

國立交通大學  
光電學院 光電科技學程

碩 士 論 文

半導體廠深紫外光(248奈米波長)雷射曝光機，A/B鏡頭及雷射共振腔壽命延長藉由高效率的功率曲線控制之研究

STUDY OF DUV 248 LENS A/B AND LASER  
CHAMBER LIFETIME EXTEND BY  
EFFICIENT POWER CURVE CONTROL

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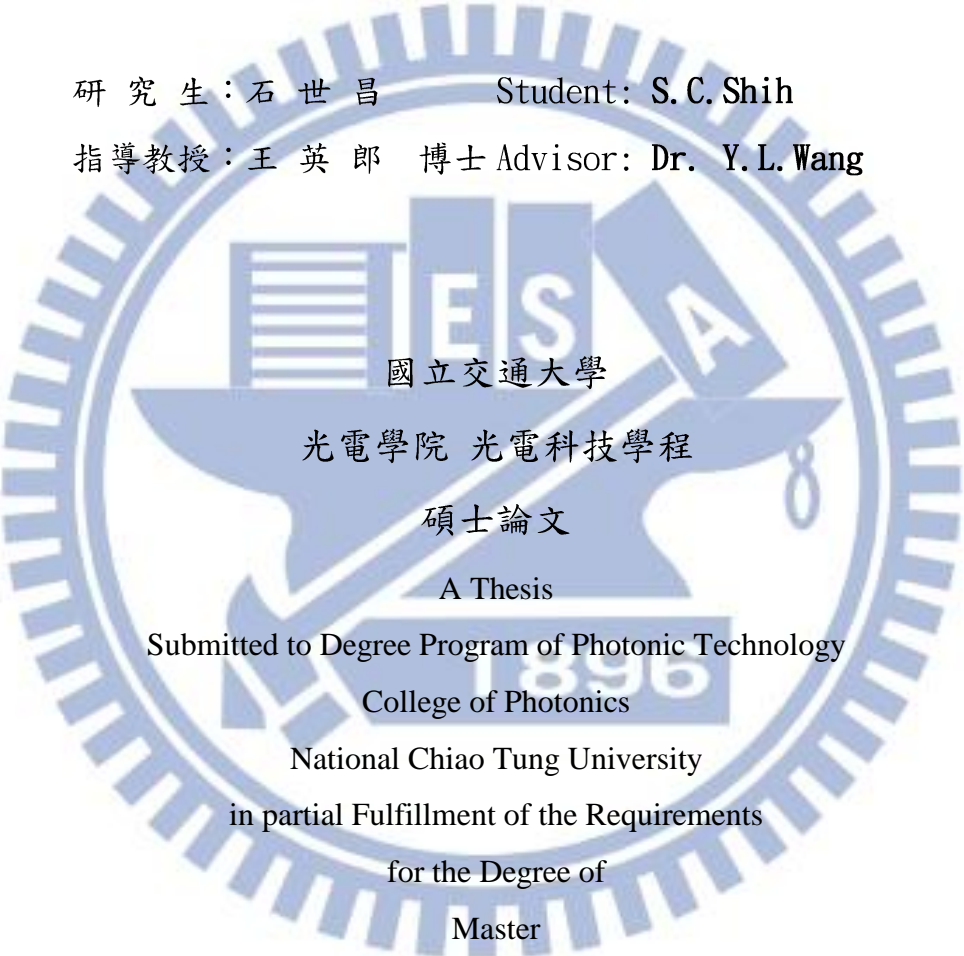
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The logo of National Chiao Tung University is a large circular emblem with a gear-like outer border. Inside the circle, there are stylized letters 'E', 'S', and 'A' arranged vertically. Below the letters is a graphic of a microscope. The year '1896' is visible at the bottom of the inner circle.

國立交通大學

光電學院 光電科技學程

碩士論文

A Thesis

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# 半導體廠深紫外光(248奈米波長)雷射曝光機, A/B鏡頭及雷射共振腔壽命延長藉由高效率的 功率曲線控制之研究

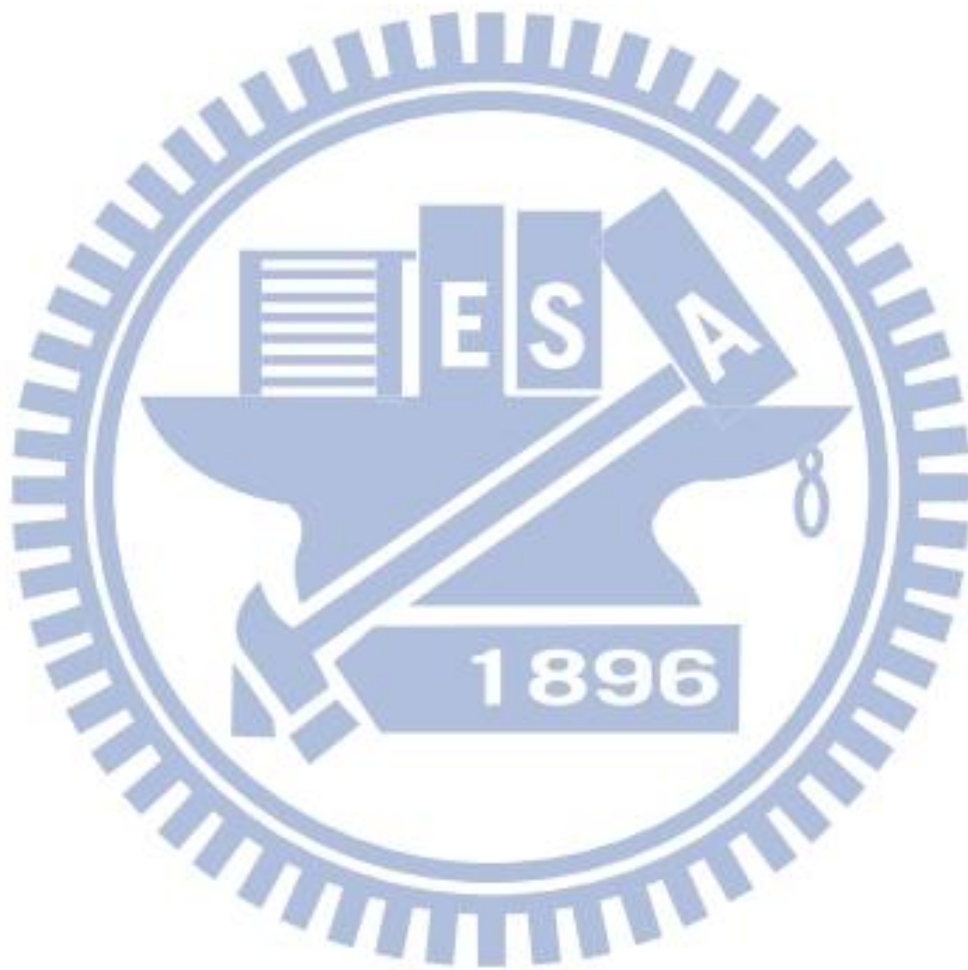
研究生：石世昌 指導教授：王英郎博士

國立交通大學光電學院 光電科技學程

## 摘 要

伴隨著積體的不斷進步到奈米等級,以雷射當曝光源取代傳統燈炮當曝光源已經是愈來愈盛行,但是雷射當曝光源雖然可以把積體電路的線寬製作到奈米等級,但是伴隨而來的花費及機台的維護亦變得愈來愈複雜而且維修保養的頻率也增加人力的效率. 本論文研製之主要目的為我們發現 ASML公司製作的深紫外線DUV248掃描器曝光機遭受嚴重的鏡頭 A / B 破壞事件。它造成的晶圓級曝光量強度趨於嚴重下降。因為我們知道,晶圓級曝光量強度嚴重影響到生產的輸出量。之前,我們可以調整可變動衰減器的角度來改善晶圓級曝光量強度的下降或更換鏡頭 A / B來解決它。但鏡頭 A / B的破壞情況卻是一再的發生。它花了很多時間,人力成本來恢復。因此,如何減少鏡頭更換或工程師的負荷來增加效率是必要的。根據經驗,我們發現,它的鏡頭 A / B 主要是受到了雷射激光的破壞。在最後的分析,根本原因是高能量激光誘導鏡頭的A / B的污染。我們創建了原始的強度控制方法,以延

