

液態製程(一)---雷射掃描製程(1)

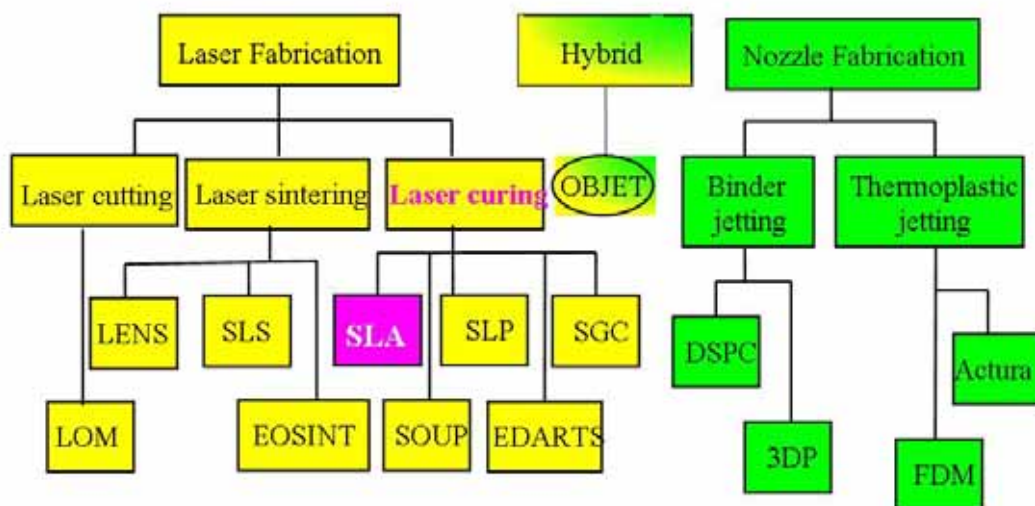
SLA 上照式製程

藍翔耀 博士

Hsiang-Yao Lan

1

Commercial RP Systems



Hsiang-Yao Lan

2

液態製程加工成形法

液態製程亦被稱為立體光造形法(Stereo Lithography Apparatus)，加工原理乃是利用UV(紫外光)雷射光掃描照射在光敏聚合物(光硬化樹脂)上，使被照射之樹脂固化，加工平台下降一層(up-and-down)使補充樹脂，如此重覆上述步驟，逐層堆積成3D的實體，而製造出產品原型。

目前使用液態快速成型原理的RP系統大約可分為以下列五種：

SLA SOUP SLP EDARTS Solifor

Hsiang-Yao Lan

3

RP機台常用雷射光比較

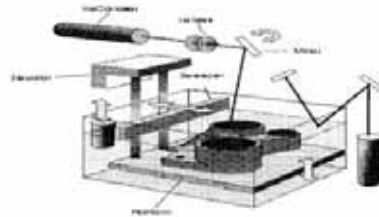
	光源對樹脂的反應	室內光害影響	加工方便性	安全性	價格 (同規格)
紫外光雷射 (UV雷射)	紫外光	不易	佳	小心紫外光的外洩	較貴
可見光雷射	可見光	易(幾乎都會)	需以黑布遮住	佳	較便宜

Hsiang-Yao Lan

4

液態製程加工的特徵

當一層硬化層凝固後，**升降機構下降(Down)**一微量的距離，使得凝固層浸於液面下，**再上升(UP)**，**使消除表面張力**，讓欲加工位置之表面上再覆蓋一層樹脂。此一**up-and-down**的動作是描述液態製程需特別注意與加強的地方。



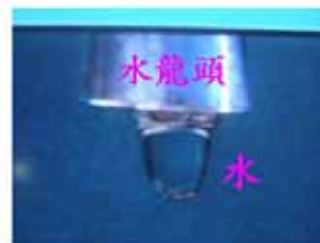
Hsiang-Yao Lan

5

液體的表面張力(1)



(a)油與水的表面張力比較



(b)水的張力(水滴下降1)



(c)水的張力(水滴下降2)



(d)水的張力(水滴斷裂瞬間3) 6

液體的表面張力(2)



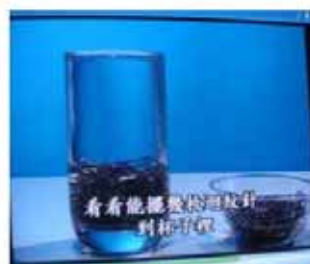
(a)放入迴紋針前



(b)放入迴紋針(1)



(c)放入迴紋針(2)



(d)放入迴紋針(3)

Hsiang-Yao Lan

7

液體的表面張力(3)



(a)針插入水滴內



(b)針抽出水滴後

Hsiang-Yao Lan

8

液體表面張力的破壞(1)



(a)震動力實驗前



(b)實驗前水滴放大圖



(c)加震動力1(輕微)



(d)加震動力2(中)



(e)加震動力3(破壞瞬間)

Hsiang-Yao Lan

9

液體表面張力的破壞(2)



