

프로그램 설계 종합 (예)

# Long-Wave-Pass Filter

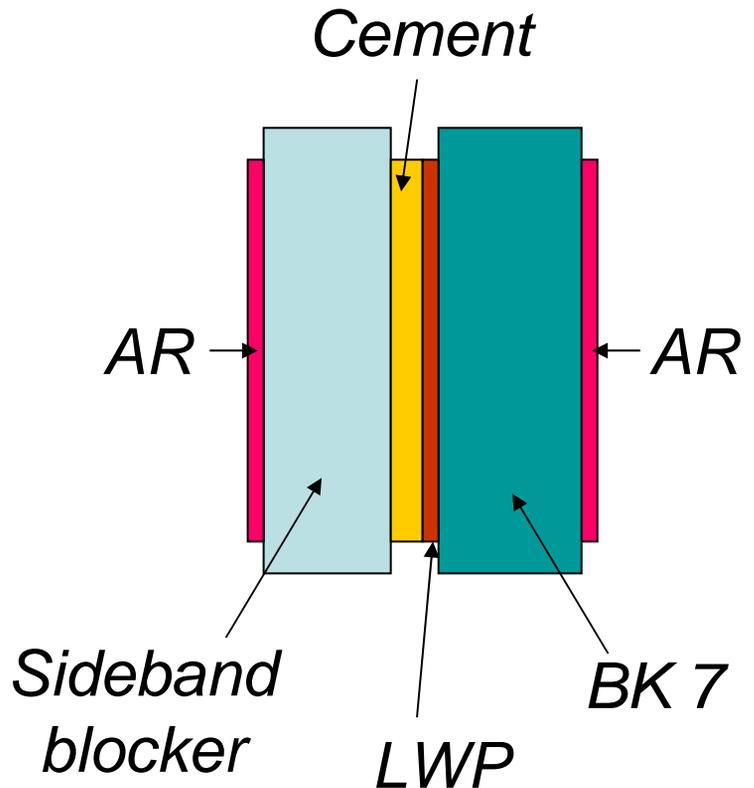
*Simple Specification:*

*600nm - 50% transmittance*

*Low ripple to 850nm*

*No short-wave sidebands*

*Materials Ta<sub>2</sub>O<sub>5</sub> and SiO<sub>2</sub>*



# Material 준비

1. Cement : 그리 중요하지 않으므로 간단히 無 Dispersion에 index of 1.55 신규로 만듭니다.
2. N-BK7는 Material Folder중 Schott 2004 폴더, OG 570b,OG570은 Schott Filter 폴더에서 Import 기능으로 불러옵니다.

Wavelength (nm)	Refractive Index	Extinction Coefficient
100.00	1.55000	0.00000
10000.00	1.55000	0.00000

프로그램 메뉴에서  
1. New > Material  
2. Save As



Material	Refractive Index	Extinction Coefficient
Air	1.00000	0.00000
N-BK7	1.50753	0.00001
SiO2	1.45044	0.00000
Ta2O5	2.10000	0.00000
OG 570 b	1.53000	0.00000
Cement	1.55000	0.00000

1. 폴더선택      3. 이동

Import from Materials Folder:  
C:\Program Files\Thin Film Center\Materials\Schott 2004\

Wavelength (nm) 510.00

Material	Refractive Index	Extinction Coefficient
N-FK5	1.49102	0.00001
N-FK51	1.48952	0.00001
N-PK51	1.53208	0.00001
N-PK52A	1.50012	0.00001
N-PSK3	1.55678	0.00001
N-PSK53	1.62516	0.00001
N-BK7	1.52092	0.00001
N-BK10	1.50162	0.00001
N-K5	1.52700	0.00001
K7	1.51546	0.00001
K10	1.50594	0.00001
N-ZK7	1.51272	0.00001

Plot Performance  
Wavelength  
Wavenumber

Import Matching Substrate

Material Import 방법.

