Technical Information of Optical Waveguide Resin :

Exguide™ ZPU12-RI & ZPU13-RI

ChemOptics Inc.

Application

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Exguide™ is a name of excellent optical waveguide resin manufactured by ChemOptics. Exguide™, ZPU12-RI & ZPU13-RI, series are photo-active UV curable fluorinated resins based on acrylate. They are useful for optical waveguide devices and optical thin film applications. The main applications are as follows:

- Passive optical waveguide devices
  - ✓Optical power splitter
  - ✓ PLC waveguide platform
  - ✓ Optical interconnection
- Thermo-optic waveguide devices
  - ✓ Optical switches,
  - ✓ Variable optical attenuators (VOA)
  - ✓ Tunable wavelength filters
- WDM related devices (AWG, router, interleaver, etc.)
- Hybrid waveguides for silica and glass waveguides

Features

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These coating resins have a low optical loss for optical communication wavelengths, small birefringence, and excellent environmental stability. To be used for various waveguide structures, precise and continuous control of refractive index is available by blending of standard polymer solutions. To achieve the best film quality, a nitrogen environment should be required during the UV exposure.

- UV curable type (solvent free)
- Low optical propagation loss
- High environmental stability
- Continuous and precise control of refractive index
- Low optical birefringence
- Good and easy ability to process
- Excellent adhesion property
- Easy control of film thickness

Performance specifications

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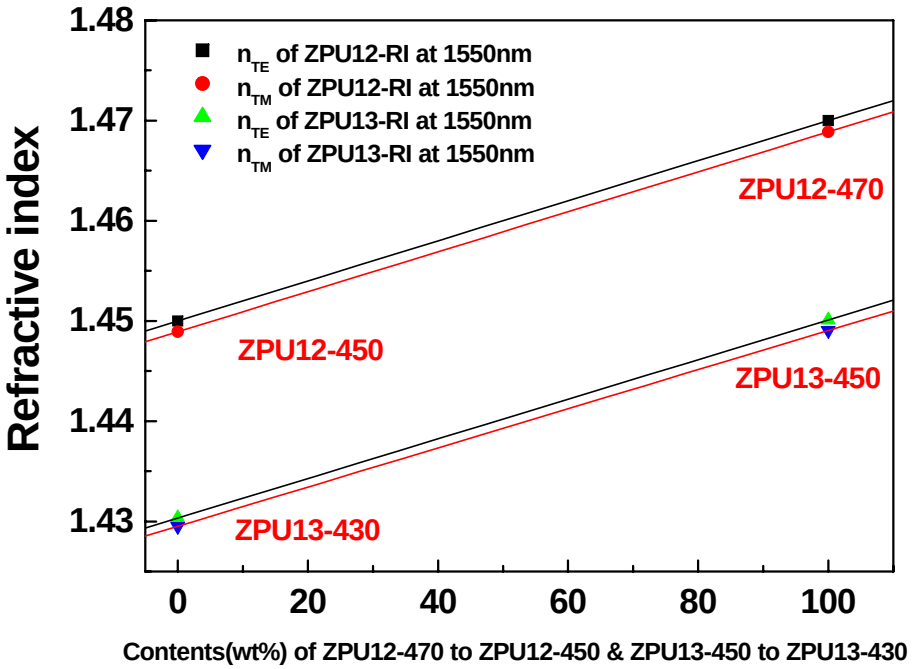
Exguide™		ZPU13-RI			ZPU12-RI		
		430	450	460	450	470	480
Liquid	Viscosity (cps @25 °C)	50 ~ 200			200 ~ 350		
	Filtration	0.1 ~ 0.2 μm absolute PTFE filter					
	UV-exposure	> 2500 mJ/cm^2 (160 °C/30 min, post baking)					
Film	Propagation loss (measured from slab waveguide)	**0.32 dB/cm @ 1.55 μm**			**0.35 dB/cm @ 1.55 μm**		
		< 0.1 dB/cm @ 1.30 μm			**< 0.1 dB/cm @ 1.30 μm**		
	Refractive Index @ 1.55 μm	1.4300	1.4500	1.4600	1.4500	1.4700	1.4800
	Birefringence ($n_{TE} - n_{TM}$)	0.0007 ± 0.0003			0.001 ± 0.0003		
	Refractive index uniformity	**<0.00012**			**<0.00012**		
	Thermo-optic coefficient	~ -1.8 x 10^{-4} / °C			~ - 1.7 x 10^{-4} / °C		
	CTE (ppm/°C, by TMA)	300~400			200~300		
	Glass Transition Temp. (Tg)	Not detectable			Not detectable		
	Degradation Temp. (1 wt%)	300 ± 10 °C			300 ± 10 °C		
	Surface roughness (AFM)	**< 0.35 nm at 8 μm thickness**			**< 0.35 nm at 8 μm thickness**		
	Film thickness	< 25 μm per coating (multi-coating available)					

Continuous Control of Refractive Index

The precise control of refractive index can be achieved by simple blending of two polymers. The blended polymers exhibit intermediate properties of original polymers according to blending ratio.