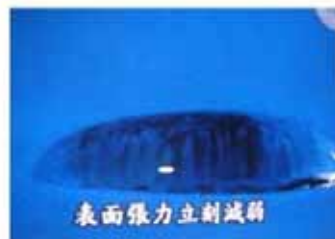
(a)肥皂接觸前



(b)肥皂接觸瞬間



(c)肥皂開始抽離

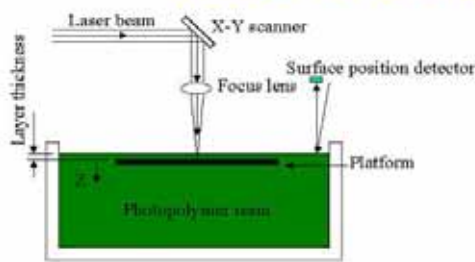


(d)肥皂抽離後

Hsiang-Yao Lan

10

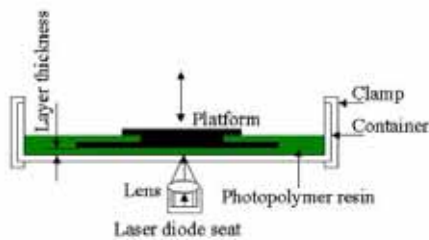
液態類製程加工成形法



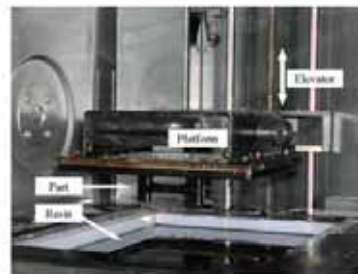
(a) 上照式加工示意圖



(b) 上照式加工--SLA系統

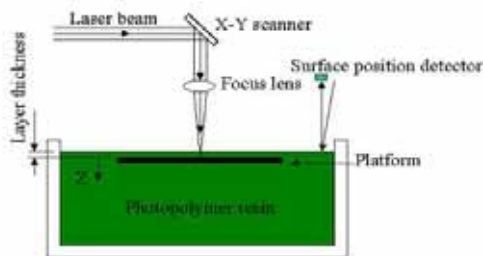


(c) 下照式加工示意圖

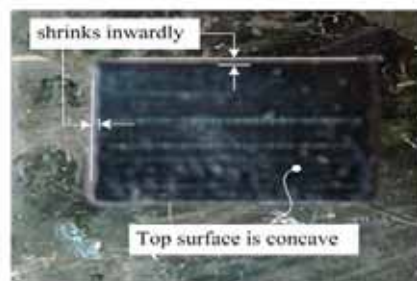


(d) 下照式加工-- E-DARTS系統

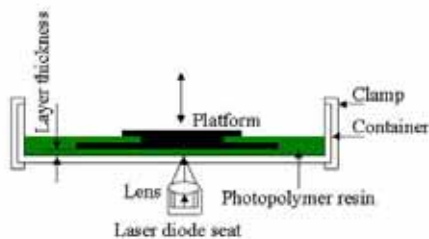
液態類製程加工成形法比較



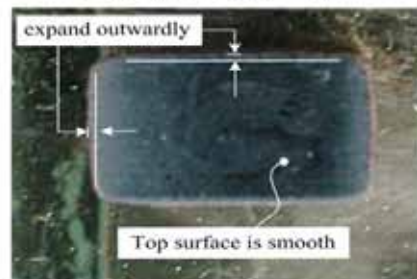
(a) 上照式成形法



(b) 上照式成形工件

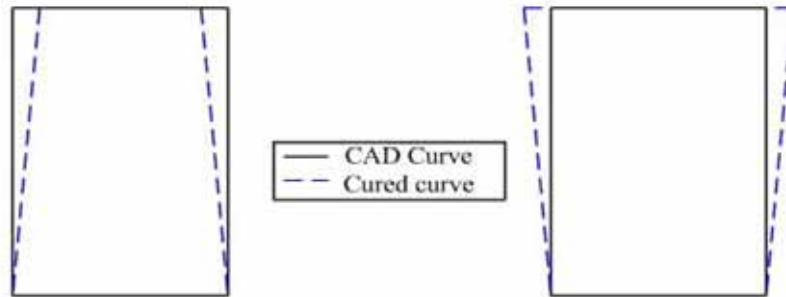


(c) 下照式成形法



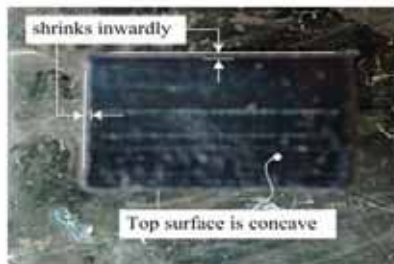
(d) 下照式成形工件

液態製程加工變形圖

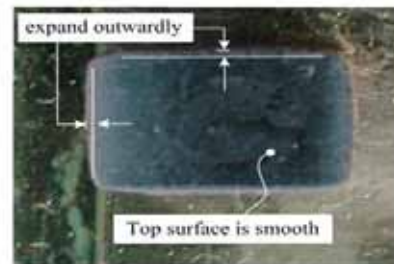


(a) 上照式成形法(正視圖)

(b) 下照式成形法(正視圖)



(c) 上照式成形法(上視圖)



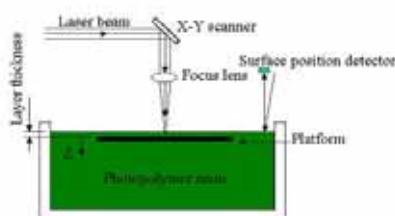
(d) 下照式成形法(上視圖) 13

上照式成形法之優缺點

• 優點

- (1) 沒有拉拔力，擔心拉拔失敗的問題
- (2) 工件完成，沉在樹脂槽內，散熱較快

• 缺點：浪費樹脂



(a) 上照式加工示意圖



(b) 上照式加工---SLA系統

上照式成形法與替代性樹脂的應用

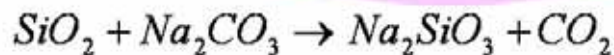
- 替代性樹脂之特性

- (1) 比重大

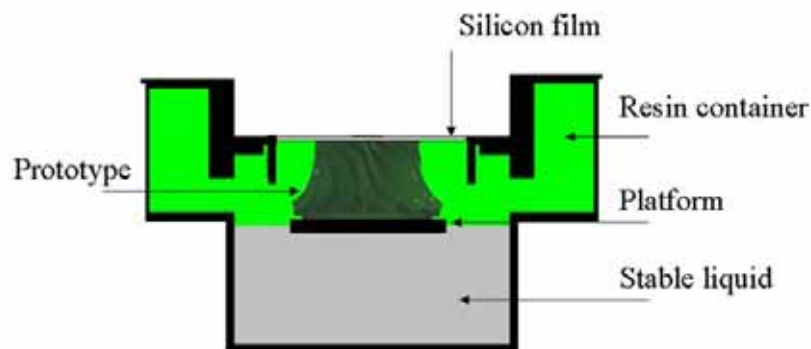
- (2) 與NAF202光硬化樹脂不相容

- (3) 沒有任何化學反應

- 矽酸鈉(Sodium Silicate)俗稱水玻璃(Na_2SiO_3)的成本低且效果佳，可以輕易的使用酒精清洗即可脫離原型表面。

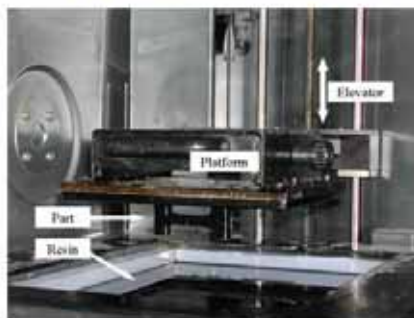


上照式成形法 樹脂槽之設計與加工示意圖

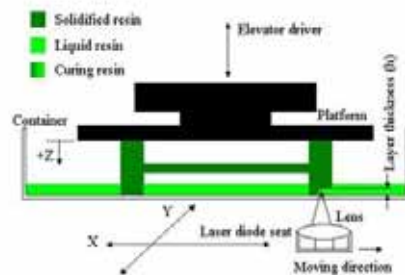


E-DARTS系統 機構圖 (下照式)

- E-DARTS系統所使用的光源為紅光雷射
(由Autostrade日本所生產)