프로그램 메뉴에서

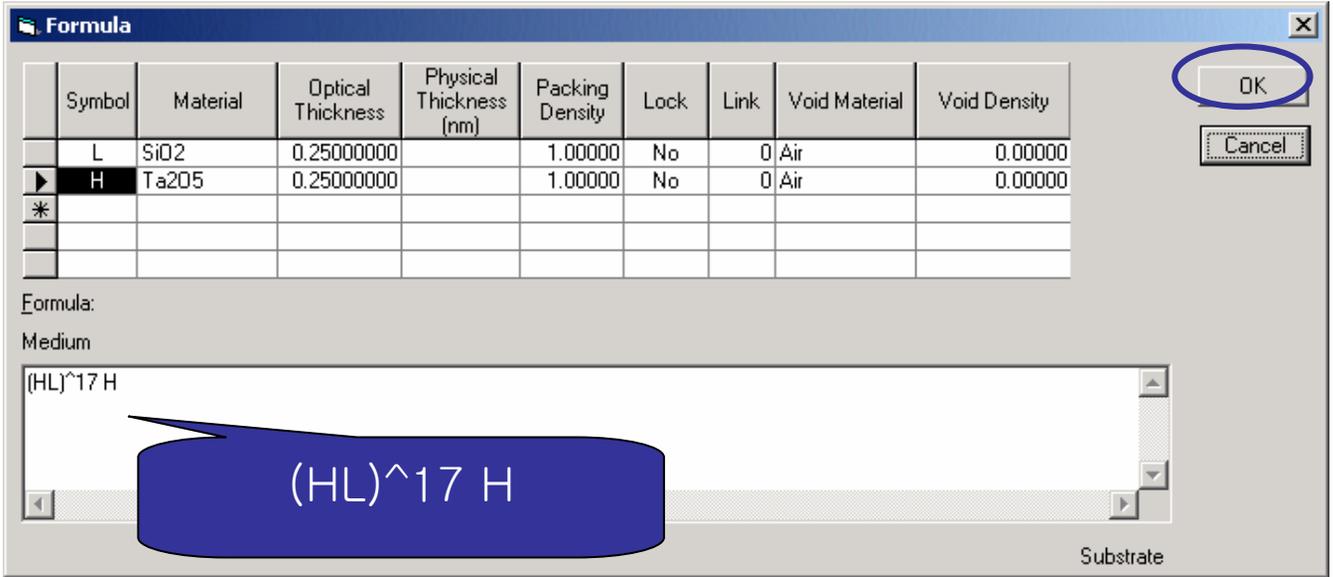
1. Tools > Materials
2. Edit > import



2. 물질 선택

※ Substartes도 같은 방식으로 import

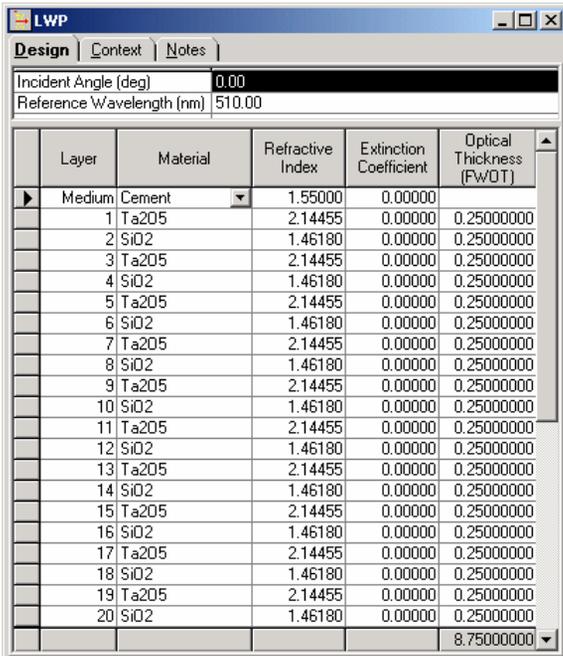
# Design File 만들기



프로그램 메뉴에서, *File > Design.*

프로그램 메뉴에서, *Edit > Formula.*

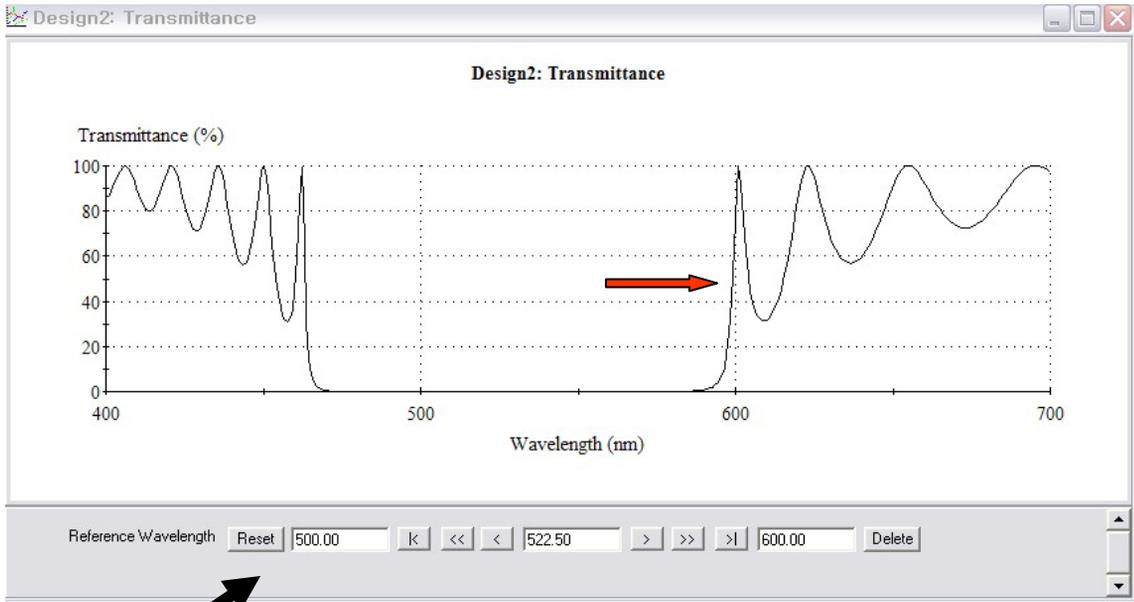
BK 7 : substrate , Cement : Incident medium.



21	Ta2O5	2.14341	0.00000	0.25000000	60.94	Yes
22	SiO2	1.46121	0.00000	0.25000000	89.40	Yes
23	Ta2O5	2.14341	0.00000	0.25000000	60.94	Yes
24	SiO2	1.46121	0.00000	0.25000000	89.40	Yes
25	Ta2O5	2.14341	0.00000	0.25000000	60.94	Yes
26	SiO2	1.46121	0.00000	0.25000000	89.40	Yes
27	Ta2O5	2.14341	0.00000	0.25000000	60.94	Yes
28	SiO2	1.46121	0.00000	0.25000000	89.40	Yes
29	Ta2O5	2.14341	0.00000	0.25000000	60.94	Yes
30	SiO2	1.46121	0.00000	0.25000000	89.40	Yes
31	Ta2O5	2.14341	0.00000	0.20335927	49.57	No
32	SiO2	1.46121	0.00000	0.27060155	96.76	No
33	Ta2O5	2.14341	0.00000	0.25256828	61.57	No
34	SiO2	1.46121	0.00000	0.18715251	66.92	No
35	Ta2O5	2.14341	0.00000	0.17234159	42.01	No
Substrate	N-BK7	1.52016	0.00001			
				8.56659345	2541.12	

# Getting the Correct Reference Wavelength

프로그램 메뉴에서, *File > Performance > Active Plot.*



프로그램 메뉴에서, *Add > reference wavelength,*

LWP

Design Context Notes

Incident Angle (deg) 0.00

Reference Wavelength (nm) 510.00

Layer	Material	Refractive Index	Extinction Coefficient	Optical Thickness (FWOT)
Medium	Cement	1.55000	0.00000	
1	Ta2O5	2.14455	0.00000	0.25000000
2	SiO2	1.46180	0.00000	0.25000000
3	Ta2O5	2.14455	0.00000	0.25000000
4	SiO2	1.46180	0.00000	0.25000000
5	Ta2O5	2.14455	0.00000	0.25000000
6	SiO2	1.46180	0.00000	0.25000000
7	Ta2O5	2.14455	0.00000	0.25000000
8	SiO2	1.46180	0.00000	0.25000000
9	Ta2O5	2.14455	0.00000	0.25000000
10	SiO2	1.46180	0.00000	0.25000000
11	Ta2O5	2.14455	0.00000	0.25000000
12	SiO2	1.46180	0.00000	0.25000000
13	Ta2O5	2.14455	0.00000	0.25000000
14	SiO2	1.46180	0.00000	0.25000000
15	Ta2O5	2.14455	0.00000	0.25000000
16	SiO2	1.46180	0.00000	0.25000000
17	Ta2O5	2.14455	0.00000	0.25000000
18	SiO2	1.46180	0.00000	0.25000000
19	Ta2O5	2.14455	0.00000	0.25000000
20	SiO2	1.46180	0.00000	0.25000000
				8.75000000

Edge가 600nm 될 때까지 reference wavelength 조정하면 약 522.50nm 됩니다.

Design2

Design Context Notes

Incident Angle (deg) 0.00

Reference Wavelength (nm) 522.50

Layer	Material	Refractive Index	Extinction Coefficient
Medium	cement	1.55000	0.000
1	Ta2O5	2.14341	0.000
2	SiO2	1.46121	0.000
3	Ta2O5	2.14341	0.000
4	SiO2	1.46121	0.000
5	Ta2O5	2.14341	0.000

# Setting Up for Refinement

프로그램 메뉴에서, *Parameters > refinement > Targets*

Design2: Targets

Standard	Color	Thickness	Wavelength (nm)	Operator	Required Value	
			400.00	=	0.000000	Reflectance (%)
			425.00	=	0.000000	Reflectance (%)
			450.00	=	0.000000	Reflectance (%)
			475.00	=	0.000000	Reflectance (%)
			500.00	=	0.000000	Reflectance (%)
			525.00	=	0.000000	Reflectance (%)
			550.00	=	0.000000	Reflectance (%)
			575.00	=	0.000000	Reflectance (%)
			600.00	=	0.000000	Reflectance (%)
			625.00	=	0.000000	Reflectance (%)
			650.00	=	0.000000	Reflectance (%)
			675.00	=	0.000000	Reflectance (%)
			700.00	=	0.000000	Reflectance (%)

Generate Targets

Wavelength (nm)  
Start: 600 End: 850 Step: 1

Incident Angle (deg)  
Start: 0 End: 0 Step: 0

General  
Context: Normal  
Operator: =  
Required Value: 100  
Weight: 1  
Target Tolerance:  
Type: Transmittance (%)  
Derivative: 0  
Pol: P

Data 입력 후  
"New" 클릭.

프로그램 메뉴에서  
, *Edit > Generate*

Standard	Color	Thickness	Wavelength (nm)	Required Value	Target Tolerance	Type
			600.00	100.000000	1.000000	Transmittance (%)
			601.00	100.000000	1.000000	Transmittance (%)
			602.00	100.000000	1.000000	Transmittance (%)
			603.00	100.000000	1.000000	Transmittance (%)
			604.00	100.000000	1.000000	Transmittance (%)
			605.00	100.000000	1.000000	Transmittance (%)
			606.00	100.000000	1.000000	Transmittance (%)
			607.00	100.000000	1.000000	Transmittance (%)
			608.00	100.000000	1.000000	Transmittance (%)
			609.00	100.000000	1.000000	Transmittance (%)
			610.00	100.000000	1.000000	Transmittance (%)
			611.00	100.000000	1.000000	Transmittance (%)
			612.00	100.000000	1.000000	Transmittance (%)
			613.00	100.000000	1.000000	Transmittance (%)
			614.00	100.000000	1.000000	Transmittance (%)
			615.00	100.000000	1.000000	Transmittance (%)
			616.00	100.000000	1.000000	Transmittance (%)
			617.00	100.000000	1.000000	Transmittance (%)
			618.00	100.000000	1.000000	Transmittance (%)
			619.00	100.000000	1.000000	Transmittance (%)
			620.00	100.000000	1.000000	Transmittance (%)
			621.00	100.000000	1.000000	Transmittance (%)
			622.00	100.000000	1.000000	Transmittance (%)
			623.00	100.000000	1.000000	Transmittance (%)

The screenshot shows the LWP software interface with the 'Design' tab selected. The 'Incident Angle (deg)' is 0.00 and the 'Reference Wavelength (nm)' is 522.50. Below this is a table with columns: Layer, Material, Refractive Index, Extinction Coefficient, Optical Thickness (FWOT), and Lock. The 'Lock' column contains 'No' for layers 1-5 and 'Yes' for layers 6-25. A blue circle highlights the 'Lock' column header, and a mouse cursor is positioned over it.