Tuning of refractive index

n_{TE} **(RI, mix) = 2 x 10^{-4} (wt%) + 1.45 or 1.43**

So,

wt% = 1/(2x10^{-4}) x (n_{TE} – 1.45 or 1.43)

Blending ratio **Target refractive index**

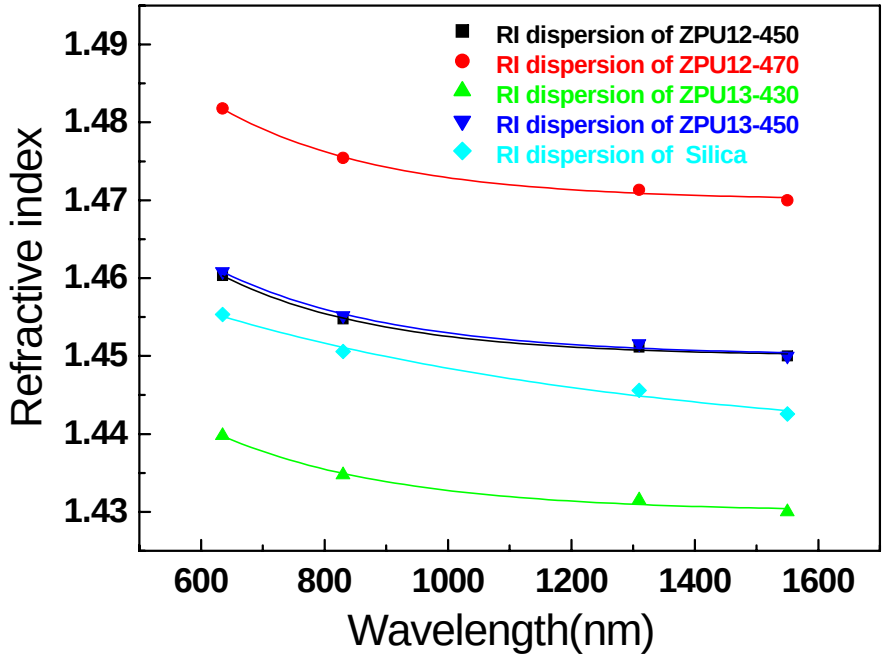
example) If you want RI(n_{TE}) = 1.4550 tuning?

Blending ratio (wt%)

=1/ (2×10^{-4}) × (1.4550–1.45) = 25

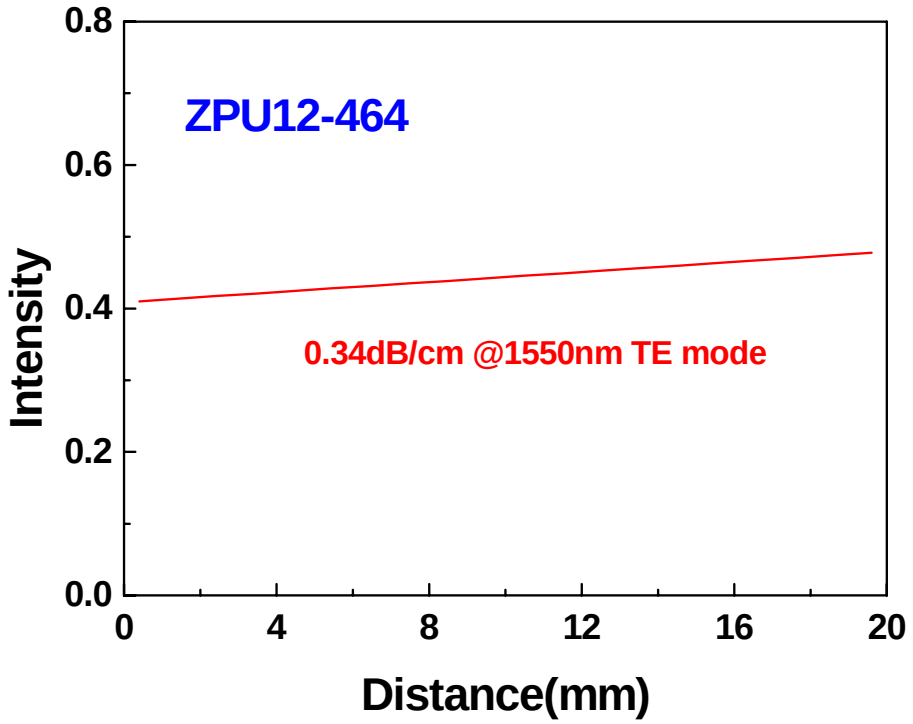
∴ blending of ZPU12-470 25 wt%
& ZPU12-450 75 wt%

Dispersion of Refractive Index



Sample name	dn / dλ (10^{-6} nm^{-1})		
	830nm	1310nm	1550nm
ZPU12-450	-9.2	-5.7	-4.0
ZPU12-470	-11.1	-6.6	-4.6
ZPU13-430	-8.0	-6.9	-6.4
ZPU13-450	-7.1	-6.4	-6.1

