管徑為 $125\mu\text{m}$ 是單模光纖尺寸用，內有介質匹配油幫助接合降低損失。
3. 2x2 光纖耦合器將兩道光結合形成干涉，所用原理是漸逝波耦合(evanescent coupler)分配最後出口兩端的比例，採用 50/50 的分配比在訊號光微弱下更為嚴重，況且另一輸出並不使用，光偵測器只接收一端，使用 99/1 的耦合器更為恰當，讓主要訊號盡量全部進入光偵測器

5.2.2 鎖相放大器(Lock-in amplifier)

將量測訊號做調變，專門偵測調變頻率的訊號，可以提高訊雜比。鎖相放大器對於微弱訊號可以作良好擷取並放大，所以本實驗中要達到訊號穩定所需的調變方式是用下列方法提供穩定的參考頻率，並在此頻率下對光訊號做調變。因為雜訊並沒有調變，像是散粒雜訊這樣寬頻譜的雜訊就可以大幅降低，在本實驗中使用石英音叉(tuning forks)來調變訊號。在機械調變機構中，石音叉的應用頗為可靠，其共振頻率大約為 32kHz 附近，遠離低頻雜訊的範圍。在掃描時，近場距離的控制亦是用石音共振頻的力回饋機制決定探針與樣本之間的距離，掃描時探針本身處於微幅擺動的狀態，所以用鎖相放大器鎖住石音叉共振頻對於訊號的提升有所幫助，甚至可以鎖此頻率的二倍頻，但在我們實驗架構中因為彎式探針的粘著方式如圖 5.6，其 z 軸方向的二倍頻並不會產生，在此二倍頻主要在 xy 方向上解析度提升有幫助。

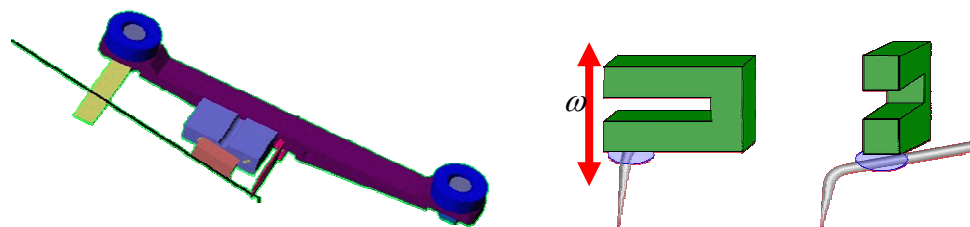


圖 5.6 光纖探針與石音叉黏著

5.3 結語

計畫執行至今，已完成光纖探針夾具以及奈米尺度探針頭的製作，並組裝自製精密移動與固定機構將光纖黏著於共震音叉上，根據初步近場表面掃描實

驗結果也驗證了探針製作流程的可行性。近場光學顯微鏡中至為關鍵的探針製作，已有能力自製。

關於近場干涉儀的部份，在加入光纖干涉儀的架構後，量測圖 5.5 的樣本，得到在二元結構上表面的形貌圖(圖 5.7(a))和近場的干涉圖(圖 5.7(b))，掃瞄所得的資料除了有光強資訊外亦包含了相位資訊(因為干涉)，為下一階段近場外差式(Heterodyne)干涉儀提供初步的驗證。目前正使用圖 5.8 的架構，利用聲光調變器移頻與鎖相放大器同步分別取得光強與相位，完成近場干涉儀量測次波長尺度下的光學反應。

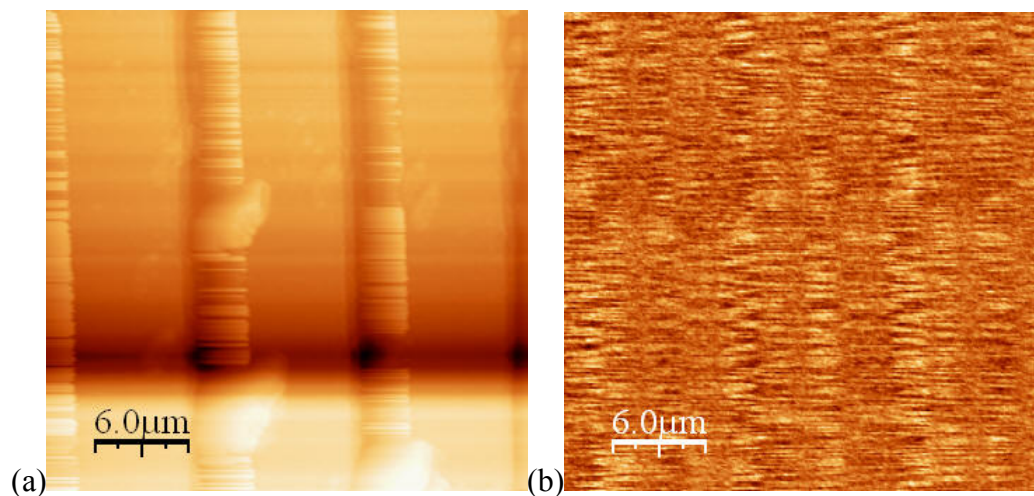


圖 5.7 二元結構 AFM 圖形與干涉圖

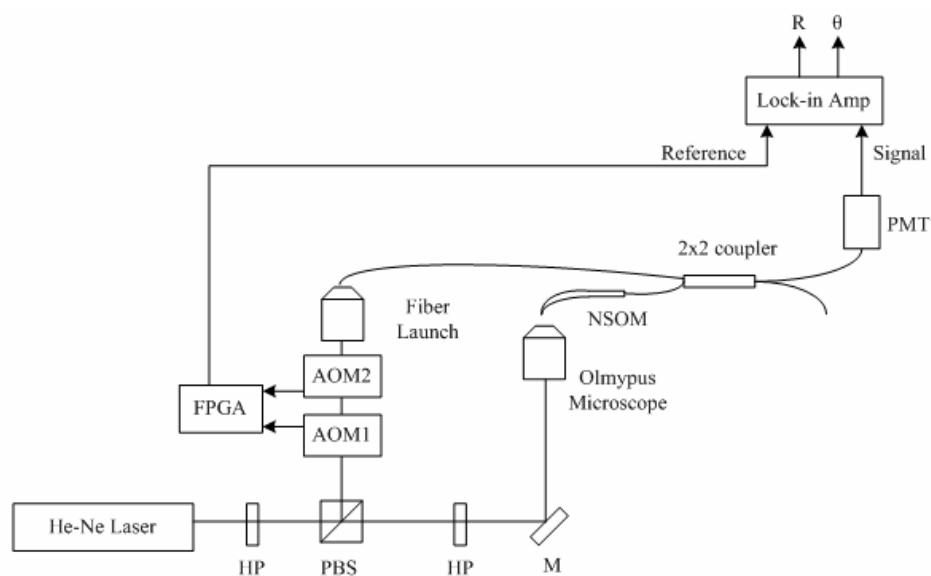


圖 5.8 外差式近場干涉儀

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攜回資料

1. Abstract Digest, SPIE Smart Structures and Materials & Nondestructive Evaluation and Health Monitoring, 14th International Symposium, 18-22 March 2007, Town and Country Reort & Convention Center, San Diego, USA

另行找尋相關研究與論文資料

1. 德州大學以 Methanol 進行的人工肌肉研究 Data from Internet
甲、Science 311, 1580 (2006); Von Howard Ebron, et al.
<http://www.sciencemag.org/cgi/content/full/311/5767/1580?rss=1>
乙、The following resources related to this article are available online at www.sciencemag.org (this information is current as of March 29, 2007):
<http://www.sciencemag.org/cgi/reprint/311/5767/1580.pdf>
丙、Methanol-powered artificial muscles start to flex
<http://www.newscientist.com/article.ns?id=dn8859>
丁、Nanotechnologists demonstrate artificial muscles powered by highly energetic fuels
<http://www.physorg.com/pdf11844.pdf>
2. George 的 Post Buckle 相關專利
甲、GA Lesieutre, CL Davis, “Transfer having a coupling coefficient higher than its active material”, US Patent 6,236,143, May 22, 2001.
<http://patft.uspto.gov/netacgi/nph-Parser?Sect2=PTO1&Sect2=HITOFF&p=1&u=%2Fmetahtml%2FPTO%2Fsearch-bool.html&r=1&f=G&l=50&d=FULL&RefSrch=yes&Query=PN%2F6236143>

2007 年 SPIE SSNDE 會議紀錄

會議與 Smart Structures and Materials 期刊編輯委員會感想

此次會議經過幾十位 Program Chairs 與 SPIE 一年的討論後，進行了一系列的會議議程與組合修正，2007 年的會議最終分成以下 10 個 Sessions:

- 1 Modeling, Signal Processing, and Control
- 2 EAP Actuators and Devices (EAPAD)
- 3 Active and Passive Smart Structures and Integrated Systems
- 4 Behavior and Mechanics of Multifunctional and Composite Materials
- 5 Industrial and Commercial Applications of Smart Structures Technologies
- 6 Nano-, Micro- and Bio-Sensors and Systems
- 7 Sensors and Smart Structures Technology for Civil, Mechanical, and Aerospace Systems
- 8 Sensor Systems and Networks: Phenomena, Technology and Applications for NDE and Health Monitoring
- 9 Nondestructive Characterization for Composite Materials, Aerospace Engineering, Civil Infrastructure, and Homeland Security
- 10 Health Monitoring of Structural and Biological Systems

來規劃、徵稿、報告、與分析。此一新的編組更清楚的指出目前智慧型結構與材料這個重要領域的發展趨勢與變化。

今年的 SPIE SSNDE 會議仍如往年一樣，約有 800 人參與，除了每天早上一場的 Plenary Speech 外，今年增加了每天一場的美國 Funding Agency 邀請講演，這些 Funding Agency 包括 DARPA, NSF, ONR, ASOSR，他們均分別說明了各個 Agency 目前推動的計畫重點以及如果對於目前研究重點有興趣，應該和誰接觸等資訊。由這些報告中可看到各 Funding Agency 對於創新想法的重視，除此之外，系統方面的知識、人員的訓練等均為計畫是否取得經費的考量重點。

在整個會議的論文報告及 Smart Structure and Materials 期刊的編輯委員會會議中可以看到智慧型結構與材料這個領域在技術方面正趨於成熟，同時各種應用也在迅速出現中。除了傳統航太領域的論文外，由於微機電、奈米科技的持續發展，此一會議也有多個 Session 專注於這些 enabling technology 的開發。整體而論，此一會議仍舊維持以往跨領域研究工作的特質，同時今年有更多的論文為跨國合作的成果，此一現象也說明此一領域的系統性、複雜度均已逐年提高。部分聆聽與參與討論的論文節錄如下。