Layer	Material	Refractive Index	Extinction Coefficient	Optical Thickness (FWOT)	Lock
Medium	Cement	1.55000	0.00000		
1	Ta2O5	2.14341	0.00000	0.25000000	No
2	SiO2	1.46121	0.00000	0.25000000	No
3	Ta2O5	2.14341	0.00000	0.25000000	No
4	SiO2	1.46121	0.00000	0.25000000	No
5	Ta2O5	2.14341	0.00000	0.25000000	No
6	SiO2	1.46121	0.00000	0.25000000	Yes
7	Ta2O5	2.14341	0.00000	0.25000000	Yes
8	SiO2	1.46121	0.00000	0.25000000	Yes
9	Ta2O5	2.14341	0.00000	0.25000000	Yes
10	SiO2	1.46121	0.00000	0.25000000	Yes
11	Ta2O5	2.14341	0.00000	0.25000000	Yes
12	SiO2	1.46121	0.00000	0.25000000	Yes
13	Ta2O5	2.14341	0.00000	0.25000000	Yes
14	SiO2	1.46121	0.00000	0.25000000	Yes
15	Ta2O5	2.14341	0.00000	0.25000000	Yes
16	SiO2	1.46121	0.00000	0.25000000	Yes
17	Ta2O5	2.14341	0.00000	0.25000000	Yes
18	SiO2	1.46121	0.00000	0.25000000	Yes
19	Ta2O5	2.14341	0.00000	0.25000000	Yes
20	SiO2	1.46121	0.00000	0.25000000	Yes
21	Ta2O5	2.14341	0.00000	0.25000000	Yes
22	SiO2	1.46121	0.00000	0.25000000	Yes
23	Ta2O5	2.14341	0.00000	0.25000000	Yes
24	SiO2	1.46121	0.00000	0.25000000	Yes
25	Ta2O5	2.14341	0.00000	0.25000000	Yes
				8.75000000	

Design file이 선택된 상태에서

프로그램 메뉴에서, lock/Link > Lock All

상위 5 Layer와

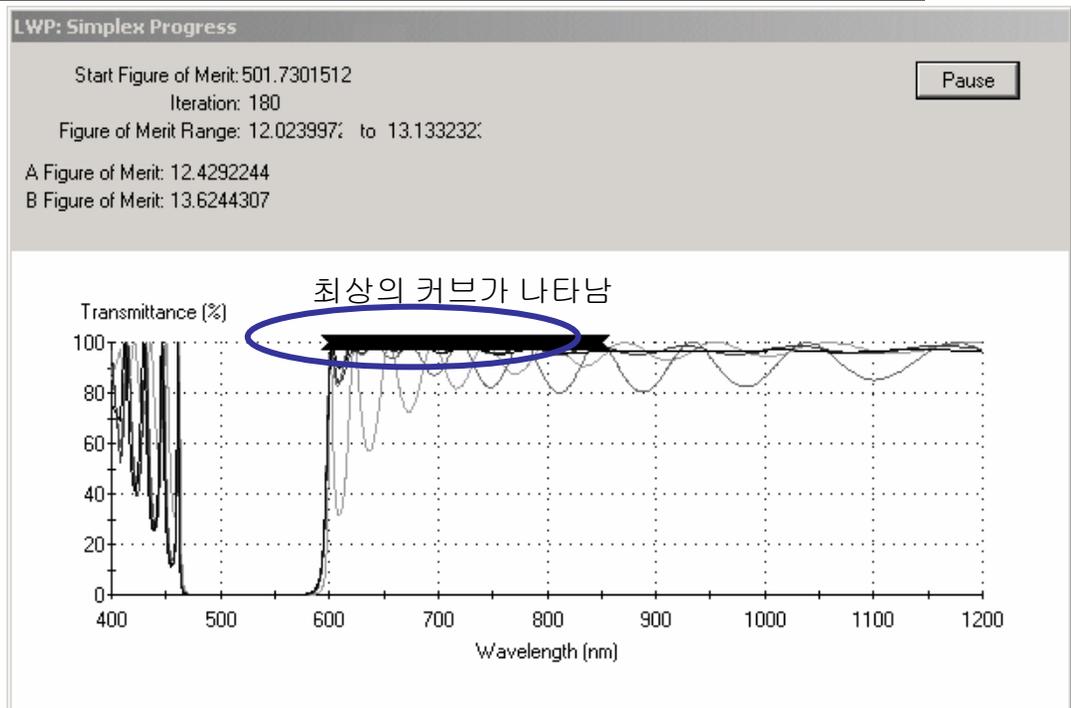
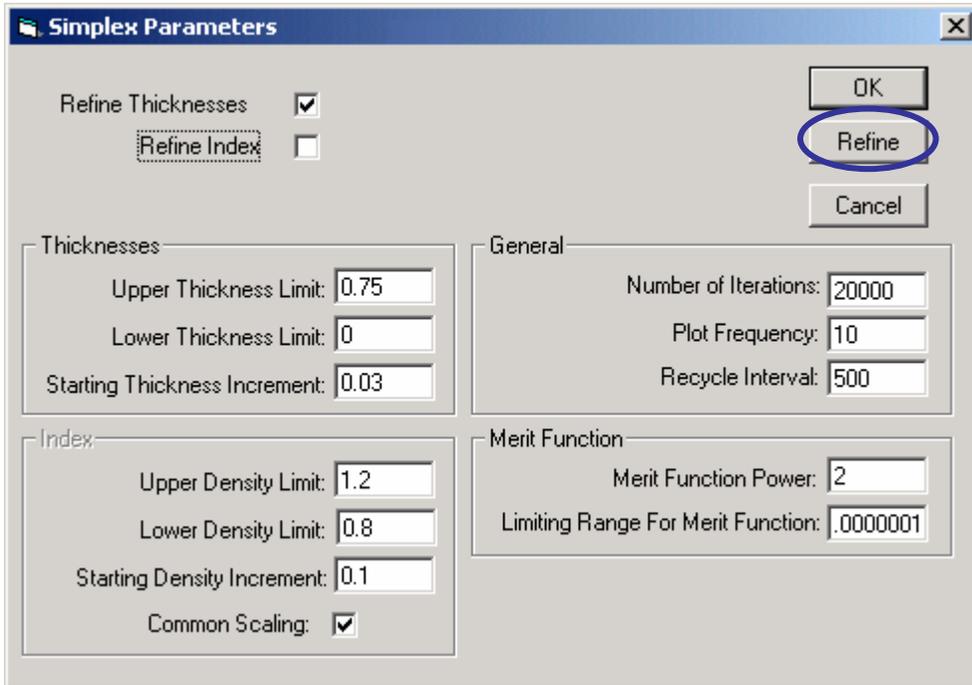
하위 5 Layer만