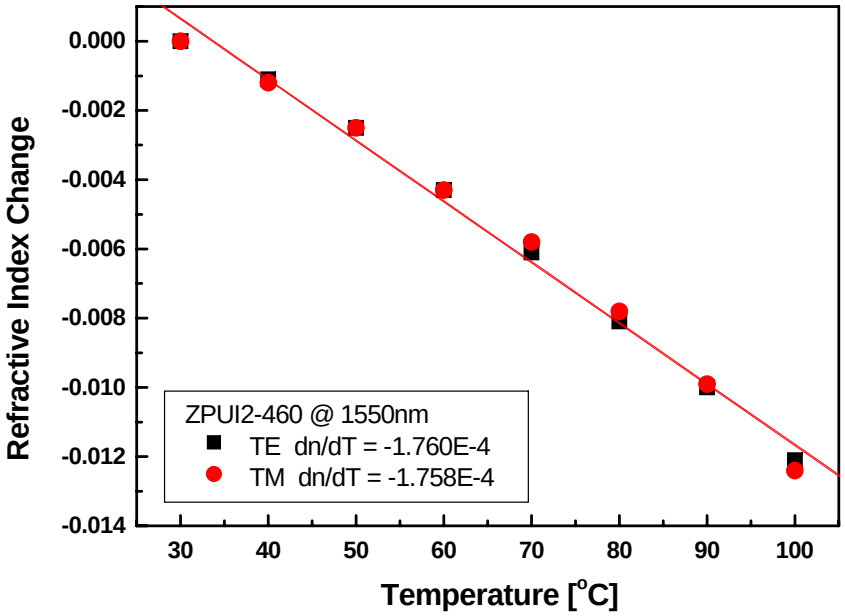
Optical Loss (slab waveguide)

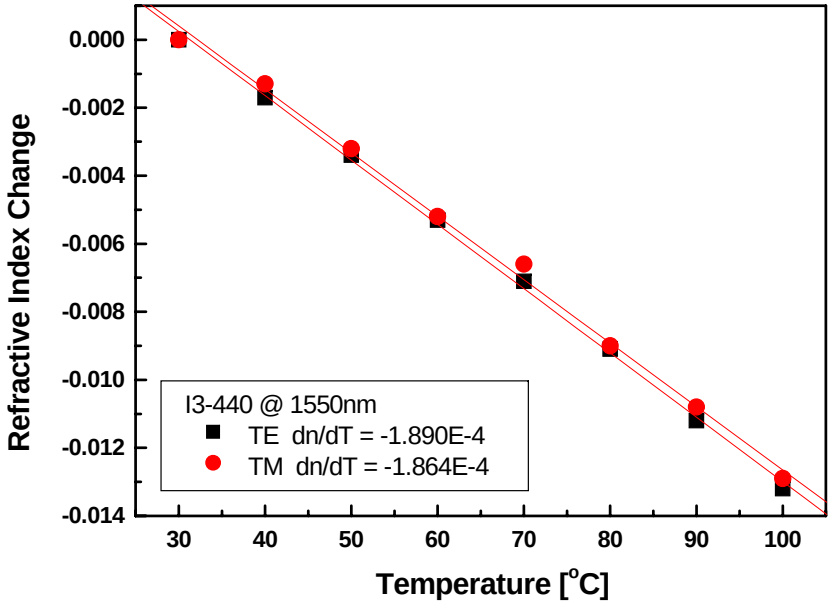


Sample name	Loss (dB/cm)		
	830nm	1310nm	1550nm
ZPU12&13-RI	<0.055	< 0.06	< 0.35

***Measured by immersion technique of slab waveguide**

Thermo-optic coefficient





	dn/dT (/℃) @1550nm	
ZPU12-460	**-1.760×10^{-4}**	**-1.758×10^{-4}**
ZPU13-440	**-1.890×10^{-4}**	**-1.864×10^{-4}**

Standard Fabrication Process of Waveguides

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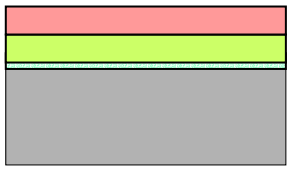
1. Adhesion Promoter treatment

ZAP1020
Spin coating : 3000rpm/30sec
Baking : 110 ºC/3min (hotplate)

2. Spin coating of lower cladding

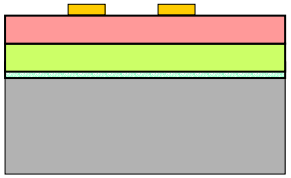
ZPU12-450
Spin coating : 1000rpm/30sec
UV exposure : 15 mW/cm^2 for 2 min
Baking : 160 ºC/30 min

3. Spin coating of core layer

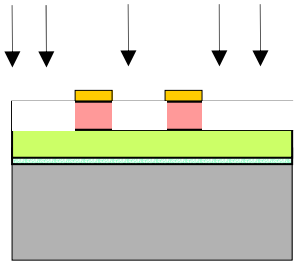


ZPU12-460
Spin coating : 1000rpm/30sec
UV exposure : 15 mW/cm^2 for 2 min
Baking : 160 ºC/30 min

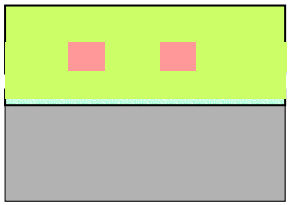
4. Resist masking process



5. Dry etching & mask removing



6. Spin coating of upper cladding



ZPU12-450
Spin coating : 1000rpm/30sec
UV exposure : 15 mW/cm^2 for 2 min
Baking : 160 ºC/30 min

Film Forming Procedure

The followings provide a general overview of the processing procedure related to ZPU12&13-RI series of optical resins.