部分論文摘要與討論

March 18, 2007

- 1 Big Picture of the Conference (Special Event)
 - 甲 EAP Actuators and Devices (EAPAD Conference #6524) by Yoseph Bar-Chen (Jet Propulsion Lab.)
 - A Invited Speech: How fish swim
 - B EAP-in-Action Demonstration Session
 - C Biology – inspiration of human innovation
 - a The honeycomb is now part of almost every aircraft
 - b The desire to fly has prompted to study birds
 - D Nastic structures pants a model for mimicking (捕蠅草、含羞草, etc.)
 - E Nature imitates technology
 - a The mynah bird
(<http://img.dailymail.co.uk/video/384Kbps.wmv>)
 - F DARPA funded prosthetic arms
 - a Human-like robots with distinguishable features
 - b Realistically looking humanlike robots
 - G Various active EAP
 - a Ionic EAP
 - b Electronic EAP
 - H Platforms for EAP Implementation
 - I Android Head
 - J Wrestling match between EAP actuated robotic arm and human
 - K Dec. 2002 The first commercial EAP product by Eamex Inc. in Japan, the fish robot.
 - 乙 Active and Passive Smart Structures and Integrated Systems: Smart Structures and Bionics (Conference #6525) by Yuji Matsuzaki (Nagoya University)
 - A 2006 SPIE: Conf. Damping and Isolation & Smart Structures; Merged this year
 - B Energy Harvesting, MR Systems, Smart Aerospace Systems, Biology-inspired and related systems, Shape memory materials and applications, autonomous materials, active control, damping and vibrations
 - C Bionics and Nature Inspired Technologies
 - a Collapsing of Iceberg in Norwegian Sea
 - b Bionics, equivalently Biomimetics (from 1950's)

- i Application of solutions, methods and systems found in nature to the study and design of engineering systems and modern technology
 - c Nature and biological systems
- D Concluding remarks:
 - a Smart structures/adaptive systems research been matured during the past two decade
 - b Biology and physiology provide us with many new research subjects on adaptive/smart/integrated system and materials
 - c We may work with bio-engineers and biologist for bionics/biomimetry which aim at sustainability for our environment
 - d Scientific knowledge on biology and bioengineering is limited
 - e The humble we are, the more we may learn from Nature
- 丙 Behavior and Mechanics of Multifunctional Composite Materials
 - A Ferroelectric Materials research by T. Liu and C.S. Lynch
 - a Interaction of Cracks and Domains in PZN-PT
 - b Phase Field Simulation and Domain Evolution
 - c Nonlinear Piezoelectric FEM
 - B Devices, Materials Behavior, Failure Modeling
 - a Domain wall –defect interactions
 - C Material models and model-based Control
 - D Solid Mechanics at AFOSR
 - a Wed afternoon- Keynote talks (L. Lee, D. Stepp, etc.)
 - E Autonomic Composites (UIUC/Duke/UCLA: White et al.)
 - F Energy Harvesting
 - G Game Changer '07 : Multifunctional Hybrid Composites
 - a Small unmanned air vehicles, etc.
 - H Self-healing polymers (Beckman institutes)
 - a Self-healing coating
 - b μ VAC (microvascular self-healing)
 - I Self-healing F-R composites
 - a Glass layer above nanoparticle-filled polymer film
 - b E-field reversible adhesion (cf: Gecko finger)
 - J Shape Memory Alloy and Magnetic Shape Memory Alloy
 - a Graphite nanotube coated with conducting coatings
 - b Problems in SMA Response (NiTi)
- 丁 Industrial and Commercial Applications of Smart Structures and

Technologies Conference by M. Brett McMickell (Honeywell Co.)

- A Plenary Speaker: Torey Davis (Thursday March 22nd, 8:20 am – 9:05 am, Town and Country Room)
 - a Smart Structures: the solution to “cheaper, faster, better’ in the space industry
- B Role of Industrial and Commercial Applications of Smart Structures and Technologies Conference
 - a Focus on applications
 - i Highlight multiple areas within broad markets
 - ii Specific examples of products currently on the market
 - b Applications to broad technology areas
 - i Aircraft, spacecraft, marine ships, automobiles, civil structures, machinery and medical equipments
 - c Provide a global forum
 - i Participants from Brazil, Canada, China, etc.
 - d Space applications, mechanisms and sensing applications, structural health monitoring applications, aircraft applications, etc.
- C Space Applications
 - a Key technical topics
 - i Isolation and pointing of jitter sensitive payloads
 - ii Flatness control of flexible membrane structures
- D Structural Health Monitoring Applications
 - a Key technical topics
 - i Lightweight healable composite structures
 - ii Monitoring of composite structures
 - iii Design of adaptive algorithms to compensate for damaged sensors
 - iv Cost advantages of SHM
- E Mechanisms and Sensing Applications
 - a Key technical topics
 - i Increase performance of parallel kinematics
 - ii Piezoelectric pumps and hydraulic amplifiers (DARPA funded projects, high power density, etc.)
 - iii Industrial mechanisms
- F Aircraft Applications
 - a Key technical topics
 - i Shape morphing wings

- ii Self repairing composites
- G Biological and Medical Applications
 - a Key technical topics
 - i Drug delivery products: water cooling systems by
 - ii Rehabilitation devices
 - iii Biological inspired mechanisms
- H Automotive Applications
 - a Key technical topics
 - i Die casting multifunctional materials
 - ii Fuel injection using piezoelectric actuation
 - iii Automotive safety devices
 - iv Vibration attenuation using smart materials
- I Energy Harvesting and Absorption Applications
 - a Key technical topics
 - i Application of energy harvesting for munitions
 - ii Energy harvesting for turbo-machinery
 - iii Vibration attenuation
- 戊 Sensors and Smart Structures Technologies for Civil, mechanical, and Aerospace Systems
 - A Invited Lectures and NSF programs
 - 己 Sensor Systems and Networks: Phenomena, technology and Applications for NDE and Health Monitoring (Conference 6530) by Kara J. Peters (NC State U.)
 - A How can sensors be integrated and multiplexed to provide structural health monitoring and non-destructive evaluations?
 - a Interaction with host structure
 - b Design, characterization, validation
 - c Reliability in field applications
 - B This conference bridges the gap between new sensor development and real applications for SHM/NDE systems
 - C Sensor packaging for harsh environments
 - a Mechanically robust
 - i Ferguson, Synder, Graver and Mendez (6530-03)
 - b High temperature, Cryogenic temperature, radiation environments
 - i Kunzler, Newman, Wilding, Selfridge, Schultz, and Wirthlin (6530-04)
 - D New Sensing Principles

- a High deformation measurements
 - i Kiesel, Peters, Abdi, Hassan and Kowalsky (6530-12)
- E Sensor Networks for imaging
 - a Ultrasonic 3D imaging: Schmitt and Hafner (6530-08)
- F Performance Issues, Data Fusion, Signal Processing
 - a Shape deformation for control of morphing structures
 - i Nishio, Mizutani and Takeda (6530-56)
 - ii Ritt, Klimcak, Pollard, Dumm and Murphey (5430-42)
- G Future of Sensor Networks
 - a Monitoring/Measuring of structures before and after the damages as well as while the damaging is happening
- 庚 Nondestructive Characterization for Composite Materials, Aerospace Engineering, Civil Infrastructure, and Homeland Security by Peter J. Shull (Penn State U.)
- A Our newest challenges are often our oldest problems!
- B What we want is what we always wanted – more than we have now!
 - a Increased: intelligence, sensitivity, speed, reliability (sensor reliability, system reliability), longevity
 - b Reduced: technical expertise, manpower, costs
- C “New” Challenges
 - a New materials
 - b New applications (security!)
 - c Increased Expectations:
 - i In-service lifetime
 - ii Greater mechanical demands
 - iii Reduced maintenance
- D Structural Health Monitoring: Smart Suitcase
- E Structural Health Monitoring: Civil Structures
- F Information Technology/Wireless
 - a Wireless Structural Health Monitoring System (eg. Sensametrics, Palo Alto, California)
- G Homeland Security / Robust, Multi-modal Biometrics Technology
- H Home Security / Microsystems
- I Some Challenges for 2008
 - a Scalable integrated sensing, monitoring, and control management
 - b Continuous and real-time quality control tools for civil construction
 - c System and methodologies for improving infrastructure

- management
- d Methodologies of protecting our national infrastructure in open fields, such as pipelines, tension leg platforms, railroads, nuclear facilities, dams, etc.
- e Multifunctional materials/ structures incorporating with sensor/actuator
- f Intelligent buildings and systems: healthy & sustainable buildings
- g NIST –ATP Awards for Industrial Harsh Environments
- 辛 Health Monitoring & Smart NDE of Structural & Biological Systems (Conference # 6532) by T. Kundu (Conference #6532)
 - A SHM for Aerospace Applications
 - a Passive and Active SHM (Develop embedded sensors in structures)
 - b Condition based maintenance+: and eLog21 initiative
 - c Embedded Sensor Development
 - d Embedded Sensor Evaluation: impact measurement
 - B Guided Waves for SHM
 - a Guided Waves for SHM I, II, III
 - b Guided Wave Modeling
 - i Finite Element Method and Boundary Element Method becomes computationally intensive
 - ii Is Distributed Point Source method (DPSM) the answer?
 - C SHM for Civil structures
 - D Damage Detection & Prediction
 - a Small changes lead to abrupt failures
 - b Slow phenomenon can lead to sudden failure
 - E Vibration-based Techniques for SHM
 - a How to excite and measure high-frequency time-varying operational conditions
 - F Nonlinear Methods in SHM
 - a Identifying sources of nonlinearity, whether they are inherent or damage induced, exploring nonlinear behavior for interactions for enhanced sensitivity to dynamic events that may indicate damages
 - G Novel Instrumentation & Sensing
 - a Electrostatic imaging of PCBs
 - b X-ray microscopy

H Biological and Medical Applications

- a Federal estimates predicate that health care spending will surpass the \$2 trillion mark in the next decade in US alone,. Within health care technology, biomedical devices are one of the fastest growing area
- b Sensing Topics: biomedical imaging and optics (acoustics, optics, etc.)

- 1 Funding Agency Talk, AFOSR – Current and Future Programs and Initiatives by Victor Giurgiutiu (Air Force Office of Scientific Research, IOAs ; 他為 U. of South Carolina 的航太系教授)
 - 甲 “Science is the key to air supremacy,” said Dr. Theodore Von Kraman.
 - 乙 “The first essential of airpower is pre-eminence in research” by General H. H. Arnold.
 - 丙 AFOSR Mission: AFOSR orchestrates the Air Force basic research program...
 - 丁 AFOSR Research Areas now reorganized into three areas: Aerospace, Chemistry, and Materials Sciences (NA); Physics and Electronics (NE); Math, Info, and Life Sciences (ND).
 - 戊 Major AFOSR Activities
 - A Encourage and fund basic research supporting USAF needs
 - B Identify and disseminate basic research discoveries
 - C Educate tomorrow’s S&E’s (DOD Education Programs)
 - D Leverage Foreign Research
 - 己 Partnership Strategy
 - A Building partnerships with excellence and relevance enabled by Program Manager authority (www.afosr.af.mil)
 - a Between several disciplines
 - b Many performers
 - c Between users and performers
 - d Merit review all proposals
 - 庚 “Anything that flies” is of interest to AFOSR
 - A Building a world class, internationally recognized program in fundamental structural mechanics by proactively engaging with the academic community to increase awareness of the USAF future needs – emphasis on multidisciplinary research projects, participation in technical conference , focused workshops and international collaborations
- 2 Morphing Wings – From Concept to reality (Dr. Jayanir N. Kudva, NextGen Aeronautics, Inc.)
 - 甲 Outline:
 - A Who: Sponsors, well-wishers, and performers
 - B What: Highlights of accomplishment
 - C Why
 - D How