長鏡頭的A / B壽命；此外，它又可以延長電射激光腔的壽命。自實施這種方案以來，這種情況已經大大的改善並被以被控制。



# STUDY OF DUV 248 LENS A/B AND LASER CHAMBER LIFETIME EXTEND BY EFFICIENT POWER CURVE CONTROL

Student: **S.C.Shih**

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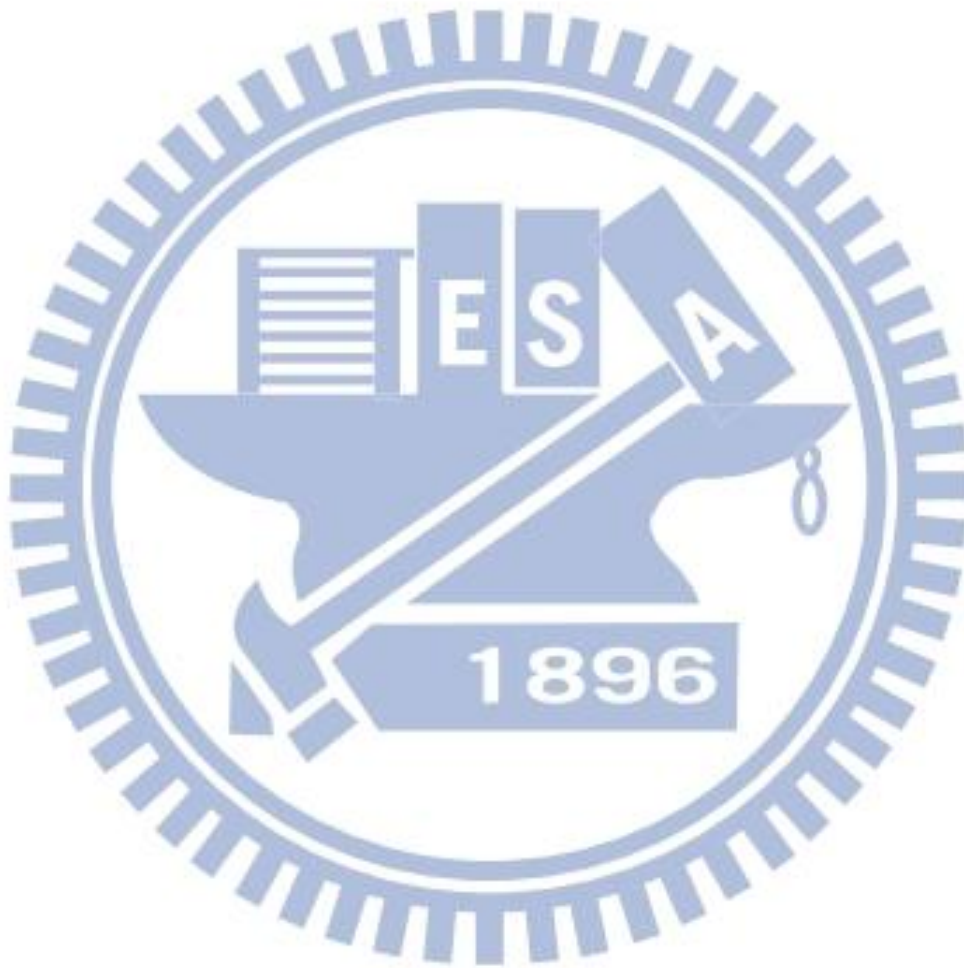
Degree Program of Photonic Technology  
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## Abstract

Along with the continuous advancement of integrated to the nanometer level, use the laser source for exposure is more and more popular to instead of the traditional bulb. We can get the benefit of the integrated line width improve to nanometer level, but the cost and maintenance of the laser machine becomes increasing complex. The frequency of repair and maintenance to increase, it also decreases the efficiency of the manpower.

The paper is study the ASML DUV 248 scanner suffered lens A/B seriously destroy event. And this event was getting worse and worse. It caused the wafer level intensity trended down seriously. As we known, the wafer level intensity affects the throughput of production. Before, we could adjust VA angle or replace lens A/B to solve it. But lens A/B contamination happened and happened again. It spent a lot of time, manpower and cost in recovery. So how to reduce lens replaced rate or engineer's loading was necessary. According to experience, we found it cause from the lens A/B

was damaged by laser. In the last analysis, the root cause was higher energy laser induce lens A/B contamination. We created original intensity control method to extend lens A/B lens lifetime; moreover, it could extend Laser chamber lifetime, either. This situation has been changed and proved it is workable after the program was implementing.



## 誌 謝

兩年的研究生的歷練，首先要感謝恩師王 英 郎教授諄諄教誨及悉心指導，指引我正確的研究與治學方向，讓我能擁有獨立思考的精神與分析判斷的能力。另外，也要感謝陳科維博士在研究理論的推導及論文方面的啟發與悉心指導，讓我受益良多。在此攻上誠摯的敬意與謝意。

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最後，僅將此論文獻給我敬愛的家人，感謝他們在我研究所期間對我精神上的扶持及關懷。

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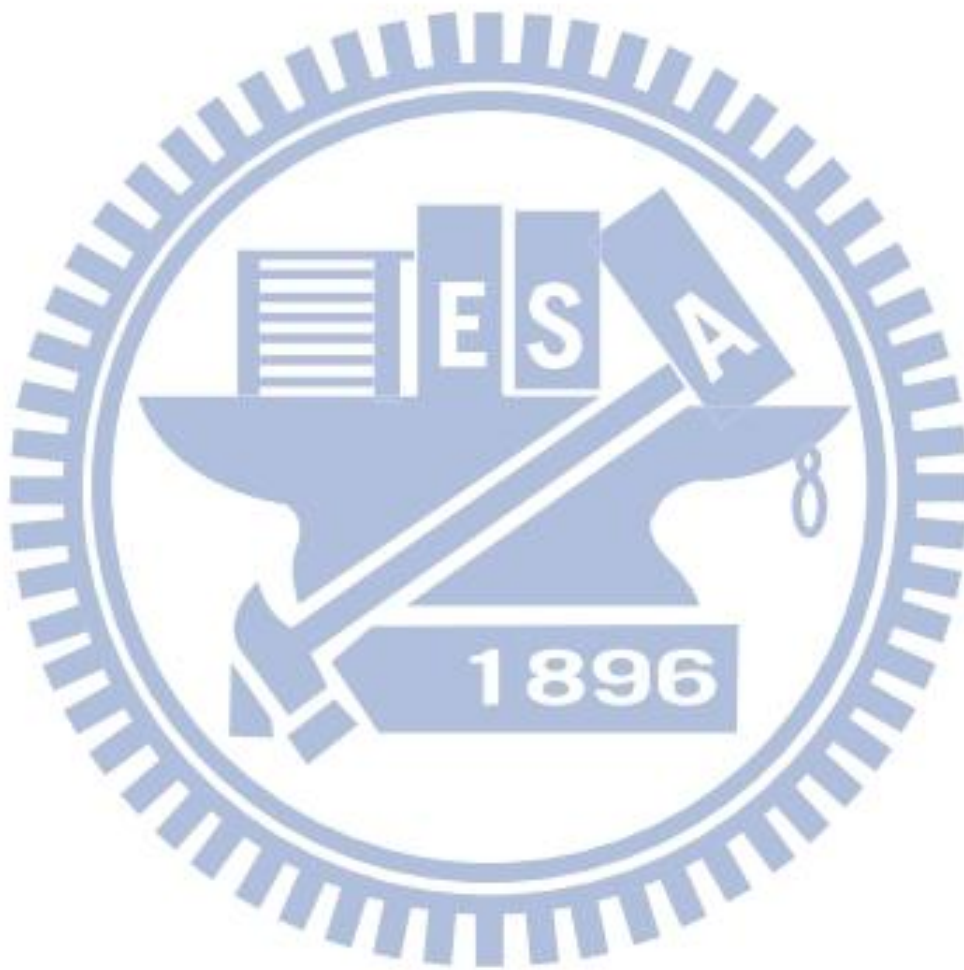
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# Chapter 1 Background Introduction

## 1.1 Investigation Motivation and Purpose

Along with the continuous advancement of integrated to the nanometer level, use the laser source for exposure is more and more popular to instead of the traditional bulb. We can get the benefit of the integrated line width improve to nanometer level, but the cost and maintenance of the laser machine becomes increasing complex. The frequency of repair and maintenance to increase, it also decreases the efficiency of the manpower. It also is a large loading in our cost and manpower control, and it is major topic for study the root cause and improved the availability due to the exposure tools is the highest cost of semiconductor factory.