Surface Treatment

Substrates to be coated with ZPU12-RI & ZPU13-RI series should be free from all organic impurities and other contaminants prior to the coating application. Use of an adhesion promoter, such as trialkoxy silane derivatives or ZAP1020 (manufactured by ChemOptics), is highly recommended for many applications. A typical application procedure for the adhesion promoter is outlined as below:

- Dispensing the adhesion promoter: Dynamically dispense the adhesion promoter solution (ZAP1020) onto the center of the substrate (3~5 ml in case of 4-inch substrate).
- Spinning: Spin the substrate at 300~500 rpm/5sec and then immediately increase spinning speed to 2000~3000 rpm/20~30sec , or until dry.
- Baking: Bake the substrate on a hotplate at 110℃ for 1~5 minutes.

Film Forming Procedure

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Coating

ZPU12&13-RI series solutions are spin casts onto the substrate directly after the adhesion promoter application. The demanded final film thickness depends on the precise conditions used to deposit resin . A typical application procedure is outlined as below:

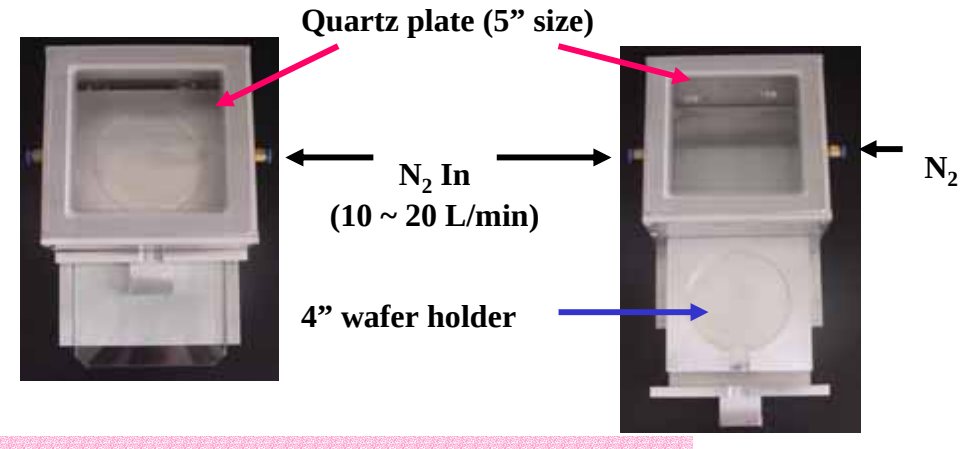
- Dispensing resin: Dispense the polymer solution onto the center of the substrate (approximately 3~5 ml in case of a 4-inch substrate).
- Spinning: Spin at 300~500rpm/5sec and then immediately increase spinning speed to 700~2500rpm/20~30sec to achieve the desired film thickness.

Note: Film thickness made of ZPU12&13-RI series depends on coating equipment and spinning procedures. Following figure shows the film thickness according to the spin rate.

UV curing

After coating, the polymer film should be cured to ensure stability during the subsequent processes such as multi-layer over coating, photolithography. The UV curing should be performed in an UV light irradiation chamber with an optical intensity higher than 15 mW/cm^2 for 3 ~ 10 minutes. Curing the films must be carried out in the absence of oxygen (<100 ppm). This environment can be easily achieved by flowing nitrogen through the chamber (about 20 L/min). For better stability, a final thermal curing at 160 ºC is necessary for 30 ~ 60 min after the UV curing.