마우스로 클릭하여

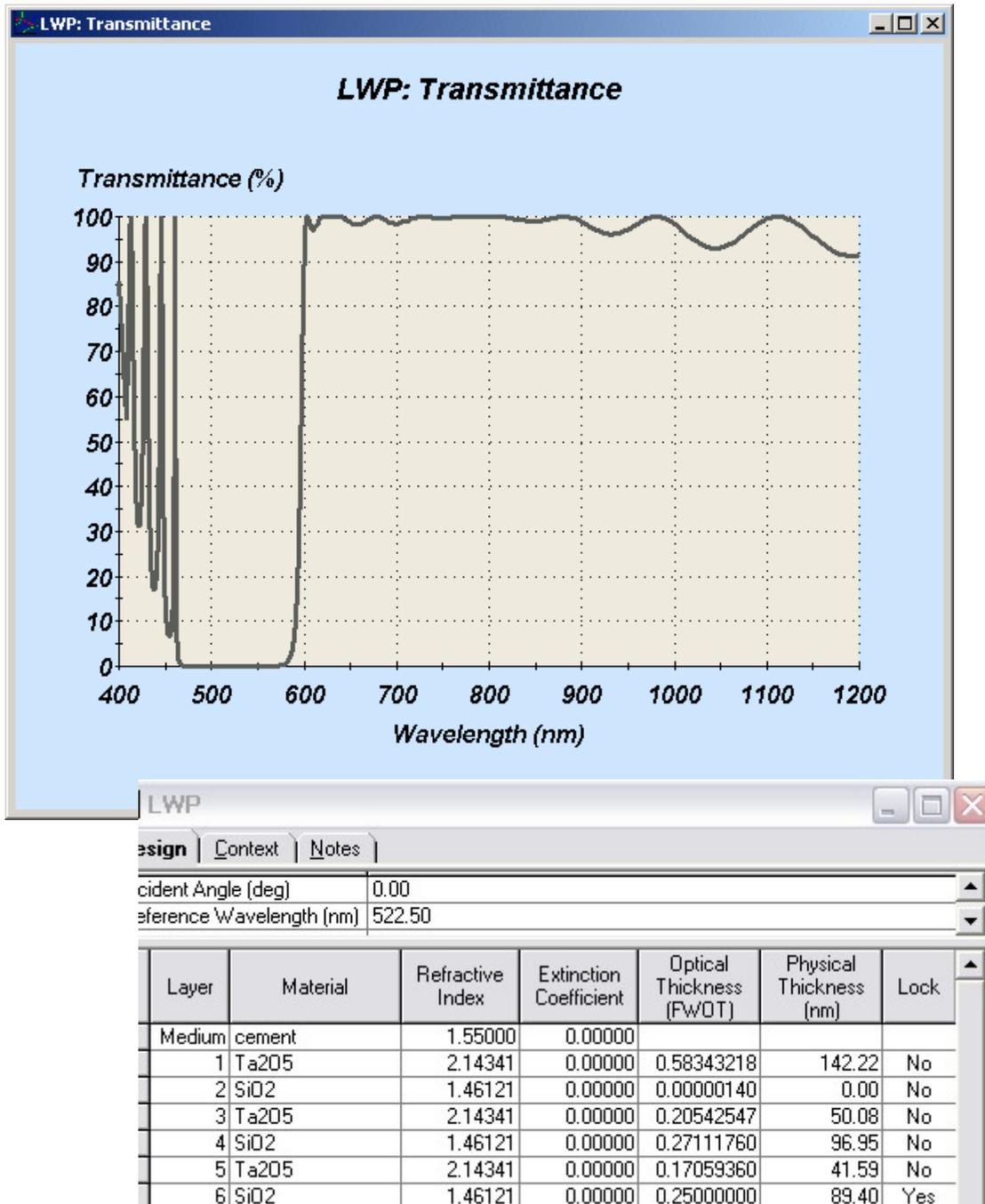
“Lock No” 로 변경

# Ripple 제거를 위한 Refinement

프로그램 메뉴에서,  
Parameters > Refinement > Simplex

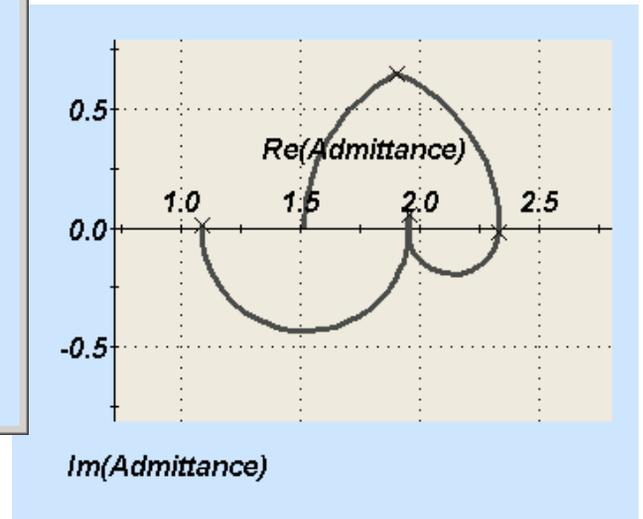
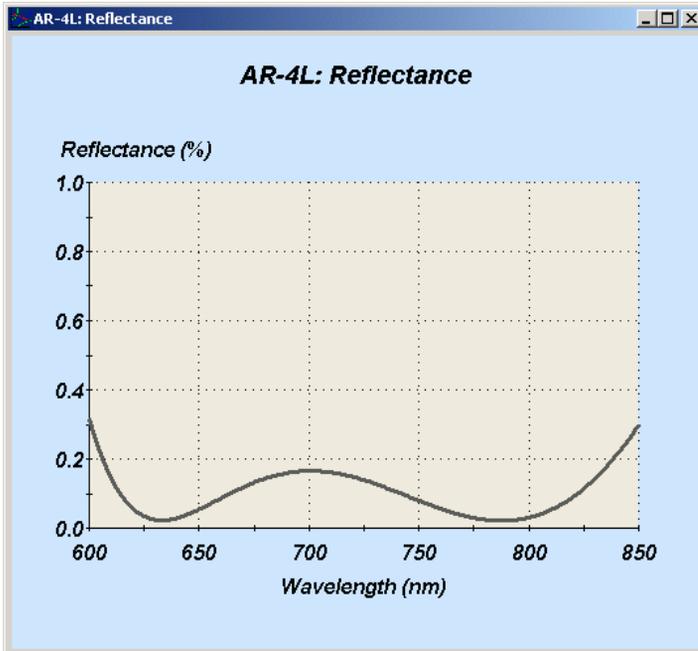


# Performance of the Long Wave Pass Filter



# The Antireflection Coating

AR-4L					
Design   Context   Notes					
Incident Angle (deg)		0.00			
Reference Wavelength (nm)		510.00			
	Layer	Material	Refractive Index	Extinction Coefficient	Optical Thickness (FWOT)
	Medium	Air	1.00000	0.00000	
	1	SiO2	1.46180	0.00000	0.35773306
	2	Ta2O5	2.14455	0.00000	0.37169681
	3	SiO2	1.46180	0.00000	0.08681442
	4	Ta2O5	2.14455	0.00000	0.15405159
	Substrate	N-BK7	1.52092	0.00001	
					0.97029588

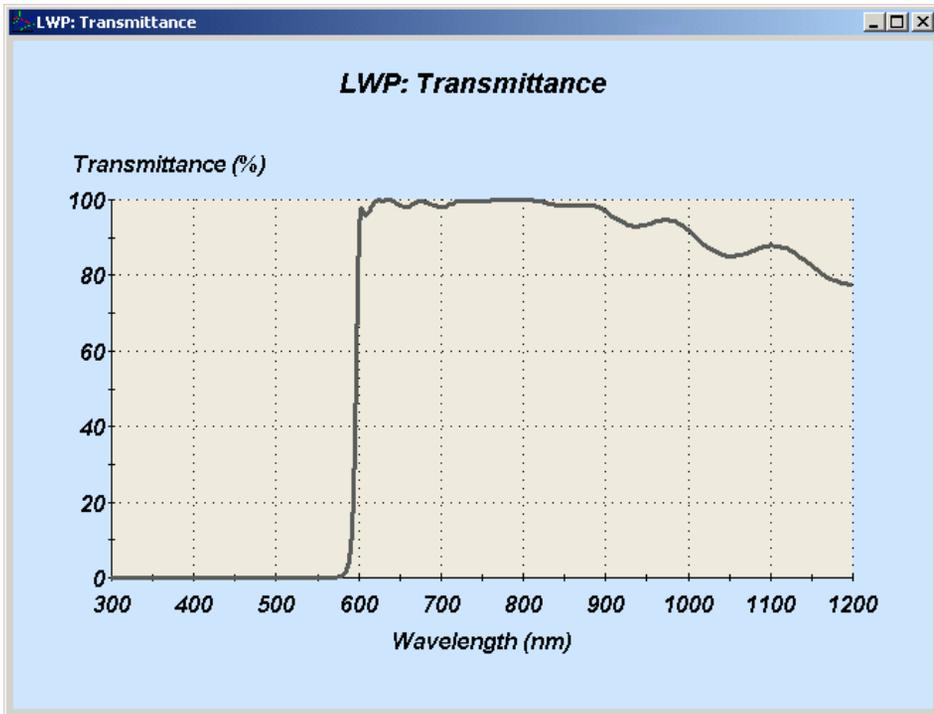


프로그램 메뉴에서, *Tools > Analysis > Admittance*

# Complete Performance Modeled by Stack

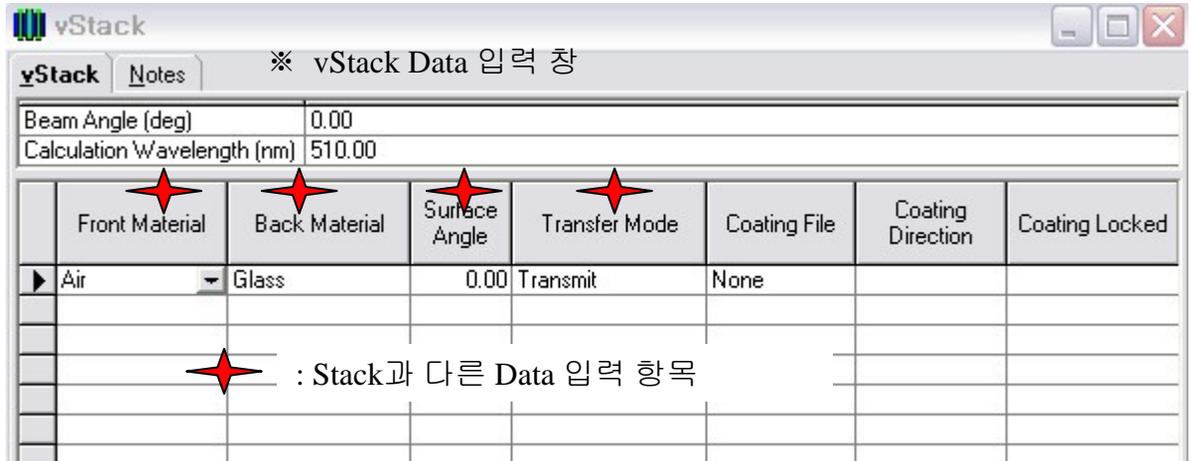
프로그램 메뉴에서, *File > New > Stack*

Medium Type	Medium Material	Medium Substrate	Medium Thickness (mm)	Coating File	Coating Direction	Coating Locked
Incident	Air					
Parallel	OG 570 b	OG 570	3.000	ar-4l.dds	Forward	No
Parallel	Cement	Lossless	1.000	None		
Parallel	N-BK7	N-BK7 25mm	1.000	lwp.dds	Forward	No
Emergent	Air			ar-4l.dds	Reversed	No



Stack을 이용하여 AR Coating과 조합.