## 1.2 Investigation Background

Base on the FAB14 ASML DUV 248 scanners with 7600 series laser suffered the wafer level intensity decay issue serially. As we known, the wafer level intensity low will affect the throughput of production. So, we need to figure out the root cause. Finally, inspect tool status then found the lens A/B had been contaminated.

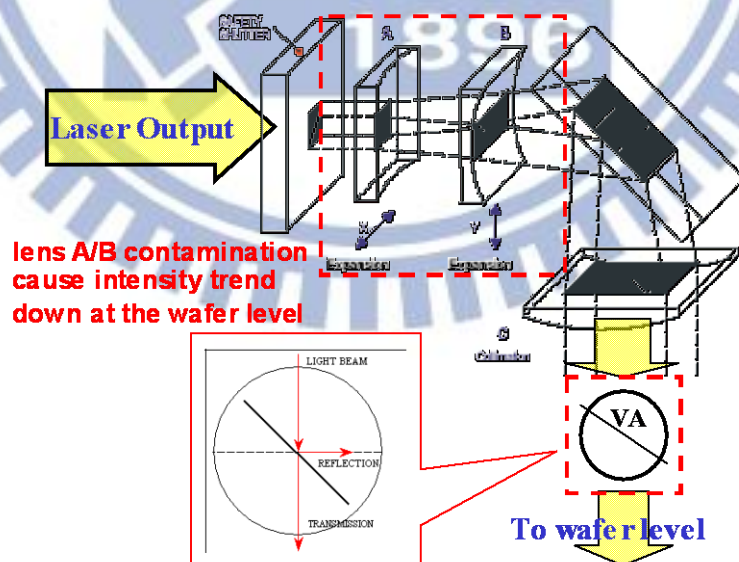
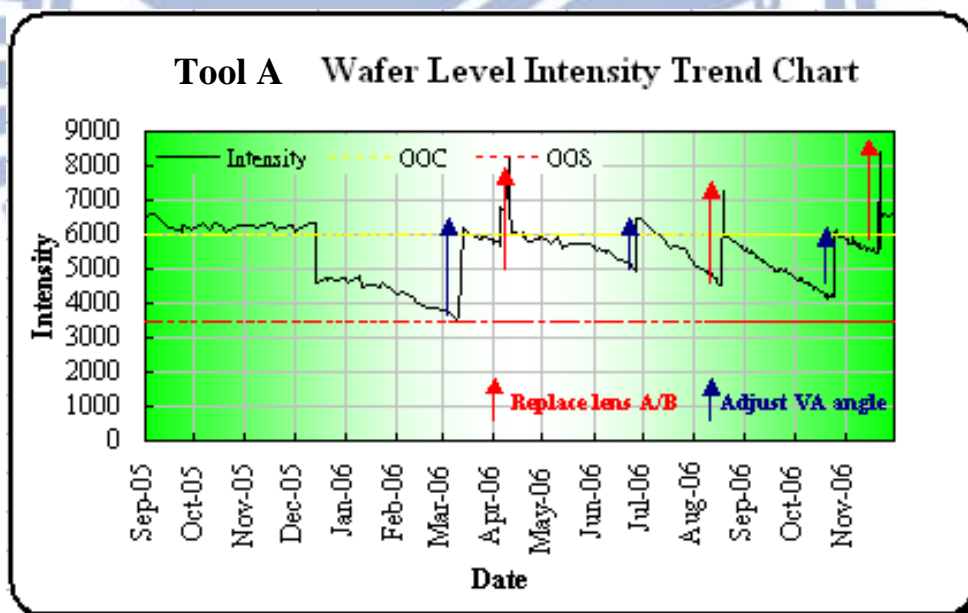


Figure 1.1 Scanner Intensity loop

Base on standard procedure, we could adjust wafer level intensity by:

Method 1 Adjust VA angle-The variable attenuator (VA) is used to control light transmission rate to the wafer level. When light hits the quartz plate of the VA, a part of light will pass through and the other will be reflected to the beam dump (absorbed). So, we adjust VA angle to obtain the required intensity (as a light regulator).

Method 2 Replace Lens A/B-After a mount of shots, the lens A/B will be contaminated. If the lens A/B status of contamination was too worse to recover by VA adjustment, the lens A/B will be replaced. But situation was out of the control; whether we adjusted VA angle or replaced lens A/B still could not fix it. As shown below, we can't keep intensity stable anymore (figure 1.2). Lens A/B contamination happened and happened again.



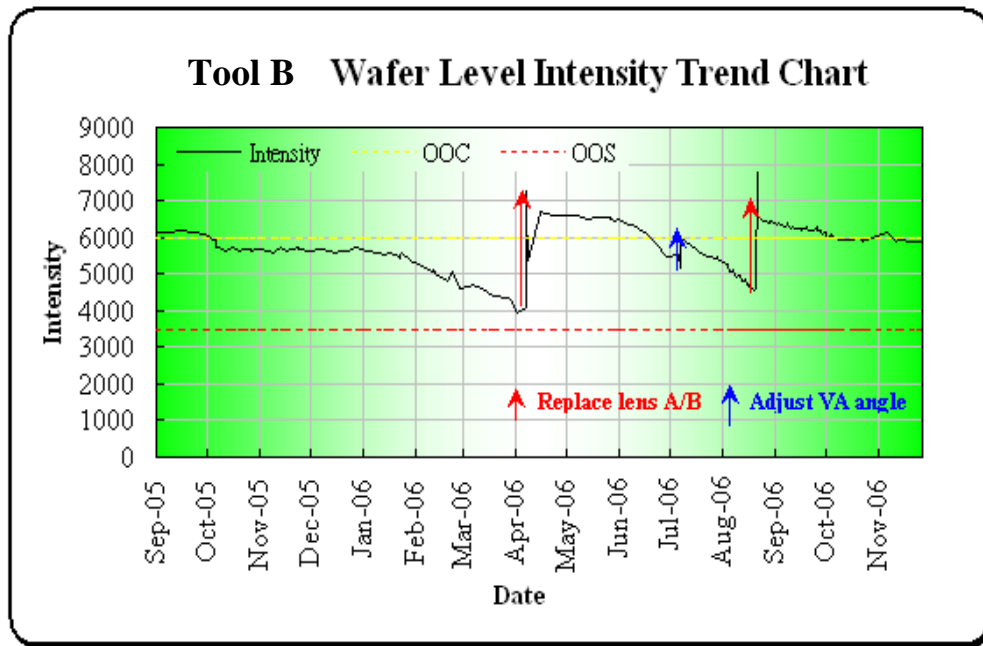


Figure 1.2 A and B tools wafer level intensity trend chart

### 1.3 Method and Instrument Description

In order to find out the lens A/B damage root cause, we need to more detail to check scanner laser intensity control loop (Figure, 1.1). Search most of the laser maintenance in other papers, we found usually to optimize the laser chamber high voltage power for exciting laser power and optimize the laser chamber for F2/Kr/Ne gas pressure to adjust the laser power and intensity, Besides it still could extend the chamber and few core module life time such as the (LNP, WSM, BAM....). but is just a little. It almost improves the life time for weekly base. It is not helpful for our maintenance.