- E 20/20 Hindsight - Lesson learned and Challenges
- F The future – opportunities and transition
- G A few closing thoughts
- 乙 Morphing Wing – A Working Definition
 - A A wing whose shape and/or state can be actively changed in flight to achieve dramatically improved system level performance in multiple flight regimes which cannot be achieved with a fixed wing
 - B Goals:
 - a Develop and Test a Full-scale, morphing wing
 - b Lay the foundation for near-term flight testing
 - C Technical Challenges
 - a Morphing skin designs (flexible skins is one step further from variable sweep wings (similar to the one in F-14))
 - b Development of kinematics and shape change structures
 - c System Integration
- 丙 Bottom Line (Each week testing in Wind Tunnel cost US\$250K)
 - A Morphing wing provides dramatically improved performance at acceptable cost and budget
- 丁 Key Innovations
 - A Flex Skins (150% skin area changes)
 - a Flexible wing skin designs which can undergo strains in excess of 100 percent while withstanding air loads of up to 400psf
 - b The material is just pre-stretched rubber. The trick is on how you support it.
 - B Distributed Actuators (hybrid actuators from CHAP program originally, eventually use hydraulic actuator for the current flying model)
 - C Optimized Morphing Configurations
 - D Kinematic load bearing structures
 - a Torsion stiffness augmentation
 - E Load Distributed over multiple joints
- 戊 Leading edge provides most of the stiffness
- 己 20/20 Hindsight: If this is not a DARPA program, we will spend 10 years in basic research and write many technical papers. However, no working / flying model will be built in such a short time.
 - A Technical
 - B Programmatic
 - C Running a Small R&D business
 - a Gets a thick skin

- 庚 Challenges and Issues
 - A Analytical methods and design tools for shape changing structures
 - a Structural optimization
 - b Airfoil optimization
 - c Linking CFD to FEM
 - d Distributed actuation system optimization
- 3 From the Piezo-Effect to a New Generation of Fuel Injection by Hans Meixner (Siemens AG, Germany)
 - 甲 Innovation for a better mobility
 - A Is vital for society founded on the division of the tasks
 - B The transport of humans, goods and information is a key element in a free market economy
 - 乙 The research started in the 80's. The first concept started was the longitudinal stack actuator. The first configuration used was a 420-layer transverse piezoelectric effect actuator. Another configuration used was a 200-layer 80 μm thick longitudinal actuator.
 - 丙 Performance improvement of the piezoelectric injector was found to be 52% in terms of smooth running, etc.
 - 丁 Mechanical stroke Amplifier (Level) was adopted
 - 戊 Multilayer Piezo actuator: problem of fast switching
 - A The problem of short response time:
 - a Switching time is in the range of 10 μs
 - b The operating temperature of the fuel injector is 380 degree C.
 - 己 Automotive Applications based on Piezoceramic Multilayer Actuators and Thin-film Technology
 - A Fuel injectors: today's technology generates oil drop in the range of 3 μm or smaller, which translates to much higher efficiency and cleaner combustion process.
 - B Parking sensors, etc.
 - 庚 Research is the transformation of money to knowledge. $\leftrightarrow$ Innovation is the transformation of knowledge to money.
- 4 Bio-inspired design of sensing, cognition and actuation: examples in real biology and is transfer to a new man-made sensor system (#6529-01) by Minoru Taya (Boeing-Pennell Professor and Director, Center for intelligent Materials and Systems, Department of Mechanical Engineering, University of Washington, Box 352600, Seattle, WA 98195-2600, Tel: 206-685-2850, tayam@u.washington.edu) with coauthor Dr. R. Stahlburg (Biology Department, UW)
 - 甲 Mechanisms in action plants

- A Bending of Mimosa Pudica Petiole (含羞草)
 - i Motor cells in stem change its size (expand above the neutral axis and shrink below the neutral axis)
 - B Leaf Folding of Venus Flytrap
 - a Insect touches sensing hair will trigger the action. The closing is done in less than 2 seconds
 - C Coiling of cucumber tendril
 - a Tendril found secure surface will induce coiling (right coil first and then with a reverse coiling point to become left coil to balance the rotation.
 - D Mechano-chemo-sensor in insects
 - a A hair-like olfactory sensilla of insect
 - E Successful and unsuccessful defense systems across the different kingdoms
 - a Cotton plant (successful model): herbivorous caterpillar vs bug sensing the volatile chemical to come to sting the caterpillar
 - b Colorado potato plants (unsuccessful model): volatile chemicals attract the bug as well. However, the bug eat the plant leaves instead of the catellipar
 - F Bio-inspired Research from the above cases
 - a Flemion and Nafion materials was compared and explored.
 - i Arrayed design and single dome-shaped Flemion IPMC
 - b Functionally Graded Microstructures (FGM)
 - i Cross section of a Mohso-Bambo along the stem cross section is also functionally graded microstructures.
 - ii Achieve same deformation with much lower strain level than the traditional bimorph configuration.
 - G Bird of Paradise Flower (Latin name: Strelitzia reginae) is a bird-pollinated flower. Small birds are attracted to this flower to help pollination of this plant.
 - a Purple flower utilizes mechanical force exerted by a bird to pen its petals sideways
 - b This flower view birds as helper and insects as enemy. This choice was done by giving spectrum attract bird and repel insect.
 - H Are we smarter than the Hawke moth?
- 5 From phtogrammetry, computer vision to structural response measurement (#6529-02) by C.C. Chang (Smart and Sustainable Infrastructure Research Center, Department of Civil Engineering, Hong Kong University of Science and

Technology, Hong Kong, China)

- 甲 Photogrammetry is the technique that measure the 2D or 3D objects
 - A Four development cycles
 - a Plan table photogrammetry (1850-1900)
 - b Analog photogrammetry (1900-1950)
 - c Analytical photogrammetry (1950-2000)
 - d Digital photogrammetry (2000-)
 - B Terrestrial technique
 - C Aerial technique
- 乙 Metric Camera provides us with a way to convert photo to drawings
- 丙 Computer vision
 - A Image processing: transforming images
 - B Image analysis: computing images components and properties
 - C Image understanding: computing the meaning of images
- 丁 Response measurement
 - A Displacement Measurement can use:
 - a Accelerometers
 - b GPS
 - i Based on satellites: 24 satellites
 - ii Need at least 4 to compute position
 - iii Accuracy: 1 cm horizontal and 2 cm vertical
 - c Laser Doppler Vibrometer
 - d LVDT (Linear Variable Displacement Transducer)
 - B Image based Measurements (in comparison to response measurement)
 - a Problems and issues (Lighting condition is important.)
 - i Camera calibration: In Metric camera case, we adopt it in the multi-collimator configuration. In computer Vision, we adopt the calibration boxes. In large scale 3D displacement, we will need at least 8 control points.
 - ii Point correspondence: Two types of point correspondence exist: between two images at a time instance (for two camera system, we will need the epipolar plan approach.) and within a sequence of images. Targets are used in this operation.
 - iii Point reconstruction: nonlinear triangulation
 - b Using PC's, each frame requires about 1 min processing time.
 - C Concluding remarks:
 - a Photogrammetry – computer vision

- b Flexible, more flexible?
 - i Rotation?
 - ii Egomotion?
- 6 A road to practical dielectric elastomer actuators based robotics and mechatronics: discrete actuation (#6524-05) by J. Plante (MIT)
 - 甲 Scientific motivation – caves, etc.
 - 乙 Bistable Actuator Module
 - 丙 System concept
 - A Highly redundant
 - a 1000s of units
 - b Sacrificial
 - B Small and light weight
 - a 100mm/100 grmas
 - C Highly agile in rough terrain
 - a Hops of 1 m clear most obstacle
 - b Hopping, rolling, bouncing
 - c Caves exploration
 - D LAN (Local Area Network) communications: each one can serve as a local controller to relay information
 - E Micro sensing
 - F Autonomous
 - a Teams group intelligence
 - G Mobility –DEA actuators
 - 丁 Conclusions
 - A The design DEA actuators to meet required force, power, work output, efficiency and reliability of many applications is very challenging.
 - B The will not meet the requirements of all challenges
- 7 Robust adaptive control of conducting polymer actuators (#6524-06) by Y. Fang (Michigan State U.)
 - 甲 Conjugated polymer is one class of electroactive polymers (EAP)
 - 乙 Challenges
 - A The actuator is time-varying system, while consistent performance is needed in applications.
 - B The electrochemomechanical dynamics is complicated
 - 丙 Motivation
 - A Utilize adaptive control algorithm to control the action
 - 丁 Model Structure
 - A The complete model consistent of three models: admittance model,

electromechanical, and mechanical modules

戊 Conclusions:

A The adaptive control achieves better results in the long run.

8 Characterization of electrolastomers based on interpenetrating polymer networks by Soon Mok Ha (soft Materials research Lab, UCLA)

甲 Prestrain Acrylic Elastomer: stress concentration, difficult to maintain flatness

乙 IPN approach; the tension in VHB network

丙 Research Objective

A How the IPN formation effect on mechanical and thermal properties

丁 Summary

A IPN electroelastomers showed much faster recovery of initial viscoelasticity

9 Development of a wireless bridge monitoring system for condition assessment using hybrid technology (#6530-16) by Mathew J. Whelan (Clarkson U.)

甲 Wireless sensor network for transportation infrastructure

A Schematic and functional overview

B Vibration monitoring, strain measurement

C Functional overview

a Design integrates a commercially available, ultra-low power wireless transceiver unit (ZigBee)

b Custom Sensorboard

c Vibration Monitoring

i Accelerometer: ADXL 203 Dual-axis MEMS

ii Conditioning electronics

iii BDI “intelliducer” strain sensor: easily deployable, reusable, field proven, 9 pounds per 100 micro-strain

iv Sampling approach with analog and digital filter representations

v Radio transmission protocol: bidirectional intelligent and coordinated radio transmission

vi Operating system: TinyOS interface with LabVIEW

D Funding: New York State Energy Research and Development Authority; St. Lawrence County Highway Department; Clarkson Univ.

10 A study of implantable power harvesting transducers (#6530-17) by B. Lee (National Taiwan University)

甲 Cantilever type for external environmental testing

乙 Disk type for implantable devices (higher operating frequency than that of

the audio frequency

- 11 How fish swim: flexible fin thrusters as an EAP platform by George V. Lauder (Harvard University) <http://www.oeb.harvard.edu/lauder>

- 甲 Fish as model systems for understanding aquatic propulsion.
- 乙 Fish fins are flexible, complex composites.
- 丙 Low frequency on fin motion (0.5-4 Hz)
- 丁 Modest strains of fin muscles (2-10%)
- 戊 The EAP useful for generating the biological platform
- 己 Focusing on the pectoral fin.
- 庚 Using polypyrrole to EAP and the applied voltage can define the displacement of the fin.
- 辛 One fin ray attach to four muscles. The material between the fin ray is the collagen..
- 壬 There are 14 fin ray of the sun fish and there are 59 muscles bundles total per fin..
- 癸 Ref. Hydrodynamic Performance of Deformable Fish Fins and Flapping Foils. 44th AIAA Aerospace Sciences Meeting and Exhibit, January 9-12, 2006, Reno, Nevada
(http://www.people.fas.harvard.edu/~glauder/reprints_unzipped/Bozkurtta_s_AIAA2006.pdf)

- 12 Benefits and challenges of using ionic polymer metal composites in medical device applications

C. Yung, N. Bhat, PAVAD Medical, Inc.

- 甲 The advantage of the ionic polymer metal composites
 - A low driving voltage
 - B no moving parts

- 13 Harvesting of electrical energy from an backpack with a piezoelectric strap (#6525-01) by H. A. Sodano (Michigan Technological University)

- 甲 This study developed an energy harvesting backpack that can generate electrical energy between the wearer and the pack.
- 乙 It is accomplished by replacing the traditional strap of the backpack with one made of the piezoelectric polymer PVDF.
- 丙 This work developed a theoretical model of the backpack strap and perform experimental testing to identify its performance in this application.
- 丁 The output power depends on the load of the backpack.