(a) E-DARTS系統製作完成H4工件之整體機構圖



(b) E-DARTS系統加工H4工件過程之分析模型示意圖

Hsiang-Yao Lan

17

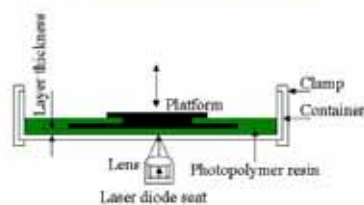
下照式成形法之優缺點

- 優點：節省樹脂

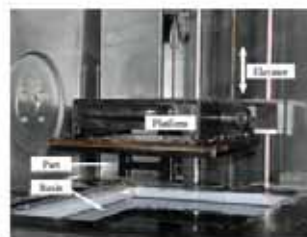
- 缺點：

(1) 有拉拔力的問題，擔心拉拔失敗。

(2) 工件完成，向上提升停留在空氣中，因此散熱較慢。



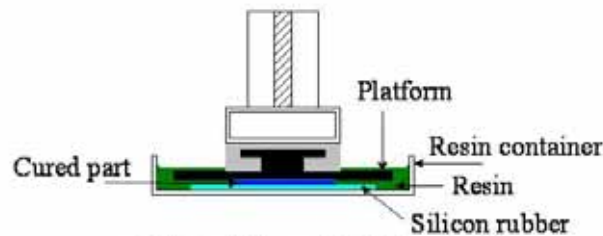
(a) 下照式加工示意圖



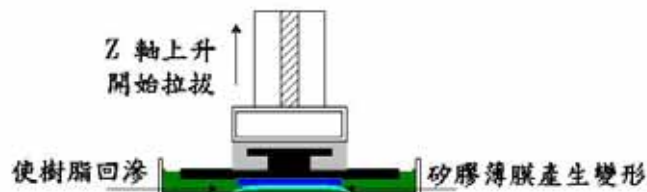
(b) 下照式加工--- E-DARTS系統

下照式成形法

樹脂槽之設計與矽膠薄膜的應用



(a)樹脂槽與矽膠薄膜示意圖



(b)向上拉拔時矽膠薄膜變形示意圖

Hsiang-Yao Lan

19

上照式成形法與下照式成型法的比較

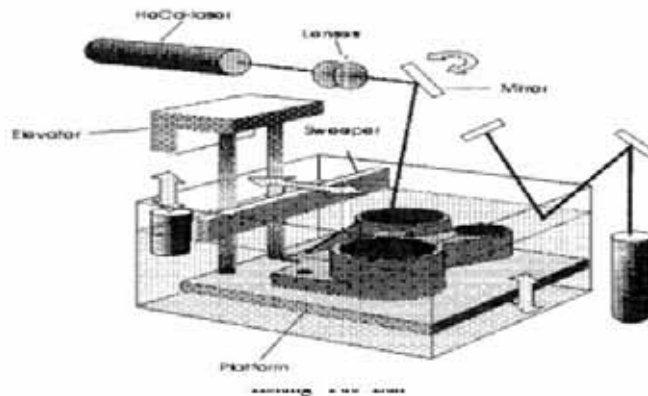
	(1) 平台 加工 方式	(2) 液面 波動	(3) 工件 完成 後	(4) 樹脂 材料	(5) 工件 拉拔 力	(6) 樹脂 槽設 計	(7) 工件 變形	(8) 工件 尺寸
上照式 成形法	先下 後上	較大	留在 樹脂 槽內	浪費	不需	替代 性樹 脂	向內 收縮	較大
下照式 成形法	先上 後下	較小	留在 空氣 中	節省	需要	底部 加矽 膠薄 膜	向外 擴張	較小

Hsiang-Yao Lan

20

SLA系統 (Stereo Lithography Apparatus)

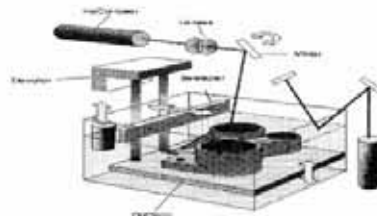
最早公開上市之SLA系統(美國3D Systems公司)，其機型有四種形式：SLA-190、SLA-251、SLA-400、SLA-500，數字所代表的意義為可加工之工件的大約寬度，單位為mm。



21

SLA加工原理

1. 是利用UV雷射光掃描照射在光敏聚合物(光硬化樹脂)上，形成一層硬化層。
2. 當一層硬化層凝固後，升降機構下降(Down)一微量的距離，使得凝固層浸於液面下，再上升(UP)使消除表面張力，讓欲加工位置之表面上再覆蓋一層樹脂。
3. 用刮板將液面刮平後等待其呈水平再進行下一層的照射、固化。
4. 如此一層層的照射固化而形成三維實體形狀。



22

SLA製程的優缺點

優點：

- (1)機構簡單，維修容易
- (2)加工速度快
- (3)適用於薄殼工件



缺點：

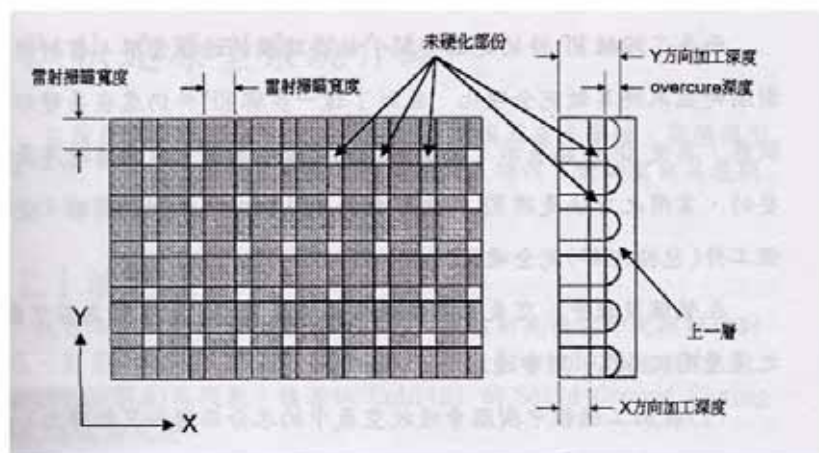
- (1)需要使用支撐
- (2)需要後熱化處理，也就是二次硬化
- (3)強度不夠，液態成品大多只能觀看用，很少能夠做組裝的動作，更別說要做功能測試了

Hsiang-Yao Lan

23

Build—Laser Drawing

- Improve part distortion
 - Preserve some areas of uncured resin

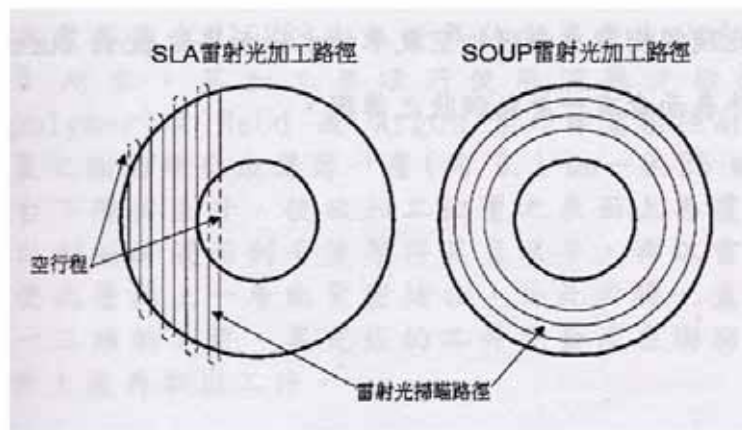


Hsiang-Yao Lan

24

Build—Laser Drawing

- SLA laser path vs. SOUP's (CMET, Japan) changeable circular laser path

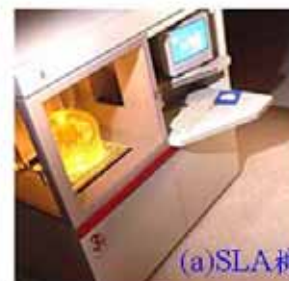


Hsiang-Yao Lan

25

SLA的商業機種

機型	SLA 7000
加工範圍	508 x 508 x 600 mm XYZ
雷射種類	Solid State Nd:YV04 波長354.7nm 功率800 mW
光點直徑	0.23-0.838 mm
成形厚度	0.025-0.127 mm
網路型態	Ethernet, IEEE 802.3 using TCP/IP and NFS
電源	200 - 240 V AC, 50/60 Hz
設備尺寸	寬1.88 x 深1.63 x 高2.02 m
設備重量	1196 kg



(a)SLA機台



(b)工作台

Hsiang-Yao Lan

26

Old SLA machines (SLA-250 series)

- **Build detailed prototypes with exceptional precision (1988)**

"The SLA system gives us the ability to predict future marketing trends. We are able to be first out the door with what the customer wants."