We check the Lens A/B contamination status and we could found the contamination picture was form by the slit profile, which we suspect it is laser slit active area, so we could doubt the lens A/B contamination was cause by the laser and we simulate the laser intensity and laser pulse energy VS the Lens A/B lifetime. We could found a related status is the Lens A/B lifetime VS Laser pulse energy come out the result is Lens A/B life time is low when the laser pulse energy is high, and Lens A/B lifetime is high when the laser pulse energy is low.

We could suspect the laser pulse energy is the key factor to influence the Lens A/B lifetime, and we could set up the experiment for the laser pulse energy with the Lens A/B lifetime related issue to figure out the root cause



Figure 1.3 Lens A/B Contamination Statuses

### Lens A/B Lifetime & Laser pulse energy

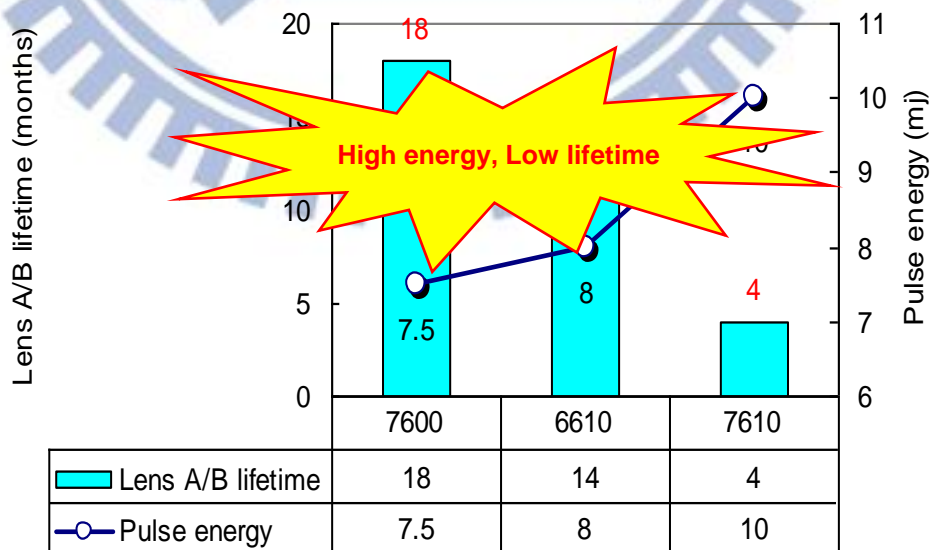


Figure 1.4 Lens A/B lifetime & Laser Pulse Energy Related Chart

We still to check the contamination part for analysis and found that most of the part was form by the  $(\text{NH}_4)_2\text{SO}_4$  , then we check the chemical and analysis the root cause. We suspect the DUV light is the major factor to provide the energy to form the  $(\text{NH}_4)_2\text{SO}_4$ . It is a major topic the study the pulse energy effect and the defect type.

Besides, we still try to remove the contamination by use many methods, even we use the removable chemical that suggest by zeiss and ASML, but it still difficult to remove it. So it is like crystal to form on the Lens A/B optics surface and it is almost could not be removed.

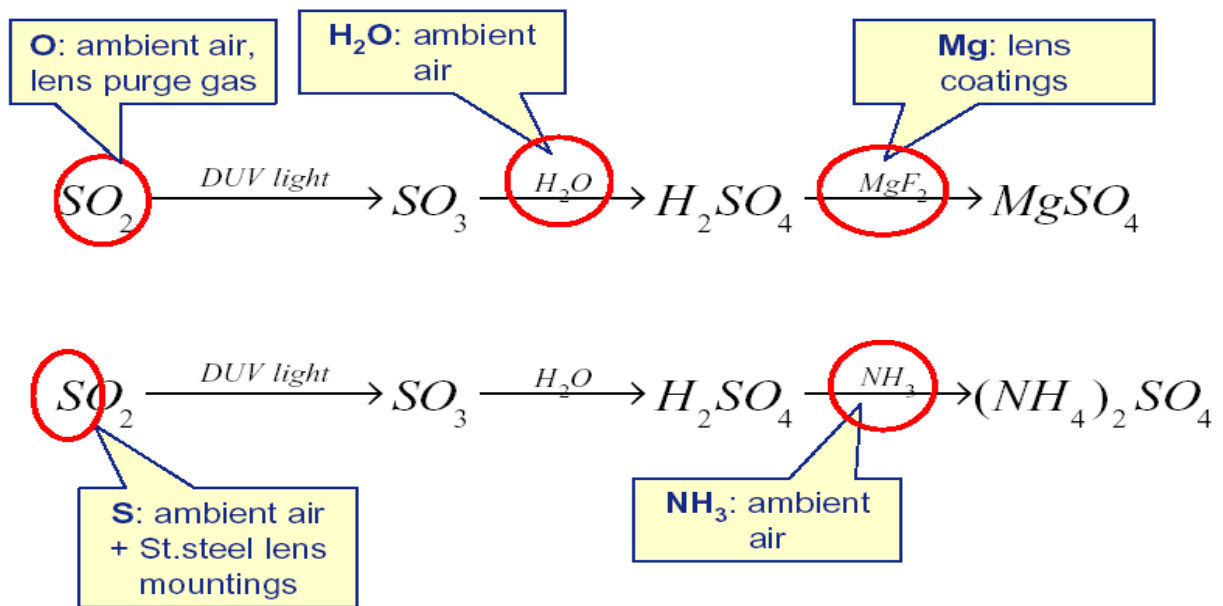


Figure 1.5 Contamination of Lens A/B Cause by the  $(\text{NH}_4)_2\text{SO}_4$

For the laser control loop, we could find the VA (variable attenuator) is a decay filter to lower down the laser intensity to fit scanner need, and it almost set around 70% lower down the laser output to fit the scanner need. And we found the lens A/B damage is major comes from the laser output is too high and it damage the lens A/B and induce the optics contamination. The contaminations also decay the intensity of the laser, and need to frequency to swap it to gain the requirement. So we need to maintain it again and again to reduce the productivity for litho scanner and waste the manpower.

If we could dynamic to control the laser output intensity and just to control the scanner requirement to fit the exposure wafer need then we can lower down 30% output to reduce the damage

of the lens A/B. We study the laser control parameter and found one of thousands of parameters is to control laser output percentage, it calls parameter C24. We think we can adjust the C24 parameter to fid the wafer level intensity and let the VA keep 100% output to minimize the damage of the lens A/B which laser output optics for beam expender of x, y control.

We can set up the experiment for parameter C24 adjustment to fit the wafer level intensity requirement and dynamic to control the C24 parameter to monitor the intensity variation and the lens A/B life time trend chart for the data collection and analysis to fit our suspect model.





# Chapter 2 Experiment

According to the lens A/B replaced record; we had replaced 14 set of lens A/B for recovery within one year (table 2.1). It spent a lot of time, manpower and cost in recovery.

| 2005 Dec. ~ 2006 Sep. lens A/B replaced statistics |               |                          |                             |                     |
|----------------------------------------------------|---------------|--------------------------|-----------------------------|---------------------|
| Laser Type                                         | Tool Quantity | Lens A/B replaced counts | Lens A/B lifetime ( month ) | Pulse energy ( mj ) |
| 7600                                               | 1             | 0                        | 18                          | 7.5                 |
| 6610                                               | 12            | 6                        | 14                          | 8                   |
| 7610                                               | 17            | 8                        | 4                           | 10                  |

P.S. The laser will fire 1 billion plus during the month generally

Table 2.1 Lens A/B replaced statistics

As table 2.1 show, the lens A/B that installed on different laser type have different lifetime. And the lifetime of the lens A/B was inverse proportion to the laser pulse energy, the higher pulse energy was the less lifetime. So, we highly suspected that was induced by higher pulse energy laser. It also could explain why the standard actions can't fix the problem.