- 14 Energy harvesting using optimized piezoelectric micro-cantilevers (#6525-02) by M. J. Parsons (The University of Tennessee)

- 甲 Simulation model of a piezoelectric MEMS-based cantilever bonded to an

aluminum base is developed and designed to harvest ambient vibration energy.

- 乙 The micro-cantilever model in this study has a single substrate layer of PZT PSI-5H4E with a base of aluminum.
 - 丙 The model is assumed to be isotropic where the material fraction for each element are allowed to vary together from 1E-5 to 1.0, where 1.0 would represent 100% material.
 - 丁 This work shows significant energy improvement using topology optimization to develop micro-cantilever devices.
- 15 Optimal AC-DC energy conversion efficiency of a piezoelectric energy harvesters (#6525-08) by Y. Shu (National Taiwan University)
- 甲 It studies the energy conversion efficiency of a piezoelectric generator that consists of a full-bridge rectifier and a filter capacitor connected to a variable resistor.
 - 乙 An analytical model is proposed and an exact expression of AC-DC power conversion efficiency is derived under the steady-state operation.
 - 丙 The relationship among the conversion efficiency, electrically induced damping and AC-DC power output is established.
 - 丁 A new finding shows that efficiency and electrically induced damping are not simultaneously maximized in the strongly coupled electromechanical system.
- 16 Dynamic analysis of a biology-inspired miniature directional microphone (#6523-01) by Z. Chen (Univ. of Maryland)
- 甲 Directional microphone inspired by the parasitoid fly *Ormia Ochracea*
 - A Ears 500 μ m apart but great directional property – recognize incident angle with 2 degree
 - B IID (Interaural intensity difference) and ITD (Interaural time difference)
 - C Abundant application (ex. Radar, antenna)
 - 乙 Theory
 - A Two DOF model – Rocking mode, bending mode
 - B Needed more complex model to describe
 - a Additional system parameter 1 : coupling effect
 - b Additional system parameter 2 : air cavity behind membrane
 - C Governing equation : diaphragm, cavity, boundary
 - D
 - 丙 Simulation and experiment
 - A Specification

- a Membrane : 0.3mm in radius, 1um in thickness
 - b Separation : 1.2mm
- B Determination parameter
 - a Rocking mode : diaphragm
 - b Bending mode : coupling effect + diaphragm
- C Soft and hard beam : small and large couple respectively
- 丁 Conclusion
 - A Cavity and coupling effect : amplify delay and intensity
 - B Simulation and experiment both declare that

- 1 Funding Agency Talk, DARPA – Material System Initiative by Donald Leo (DARPA)
 - 甲 Year of 2007 is the 50th anniversary of DARPA, which was started by President Eisenhower after SPUNTIK was launched.
 - 乙 Autonomous Material Systems: Can we make the “smart” an intrinsic property of the material without any need for additional sensors, power, and control?
 - 丙 BAA 06-19 details
 - A MSAT BAA Objective:
 - a Demonstrate the use of circulation in structural materials for
 - i 10X changes in structural material properties (electrical, thermal, mechanical)
 - ii Development of capability not possible without circulation (e.g. healing and surface regeneration)
 - b Autonomous Materials sessions: co-organized with Dr. Les Lee of AFOSR, Keynote speaker: Dr. Scott White UIUC, Golden West 1:30-2:10
 - B A white paper is needed for a potential PI to work with the Program Manager to discuss the possibility for funding.
- 2 Review: Piezoelectric Actuators – Expansion from IT/Robotics to Ecological/Energy Applications by Kenji Uchino (International Center for Actuators & Transducers, The Pennsylvania State U.; Micromechatronics Inc., State College)
 - 甲 $\text{Pb}(\text{Zr}, \text{Ti})\text{O}_3$ Piezoelectric has high hysteresis, but close to linear; $\text{Pb}(\text{Mg}_{1/3}\text{Nb}_{2/3})\text{O}_3$ electrostrictor has lower hysteresis, but nonlinear (square law) between electrical and mechanical
 - 乙 Piezoelectric Actuator Development History
 - 丙 1978 PMN electrostrictor (PSU) 1996 Space shuttle Hubble telescope
1978 Cofired MLA (PSU)
1981 High d/k Single crystal (TIT)
etc.
 - 丁 Advantage of Piezoelectric Devices over Electromagnetic Types
 - A More suitable to miniaturization
 - a Stored energy is larger than that of an EM type
 - b 1/10 smaller in volume and weight
 - B No electromagnetic noise generation

- a Magnetic shielding is not necessary
- C Higher efficiency
 - a Insensitive to the size
- D Non-flammable
- 戊 Focusing/Zoom mechanisms in a cellular phone
 - A Autofocus 0.2mm displacement range, done by the end of 2005
 - B Optical Zoom 2 mm displacement range, pursued now
 - a Heli-morph by One Limited
 - b Metal Tube Ultrasonic motor (Penn State Patent filed 2000)
 - i Keys: “Gentle to Ceramic” – Uniform poling
 - ii 90 degree phase difference in x and y axis driven on a tube
- 己 Piezoelectric transformer
 - A Smaller, lighter & thinner; No magnetic noise
 - B 20 – 25% of notebook used today
 - C Evolution of High Power PTs since 90s
 - a 10W backlight inverter → 35W high power adapter
 - b Penn State collaborate with Taiheiyo Cement Corp & Face Electronics
- 庚 EPSON MACH Printer Head Structure
- 辛 Optical Fiber Alignment
 - A V-shaped actuator: sine and cosine with 0 or 90 degree phase difference to have left/right versus circular motion
 - B LTCC combined with piezoelectric actuator
 - a Lower temperature sinterable ultrasonic motor
- 壬 Active Damping of Train bodies (EADS)
 - A TGV trains in France
- 癸 70W multilayer piezoelectric transformer was developed to form: driver integrated transformer
- 11 Transformer integrated ultrasonic motor by Penn State Univ.: ultrasonic motor + Piezo-transformer + battery
- 12 From Passive Dampers to Adaptive Dampers with Energy Harvesting
 - A K. Uchino, T. Ishii, J. Ceramc Soc. Japan Vol. 96, 883 (1980)
 - B K2 & ACS
- 13 Micropositoner by Physik Instrument
- 14 Piezoelectric MicroRobot by Applied Micro Systems in Japan
- 15 Microvehicle by Penn State U.
- 16 Compact Helicopter with 4 micro actuators by Seiko Co.
- 17 Piezoelectric impact actuator for manipulating the cell in artificial

- fertilization by U. of Tokyo, Nano Control
- 18 Endoscope and medical catheter
- 19 Popular mechanics 2003 Insulin injection without needle
- 20 Ecological Pb-Free Piezoelectric: (Na, K) NbO₃ type compound; 49 patents, almost all taken over by Japanese Industries
- 21 Noise Barrier by Kobayshi Institute of Japan; Curved PVDF
- 22 Magnetic noise sensor: Penn State Univ. & Seoul National U., Magnetoelectric based shield
- 23 Energy Harvesting by Penn State Univ. & DENSO; vibration suppression and energy harvesting
 - A Cymbal actuator
- 24 IC: Intelligent Clothing
- 25 Multilayer Actuators for Diesel Injection Valve
 - A Energy consumption by LCA (Well to Wheel)
 - <http://www.marklines.com/ja/amreport>
- 26 Trend
 - A Technology maturing with price reduction
 - B Special specs with price maintaining
 - C Upsizing in space/air vehicle structures
- 27 Key Factor
 - A Hybridization /integration
 - B Simplification/miniaturization
 - C Low manufacturing cost
- 3 Energy conversion in piezoelectric superlattice by Y. Chou (周元昉, Dept. of Mechanical Engineering, National Taiwan University)
 - 甲 Polariton was developed to match EM and Acoustic wavelength for maximum energy coupling
 - 乙 The LiNbO₃ crystal of 3m symmetry was examined to explore the energy contents
- 4 Switching characteristics of (Bi_{0.5}Na_{0.5})TiO₃-BaTiO₃-(Bi_{0.5}K_{0.5})TiO₃ lead-free ferroelectric ceramics by Jay Shieh (謝宗麟, Dept. of Material Sciences, National Taiwan University)
 - 甲 300 pC/μm coefficient in these material systems were achieved, a good number in lead-free system
 - 乙 Curie temperature for this system is around 300 degree C. However, for this relaxor system, depolarization temperature will appear lower than the Curie temperature. In this case, the depolarization temperature is around 190 degree C.

- 丙 0.5 to 2 μm grain size approximately.
- 5 Ornithopter by J. M. Dietl & E. Garcia (Cornell University)
- 甲 Flapping-wing aerodynamics
- A The airflow is time dependent and 3D $\rightarrow$ practically unsolvable
- 乙 Cannot achieve simple steady state flight. It can achieve limit cycle, in fact, two limit cycles.
- A Monodromy Matrix: defined as the Jacobian of the limit cycle's Poincare map
- 丙 Control was done by linear stabilization.
- 丁 More flight regimes; hoer, takeoff/landing, maneuvering, 6 degree of freedom
- 戊 Acknowledgement: Eglin AFB, ASEE NDSEG Fellowship
- 6 Evolutionary flight and enabling smart actuator devices by Justin Manzo & E. Garcia (Lab for Intelligent machine Systems, Cornell U.)
- 甲 Unique evolved flight devices (vertebrate)
- A Birds
- a Alula (slat/Krueger flap)
- b Span change (F-14)
- c Tip feathers (Spillman 1987)
- d Tail
- e TE Feather Turbulators
- B Bats
- a Camber change
- b S-wing flexion
- c Uropatagium
- C Pterosaurs
- a Pteroid bone
- b Active twist
- 乙 Evolutionary flight similarities
- A High sensory capacity
- a Merkel cells
- b Cutaneous feather deflection sensors
- c Actinofibril network
- B Passive high-lift /low drag devices
- a Cambered airfoils
- b Leading edge roughening
- c Optimized feathers
- C Typical modern camber drawbacks

- a Continuous camber more effective
- 丙 Cambered flight advantages
 - A Bats maneuvering in rotating
- 丁 Enabling materials used: Shape memory alloy (eg. Cornerstor)
 - A Smart joint schematic and tri-phase operation
 - B SMA, Nichrome, etc.
- 戊 Physical interpretation on bat-wing aircraft
 - A In baseline model, try smart joint in the wing
 - B Capable of increased L/D
- 7 Post-buckled precompressed (PBP) subsonic microflight control actuators and surface by Ron Barrett (Aerospace Eng., U. of Kansas, Lawrence)
 - 甲 Purposes: deliver an abbreviated update on a new class of high performance systems
 - 乙 Approach:
 - A To design a flying machine is nothing...
To make a flying machine is something ...
But to fly, that is everything ... by Otto Lilienthal 1906
 - 丙 1994-1997 Kolibri: the 1st Micro Aerial vehicle; Sponsor: DoD CounterDrug Technology Office; Power Consumption is 14mW, piezoelectric stabilizer
 - 丁 Ultra-high performance UAVs
 - A Heinkel Wespe (1944) by Ernst Heinkel Flugzeugwerke A.G.
 - B XQ-138
 - C www.staero.aero
 - 戊 Used a Post-buckled Precompressor as Electrical Transformer (US Patent by George Lesieur of the Penn State U. → **Locate and Examine!**): Increase apparent coupling coefficients
 - 己 Solution to most challenging PBP issue: failure on tension face
 - A Problem: tensile depoling & fracture
 - B Solution: 2007 SDM conference
- 8 Insect Cyborgs: A new frontier in flight control systems by Tim Reissner (Cornell University)
 - 甲 Past telemetric method: ground radar scanner
 - 乙 Propose: insertion of payload (mass production) in pupa state with new ideas: **(instrument the environment)**
 - A Implementation of microsystems and active components at the pupa development stage
 - B On-board direction control of insect motion through ultrasonic