- Morison Cousins, Vice President of Design, Tupperware, Inc

Hsiang-Yao Lan

27

Old SLA machines (SLA-250 series)

- The most widely used SLA system in the world
- Ideal for building small, detailed, precision parts
- Laser: He-Cd laser, 325nm, 16-7.5 mW
- Zephyr Recoating System
- U.S. price: \$220,000
- Build envelope: 250 mm x 250 mm x 250 mm
- Scan speed: 380 mm per second (max.)
- Machine size: 0.7 m x 1.2 m x 1.6 m, 295 KG
- Series:
 - SLA 250/30 : entry-level
 - SLA 250/50 : for faster, more versatile performance
 - SLA 250/50HR : for the ultimate in precision

Hsiang-Yao Lan

28

Old SLA machines (SLA-350 series)

- Greater capacity than SLA 250 series, but lower throughput or part size than SLA 500 products
- Throughput 2.5X higher than SLA 250
- Build envelope: 350 mm x 350 mm x 400 mm
- Zephyr Recoating System



Old SLA machines (SLA-190 & 500)

SLA-190

- Envelope: 190 x 190 x 250 mm
- Laser: He-Cd, 325 nm, 7.5-4.5 mW
- Scan speed: 380 mm
- Price: \$110,000

SLA-500 (1989)

- Envelope: 500 x 500 x 500 mm
- Laser: Ar⁺, 351, 364 nm, 200-166mW
- Scan speed: 2540 mm
- Price: \$450,000

SLA 3500

- **Get industrial-strength solid imaging performance in a mid-size package (1998)**

"Total time from request for quote to finished prototype: Seven working days! The model helped us clinch the business and beat a good competitor."

- Spencer Johnson, OEM Sales Support Manager, Logitech Corporation



Hsiang-Yao Lan

31

SLA 3500

- Solid state Nd: YVO₄ laser, 354.7 nm, 160mW, 5000 hours or 18 months warranty
- Zephyr recoating system
- Min. build layer: 0.05 mm
- Beam dia.: 0.20-0.30 mm
- Vertical resolution: 0.00177 mm
- Build envelope: 350 x 350 x 400 mm
- U.S. price: \$350,000

Hsiang-Yao Lan

32

SLA 5000

- **Bring industrial-strength performance and part quality to your organization (1998)**

"Rapid prototyping, and plenty of it, means more and smarter planning sooner -- and far fewer bugs. So put down that planning memo and make something!"

- Tom Peters, Co-author of *In Search of Excellence*



Hsiang-Yao Lan

33

SLA 5000

- Solid state frequency tripled Nd: YVO₄ laser, 354.7 nm, 216mW, 5000 hours or 18 months warranty
- Zephyr recoating system
- Min. build layer: 0.05 mm
- Beam dia.: 0.20-0.30 mm
- Vertical resolution: 0.00177 mm
- Build envelope: 508 x 508 x 584 mm
- U.S. price: \$438,000

Hsiang-Yao Lan

34

SLA 7000

- **Innovate and compete like never before - with the fastest, highest resolution solid imaging system ever built by 3D Systems**

"Past process improvements were in the range of 10 to 25%, so 300% is tremendous. We believe the SLA 7000 system's speed and surface finish improvements will permit Hasbro to shorten product development lead times and reduce project costs." (1999)



- Steve Deak, Manager of Rapid Prototyping, Hasbro, Inc.

Hsiang-Yao Lan

35

SLA 7000

- Solid state Nd: YVO₄ laser, 354.7 nm, 800mW, 5000 hours or 18 months warranty
- Zephyr recoating system
- Min. build layer: 0.076 mm
- Beam dia.: 0.23-0.28 mm (small spot)
- Vertical resolution: 0.001 mm
- Build envelope: 508 x 508 x 584 mm
- U.S. price: \$526,000

Hsiang-Yao Lan

36

3D Systems — SLA Parts



(a)



(b)

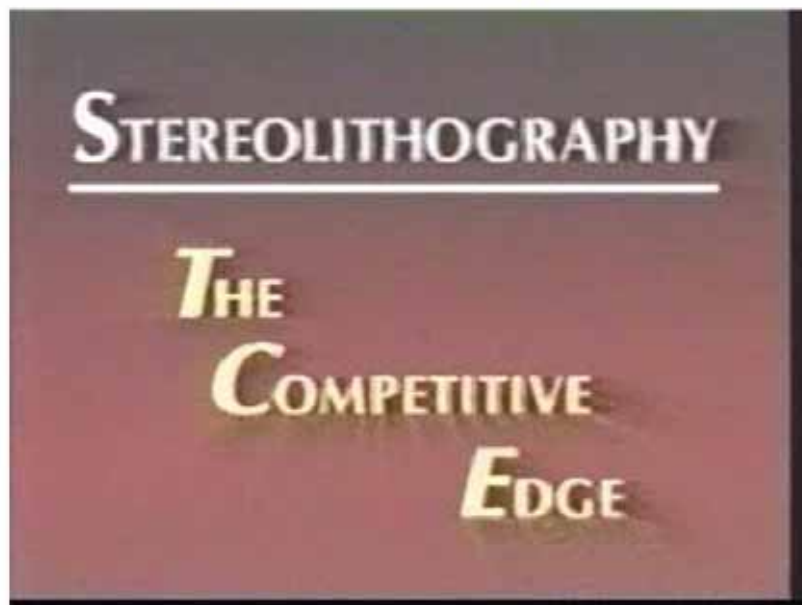


(c)

Hsiang-Yao Lan

37

液態製程加工影片(1) SLA機台—上照式加工 (1'14")



38

液態製程(二) --- 雷射掃描製程(2)