## 2.1 Standpipe Diagram

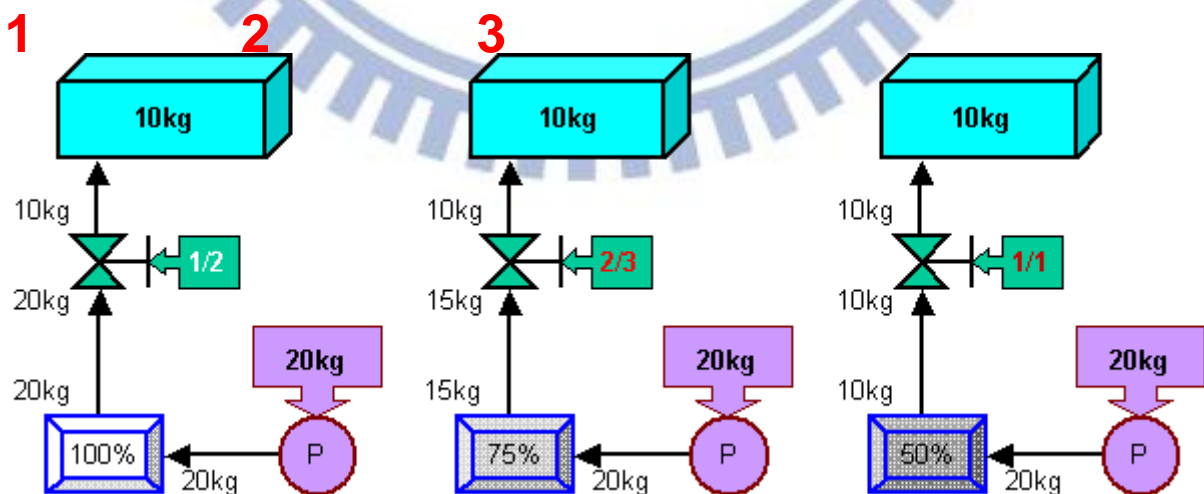


Figure 2.1 Standpipe system flow

In figure 2.1 you can see the processing flow of the standpipe-filled. Blue box is a standpipe that has a kilogram capacity of 10. Violet object is a pump for supplying 20 kilograms water to the standpipe. The water of the pump source passes through the pipe (while object) that with one hundred percent of the transmission rate, the water will flow over of the standpipe. So, we used regulator with 1/2-proportioned (green object) to control 10 kilograms water could transfer to the standpipe only. One day, the pipe was blocked to have seventy-five percent of the transmission rate only (figure 2.2). The regulator must be adjusted to 2/3-proportioned to ensure enough capacity of the standpipe. As the same reason, the regulator must be adjusted to 1/1-proportioned to cover the pipe with fifty percent of the transmission rate (figure 2.3).

In the program, we could found a doubtful point: If the standpipe needs to be filled by 10 kilograms water only, why should we need to support 20 kilograms? And install the regulator especially for filter out unnecessary water?

## 2.2 Scanner Intensity Loop

Scanner intensity loop is like the standpipe system (figure 2.2). Laser is like the pump that supports the intensity for system, lens A/B is a medium for light that is like the water pipe or filter, the VA is like the regulator to filter out unnecessary light.

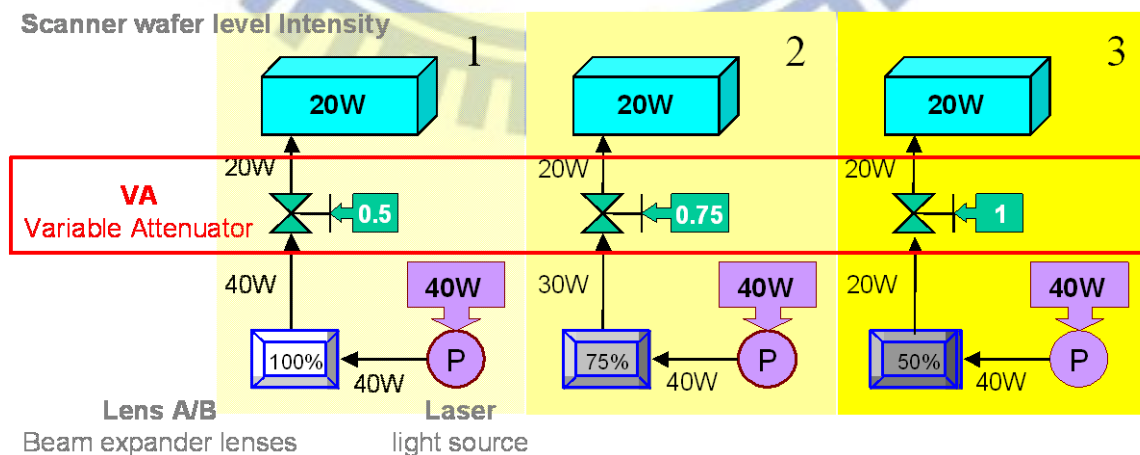


Figure 2.2 Standpipe system flow with scanner intensity control loop

VA was the adjustable device in the original ASML scanner intensity control system. It blocked and filtered out unnecessary light (figure 2.3). So, the higher laser energy induced the lens A/B contamination and replacement needed the VA adjustment happening with increasing frequency.