Photograph of UV curing box

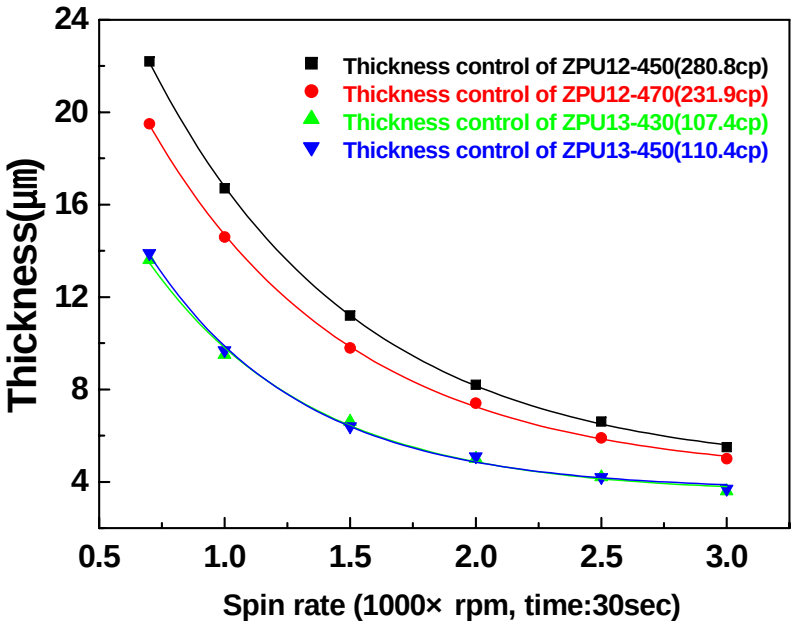


Curing box size : L x W x H = 150 x 150 x 100 mm

a) Closed curing box

b) Opened curing box

Film Thickness

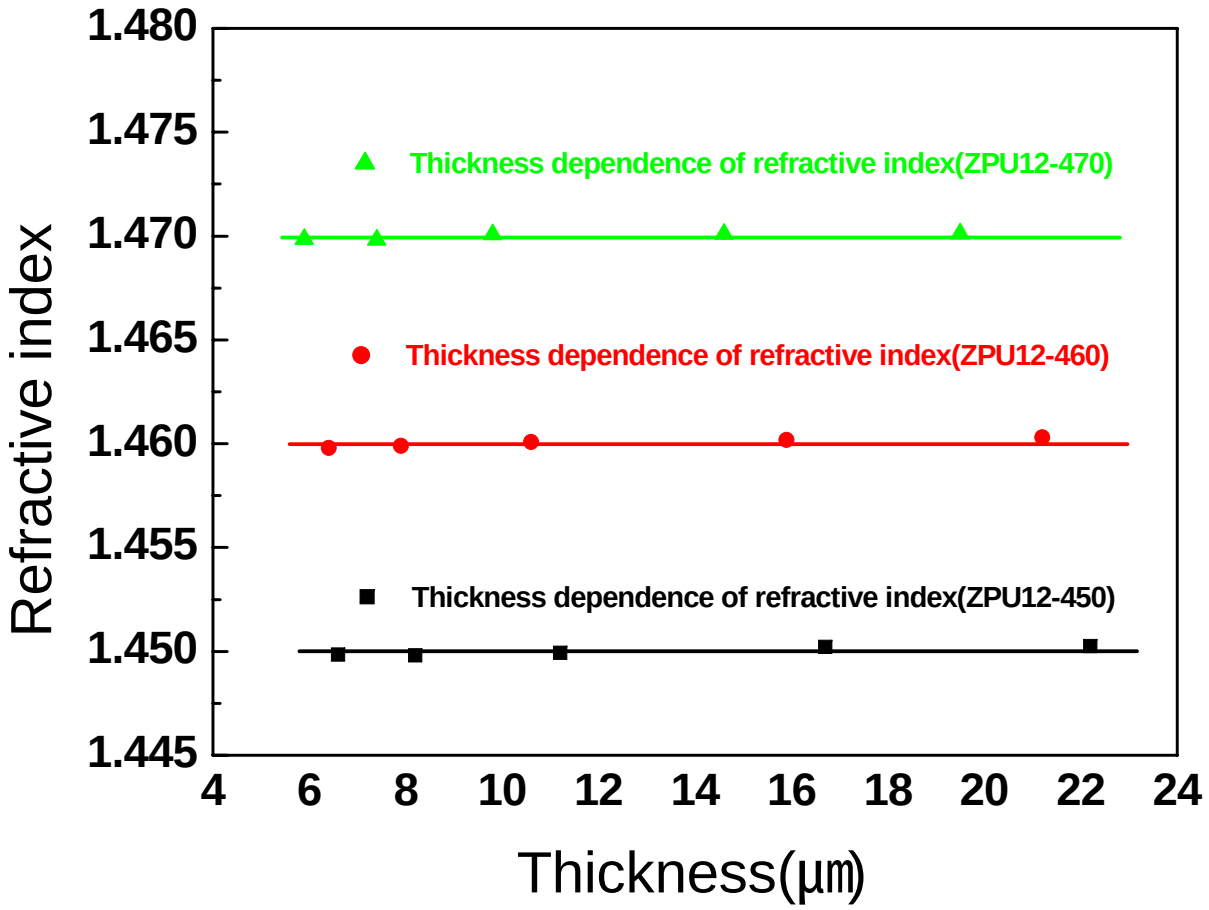


sample / Rate(rpm)	12-450 (μm)	12-470 (μm)	13-430 (μm)	13-450 (μm)
700	22.2	19.5	13.6	13.9
1000	16.7	14.6	9.5	9.7
1500	11.2	9.8	6.6	6.4
2000	8.2	7.4	5.0	5.1
2500	6.6	5.9	4.2	4.2
3000	5.5	5.0	3.6	3.7

Note: Film thickness depends on coating equipment and spinning procedures.

Measured by a prism coupler.

Thickness dependence of refractive index



Film Uniformity (Refractive index & Thickness)

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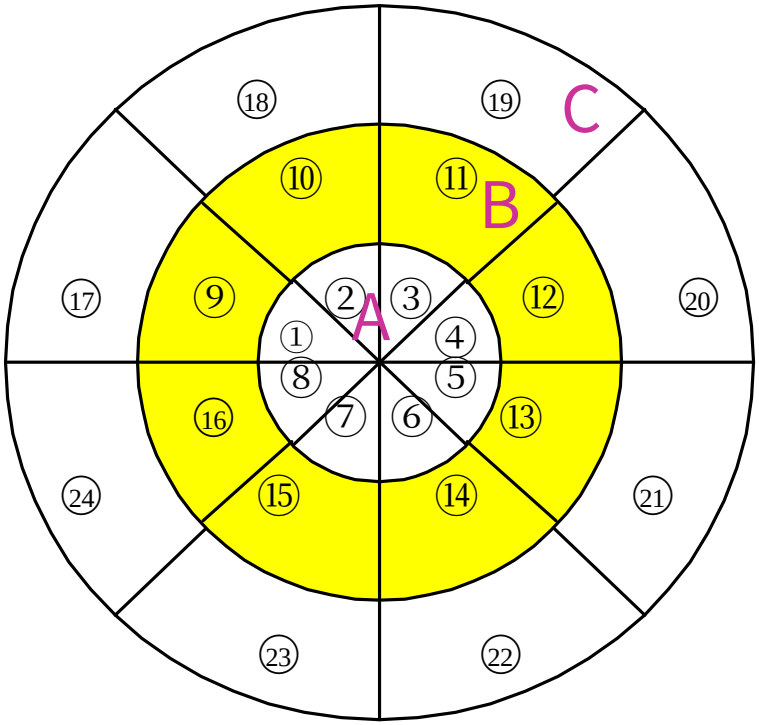
4” Si wafer



	Refractive index[a]	Thickness[b] (μm)
A area (average)	1.46433	7.8474
B area (average)	1.46419	7.8467
C area (average)	1.46414	7.8439
Total average	1.46422	7.8460
Uniformity	**< 0.008 % (0.00012)**	**< 0.03% (0.0024)**

ZPU12-RI & ZPU13-RI show the excellent uniformity of refractive index and film thickness.