EDARTS 下照式製程

藍翔耀 博士

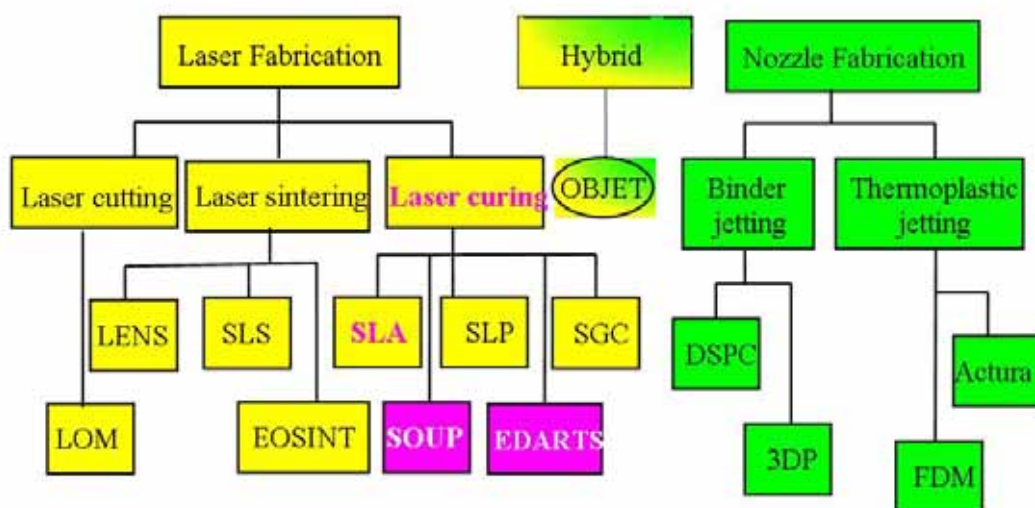
Office：至正樓J102

Email：lan@cc.chit.edu.tw

Hsiang-Yao Lan

39

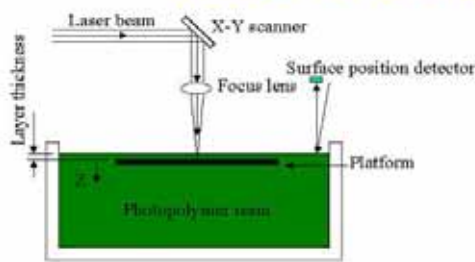
Commercial RP Systems



Hsiang-Yao Lan

40

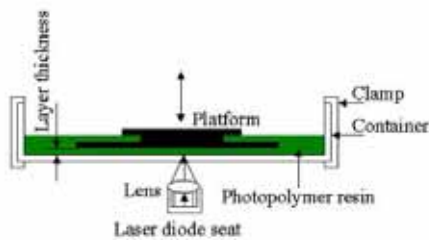
液態類製程加工成形法



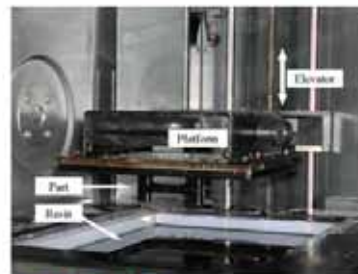
(a) 上照式加工示意圖



(b) 上照式加工---SLA系統

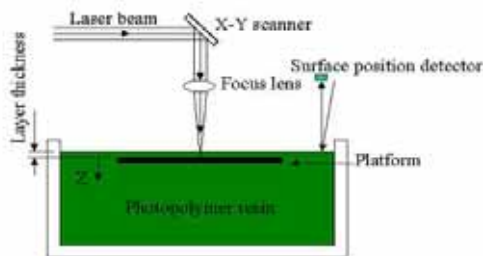


(c) 下照式加工示意圖

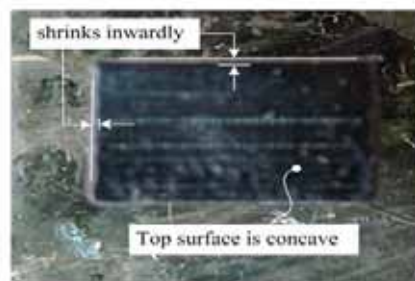


(d) 下照式加工--- E-DARTS系統

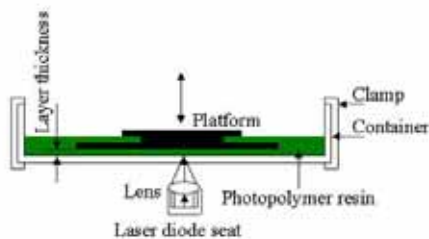
液態類製程加工成形法



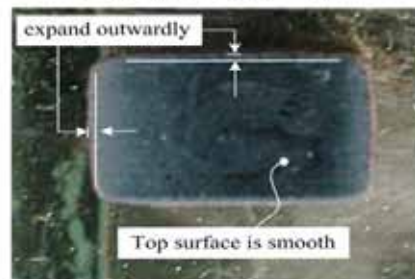
(a) 上照式成形法



(b) 上照式成形工件

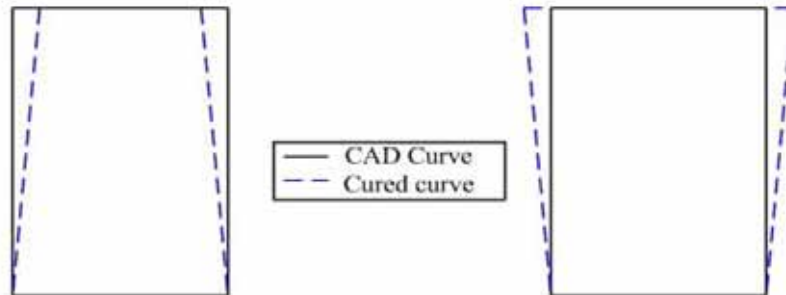


(c) 下照式成形法



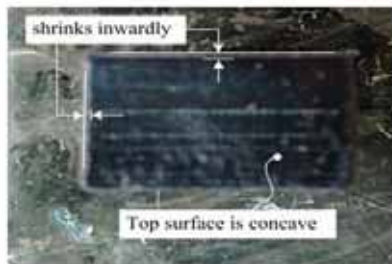
(d) 下照式成形工件

液態製程加工變形圖

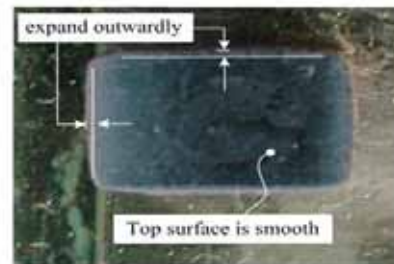


(a) 上照式成形法(正視圖)

(b) 下照式成形法(正視圖)



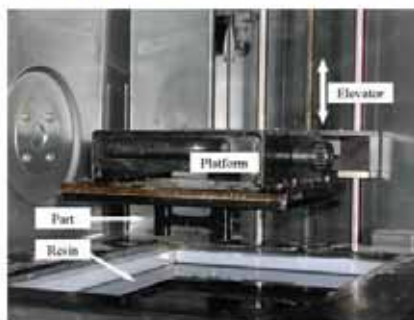
(c) 上照式成形法(上視圖)



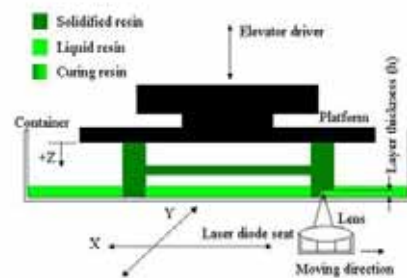
(d) 下照式成形法(上視圖)

E-DARTS系統 機構圖 (下照式)

- E-DARTS系統所使用的光源為紅光雷射
(由Autostrade日本所生產)