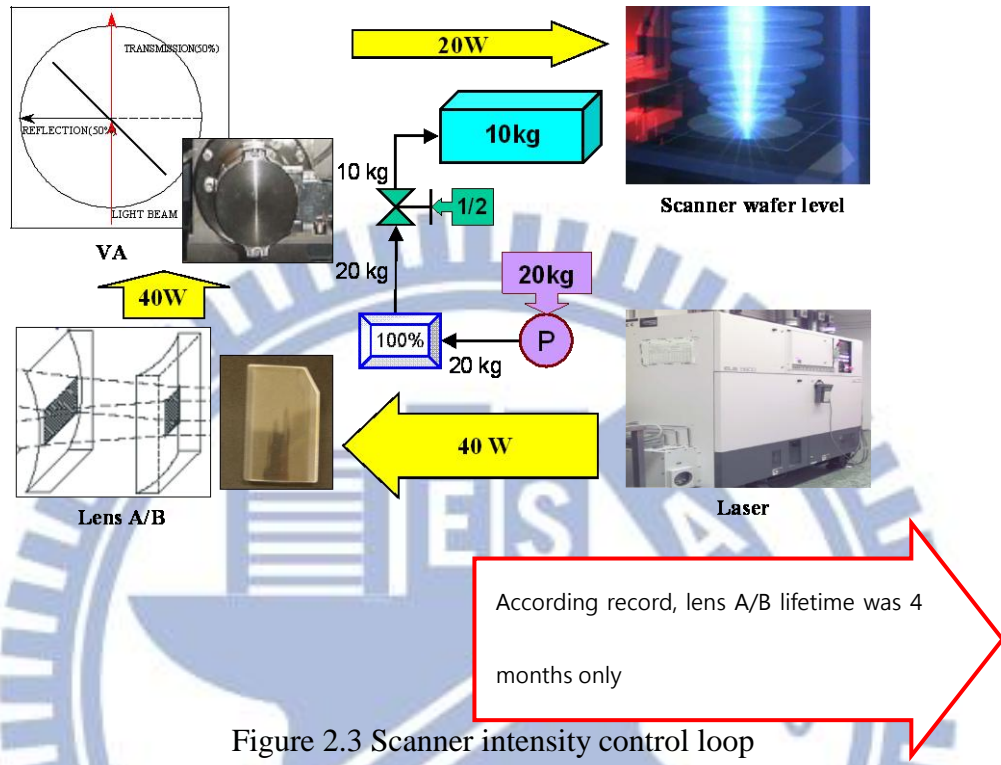


Figure 2.3 Scanner intensity control loop

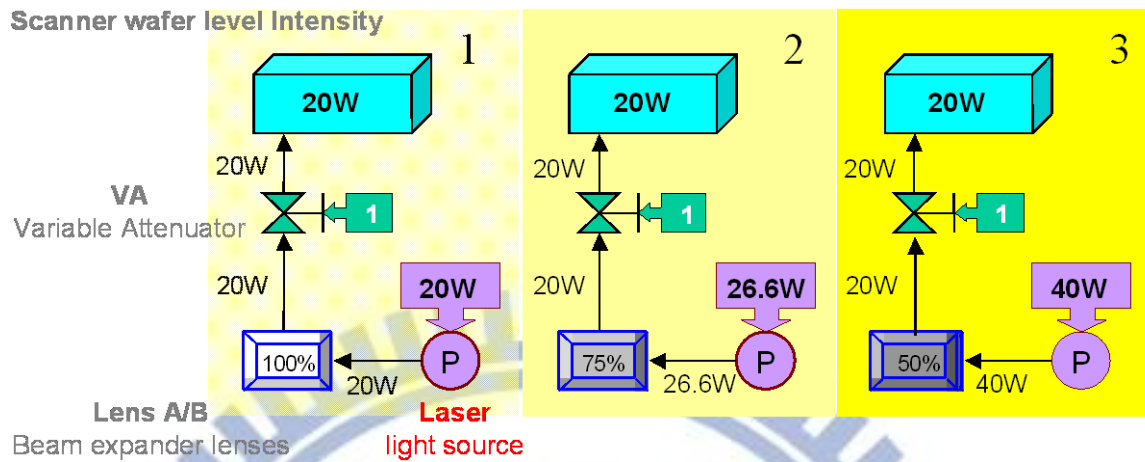
| Tool   | LASER Power (f = 4000 Hz) | Energy sigma | Bandwidth | Dose Accuracy and Repeatability | VA(FIS)    | 100 pulse Wafer level Intensity ( mW/cm2 ) | 1 st Intensity decay start (months) |
|--------|---------------------------|--------------|-----------|---------------------------------|------------|--------------------------------------------|-------------------------------------|
| APD8E5 | 10 mj / Pulse (40 W)      | OK           | OK        | OK                              | 0.71397148 | 6594.01                                    | 0.8                                 |
| APD8A5 | 9 mj / Pulse (36 W)       | OK           | OK        | OK                              | 0.82421447 | 6416.59                                    | 3                                   |
| APD8C7 | 8 mj / Pulse (32 W)       | OK           | OK        | OK                              | 0.94714454 | 6537.34                                    | 4.23                                |

Table 2.2 Laser power W.R.T VA angle or the transmission rate

According to the understanding of the ASML scanner intensity control system, we have a new idea as below.

1. To fix the transmission rate of the VA to the maximum as possible. (figure 2.4 transmission rate of the green object was 1/1-proportioned)
2. Adjust laser energy to match the required of the wafer level intensity,
3. Increase laser energy if the lens A/B had contamination

In other word, we would use Laser power adjustment to instead of ASML standard VA angle adjustment method.



Increase laser energy to follow lens A/B contamination

Figure 2.4 New Scanner intensity control loop

### 2.3 Laser Energy Control Loop

Laser energy could be controlled by the piezoelectric devices or software. In the case of Laser energy adjustment, we are willing to use software. It had no difficulty in operation and spent less time.

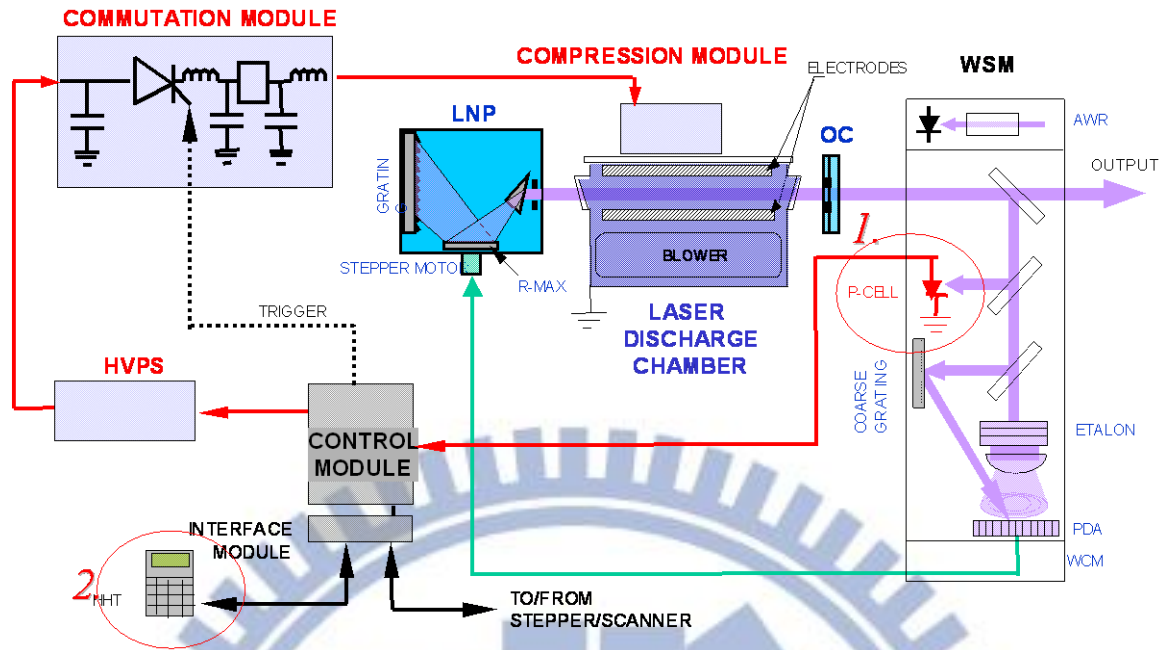


Figure 2.5 Laser energy control loop

Laser had one parameter “Configure 24” that was the gain calibration for the photocell signal from the energy monitor in the WSM. After experiment, then found it had fine linear curve (figure 2.6). Simply operation and linear power curve decided us to use it.

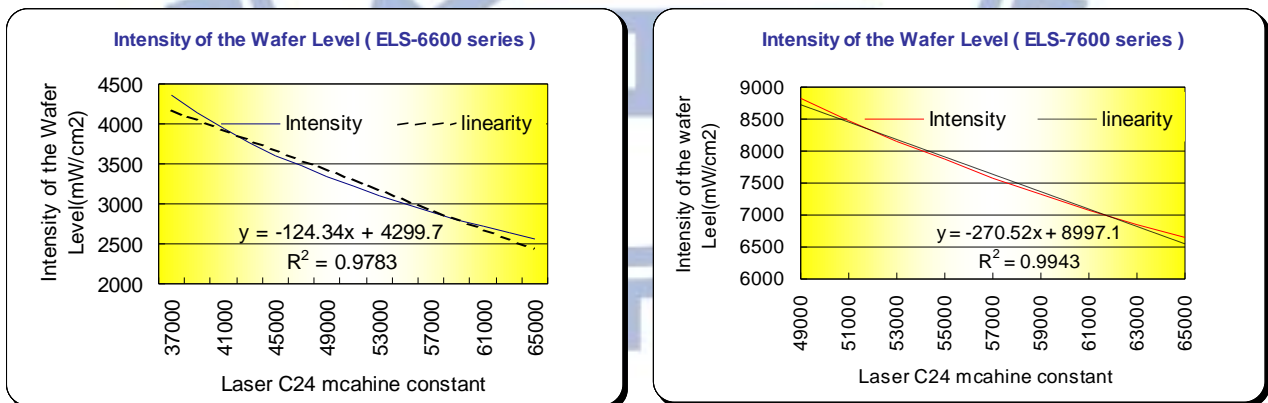


Figure 2.6 Intensity curve

From performance index, the new method could lower LASER working voltage but other performance index like E95 of laser pulse bandwidth was kept with original data (figure 2.7) which is major concern by the CD variation of the proximity effect. Secondly the laser pulse energy was kept

the same and stable (figure 2.8). The laser pulse energy is still concern by the CD variation which was impacted the CD mean value effect. The result is which we had anticipated. Lower LASER working voltage will extend LASER chamber, WSM and LNP lifetime.