- stimulation of tympanum and/or direct electrical neuromuscular actuation
- C Systems integration of life with power scavenging, navigation, nanofluidics and sensors
- 丙 Interdisciplinary study
 - A Life sciences: study behavior and response to changes in the environment in insects
 - B Engineering: develop cheap, mass produced, yet efficient, MAVS to carry payload for surveillance
- 丁 Subsystem development
 - A Surgical implantation, power scavenging, etc.
 - B For moth, the power extractable from vibration is 0.164W
 - a Piezoelectric strain power harvesting method
 - b Solenoid generator with minimum power generation of 20mW and 1.5 voltage output
- 戊 Behavior Control
- 己 Status and Forecast
 - A DARPA Microsystems technology Office (MTO) HI-MMES Program
Dr. Amit Lal
- 9 Towards artificial molecular moto-based electroactive/photoactive biomimetic muscles by Tony J. Huang (The Penn State)
 - 甲 Rotaxane: An artificial molecular machine (J. Fraser Stoddart, Chemist at UCLA)
 - A Mechanical properties:
 - a High strain (40-60%)
 - b Large force (100pN)
 - c Multi stimuli (Chemical, Electrical, Optical)
 - d Low Voltage
 - 乙 Comparison to Biomotors and NEMS Actuation Materials: Rotaxane is more robust and has wider application regimes
 - 丙 Objective: Rotaxane-based nanosystem using the hybrid top-down/bottom-up approach
 - 丁 To make this system useful, we need to explore the possibility of actuating Rotaxane in condensed phase on top of solid substrate, which originally switch only in solution.
 - 戊 Even AFM does not have enough resolution to study the 8nm expansion of Rotaxane.
 - 己 One of the methods found is:

- A X-Ray Photoelectron Spectroscopy (XPS)
 - a Tony Jun Huang et al, Nano Letters, 2004
 - b The XPS technique is surface specific in nanometer scope due to the short range
 - c The data provide us with strong evidence that Rotaxane indeed switch in condensed phase on solid surfaces.
 - d 4.5 nm motion was measured, which compares reasonably well with theoretically predicted 8 nm.
- B A Rotaxane “Molecular Muscle”
 - a Tony Jun Huang et al., Applied Physics Letters, 2004
- C On-going Research : Assemble molecular machine-based active nano-metamaterials from Nano to micro to Meso
- D Future applications
 - a Micro/nano fluidics
 - b Optical switch
 - c Nanodrug delivery system
- 10 Stress Monitoring Using EM sensors on Penscot River Bridge (USA) by Ming Wang (王明亮)
- 11 Soft matter acoustics – non-acoustic health monitoring of polymer blend films (#6531-05) by A. Kamanil, Jr. (Institute of Physics, University Leipzig, Germany)
 - 甲 Scanning acoustic microscope
 - 乙 Phase contrast (A. Gritt, Advances in acoustics)
 - A Height resolution $\Delta h < 2.5 \text{ nm}$
 - B Allows tilt and topography correction of amplitude data
 - C Permits pseudo 3D rendering of sample topography
 - D Discrimination of surface and subsurface features
 - 丙 Un-annealed polystyrene/polymethylmethacrylate (PS/PMMA) polymer blend film on glass
- 12 Epoxy hydrogels as sensors and actuators by Paul Calvert (Department of Materials and Textiles, University of Massachusetts, Dartmouth)
 - 甲 Acrylates vs Epoxies
 - 乙 Amine curing agent
 - 丙 Glucose sensing
 - A Conductive hydrogels containing immobilized glucose oxidase. As acid is formed, gel swells and conductivity decrease (?).
- 13 Novel impact-based peak-energy locking piezoelectric generators for munitions (#6527-31) by J. S. Rastegar
 - 甲 The firing duration of the firing acceleration is very short

- 乙 It provides a solution that the strain applied to the piezoelectric can be maintained at its in-firing peak value
 - 丙 Mechanical design
 - 丁 The modeling and simulation only.
- 14 Novel vibration-based electrical energy generators for low and variable speed turbo-machinery (#6527-33) by J. S. Rastegar
- 甲 For the applications such as wind mills, tidal flows, and the like.
 - 乙 Mechanical design
 - 丙 The generator is simple, can efficiently operate over a very large range of input speeds, and should require minimal service and maintenance
 - 丁 Analytical modeling and simulation only.

- 1 Funding Agency Talk, Current and Future Programs and Initiatives by Shih-Chi Liu (Program Director, Sensor Innovation & Systems, National Science Foundation; sliu@nsf.gov; Tel: (703) 292-7017)
 - 甲 The National Science Foundation (www.nsf.gov) funds people, ideas and tools. The focus is knowledge at the frontiers of discovery, learning and innovation in Science and Engineering.
 - A The ideas is to do innovative research.
 - B NSF funding is competitive, based upon merit-review (typically panel review). The two main review criteria are: (1) intellectual merit, and (2) broader impacts.
 - C This funds research awards (including individual investigator, group awards, centers) as well as education awards, fellowships and major research facilities.
 - 乙 Civil and Mechanical Systems (CMS) Division is split into three tracks: Engineered materials and Mechanics, Intelligent Civil and Mechanical Systems, etc.
 - 丙 The NSF funding rate is around 20% in 2005 and the Engineering division funding rate is around 13% in 2005. The CMS division funding rate is around 10% in 2005.
 - 丁 The Sensors Initiative
 - A Thrust Research Areas
 - a Design, materials and concepts for new sensors and sensing systems
 - b Sensor arrays and networks
 - c Interpretation and use of sensor information
 - 戊 ASMASST: Asia-Pacific Networks The World Forum on Smart Materials and Systems Technology, May 27-30, 1997, China.
 - A
- 2 Revolutionary Transitions of GE Technology in NDE Prognostics and Health Monitoring by Tom Batzinger (GE Global Research Center), Thadd C. Patton (GE Aviation)
 - 甲 What we imagine, we are making happen...
 - 乙 Agenda
 - A GE's technical synergy
 - B Challenges of Prognostics and Health management
 - C PHM Objectives at GE Aviation
 - D Nondestructive evaluation at GE

- E Leverage opportunities for PHM technology within GE's businesses
- F Questions
- 丙 GE – A simplified company pursuing growth
 - A Infrastructure: oil and gas, engine, financial services, etc.
 - B Industrial: working other industries, securities, etc.
 - C Healthcare: medical instruments, biological sciences, etc.
 - D NBCU
 - E Commercial Finance
 - F Consumer Finance

GE Global Research Centers is the technology clearing house with US\$3.5B budget with US\$0.5B from GE Aviation.
- 丁 Technical Synergy:
 - A Materials & Modeling (new coatings, new composites, new metal alloys, etc.)
 - B From imaging to NDT & Security (Digital X-ray, phased array ultrasound, eddy current, thermography, optical metrology, image processing, etc.)
 - a The reason for NDE must be thought of. If there is no fundamental reason
 - C From Biosciences to Security to Water (imaging, contrast personal medicine → personalized maintenance, discovery sciences, security BioDetection, Water analysis, etc.)
- 戊 DoD Sustaining Dilemma
 - A Today's asset management
 - a Fixed schedule maintenance based upon fleet wide statistics
 - b Discard parts based upon hard time limit
- 己 PHM (Part Health Management) Objectives
 - A Enable wing commanders to adaptively manage their assets...
 - B Real-time asset capability prediction
 - a Field operation database
 - i Failure mechanisms + sensor interrogation → physics – based material damage & life models & life meter (associated with each part)
 - ii Prognosis & asset management systems
 - (i) + (ii) → prognosis advisor
 - C Engine by Engine mission severity is not captured in current lifing process
 - D Part Health Prognostics – Approach

- a More output from single sensor (multi-sensing capabilities), more active sensing, etc.
 - b Failure mode & probability of failure
- 庚 How does NDF Fit within the PHM Strategy
- 辛 Accurate Sensing + NDE + Physics –based models = improved remaining life accuracy
- 壬 NDE and Sensing Leverage Opportunities
 - A GE healthcare, GE Sensing, GE Security, GE Energy, GE Nuclear, etc.
- 癸 Evolutionary Transitions GE Technology
 - A Clinical Diagnostics → Industrial Diagnostics
 Digital Mammography System → Industrial Digital X-ray system
 - B Essentially Cradle to Grave Diagnostic Capability
- 11 The Quest for Personalized Medicine → Personalized maintenance of parts
- 12 Performance based engine prognostics
- 13 Volume CT: Where the patient is the engine
- 14 Fusion of Geometric & NDE Inspection Data
- 3 Design of active nanocomposites by Minoru Taya (Boeing-Pennell Professor and Director, Center for intelligent Materials and Systems, Department of Mechanical Engineering, University of Washington, Box 352600, Seattle, WA 98195-2600, Tel: 206-685-2850, tayam@u.washington.edu)
 - 甲 Processing of laminated FSMA composite
 - A CuAlMn laminated composite, etc.
 - B Spark Plasma Sintering (SPS) System: new processing instrument for making new nano-composites
 - C Piezo-SMA composite by SPS
 - 乙 Future applications
 - A Micropump
 - B Energy harvesting
 - 丙 Nanocomposites as new airborne energy harvesters
 - A Dye-sensitized solar cell
 - 丁 Airborne actuators
 - A Thermoelectric materials: energy conversion system from thermal energy to electric energy using Seebeck effect. It is p & n type material connected electrically in serial and heat in parallel.
 - a Advantages of Mg_2Si for TE material as a new airborne energy harvester
 - b Improvement of figure of merit by nanocomposites
 - c Al_2O_3 and SiO_2 (<10nm) are selected as candidates of inclusion

- d $\text{Mg}_2\text{Si}_{1-x}\text{Ge}_x$ is another candidate being looked at (funded by JPL)
 - B Solar cell systems (Ref: Improvements in solar cell efficiency by system from 1976 to 2005)
 - a TiO_2 and Ru Complex: Dye-sensitized solar cell (DSSC); a few company reported 10% efficiency now. The UW research goal is to achieve 15% by 2010.
 - b Compound semiconductor
 - c Silicon semiconductor
 - d The structures of a antenna complexes from purple photosynthetic bacteria (Nature, Science 2005)
 - i Nature photosynthesis: photosynthetic bacteria SP: BCMa_2
 - ii Dye-sensitized solar cell: Dye:Ru complex
- 戊 Conclusions:
 - A Nanocomposite has high potential to be used as airborne sensors and actuators
 - B Bio-inspired design can be a good approach to next generation development.
- 4 Instrumented Indentation of shape memory polymers by M. Dunn (U. of Colorado)
 - 甲 Outline
 - A Shape memory effects and shape memory polymers (SMPs)
 - B Thermal mechanical behavior of SMPs
 - a Thermal-mechanical behavior
 - b Shape memory mechanisms
 - C SMP thermo mechanical constitution model
 - D ...
- 5 Packaging of an iron-gallium (galfenol) nanowire acoustic sensor by Jan Stadler (U. of Minnesota)
 - 甲 Material section
 - A Polyurethane: its acoustic impedance is close to that of sea water with minimum attenuation of sound waves expected
 - B Advantages of PDMS over polyurethane
 - C Predefined MEMS materials with well-known processing conditions
 - 乙 Final package chosen: the microphone was placed within a PDMS case filled with silicon oil.
 - 丙 Water (20 degree C) has acoustic impedance is 1.48, seawater (20 degree C) has acoustic impedance at 1.56, Castor oil is 1.43, polyurethane is 1.56,

PDMS is 1.05, and Silicon oil is 0.96.