(a) E-DARTS系統製作完成H4工件之整體機構圖



(b) E-DARTS系統加工H4工件過程之分析模型示意圖

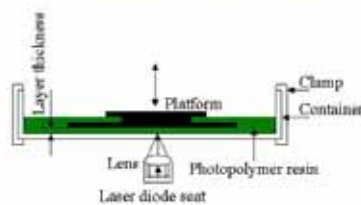
下照式成形法之優缺點

- 優點：節省樹脂

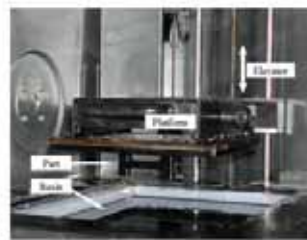
- 缺點：

(1) 有拉拔力的問題，擔心拉拔失敗。

(2) 工件完成，向上提升停留在空氣中，因此散熱較慢。



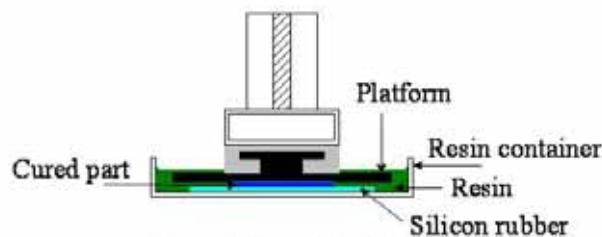
(a) 下照式加工示意圖



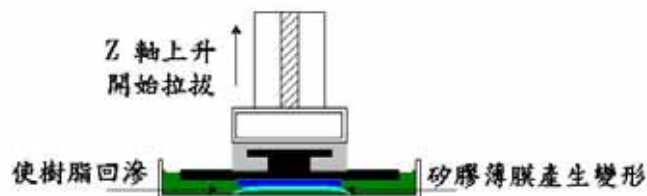
(b) 下照式加工--- E-DARTS系統

下照式成形法

樹脂槽之設計與矽膠薄膜的應用



(a) 樹脂槽與矽膠薄膜示意圖



(b) 向上拉拔時矽膠薄膜變形示意圖

E-DARTS– Autostrade

- http://www.autostrade.co.jp/english/e_darts_eng.html
- Autostrade Co., Ltd. has started marketing a moderately priced optical forming system E-DARTS that is available at a domestic price of less than 3 million Yen for manufacturing products of complicated shapes. Plastic models are produced rapidly, at low cost and with simple manipulation by using three-dimensional computer-aided design (CAD) data. Models with sizes of up to 20 cm x 20 cm can be produced.
- This optical forming system transform CAD data into lamination data with a special-purpose software, and solid models are drawn up while hardening layers made of a fluid optically hardening resin with a semiconductor laser system, one layer at a time. The power is supplies by the computer, and the lamination system can be incorporated with up to four units of semiconductor laser system for high-speed production.

Hsiang -Yao Lan

47

E-DARTS– Autostrade

- E-DARTS has been designed compact and lightweight to enable one person to set up the system.
- The system is workable with low power consumption since the moving parts have been made lightweight and electronic components miniaturized (12V instead of 100V, supplied by a PC interface card).
- Considerable cost reduction will be possible. The system is sold at a domestic price of 2,980,000, excluding the PC and sales tax.



Hsiang -Yao Lan

48

E-DARTS: Specifications

- Dimensions 43 cm (W), 50 cm (D), 51 cm (H)
- System proper weight 21 kg
- Forming domain X-axis 20 cm, Y-axis 20 cm, Z-axis 20 cm
- Hardening resin Special-purpose resin (10,000/kg)
- Editing software STL input, compatible with Windows 98 with ports I/F Use of ISA bus

Hsiang-Yao Lan

49

E-DARTS– Strong Points

- **Remarkable Performance**
One E-DARTS system has editing software of STL format data and photopolymers. It is available at a low price, compared with other Stereolithography system (Rapid Prototyping System).
- **Low running cost**
The introduction of an improved fluid surface regulation system has decreased the necessary volume of resin, which actually eliminates the need to stock the resin. As the result, we realized the lower running cost machine.
- **Extension**
E-DARTS use the original desined small and low-costed semiconductor laser. It is supplied the one head laser (30mW) unit in the initial stage and you can be incorporated with up to four units of semiconductor laser system for high-speed production.

Hsiang-Yao Lan

50

E-DARTS– Strong Points

- *Small Size*

E-DARTS has been designed compact, actually 430*500*515(mm) but it is able to product the 200*200*200(mm) size model. The occupied space is the same as ordinary laser printers. The system is workable with low power consumption since the moving parts have been made lightweight and electronic components miniaturized. Instead for commercial 100-V power, the system can be worked with power of 12 V supplied by a personal computer interface card.

Hsiang -Yao Lan

51

液態製程加工影片 (2) EDARTS機台一下照式加工 (11'22'')



Hsiang -Yao Lan

52

報告完畢



謝謝！

Hsiang-Yao Lan

53

液態製程(一)---雷射掃瞄製程(3)

SOUP 上照式製程

上照式 多光源快速原型系統之組裝

藍翔耀 博士

Hsiang-Yao Lan

54

SOUP-CMET (三菱)

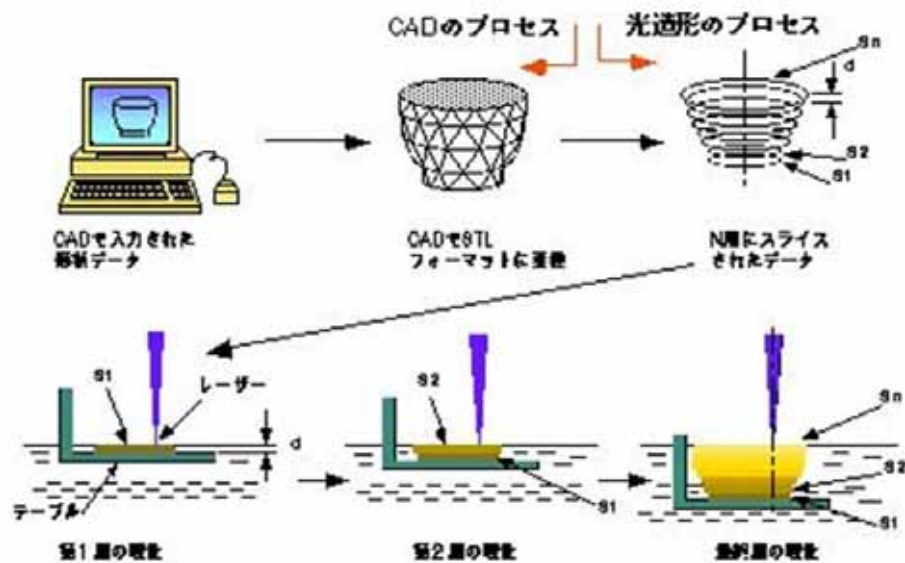
SOLIFORMとSOUPの沿革



SOUP

- SOUP系統為日本東京CMET(Computer Modeling and Engineering Technology)公司所發展出來的快速成型系統，其成形過程與3D Systems公司SLA系統相似。
- **加工原理**：與SLA類似，不同點在於升降台的控制與刮板的做動方式，例如SOUP之升降台不需要像SLA機器要“up-and-down”來披覆樹脂，如此可節省加工時間。第二個差別是SOUP所提供的軟體在建構RP件時，有X，Y，Z三軸offset補償之功能並可做加工模擬。
- 使用掃瞄鏡或使用xy plotter
- 使用xy plotter的方式加上以光纖導引雷射光於液面掃瞄；xy plotter 無法達到如同galvanometer-mirror的掃瞄速度
- 雷射光束是在投射末端才聚焦，因此可以輕易的改善焦點的大小，達到外輪廓精密且內部充填快速的目的。
- 使用的樹脂有很小的收縮率及極優良的機械性質而可以不需要後硬化的過程。