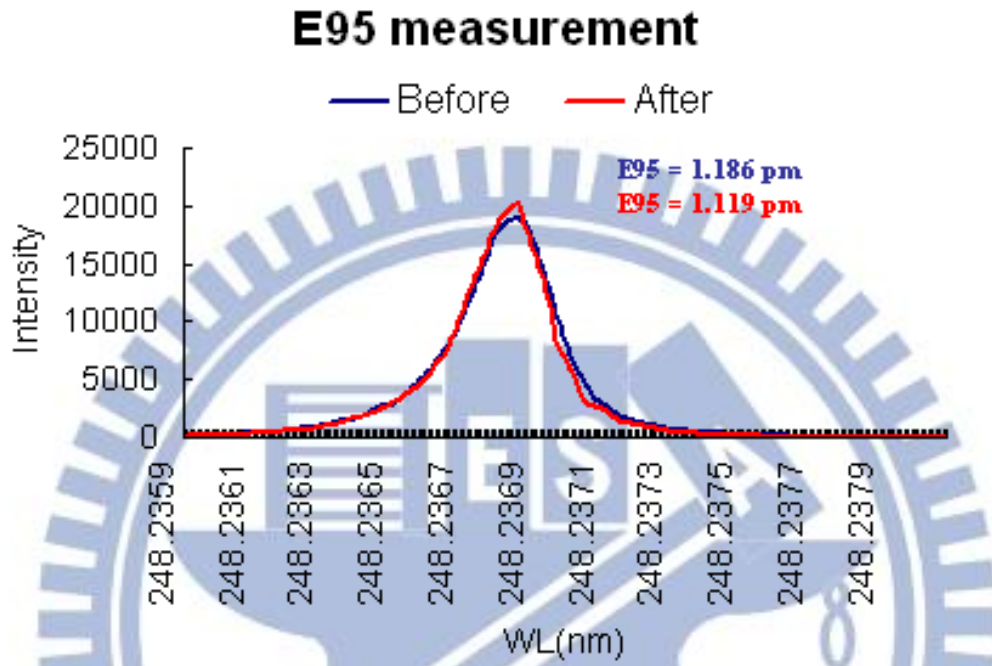


Figure 2.7 Laser E95 Comparable Data

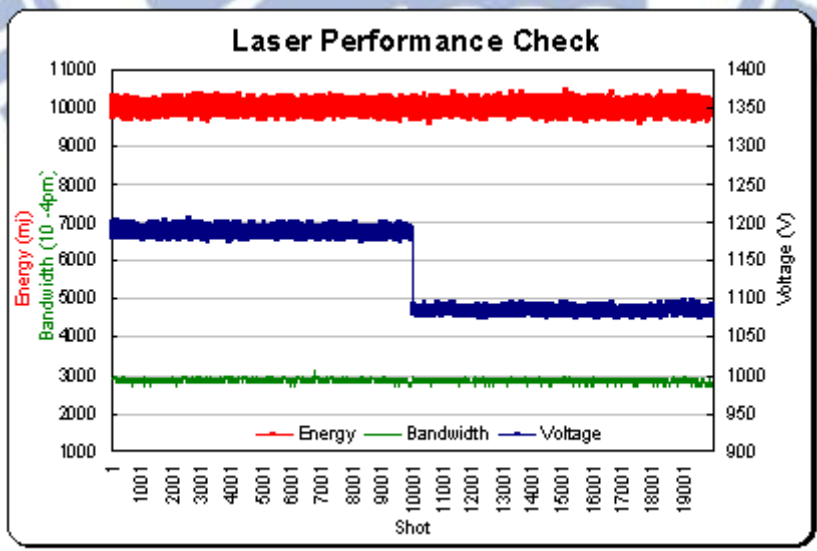


Figure 2.8 Laser Performance Check

# Chapter 3 Result/Discussion

## (Experiment, Result, Analysis...)

### 3.1 Lens A/B have double lifetime.

We used old type Lens A/B and new methodology at APD8E3 from Nov. 2006, then it got great improvement, kept wafer level intensity stable more than 8 months and low intensity decay rate (<15 mW/cm<sup>2</sup> / month) till now. Besides, we tried to assess the effects of the long-life Lens A/B that was new design from ASML at APD8E5. The performance shows new method with old lens A/B is better than old methodology with long life lens A/B, kept stable 5 months and have monthly 334 mW/cm<sup>2</sup> intensity decay rate. (Old type: 66,000 NT/set; New type: 102,400 NT/set)

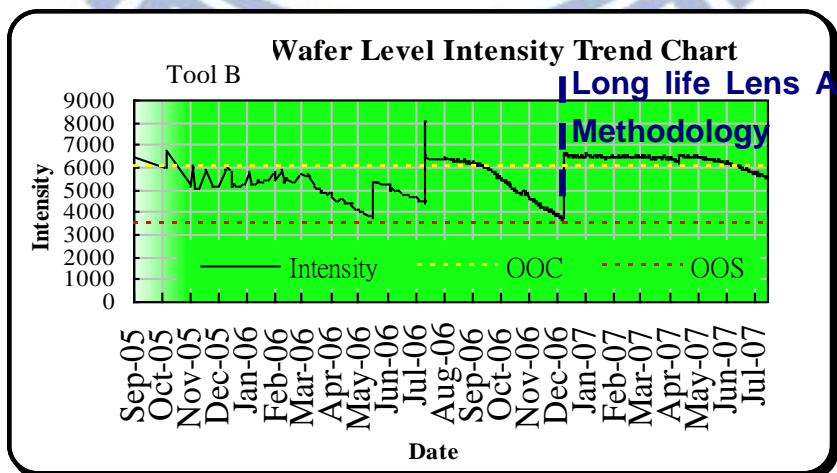
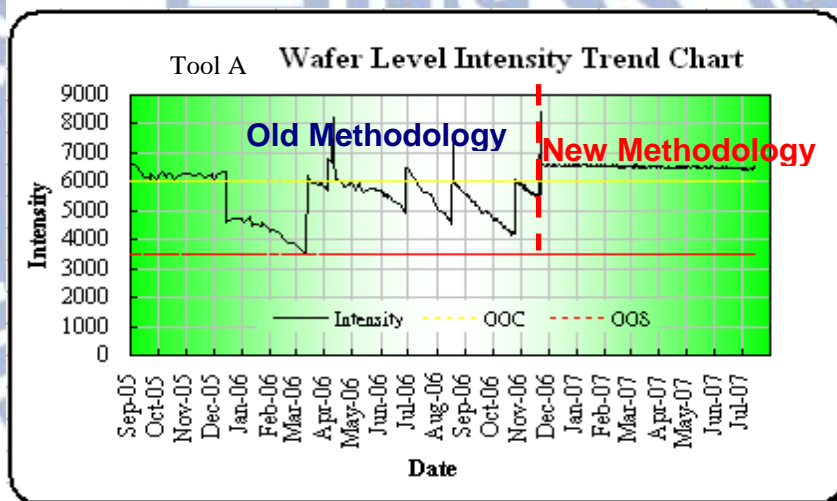


Figure 3.1 Tool A and Tool B wafer level intensity trend chart

According to long lifetime Lens A/B's profitability was better than old type. We will be glad to combine long lifetime Lens A/B with new intensity control methodology in the future. It's effects was assessing. Currently, our Lens A/B lifetime had extended form 4 months to more than 8 months and it will help us to reduce **1,683,000 NT/year** [ $17 \times (12/4 - 12/8) \times 66,000 \text{ NT/set}$ ].