※ Stack과 선택사항인 vStack 차이.



**Front Material** specifies the material in which the light is incident on the surface.

**Back Material** specifies the material on the other side of the surface from the front material.

**Surface Angle** specifies the angle that the surface normal makes with the reference direction

**Transfer Mode** specifies the component of light that is transferred from one surface to the next. This parameter has seven values:

**Transmit:** The transmitted portion of the beam is propagated to the next surface and the reflected beam is discarded.

**Reflect:** The reflected portion of the beam is propagated to the next surface and the transmitted beam is discarded.

**Perfect Reflect:** This special mode reflects 100% of the beam and propagates it to the next surface.

**Rotate 0:** This special mode rotates the beam 90 degrees about its axis and propagates it to the next surface.

**Rotate 90:** This special mode has no effect on the beam and propagates it to the next surface. It is included to make it easy to switch off any of the rotations listed below.

**Rotate 180:** This special mode rotates the beam 180degrees about its axis and propagates it to the next surface.

**Rotate -90:** This special mode rotates the beam 270 degrees about its axis and propagates it to the next surface.

**Perfect Retro:** This special mode reflects 100% of the beam back along the direction that it entered and propagates it to the next surface.

# 제조(생산)를 위한 고려 사항들

RunSheet 와 Simulator를 이용하여 제조(생산)에 대한 검토와 계획을 할 수 있습니다.

## 1. Machine Configuration

Coating machine, monitoring systems, sources, tooling factors, monitoring chips 등의 세부사항을 설정, 설계에 반영합니다.

## 2. RunSheet

증착 동안의 layer thickness 제어에 대한 계획을 세우기 위한 monitoring signals을 예측 합니다.

## 3. Simulator

완성된 RunSheet를 이용하여 errors in tooling factors, wavelength, packing density, temperature 및 signal noise가 포함된 실제 코팅 생산 예측(Simulation)을 합니다.

# Machine Configuration

프로그램 메뉴에서, *File > New > Machine Configuration*

RunSheet를 이용하기 위해서는 Machine Configuration에서 General, Sources와 Monitoring Chips 정보와, 그리고 필요시 Wideband 정보가 필요 합니다. 그 외 입력 정보들은 Simulator에 필요하며 그 값들은 지금 설계한 Edge Filter에 사용, 시험해 보겠습니다. 두께 제어를 위한 optical tooling factors 를 1.2 설정합니다.

The screenshot shows the 'Machine 1' configuration window with three tabs: 'General', 'Sources', and 'Monitoring Chips'. The 'General' tab is selected and circled in blue. The 'Sources' tab is also circled in blue, and its table is highlighted with a red border. The 'Monitoring Chips' tab is circled in blue in the bottom window.

**General Tab Settings:**

- Plant Configuration: Incident Angle: 0.0, Deposition Medium: Air
- Crystal Controller: Thickness Scale Factor: 0.0000001, Thickness Symbol: kÅ
- Monitoring Capability:  Optical,  Crystal
- Dynamic Tooling Factor: Reset for each Layer: , Tooling Scale Factor: 0.000000001, Tooling Unit Symbol: nm

**Sources Tab Table:**

Source	Material	Optical Tooling Factor	Crystal Tooling Factor	Deposition Rate (nm/s)	Line Color
Titania	Ta2O5	1.2000	1.0000	1.00	Blue
Silica	SiO2	1.2000	1.0000	1.00	Red
*					

**Monitoring Chips Tab Table:**

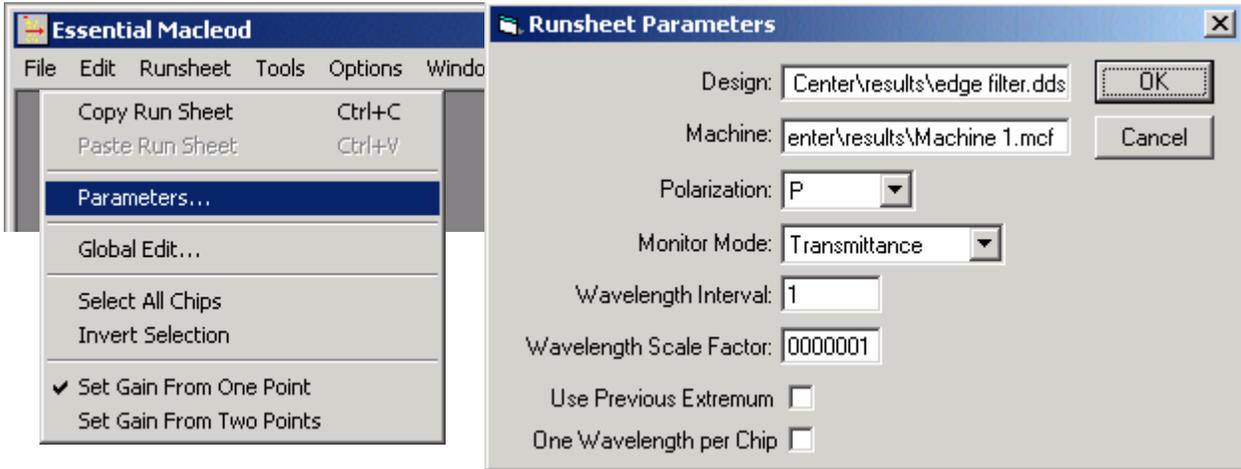
Name	Material	Substrate	Thickness (mm)	Back Surface
Glass	Glass	Lossless	1	Untreated
*				

# RunSheet

프로그램 메뉴에서, *File > New > RunSheet*

프로그램 메뉴에서, *Edit > Parameters*

Default values can then be changed easily by *Global Edit* or manually.



Run Sheet

Chip	Layer	Source	Material	Crystal Thickness (kÅ)	Monitor Wavelength (nm)	Monitor Bandwidth (nm)	Quarterwave Optical Thickness on Chip	Monitor Spectrum	Simulation Spectrum	Zero Offset	Gain	Monitor Type	St.
	20	Silica	SiO2	0.893954	510.00	10.00				0.000	1.000	Optical	
	21	Titania	Ta2O5	0.609426	510.00	10.00				0.000	1.000	Optical	
	22	Silica	SiO2	0.893954	510.00	10.00				0.000	1.000	Optical	
	23	Titania	Ta2O5	0.609426	510.00	10.00				0.000	1.000	Optical	
	24	Silica	SiO2	0.893954	510.00	10.00				0.000	1.000	Optical	
	25	Titania	Ta2O5	0.609426	510.00	10.00				0.000	1.000	Optical	
	26	Silica	SiO2	0.893954	510.00	10.00				0.000	1.000	Optical	
	27	Titania	Ta2O5	0.609426	510.00	10.00				0.000	1.000	Optical	
	28	Silica	SiO2	0.893954	510.00	10.00				0.000	1.000	Optical	
	29	Titania	Ta2O5	0.609426	510.00	10.00				0.000	1.000	Optical	
	30	Silica	SiO2	0.893954	510.00	10.00				0.000	1.000	Optical	
	31	Titania	Ta2O5	0.529007	510.00	10.00				0.000	1.000	Optical	
	32	Silica	SiO2	1.052677	510.00	10.00				0.000	1.000	Optical	

프로그램 메뉴에서, *RunSheet > Calculate*

Chip	Layer	Source	Material	Crystal Thickness (kÅ)	Monitor Wavelength (nm)	Monitor Bandwidth (nm)	Quarterwave Optical Thickness on Chip	Monitor Spectrum	Simulation Spectrum	Zero Offset	Gain	Monitor Type	Start At	First Maxima	First Minima	Last Maxima	Last Minima	Finish At	Final Swing	Peaks
1: Glass	1	Titania	TiO2	0.223289	500.00	1.00	0.505			0	1	Optical	91.7980					76.2047	16.9865	↑
	2	Silica	SiO2	0.937082	500.00	1.00	1.316			0	1	Optical	76.2047	93.8514	74.4274			93.2887	2.8965	↓
	3	Titania	TiO2	0.424921	500.00	1.00	0.962			0	1	Optical	93.2887		41.5628			41.5704	0.0147	↓
	4	Silica	SiO2	0.804786	500.00	1.00	1.130			0	1	Optical	41.5704	67.9001				66.0113	7.1738	↑
2: Glass	5	Titania	TiO2	0.642370	500.00	1.00	1.454			0	1	Optical	66.0113		19.3072			32.2773	27.7707	↓
	6	Silica	SiO2	0.719674	500.00	1.00	1.010			0	1	Optical	32.2773	49.6602				39.2242	60.0361	↑
	7	Titania	TiO2	0.554994	500.00	1.00	1.256			0	1	Optical	39.2242		14.6080			24.1182	38.6339	↓
3: Glass	8	Silica	SiO2	0.881331	500.00	1.00	1.237			0	1	Optical	24.1182	38.9356				24.6664	96.2999	↑
	9	Titania	TiO2	0.554994	500.00	1.00	1.256			0	1	Optical	24.6664		14.0321			35.3541	200.5013	↓
	10	Silica	SiO2	0.881331	500.00	1.00	1.237			0	1	Optical	35.3541	46.6087				26.7761	176.2172	↑
	11	Titania	TiO2	0.554994	500.00	1.00	1.256			0	1	Optical	26.7761		22.8730			74.3369	318.5114	↓