[a]Refractive index was measured by a prism coupler at 1550 nm.
[b]Film thickness was measured by α-step surface profiler

Film surface roughness (AFM)

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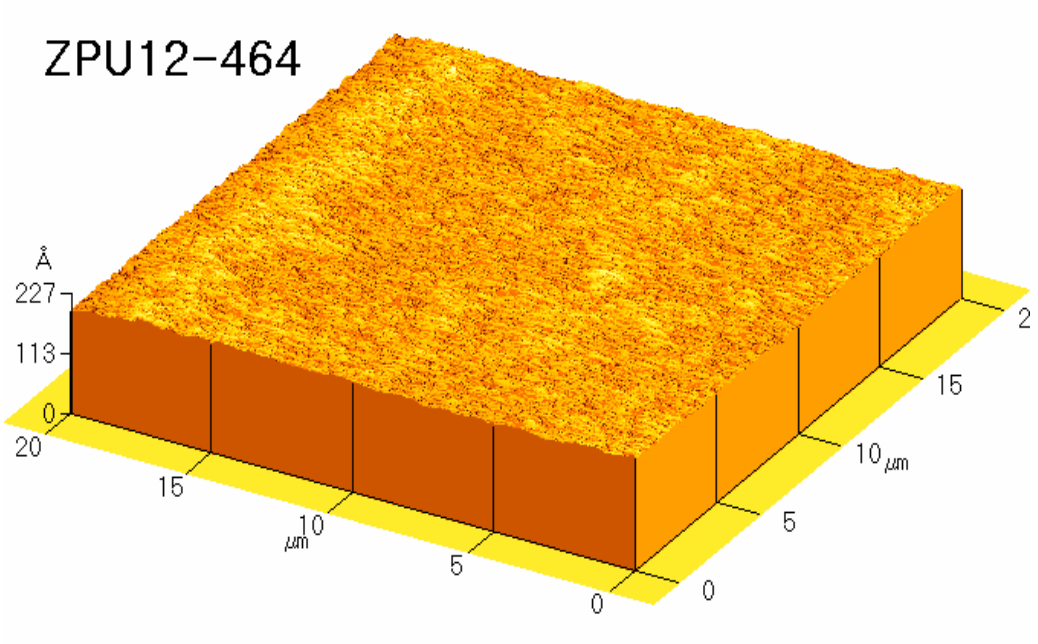
RMS Roughness: < 0.35 nm



Area	RMS roughness
20μm × 20μm	3.42 Å (0.342 nm)
5μm × 5μm	3.24 Å (0.324 nm)
1μm × 1μm	3.09 Å (0.309 nm)

Film stability :Pressure Cooker Test

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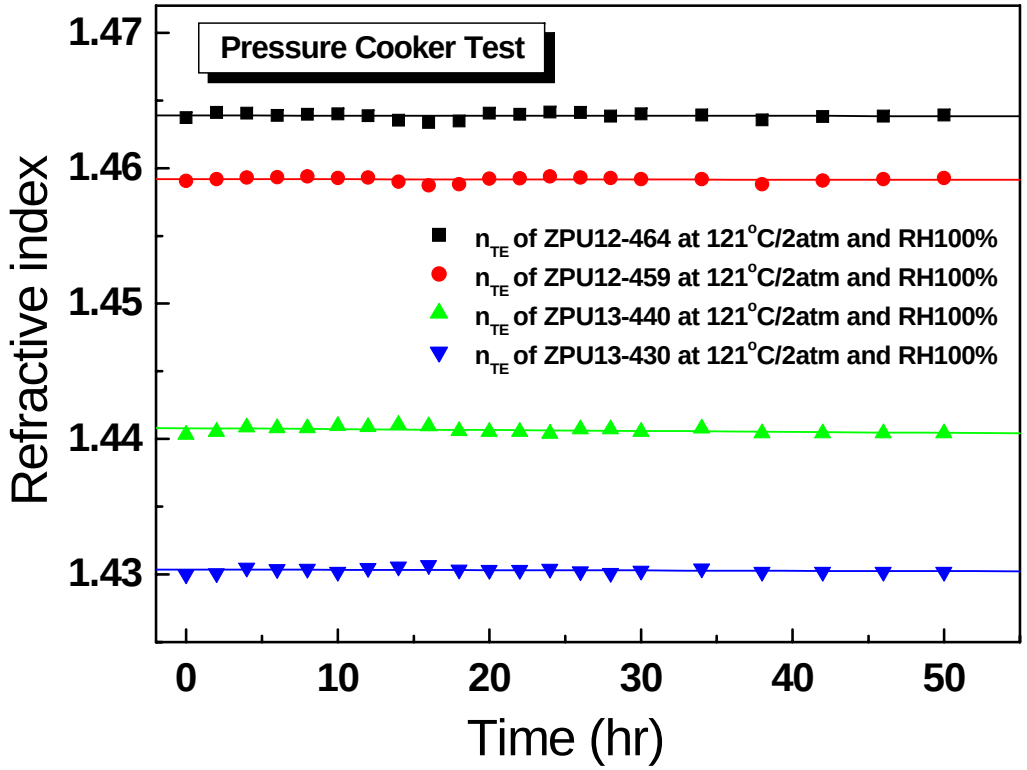

All of the samples were treated with an adhesion promoter ZAP1020 between a Si wafer and a polymer film.