### 3.2 Laser Chamber have double lifetime.

Lower LASER working voltage will extend chamber lifetime from 19 billion ( $\approx$  16 months) to 39 billion ( $\approx$  32 months), and it will help us to reduce **20,429,516 NT/year** [ $17 \times (12/16 - 12/32) \times 3,204,630 \text{ NT/year}$ ].

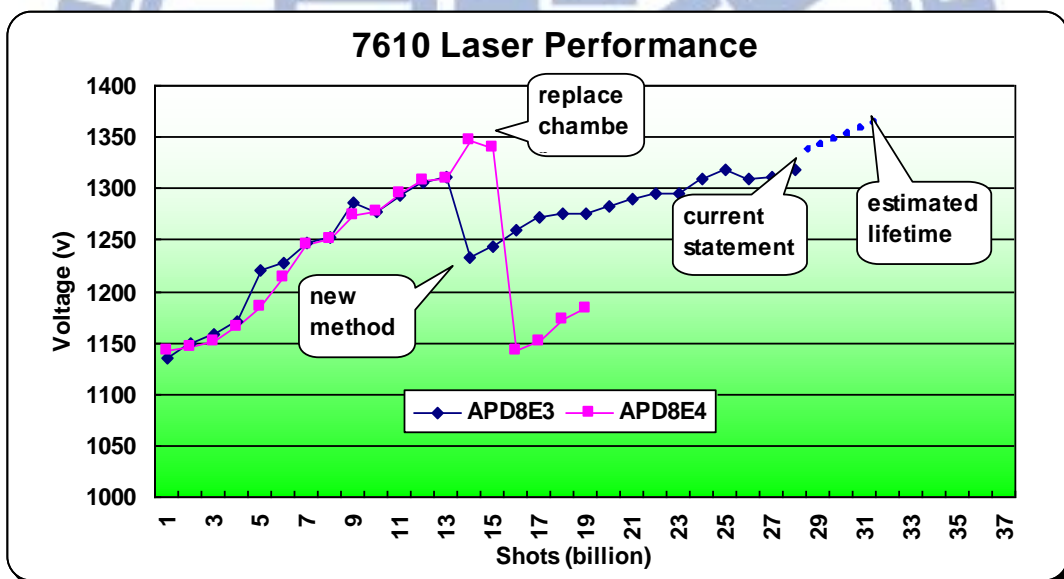


Figure 3.2 APD8E3 Lifetime extend estimate by LASER working voltage

### 3.3 Methodology change compare with production yield.

-No yield impact



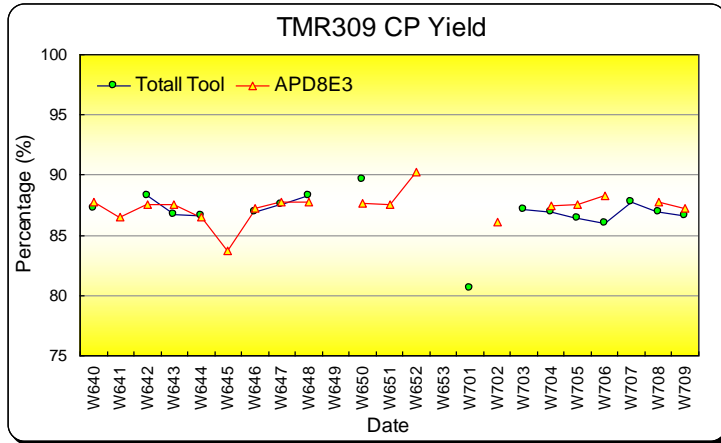


Figure 3.3 Production yield compared



# Chapter 4 Conclusion With the Model of Car Speed

We could easy to fit the research of the simple model for car speed control. In general, ASML request laser vender to provide the fully laser pulse energy to fulfill the scanner need to achieve the maximum WPH, but scanner side need to control the maxmum intensity to prevent the post optics damaged by the high intensity, so it design the VA (variable attenuator) to lower down the intensity to specific value. But it waste the intensity due to VA is a attenuator to decreased the intensity and waste around 30% intensity when all optics is new.

It like the car speed control. We fully use the engine to fulfill value to gain the maximum speed but due to we need to control the maximum speed to achieve the speed control is within the rule. So we add the brake to lower down the speed, but we waste the brake effect and the engine efficiency (figure 4.1)



Figure 4.1 Old Concept of the Car Speed Control

In the new model of the car speed control, we could control the engine by control the engine driving value to control the car speed and do not need to add the brake to lower down the speed. This is dynamic control the car speed by efficiency control to achieve accuracy value, which is a new concept to control car speed. It is like the new methodology to control the laser pulse energy to make it more efficiency and could lower down to the require value to achieve exposure energy and it could improve the Lens A/B life time and Laser chamber lifetime. (Fig 4.2)



Figure 4.2 New Concept of the Car Speed Control

# Chapter 5 Conclusion

## (Root Cause, Improvement, Prevention)

According to experiment's result, we make sure the root cause of the wafer level intensity decay issue is due to higher energy laser. And we find the new intensity control method is effective in extending lens A/B & laser chamber lifetime. The new intensity control method flow as below:

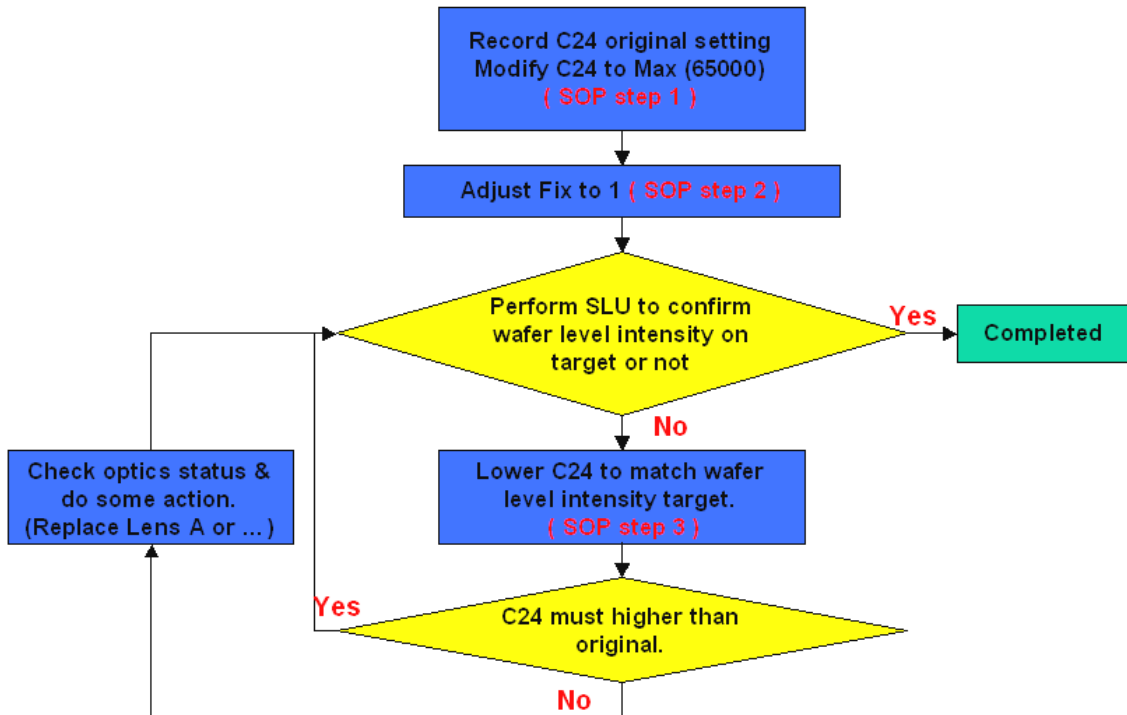


Figure 5.1 The New Intensity Control Method Flow

This methodology could save a lot of cost and also pass ECIP change management for cross FAB experiment sharing.

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高效率的功率曲線控制之研究

Study of DUV 248 Lens A/B and Laser Chamber Lifetime Extend by Efficient  
Power Cure Control

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