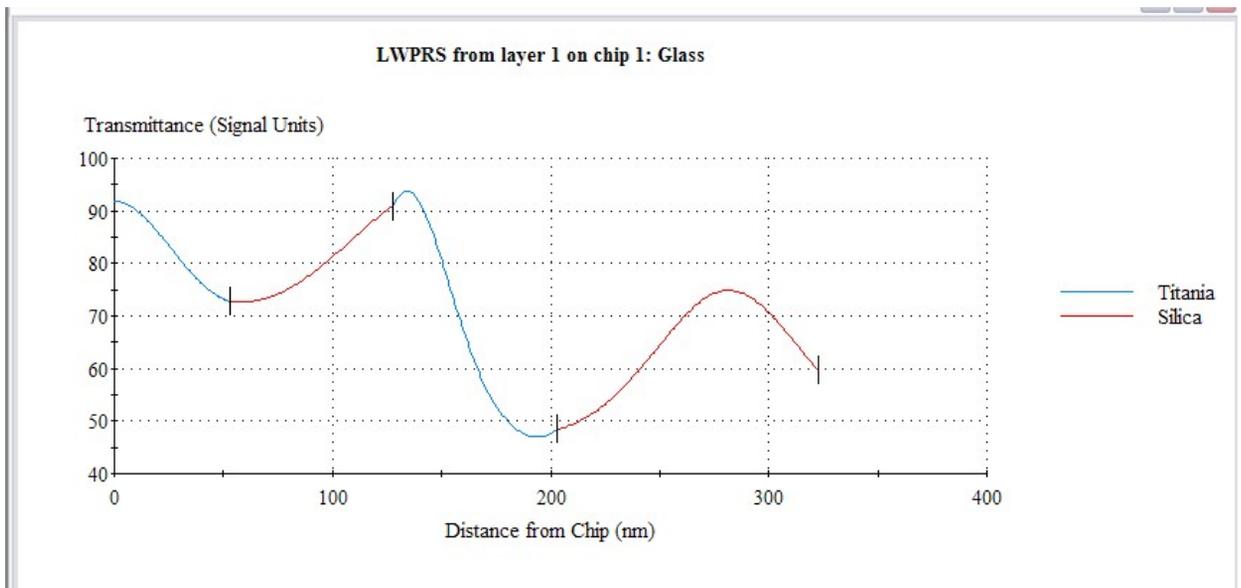
Monitoring chips은 항상 Titania 시작해서 두 Layer의 Silica를 갖는 경우입니다. 해당 Chip에 마우스를 놓고 클릭하면 Chip 번호가 순서대로 나오게 됩니다.

LWPRS

Chip, 1.Glass를 마우스로 클릭하고

Chip	Layer	Source	Material	Crystal Thickness (kÅ)	Monitor Wavelength (nm)	Monitor Bandwidth (nm)	Quarterwave Optical Thickness on Chip	Monitor Spectrum
1: Glass	1	Titania	Ta2O5	0.444625	510.00	10.00	0.897	
	2	Silica	SiO2	0.617631	510.00	10.00	0.850	
	3	Titania	Ta2O5	0.629584	510.00	10.00	1.271	
	4	Silica	SiO2	0.996188	510.00	10.00	1.371	
2: Glass	5	Titania	Ta2O5	0.481766	510.00	10.00	0.972	
	6	Silica	SiO2	0.893954	510.00	10.00	1.230	
	7	Titania	Ta2O5	0.609426	510.00	10.00	1.220	

프로그램 메뉴에서, *RunSheet > Plot one Chip*



LWPRS Chip, 2.Glass를 마우스로 클릭하고

Chip	Layer	Source	Material	Crystal Thickness (kÅ)	Monitor Wavelength (nm)	I B.
1: Glass	1	Titania	Ta2O5	0.444625	510.00	
	2	Silica	SiO2	0.617631	510.00	
	3	Titania	Ta2O5	0.629584	510.00	
	4	Silica	SiO2	0.996188	510.00	
2: Glass	5	Titania	Ta2O5	0.481766	510.00	
	6	Silica	SiO2	0.893954	510.00	
	7	Titania	Ta2O5	0.609426	510.00	
	8	Silica	SiO2	0.893954	510.00	

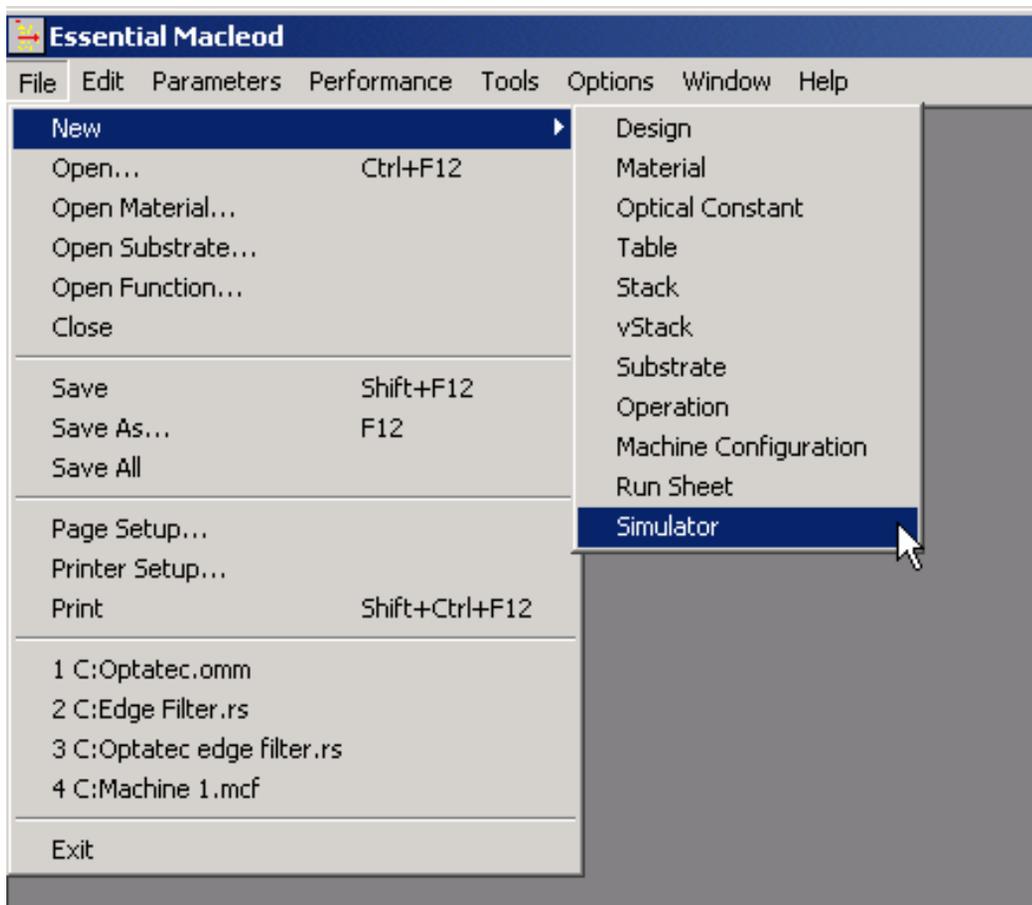
프로그램 메뉴에서, *RunSheet > Plot one Chip*



Run Sheet 파일은 “File” > “Export” > “CSV File “ ( a comma-separated variable) 기능으로 엑셀 또는 Note 포맷 파일 등으로 변환 하여 Coating Controller 등 다른 프로그램에서 그대로 활용이 가능 합니다.