Conditions

- **Temperature : 121 ºC (±2℃)**
- **Pressure : 2 atm**
- **Relative Humidity : 100% (±2℃).**

→

- **Passed more than 50hr**
- **No peel off from a substrate**
- **Negligible changes of RI**

Film stability : High Temp. storage/dry heat

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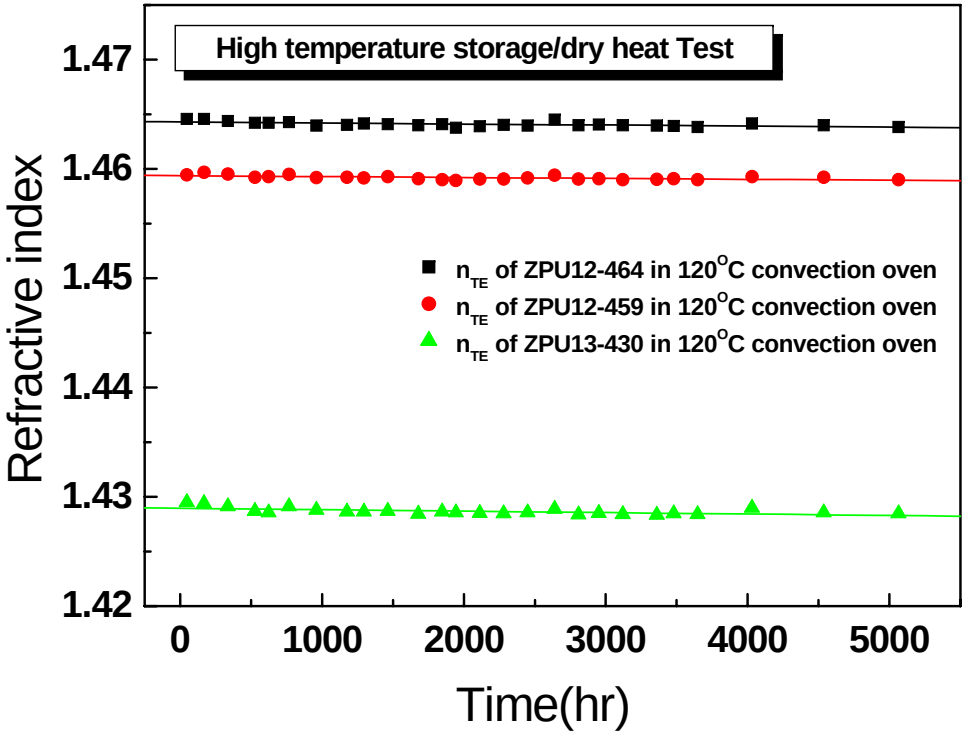
❖ Long-term refractive index stability

❖ Convection Oven

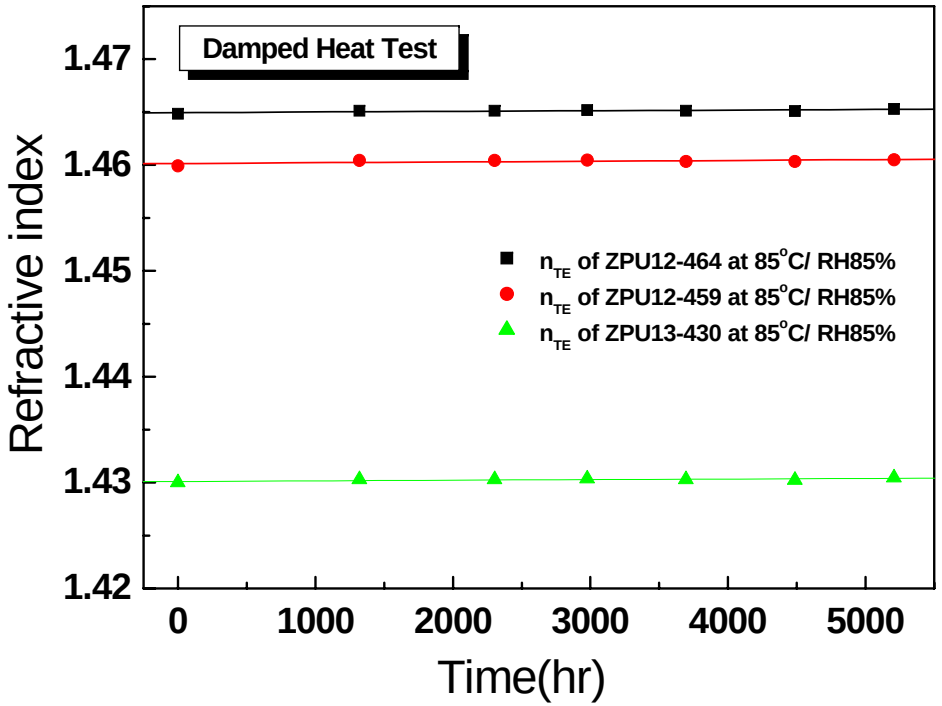


Conditions

- Temperature : 120 ºC (±2℃)
- Pressure : 1 atm
- Relative Humidity : Amb.