SOUP 製程



Hsiang-Yao Lan

57

液態製程樹脂補充的方式

	機構	添加樹脂時，機構 up-and-down 的動作	樹脂材料	專利權的限制	加工時產生氣泡	代表性機種
加工所需樹脂一次全部倒入樹脂槽中	簡單	有	浪費	有 (美國3D Systems公司)	較少	SLA EDARTS
加工一層就送入一層樹脂	複雜	無	節省	無	有	SOUP SGC

Hsiang-Yao Lan

58

CMET Products

- New Systems
 - Rapid Meister 6000
 - Rapid Meister 2500F
 - Rapid Meister Multi
- SOUP
 - SOUP II 600GS
- Soliform
 - Soliform 250



SOUP II 600GS

Hsiang-Yao Lan

59

Soliform 250 series and Multi



- Can use various resins
 - 耐熱樹脂
 - 軟質樹脂
 - 韌性樹脂
 - 射出成型型
 - 高機能樹脂

60

Soliform 250 series

機種	250B	250EP
Laser	LD励起UV固体レーザー200mW	LD励起UV固体レーザー1000mW
Scan method	デジタルスキャナミラー	
Scan speed	Max. 12,000mm/sec	
繰り返し精度	$\pm 10 \mu\text{m}$	
硬化径	固定方式/可変方式（オプション）	
Build size	250 × 250 × 250（mm）	
Zテーブル	最小積層ピッチ50 μm	
樹脂槽	槽交換方式	
リコータ	ディップコート方式	
液面制御	カウンターボリューム方式	
電源仕様	AC 100V 単相 30A	
装置外形寸法	W 1430 × D 1045 × H 1575（mm）	
装置重量	約400kg（樹脂含まず）	

Hsiang-Yao Lan

61

Solidform Multi

機種	Multi 600	Multi 1000
Laser	LD励起固体レーザー2基もしくは4基	
Scan method	デジタルスキャナミラー	
Scan speed	Max. 28,000mm/sec	
繰り返し精度	$\pm 25 \mu\text{m}$	
硬化径	固定方式/可変方式（オプション）	
Build size	600×600×500（mm）	1000×600×500（mm）
Zテーブル	最小積層ピッチ50 μm	
樹脂槽	槽交換方式	
リコータ	ディップコート方式	
液面制御	カウンターボリューム方式	
電源仕様	AC 200V 三相 50A	
装置外形寸法	W2300×D1200×H2280（mm）	W2800×D1200×H2280（mm）
装置重量	約1350kg	約1600kg

Hsiang-Yao Lan

62

SL快速原型機型價格比較表(1)

光造形法			
商品名	造形寸法 (mm)	価格 (百万円)	問い合わせ先
SLA250 Series50	254×254×254	24.8	(株) インテス TEL:03-5351-1919 http://www.intec.co.jp
SLA250 Series50HR	254×254×254	24.8	
SLA3500	350×350×400	39.8	
SLA5000	508×508×584	49.8	
SLA7000	508×508×584	59.8	
(3D Systems)			
RapidMeister6000	600×600×500	65	シーメット(株) TEL:045-478-5561 http://www.cmet.co.jp
RapidMeister3000	300×300×250 ダクト型仕様の場合 250×250×250	35	
RapidMeister2500F	250×250×250	37	
E-DARTS	200×200×200	2.98	株式会社アウストン TEL:097-543-1491 http://www.austone.co.jp

63

SL快速原型機型價格比較表(2)

光造形法			
商品名	造形寸法 (mm)	価格 (百万円)	問い合わせ先
SCS-300P	300x300x270	25	(株) デューメック TEL:03-5565-6661 http://www.dmecc.co.jp
SCS-1000HD	300x300x270	51	
JSC-2000	500x600x500	50	
JSC-3000	1000x800x500	75	
SLP-4000R	200x150x150	5	(株) デンケン TEL:097-583-5535 http://www.denken-cng.co.jp/
SolidJet SJ-200P	200x150x200	8.8	
MEIKO(LC-510)	100x100x60	7.8	(株) メイコー TEL:0551-28-5111 http://www.yamada-shi21.co.jp/~meiko/
MEIKO(LC-315)	160x120x100	14.1	
UR2-SP1502	150x150x150	7.9	(株) ユニラピッド TEL:0489-50-1460 http://unirapid.com
マイクロ光造形実験機 URM-HP301	30x30x30	8.95	

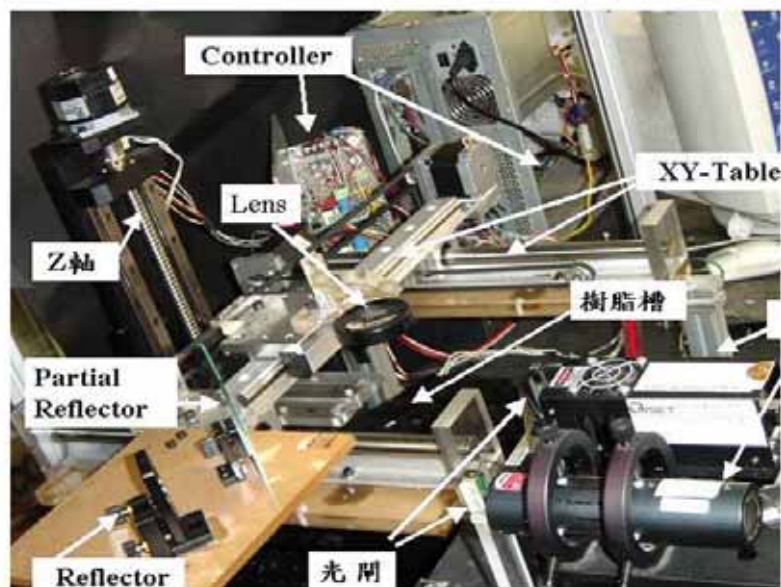
64

上照式多光源 快速原型系統之組裝

Hsiang-Yao Lan

65

多光源系統之機構圖 (上照式)