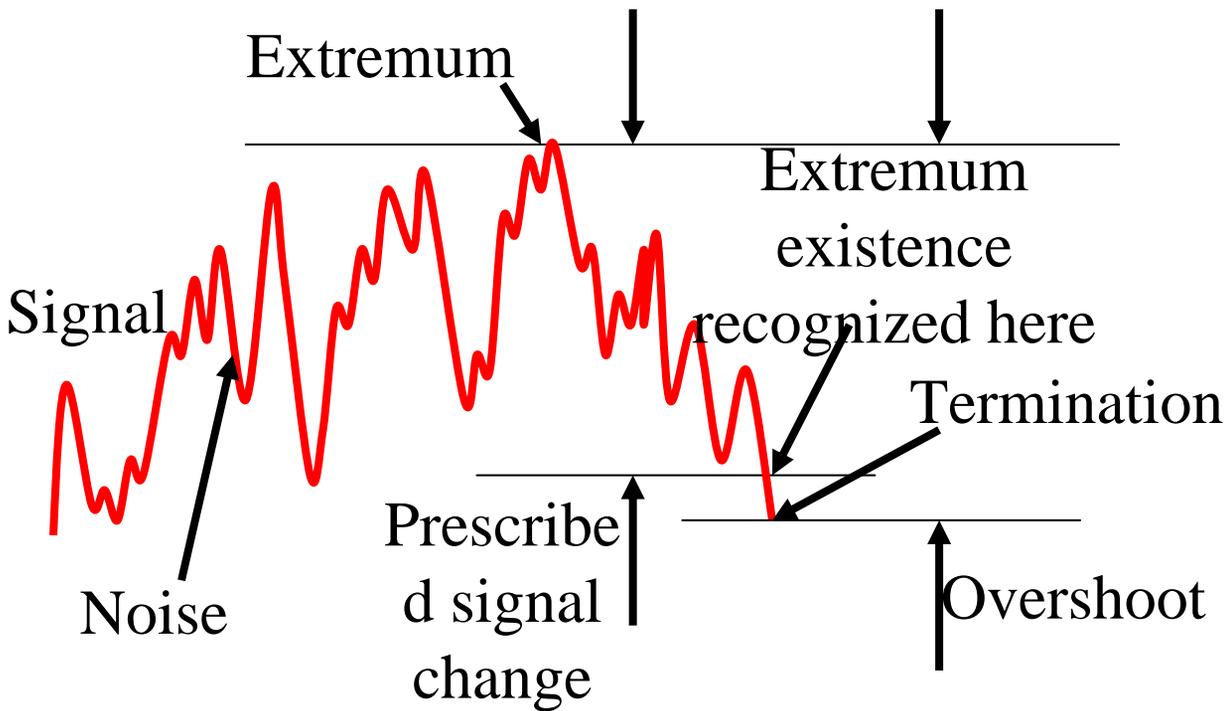
# Simulator

Simulator를 이용하여 코팅 생산을 시뮬레이션 하여 모니터링 수행의 유효성 체크를 해 보겠습니다.

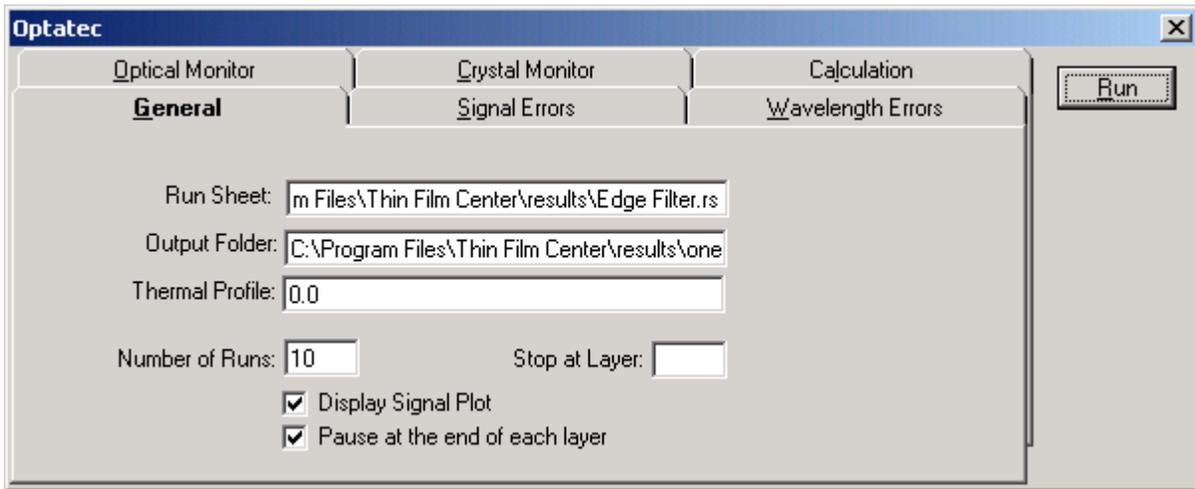


# Monitoring Simulation

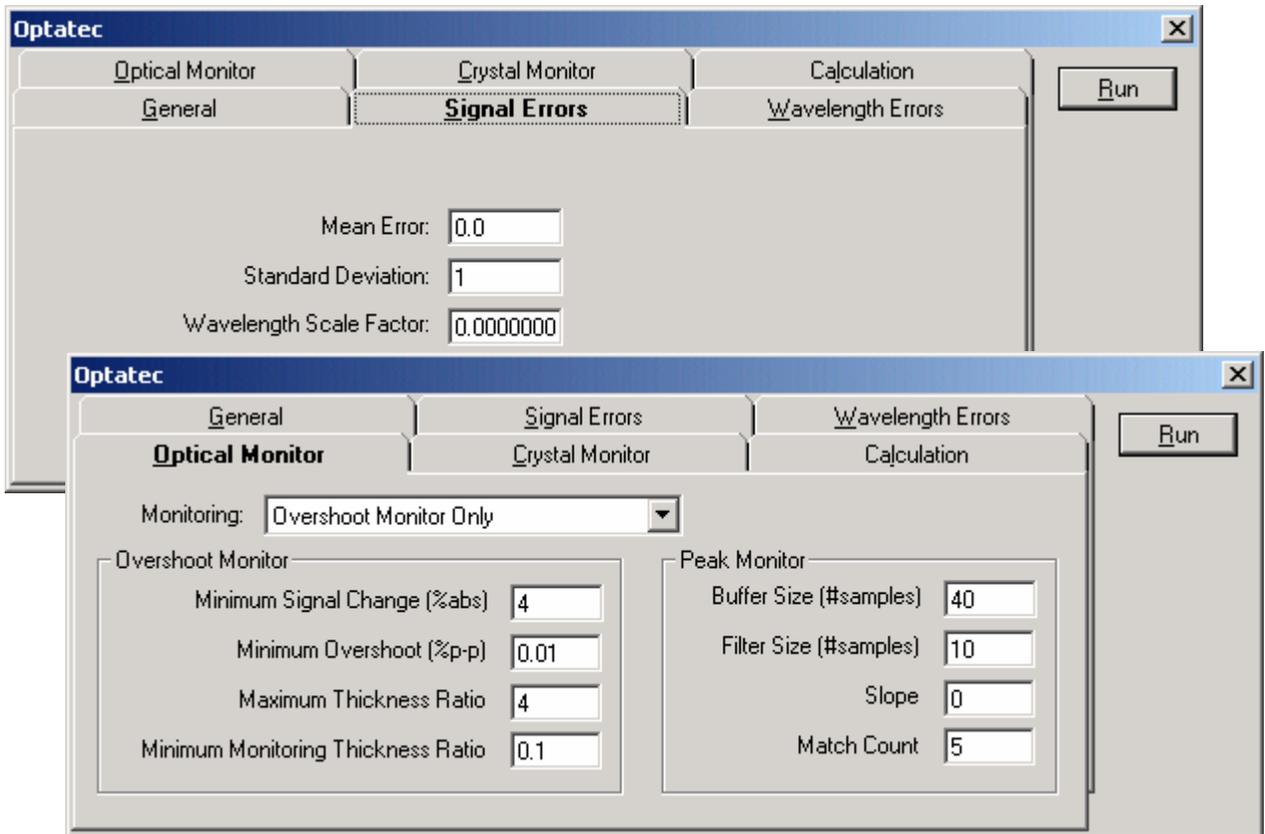
Simulato에서 극점 검파은 최대 또는 최소를 지나가는 규정된 신호 변화에 의해서 되며  
 추가적인 overshoot 역시 정의 할 수도 있고 , 그것이 규정된 신호변화 보다 작은 경우의  
 Layer는 극점에서 종결 될 수도 있습니다.