丁 Conclusions

A A bio-inspired MEMS nanowire acoustic sensor is developed based on the transduction process of a human—ear inner cochlea.

B The package is designed to fulfill all the anticipated challenges: restricting moisture and salt ions, allowing sound wave to penetrate with minimum loss.

6 Autonomous Multifunctional Nanobrush-autonomous Materials by Mehrdad Ghasemi Nejhad (Hawaii Nanotechnology Laboratory, Dept of Mechanical Engineering, U. of Hawaii)

甲 Nanobrush

A SiC fiber after partial masking to have Au coated partially. Nanotube-bristles was then done with CVD to coat on the SiC fiber. (Ref. Nature Mater, 4, 540-545 (July 2005))

B Applications: nano-brushes clean the nano-world

a Removal of heavy metal ions

7 Autonomous carbon nanotube and shape memory yarn, sheet, and wire systems by Ray H. Baughman

甲 Goal: demonstrate artificial muscles that are powered (like natural muscle) by a high-energy-density fuel. Deploy these muscles for autonomous systems. (In memory of Alan MacDiarmid, April 14-1927-February 7, 2007)

乙 One reason we need artificial muscles: billion results have been achieved in mind-control of motors. Still six motors in present arms cannot provide natural function. There are more than 630 muscles in human arm.

丙 Kitech “Partner Robots in Korea

丁 EVE RI of KITECH in Japan

戊 Some strategies for artificial muscles

A Dopant integration charging

B Electrochemical double layer charging: store high charge at low voltage, but needs electrolyte

己 The actuator and energy storage functions use Electrochemical Charge Injection

A Inject charge into bonding orbit, the carbon-carbon bond length will shorten. Inject charge into non-bonding orbit, the carbon-carbon bond length will expand.

B Very high strain was found

庚 The energy density of batteries is 30x lower than for fuels like methanol (2)

battery power densities are low.

- A Demonstrate artificial muscle that is
- B Honda's ASIMO
 - a Can run 6 km/hr
 - b Has 26 degrees of movement
 - c About 0 min of activity per battery charge
 - d Four hours needed to recharge batteries

辛 Proton Exchange membrane fuel cell

- A Comparison of fuel and electrically powered carbon nanotube muscles
 - a Electrically powered muscle
 - b Hydrogen powered muscle
- B Fuel powered carbon nanotube muscle
 - a The electrodes charge when the circuit is open (it is chemically charged and not electrochemical charged)
- C New Second type fuel cell based actuator
 - a Cost NiTi wire with Pt in O₂
 - b Does not need shape memory alloy. The only thing needed here is the heat generated. In fact, the author adopted metallic bimorph or metallic spiral spring to do the actuation as well.

壬 Summary (www.SciencCentral.com)

- A The fuel powered shape memory muscle supported ~150MPa stress while undergoing ~5% contraction.
- B It is to be noted that this discussion is fundamental and not limited to fuel cell directly
(An interesting topic to look into. Dig out related papers and investigate.)

8 Impingement, adhesion, and size-scale effects of a single polymeric nanofibers by Min Kyoon Shin (Center for Bio-artificial muscle, Dept. of Biomedical Engineering, Hanyang University)

甲 Background

- A Nanomaterials, produced mostly by synthetic bottom-up methods, are discontinuous objects, and this leads to difficulties with their alignment, assembly. Etc. A different method will be needed.
- B Electrospinning is a potential candidate (Adv. Mater. 16, 1151 (2004))

乙 Some additional testing methods

- A Impingement : shape of nanofibers
- B Adhesion surface effect of nanofibers
- C Size effect: unexpected properties of nanofibers

丙 Size dependent elastic modulus

A It is known that the elastic modulus is strongly dependent on the size.

B In the electrospinning, the size effect is strong (J. Appl. Phys. 89, 018, 2001).

- 1 Funding Agency Talk, Naval Perspective on Smart Structures/Materials by Mike Yu (Program Director, NAVAIR)
 - 甲 Towards the Navy-after Next
 - A Operational Navy (current)
 - B Acquisition Community (5-20 years)
 - C Domain of Science and Technology (>20 years)
 - 乙 Hybrid, active FSMA/polymer micro-composites and electrostrictors by Bob O’Handley, MIT
 - 丙 Multifunctional Materials – ONR MURI, Artificial and Natural Multiferroics, Manfred Wutug, Virginia Tech
 - 丁 Littoral Combat Ship (LCS) by General Dynamics & Lockheed-Martin
 - 戊 Unmanned sea surface vehicle (USSV): two designs span the LCS mission space
 - A Premise – USVs with hull and propulsion optimized for the mission will perform better than manned boats adapted for the mission
 - 己 USSV Stabilization and Collision Avoidance
 - A Performer: SBIR: Intellitech Systems
 - B Technology Challenges
 - a Larger payload/fuel fraction
 - b Increased platform stability
 - c Weight and space efficient power sources for USV payloads, etc.
 - 庚 Smart Sleeve Demonstration
 - A Smart sleeve concept to reduce the noise in order to achieve Stealth
 - B Demonstrated >10dB in noise deduction
 - C Performer: Dr. Steve Winzer, Lockheed Martin
 - 辛 ACORN (Active control of radiated noise)
 - 壬 Naval Aviation Weapon Systems
 - 癸 V-22 Reconfigurable Rotor Blade (RRB)
 - A Shape memory alloy actuation system to make a compromise between the blade between a helicopter and a propeller airplane
 - B V-22 airplane is at least 2 times faster than helicopter
- 11 The way ahead for Naval S&T
 - A Today’s Navy and Marine Corps.
 - B Next Navy and Marine Corps
 - C Navy and Marine Corps After Next
- 2 Smart Structures: The Solution to “Cheaper, Faster, Better” in the Space Industry by Torey Davis (Honeywell Defense and Space)

- 甲 Overview
 - A Past smart structures space mission
 - B Present smart structures space mission
- Past**
- 乙 Hubble reaction wheel assembly isolation system
 - A Launched in 1990
 - B Hubble space telescope objective: to provide 20dB noise isolation
- 丙 ACTEX-I (Advanced Control Technology Experiment I)
 - A Program initiated in 1991 and launch in 1996
 - B Piezoelectric actuator
- 丁 CASTOR damping experiment
 - A Started in 1992, tested on MIR in 1996 and 1999
 - B Viscous damping was tried
- 戊 Cryo-cooler vibration suppression experiment
 - A Started in 1992 and launched in 1994
 - B Piezoelectric vibration suppression for temperature control unit
- 己 Shape memory actuated release device (SMARD)
 - A Started in 1994, deployed in 1998
 - B Part of MightySAT I
- 庚 Vibration isolation, suppression, and steering system (VISS)
 - A Stated in 1994, launch 2000
 - B Passive technology uses viscous damping and hydraulic active actuator
- 辛 ACTEX-II (Advanced Control Technology Experiment II)
 - A Qualified on ground, launch failure in 1995
 - B Passive and active damping to control spacecraft jitter created by solar panel expansion
- 壬 Middeck Active Control Experiment (MACE)
- 癸 Magnetically damped vibration isolation system
 - A Launch in 1997, used again in 2002
 - B Space shuttle for Hubble Space Telescope serving Mission
 - C Passive eddy current damper
- 11 Viscoelastic Struts for FORTE
 - A Viscoelastic material
- 12 Satellite Utraquiet Isolation Technology Experiment
 - A Piezoelectric Actuator
- 13 Hubble Solar Array Damper
 - A Viscoelastic damping material

14 SMA Hinge for Lightweight Flexible Solar Array

- A Launched in 1999
- B Experiment on STS-93
- C Shape memory alloy

15 QWKNUT SMA Release Application

- A Qualified in 1999 and launched in 2002
- B SMA technology

16 Whole Spacecraft Launch Isolation

Present

17 2007 Conference 6527 Session 1

18 Smart Materials Implementation Benefits for Space Flight

- A Significantly reduced structural resonance
 - a Reduced loads
 - b Reduced vehicle control
- B Significantly reduced dynamic loads
 - a Discrete optimal damping
 - b Vibration damping
- C Significantly reduced mechanism release loads
- D Increased performance predictability
- E Benefits equal reduced risk, reduced analysis, reduced verification steps = \$\$\$ savings

19 Possible Future Applications of Smart Materials

- A Active composite fuel tanks
- B Viscous fluid damped landing feet
- C Constrained layer structural damping
- D EAP tie downs/
- E Piezoelectric strut vibration suppression

20 Conclusion

- A Smart structures and materials have been implemented on numerous space-borne missions to improve performance and in some cases to ensure mission success through
- B Reduced dynamic loading, increased controls robustness, improved pointing resolution, increase performance predictability
- C Smart structures and materials continue to be used on spacecraft and the industry is taking progressively greater advantages of their performance advantages
- D Future space missions will be in need of smart structures and materials

technology advancements to perform their tasks, so let's get started.

21 Comment

- A The viscous fluid adopted in Hubble Telescope has been in use for more than 17 years. It does perform well in space and in vacuum conditions

3 Adaptive and Controllable Compliant Systems with Embedded Actuators and Sensors by Brian Trease (Compliant Systems Design Laboratory, The University of Michigan)

甲 Overview

- A Traditional mechanism design
- B Compliant mechanism design
- C Compliant Mechatronic system design
 - a Sensing, biomaterials, actuators in flexible structure
 - b www.spacedaily.com/news/materials-04zzp.html
- D Scope: intersection of disciplines
 - a Compliant mechanism, distributed sensing, embedded actuation, control → adaptive
- E Survey paper by M. Frecker, 2003
 - a Actuator placement on non-compliant predetermined structures
 - b Actuator material distribution problem
 - c Couple structure

乙 Genetic algorithm was adopted to convert the continuous structures to discrete structures

- A Actuators were added into one of the truss element to perform actuation

丙 Controllability

- A Design space for the “design for control” synthesis problem

丁 Balance of deflection vs orthogonality

- A Tradeoffs, toward a critical balance

戊 Future works: observability

己 Comments: geometric nonlinearity and singularity (e.g. three linear bar mechanism linked in horizontal facing vertical load) that may appear must be considered in the future

4 Metal RubberTM sheet and fabric materials and devices by Richard Claus

甲 ESP process advantages: versus sputtering

- A Made layer by layer using self-assembly process
- B ESP process: polymer/polymer; polymer/particle; particle/particle
- C Conformal, homogeneous molecular layer by layer

- D Précis nanoscale control over thickness
- E Excellent long-term environment tolerance
- 乙 Properties now
 - A Electrical conductivity: 0.1-1 ohm-meter; 10^{-6} ohm-meter
- 丙 Design: polycarbonate substrate, surface preparation ,EMI shielding, abrasion resistance, electrostatic dissipation, chemical resistance
- 丁 Synthesis and Scale up: can do 100liter per batch now
- 戊 Automated process, can coat in flat as well as curved surfaces
- 己 Self-assembled nanocomposites; metal rubberTM pm of metal
 - A Metal contents is only 0.007% even for conductive case: effect of electrical percolation, etc.
 - B Since the metal particle is not connected, this configuration does better when facing high strain, experiencing flexible bending. Perform much better than sputtering
- 庚 MRTM textiles: RF Shielding properties
- 辛 Metal Rubber – Velco: electric and mechanical interconnects
- 壬 Large area light-weight MRTM Textiles
- 癸 Summary
 - A Self-assembled materials
 - B Lower resistance and lower modulus (0.01 MPa)
 - C Interconnected flexible electrically and mechanically
- 11 Comments:
 - A does not solder well on the flexible sheet made by this process at this moment
 - B gold is not the cost driver
 - C can achieve US\$10 per square foot in the future (currently sell to high-school student for US\$1000 a sheet!)
- 5 Test/analysis correlation for a Nomex-based honeycomb with piezoelectric patch for a by Ms. Corine Florens (Ph.D. students, Ecole Centrale Paris, France)
 - 甲 Material properties depend on temperature and frequency, which is typical for plastic materials
 - 乙 QuickPack QP20W Mide' (46 x 33.3 x 0.25 mm) piezoelectric patch is embedded within the honeycomb beam
 - 丙 Local phenomenon: blister for the piezoelectric patch was found by FEM and in experiment; good agreement between the theoretical and the experimental results was found.
 - 丁 Future work: application on a realistic helicopter trim panel; taking into account of viscoelastic law in FEM

6 Zero-power shock sensors using bistable compliant mechanisms by Brian Hansen
(Brigham Young University)

甲 MEMS accelerometer makes up a large portion of the available accelerometers. Packaging makes up most of the cost of the accelerometers.