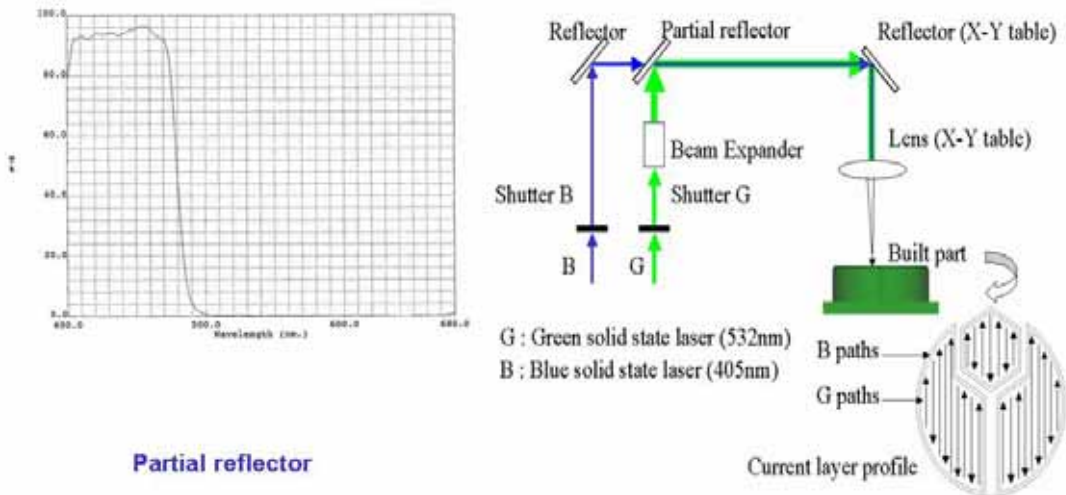


Hsiang-Yao Lan

66

多光源機台之光路設計 (上照式)

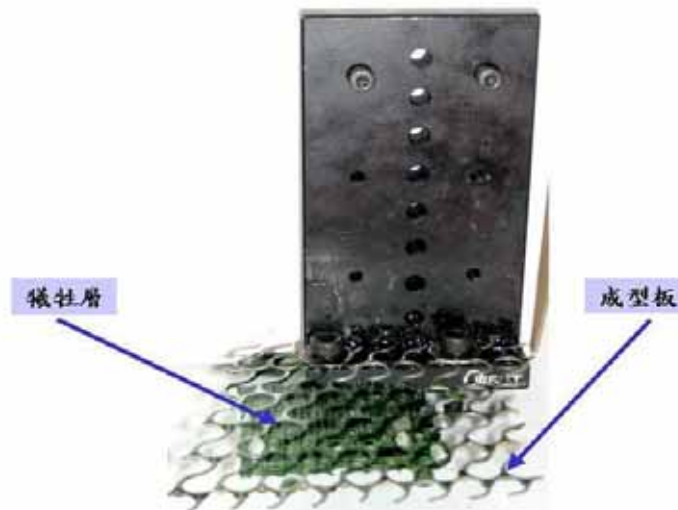
• Optical Design



Hsiang-Yao Lan

67

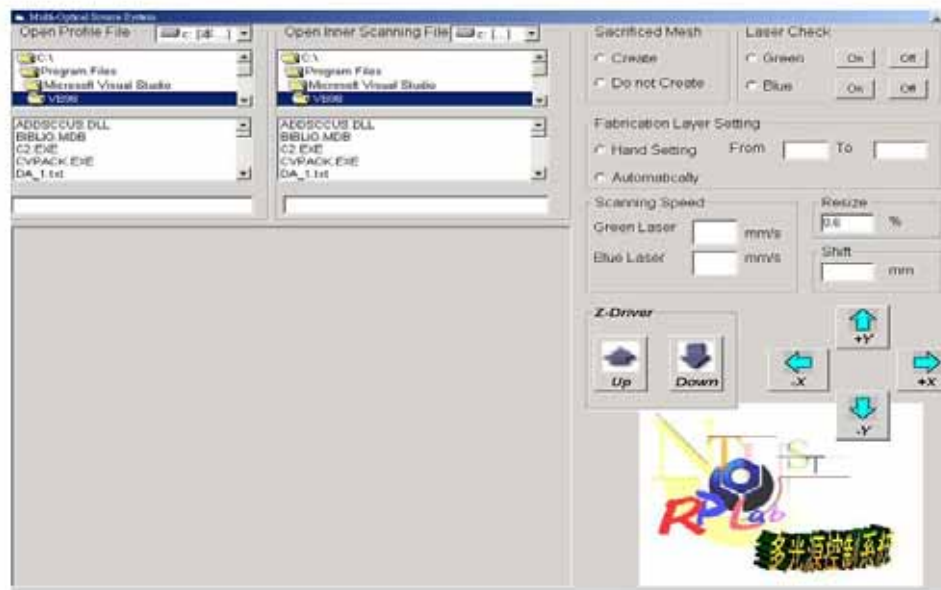
上照式加工 成形板與犧牲層網格



Hsiang-Yao Lan

68

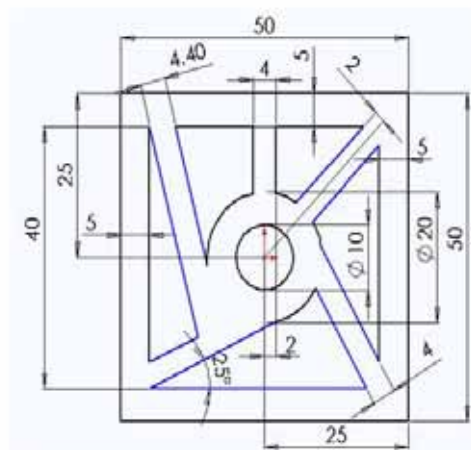
多光源機台之控制介面視窗圖



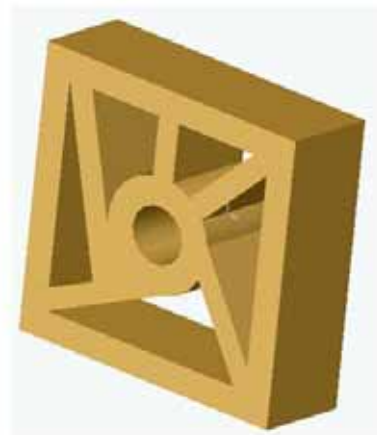
Hsiang-Yao Lan

69

實驗結果(尺寸圖)



(a) 2.5D 工件幾何尺寸圖



(b) 2.5D 工件立體圖

Hsiang-Yao Lan

70

實驗結果(成品比較圖)



(a) 下照式面罩成形法



(b) 多光源系統成形法

Hsiang-Yao Lan

71

快速原型機型價格比較表

RP系統	多光源 快速原型系統	E-Darts 系統	MM系統	SLP系統
建構材料	光硬化 樹脂	光硬化 樹脂	臘材	光硬化 樹脂
產品價格	自行研發 約30萬	100 萬	100 萬	130 萬

Hsiang-Yao Lan

72

快速原型系統加工效益評估表

RP 系統	多光源快速 原型系統	E-DARTS 系統	SLP 系統	面光罩系統
建構層數	50 層	50 層	50 層	50 層
建構層厚	0.2 mm	0.2 mm	0.2 mm	0.2 mm
建構材料	光硬化樹脂	光硬化樹脂	光硬化樹脂	光硬化樹脂
建構時間	300 分鐘	550 分鐘	600 分鐘	50 分鐘
產品價格	自行研發約 30 萬	100 萬	130 萬	自行研發約 30 萬
改善效率	1	- 1.8 倍	- 2 倍	6 倍

報 告 完 畢

謝 謝 ！