# Simulator

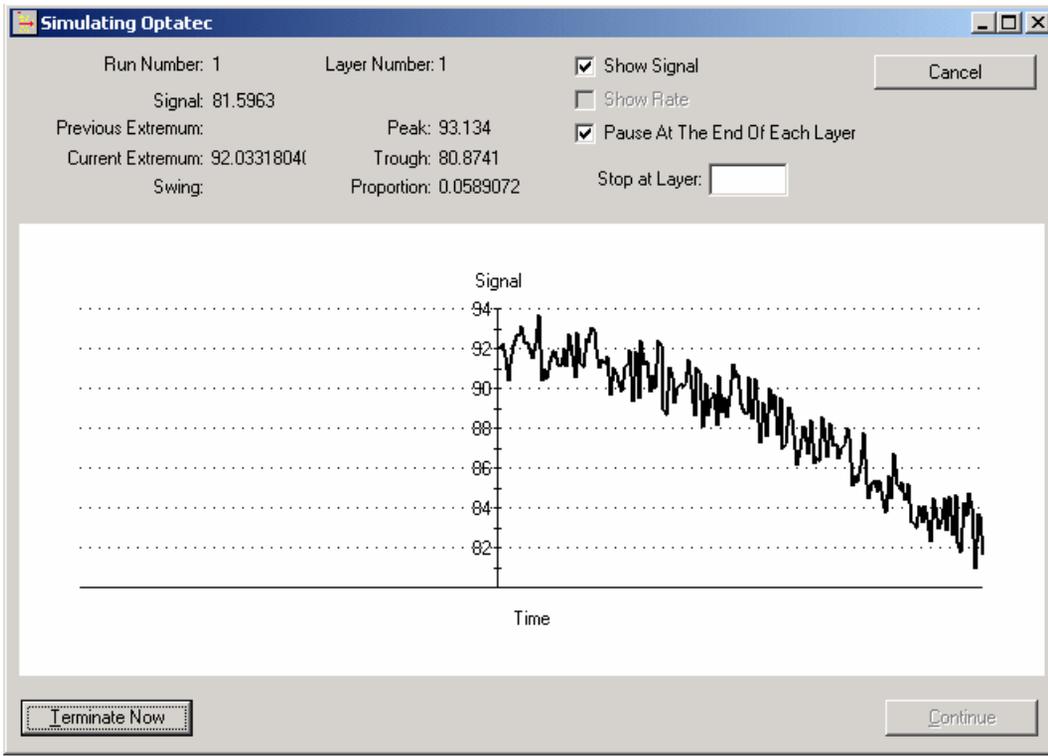


Standard deviation for optical signal noise : 1 입력.

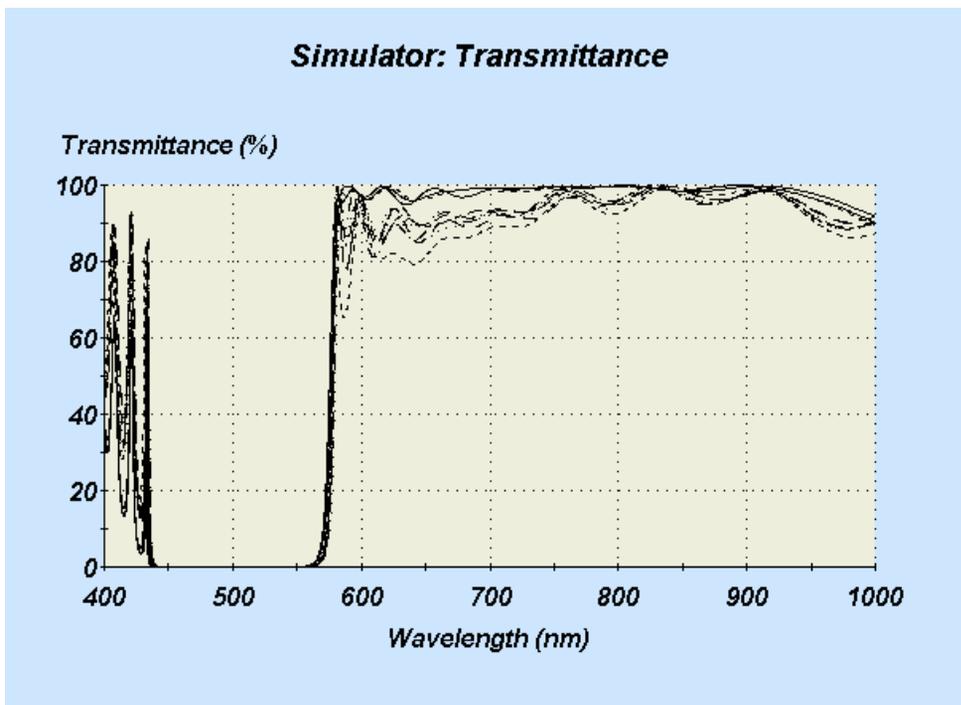


Minimum signal change 값은 signal noise의 4배와 같거나 이상.

아래 그림 : The signal during the monitoring of the first layer on the first chip

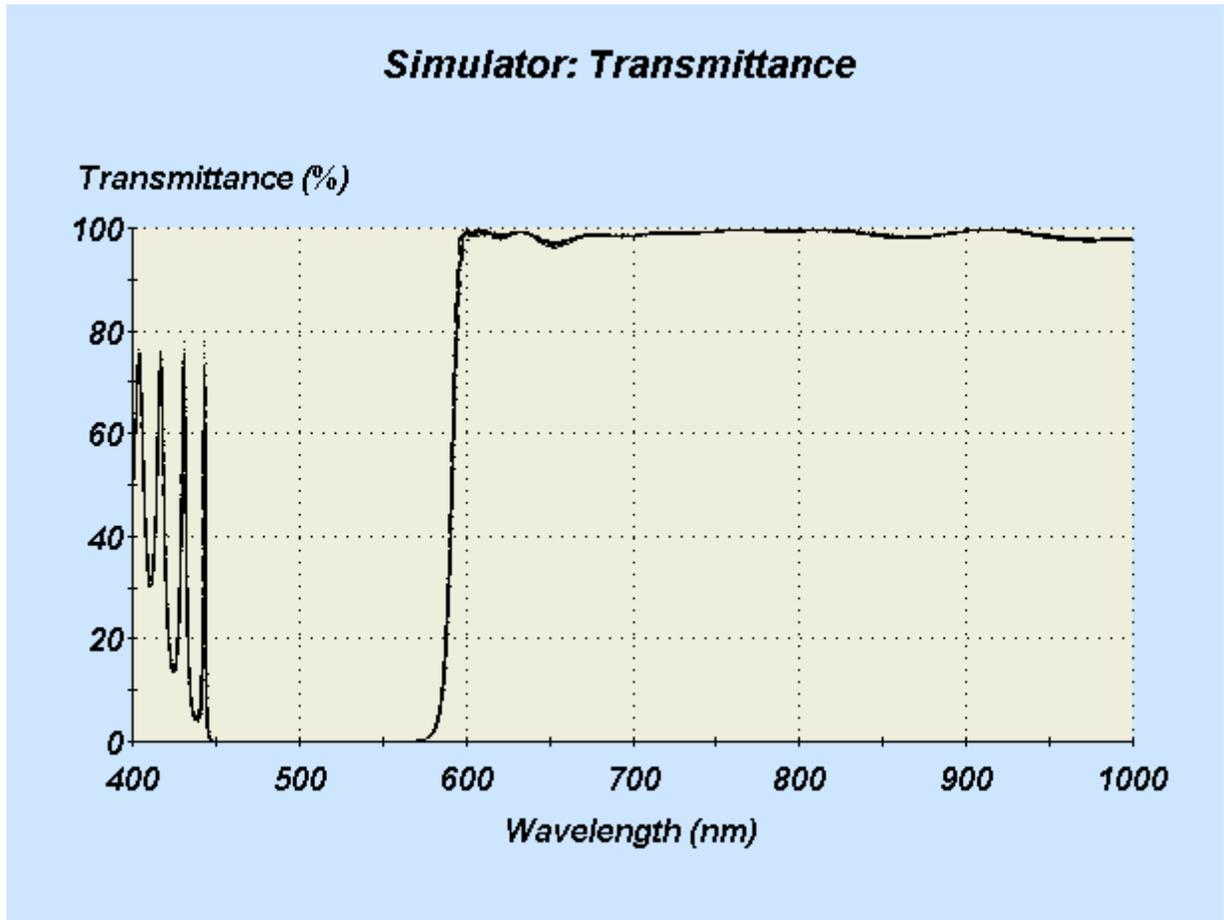


Simulator의 10회 최종결과 목표치 대비 조금 미흡 하므로



Signal Errors에서 standard deviation : 0.4%,

Optical Monitor에서 minimum signal change : 2% 수정한 후 다시 Simulation 하면



거의 완벽한 결과치를 보여주며 보다 더 완벽한 설계를 위해서는  
Edge를 600nm로 가계꿈 조금 수정 하거나 tooling factor errors  
또는 temperature 등의 변화를 주어 다시 Simulation을 하면 됩니다.

# *Theoretical Performance of the Final Design*