乙 Packaging – cost minimization

A Design: zero power, compliant mechanism

丙 Compliant mechanism characteristics

A Fabricated from a single substrate

B Entire device is a single component

C Designed to be flexible

D Bi-stable mechanism has two stable states (similar to that of a light switch)

E Activation energy causes switch actuation

F First activation force much greater than second activation force

丁 Fabrication

A Switch cut of plastic with laser-cutter

B Center piece attached to the sheet

C Various materials used

D Plastic needed specific laser-cutting properties

E Must cut cleanly, not melt, and be somewhat flexible

F ABS and Delrin plastics yield successful results

G While and back ABS used for visual information

戊 Testing

A Sensors' activation energy measured with centrifuge

B PRM's increased until switch actuation

己 Performance

A Customized by varying free-moving mass area

B Plastic thickness had no real effect on switching acceleration

C Approximate 10-15% sensitivity difference between each piece of accelerometers

a Individual switch variations due to laser-cutting step

b Slight variations in leg profile and leg edges

D Activation energy settles at ~15 actuations

E Slight increase in second activation energy

F Large gap between energies maintained

庚 Summary

A Low cost shock sensor

- a Zero required power
 - b Visual readout
 - c Bi-stable compliant mechanism
 - d Laser cutting of plastic
- B Customizable switch parameters
- 辛 Comments:
 - A This design is based on thin bi-stable wire with shallow cutout. This type of device is very sensitive to the slight imperfection, which may be a problem in the manufacturing process used here.
- 7 Electric field sensor based on core-replaced optical D-fiber by M. Schultz (Brigham University)
 - 甲 Background
 - A E-field sensors needed for
 - a Characterization of devices
 - b Electromagnetic interference, etc.
 - 乙 Optimal electro-optic sensor
 - A Optimum design parameters
 - a Sensor size of fiber
 - b Seamless fiber transition
 - B Innovative solution
 - a In-fiber sensor
 - i Flexible and small cross section
 - b D-fibers
 - 丙 D-fiber platform
 - A Undoped silica cladding, fluorine cladding
 - 丁 In-fiber hybrid waveguide
 - A Expose fiber core
 - B Fabricate hybrid waveguide
 - C Poly hybrid waveguide
 - 戊 Selective chemical etch
 - A Core etches faster than cladding
 - B Structural integrity maintained
 - C Hydrofluoric acid was used to etch the core away (8 x faster etching speed in core than that of the clad)
 - 己 Deposition of polymer into core
 - A PMMA/DR1 used as proof of concept
 - B Thin polymer → low loss
 - C Thick polymer → sensitivity

- 庚 Corona Poling
 - A 10KV
 - B Polymer heated, high voltage applied, positive ions build up on surface, molecule aligned
 - C Efficient corona poling: heated to 95 degree C, 10KV applied, polymer cooled back to 40 degree C.
- 辛 Sensor testing of DC and AC signal
- 壬 Summary
 - A Demonstrate in fiber electric field sensor
 - B Basic fabrication process
 - a Controlled chemical etching
 - b Polymer deposition
 - c Corona poling
- 8 Analysis, construction, and testing of a large displacement bistable piezoelectric actuator by J. Monreal (Royal Belgium Military Academy)
 - 甲 Solution to amplify displacement
 - A George A. Lesieutre: precompressed actuator increased actuation capability of a piezoelectric bimorph in 1997
 - B Ron Barrett in 2005
 - 乙 Snap through mode performance
 - 丙 Actuators construction
 - A 72 mm long and the displacement is around 2 mm
 - B Vacuum is applied for better bonding and thinner structures
 - C The elevation temperature during cure results in pre-compression in the PZT layers due to CTE mismatch
 - D Depoling in PZT's is thus prevented
 - 丁 Analytical and FE models
 - A Course of the analyses
 - a Euler-Lagrange equation →
 - i Deformed shape
 - ii Critical buckling load
 - b Snap through analysis
 - i Maximum lateral deflection, etc.
 - B Analytical model
 - a Starting point: when applying two moments at the tips of the piezoelectrics, find the shape of the beam that minimizes its total potential energy under the constraint of a given length
 - b No electromagnetic coupling is considered in the analytical

- model
 - c Without the spring, the actuator is not able to achieve high displacements
 - C Experimental verifications
 - a A voltage ramp from 0 V to 120 V is sent to the actuator
 - b The same actuator can perform in quasi-linear and non-linear mode depending on the amount of compression and the applied voltage
 - D Conclusion
 - a Snap through mechanics
 - i Considering relaxed boundary conditions
- 9 Active Mounts for Marine Applications: the BMBF research projects – active aggregate mounts to reduce structure vibrations and structure-borne sound transmission by M. Matthias (Fraunhofer Institute, Germany)
- 甲 Active aggregate mounts with piezoelectric actuators in the force transmission (elastomer mounts for the low-frequency isolation and piezoelectric actuators for the high-frequency isolation)
 - 乙 Testing setup
 - A 30 feet ship as the platform
 - B 8x triaxial accelerometer, 2x laser displacement meter, etc.
 - C Long-term measurements in EOS (much larger sailing ship) to evaluate time effect
 - D Test set-up to derive dynamic displacements and forces
 - E Consider misuse (boat overturn, etc.) conditions as well.
 - 丙 Design/construction/building of the test base (reduced ship structures)
 - 丁 Matlab/Simulink model was used to extract the open-loop experimental data and then to design the closed-loop performance
 - 戊 Piezoelectric actuator purchased from the catalog
 - A 0-1000 driving voltage
 - B Displacement 80 micrometer, etc.
- 10 MEMS glaucoma monitoring device by Ms. Smitha Shankar (GE India Technology IP Dept., was with MIT)
- 甲 Glaucoma
 - A Flow in anterior chamber
 - B Steady state Intra ocular pressure (IOP)
 - C Flow block
 - D IOP rises
 - E Optic Nerve Damage

- F Permanent blindness
- 乙 Analysis
 - A IOP & Flow Dynamics
 - B Compare working to a closed loop feedback system
 - C System stabilizes high IOP with reduced flow
 - D With the disease, the negative feedback mechanism goes away. This drawback will induce ultra-high eye pressure, which eventually lead to eye blindness
- 丙 Need for continuous monitoring (even though there is no cure for glaucoma)
 - A Dynamic and continuous process of deterioration – sneak thief of sight
- 丁 Characterization of MEMS sensor
 - A IOP measurement using MEMS sensor
 - B FEM analysis to characterize MEMS piezoresistive pressure sensor
 - C Location of Piezo resistors determined
 - D Output voltage due to IOP as surface loads estimated
- 戊 MEMS Sensor output
 - A Wheaston bridge adopted
 - B Output 5 μ V/mmHg
- 己 Challenges
 - A Packaging – biocompatible and waterproof – candidate polymer silane Nu-Sil
 - B Packaging – strain free, inert environment – not compromising system output – challenge
 - C Powering - candidate micro batteries/ RF coupling – subject to changes
- 庚 Conclusion
 - A Math model of intraocular dynamics simulated and analyzed
 - B MEMS sensor proposed with estimated size in 55 mm x 2 mm x 4 mm
- 11 Viability study of oscillatory flow pumps using bimorph piezoelectric actuators by Rogerio Felipe Pires (Dept of Mechanical Eng., Polytechnic School of University of Sao Paulo – Brazil; rogerio@inoveo.com.br)
 - 甲 Piezoelectric pump concept
 - A Propagating wave principle → ultrasonic piezoelectric pump (Bar-Chon Y. and Chang Z., 2001)
 - B Diaphragm Piezoelectric pump
 - C Piezoelectric fan (Acikalin T. et al, 2004)
 - D Aquatic vehicle propulsion (Borgen ; Washingto, Kinzzel, 2003)
 - 乙 Applications

- A Bioengineering
- B Electronic industry
- C Advantages:
 - a Miniaturized potential
 - b Better energy efficiency, etc.
- 丙 System for cooling an electronic device: new device here adopted two parallel piezoelectric bimorph fan to increase the flow rate; concept similar to fish swimming
- 丁 Computation results indicate that putting two fan within the same chamber will have higher flow rate than the case of putting two parallel chamber with a fan within each chamber.
- 戊 Conclusion
 - A At a frequency of 416 Hz with 60V peak-to-peak load, the pump prototype had flow rate of 44 cm³/min
- 12 Measurement of Stresses in MEMS Structures by Stress Release by Dr. D. Vogel (Fraunhofer Institute for Reliability and Microintegration; dietmar.vogel@izm.fraunhofer.de)
 - 甲 fibDAC stress release: basic approach
 - A mechanical solution for elastically induced stress release, analytically, numerical simulation
 - B material removal by FIB milling → stress release, i.e, deformation nearby milling pattern → quantifying exp. Deformation field, DIC analysis
 - 乙 Stress release: measurement example for thin membranes
 - A Stress release by FIB hole milling into a 200 nm Si₃N₄ membrane
 - B Stress level 1085+/-75MPa
 - 丙 Practical solutions aiming at
 - A High stress sensitivity
 - B Recognition and suppression of major error sources
 - C Spatially small affected object volume by stress release
 - D Solution applicable to layer system on substrate
 - E Effective and stable stress extraction
 - 丁 Potential error sources of stress measurement
 - A Wrong residual stress hypothesis
 - a Assumed $\sigma_{xx} = \sigma_{yy}$ is not valid
 - b Non homogeneous stress over measurement area
 - c Rotation induced stress asymmetry solutions
 - B Different stress building mechanisms than assumed

戊 Conclusion

A A new approach to local residual stress measurement has been demonstrated

- a Based on stress release by FIB milling
- b DIC analysis used to determine stress release deformation
- c Mechanics theory for different milling pattern discussed
- d Slot/trench milling as efficient approach
- e First results to access stress in thin layers on substrate discussed

13 Development of amperometric glucose sensors with heterostructured nanowire arrays for continuous subcutaneous monitoring by H. Yoon (U. of Arkansas)

甲 Glycemia is the presence of glucose in our blood. Usually expressed as mg/dl

乙 Closed-loop glucose sensing and insulin infusion devices allow for dynamic adjustments, especially for pediatric patients where hypoglycemia is a greater worry.

丙 Needle-based glucose sensors for continuous glucose monitoring (CGM)

A Comprised metal electrodes with glucose oxidase (GOx) which measure an electrical current interstitially generated by glucose reaction every tens of seconds

B in this paper: to avoid hypoglycemia through use of CGM in pediatric patients → must consider the accuracy of these devices, particularly in the lower range of glucose level

丁 Focus of sensor design

A Use hetero-structured (Pt/Au) nanowires, enzyme is immobilized on Au electrodes and hydrogen peroxide produced from enzyme reaction is sensed on Pt surface without any mediator use

戊 Principles of glucose sensing on hetero structure nanoelectrodes

己 E-beam deposition of platinum on nanowire electrodes

庚 Enzyme immobilization using self-assembled monolayer (SAM)

A 75:25 (v/v) ethanol/water with 10 mMMPA (24 hours)

B 2mM EDC and 5mM NHS in 0.1 M MES buffer, pH 5.5 (2 hrs)

C ...

辛 Enzyme immobilization using Polypyrrole

A 840 units glucose oxidase and 20 mM Pyrrole in 17 ml, ...

壬 Conclusion

A Heterostructured nanowires showed promising performance by playing dual roles of providing immobilization in Au and sensing in Pt

14 Coupled flexural-torsional nonlinear vibrations of microcantilever beams by

Nima Mahmoodi (Clemson Univ.)

- 甲 Microcantilevers are the most mass-produced MEMS devices
 - A Their miniature size make them very practical in small scale
 - B Applications include surface scanning, mass sensing, interfacial stress and force sensing, etc.
 - C AFM (Ref. www.stanford.edu);
 - D Mass sensing: resonant frequency changes due to added mass

乙 Veeco Instruments made the microcantilever used for this paper

丙 Conclusion

- A Quadratic and cubic nonlinearities were observed in the microcantilever

15 Visualization of buried structures in atomic force acoustic microscopy by Nobert Meyendorf (Fraunhofer Institute, Germany) A Contrast Technique worth looking into!

- 甲 Electronic industry need to visual 250-500 nm buried structures
- 乙 Motivation: Kirkendall voids, electron migration of Al-wire, acoustic microscopy, X-ray CT → resolution down to mm, FIB cross section measurement → resolution down to nm, but is destructive testing

丙 From atomic force microscopy to Acoustical Excited AFM

- A Combination of AFM with ultrasound techniques (Atomic Force Acoustic Microscopy, AFAM)
- B Excitation of both bending and torsional modes simultaneously
- C AFAM contrast mechanism
 - a Contact resonance frequency changes in dependence of the effective elasticity of the material
 - b Change of the vibration amplitudes for constant excitation frequency
 - c Contrast inversion is possible: protein surface layers with a thickness of 5-7 nm (bottom up nano structures)
- D Hertzian contrast: penetration depth 3x the radius
- E The potential of AFAM for subsurface mapping (Ref: Gajendra S. Shekhawt, Science 310, 2005) → Examine and See if we can look into this instrument and explore the use of this instrument

丁 Conclusions

- A AFAM gives images with a strong elastic contrast
- B Using careful designed samples, it could be proved that subsurface features can be imaged.

- C Sharpen the tip→ increase the spatial resolution, but reduce the image penetration depth; Un-sharpen the tip→ decrease the spatial resolution, but increase the image penetration depth; image penetration depth is around 3x of the tip radius
- 16 Micro-deformation analysis by Atomic Force Acoustic Microscopy by Nobert Meyendorf (Fraunhofer Institute, Germany) A Contrast Technique worth looking into!
- 甲 Microstructure of Al alloys by AFM/AFAM
- A Scan size 800 nm, transducer frequency 478.3kHz
- B Yi-Yang Tsai, CMD, Univ. of Dayton
- 乙 Image Correlation technique NanoDAC by D. Vogel of IZM
- A AFM/UFM/WLIM images → correlated → software images
- 丙 Conclusion
- A Deformation fields could be determined with AFM/AFAM and an image correlation technique
- 17 Ionic polymer-metal composite as energy harvester (#6524-48) by R. Tiwari
- 甲 Use IPMC (Ionic Polymer Metal Composite) as harvester material
- 乙 Operate at low frequency.
- 丙 Experiment data are strange (output voltage and power)
- 18 Smart structures product implementation award winner: a reviewer of real-world experience by E. A Anderson (CSA Engineering)
- 甲 History of the award
- A 1998 Vibration isolation and suppression system (VISS)
- B 1999 Distributed system skin seat sensor (DSK)
- C 2000 Fiber Sense
- D 2001 Smart Magnetic knee prosthesis with Motion MasterTM MR fluid damper
- E 2002 Smart Screen
- F 2003 Smart health monitoring system
- G 2004 No Award
- H 2005 VeriflexTM reusable mandrel
- I 2006 Soft-ride launch load alleviation system
- 乙 小公司比較容易 award
- 丙 上述獎項目前只有兩個尚未演變為真正的產品
- 丁 得獎作品從大的產品慢慢演變為小的產品
- 19 Optical payload isolation using miniature vibration isolation system (MVIS-II) by M.B. McMickell (Honeywell Defense and Space Electronic Systems)
- 甲 Hybrid isolation system including:

- A 3-parameter D-Strut (Passive) to enhance performance in mid-to-high frequency range
 - B Piezoelectric actuator (Active) to enhance performance in low frequency range
- 乙 Using Power IC 500MHz clock < 10% utilization
- 丙 Conclusion
 - A 40dB/decade attenuate
- 20 Isolation, pointing, and suppression (IPS) system for high performance spacecraft by T.A. Hindle (Honeywell Defense and Space Electronic Systems)
 - 甲 過去的系統稱為 Vibration, Isolation, Suppression and steering system (VISS), IPS system 為 VISS system 之延伸
 - 乙 VISS 與 IPS 的基本架構
 - A 6-DOF in passive control
 - B Hybrid control (active compensate passive)
 - 丙 Conclusions: IPS 之創新
 - A A dual-stage voice coil design for improved dynamic range as well as improved low-noise drive electronics
 - B Integral load cells, gap sensors and payload-side accelerometers for control and telemetry purposes.
 - C Smaller size
- 21 Nonlinear dynamics and chaos of a SMA passive vibration isolation and damping device by L.G. Machado, Texas A&M Univ.
 - 甲 作者認為 SMA 本身具有 highly nonlinearity 主要來自 thermo-mechanical properties & 遲滯效應，而過去在 constitutive equations 中忽略了這些效應
 - A 作者利用 phase space plot 去分析 SMA actuator 的行為。認為可以用 Lyapunov exponent 的大小可以去預測是否會發生 Chaos. 作者認為在某些微小頻段會發生 Chaos 的效應。
 - B Conclusions: 作者認為過去的 Boyd, Lagodas and Capatures 所提出的遲滯 Model 雖然可以預測 SMA actuator 的行為，但並不完整。
 - a second-order polynomial hardening function should substituted by general power law hardening function to smooth the transitions between elastic and phase transformation regimes, eliminating the presence of kinks in SMA stress vs. strain response
 - b the fully-coupled energy balanced heat equation 需同時被考慮進 constitutive equation
 - c 作者主要是提出此現象並提出對應模型(Modeling)，而非應用

此現象做設計。

- 22 On semi-active enhancement of dissipation provided by piezoelectric films by U.A. Krode (South Dakota School of Mines and Technology)
- 甲 負電容為 piezoelectric passive 和 semi-active structural control 中常用之元件，筆者(元平)認為與傳統技術的不同為二：
- A 加入電邊界參數考慮，並對電性邊界條件做詳細分析及應用（主要）
- B Model 負電容的 performance
- 23 Generation of quasi-resonance by variable damping by D. Iba (Kyoto Institute of Technology, Japan)
- 甲 傳統上 damping 是用來消散能量，本篇作者強調此篇論文顛覆傳統想法是利用 damping 產生能量。然而，筆者(元平)認為 damping 不會產生能量，此篇論文的”說法”有謬誤，但是並非”錯誤”之想法。
- 乙 作者使用 variable damping 去產生能量，此 variable damping 是根據不同的頻率下的 sine wave 所得到，並非特定鎖定在 resonant frequency 上，因此稱為 quasi-resonance。簡單來說，筆者捨棄過去以定值 damping 最佳化 modal damping 的方法，而使用 variable damping。
- 丙 感想：認為作者利用 variable damping，事實上是增加了壓電與外部電路阻抗匹配的範圍，因此在不同的頻率(如共振頻的附近)下都能取出或消耗更多的電能。本篇作者所說之”產生能量”，實際上應該是指”增加消耗的能量”。或是說同時增加系統的 performance robustness 和 performance.
- 24 On the effect of electrical uncertainties on resonant piezoelectric shunting by M. Porfiri (U. Andreaus, Italy)
- 甲 Consider the uncertainty of the electrical parameters
- 乙 分析 perturbation of inductor and resister vs. performance
- 丙 將 perturbation of inductor and resister 當成 random variables 再分析一次
- 丁 筆者根據內容以及作者實驗結果認為討論 passive control 的 uncertainty 效用不大
- 25 Integral control of collocated control by S.S. Aphale (The Univ. of Newcastle, Australia)
- 甲 PPF (Positive Position Feedback) control 於結構控制上相較於傳統控制器(LQG, direct velocity control)有許多優點
- A Roll of quickly at high frequency (spillover robustness)
- B 缺點：require a model based design process (often requiring a non-linear search)
- 乙 作者提出 simple, robust and well-performing 的方法即在控制器設置時先原點加入一 zero 後，再去設計控制器
- A Collocated control 會使 pole-zero 交替出現，使系統易達到穩定。而

傳統 PPF control 控制器與 Collocated control 形式相同，pole 在 zero 前面交替出現。當加入此 zero 後，並不會改變 collocated 的易穩定特性，只是 zero 在 pole 前面先出現。

B 可使控制器的設計變簡單。

C 由於前面先加入 zero，同時解決 PPF 在低頻 Gain 的問題。筆者(元平)註：傳統 PPF controller 為低通濾波器的累加，因此在 multi-modal control 時低頻處會有累加的現象，此累加會造成兩個問題：1. 再低頻處的累加可視為 P-control 因次會讓結構變的 flexible，而可能違犯之前結構的設計需求；2. 增加系統 uncertainty。

D 由於原點加入 zero 像一積分器稱作 integral control

丙 感想：大多數的控制器設計本來就是希望以積分器去取代微分器，PPF 的出發點也為此。作者提出一更接近直接以積分器設計的方法。

26 Nonlinear modeling of piezoelectric layer beams by N. Jalili (Sharif Univ. of Technology, Iran)

甲 本篇討論 hysteresis model 以及 piezoelectric 貼在 beam 上的 model

A Nonlinearity are due to extrinsic contributions to behavior of piezoelectric and arise even when the applied electric field is not strong

B Add Bouc-Wen type hysteresis model to dynamic equation.

C The final equation shows stiffness is a function of applied voltage

D Bimorph and unimorph actuator are both discussed

乙 感想：目前討論遲滯效應主要是在壓電本體的振動上，而目前有一部分的研究開始熱烈討論壓電貼在結構時的遲滯效應。筆者認為設計 feedback controller 時討論遲滯效應意義不大，因為可以利用 Robust Control 利用 norm 的量測 uncertainty 方法，把遲滯效應所造成的非線性項忽略不計。然而，筆者認為真正有用的地方可能是 feedforward control 上。