- Passed more than 5,000hr
- No peel off from a substrate
- Negligible changes of RI

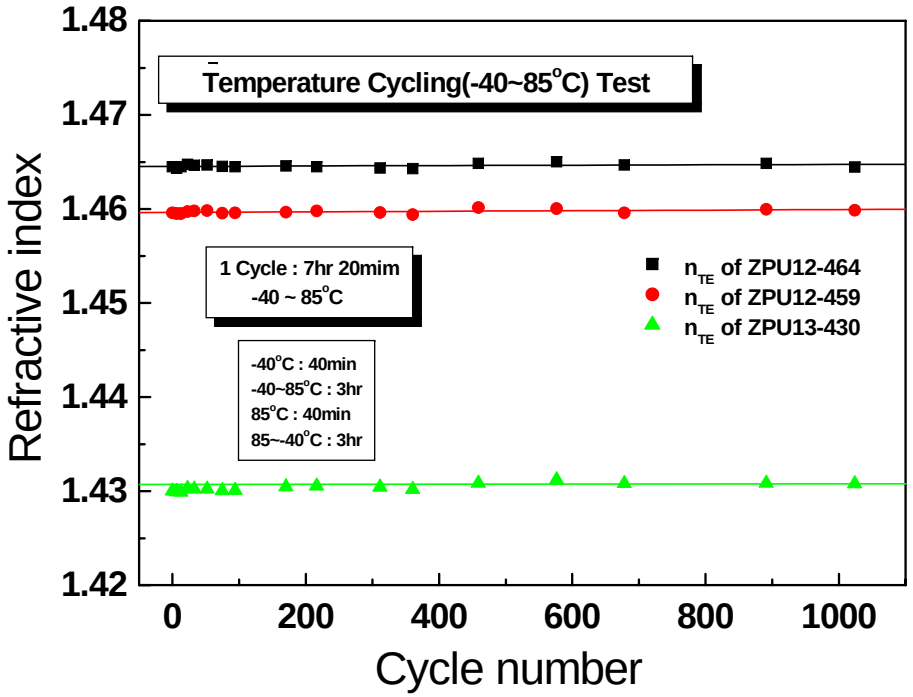
Film stability : Damped Heat (85℃/85%RH)

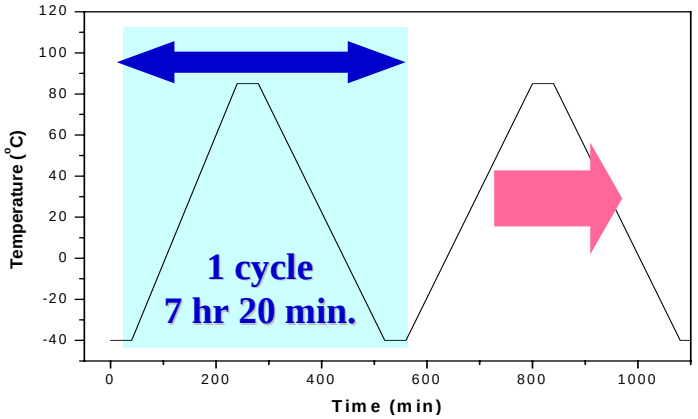


Conditions
- Temperature : 85 ℃ (±2℃)
- Relative Humidity : 85% (±5 %)

- Passed more than 5,000hr
- No peel off from a substrate
- Negligible changes of RI

Film stability : Temp. Cycling Test (-40 to 85℃)





Conditions

- Temp. cycle : -40 to 85 ºC (±2℃)
- 1 cycle : 7hr 20min

→

- Passed more than 1,000 cycle
- No peel off from a substrate
- Negligible changes of RI

Dry Etching

Dry etching of the waveguide patterns on the film can be accomplished by ICP or RIE in gas containing oxygen etc. Various etching masks like photoresist, metal or inorganic oxide could be used as long as the materials have enough selectivity in the oxygen plasma etch. Etching masks commonly used are Au, SiO_2 and Si based photoresist. The ultimate etching rate depends on a function of a gas composition, system power, and chamber pressure.

Reference ICP or RIE dry etching condition

Equipment	ICP	RIE
Etching Mask	Cr/Au or Si-PR	Cr/Au or Si-PR
Etching gas :	O_2	O_2
Initial pressure	5 mtorr	Less than 0.1 mtorr
Working (base) pressure :	5 mtorr	50 mtorr
O_2 Gas flow :	20 sccm	50 sccm
RF power /ICP power:	80 W / 700 W	350 W
Etching rate :	2.0 μm/min	6.0 μm/min

Storage & Precaution

Storage

The ZPU12&13-RI series should be stored under dark and cool place 10 ~ 25 ° C. Moisture can affect the product performance so that it should be avoided. Keep the bottles capped when not in use. The recommended shelf life for the product is at least three months from the formulation date denoted in the information sheet.

Precaution

These solutuins may cause skin and eye irritations to a sensitive person. Therefore you should avoid direct skin and eye contact. In case of contact, immediately wash the exposed area with water and then wash thoroughly with soap and water once again.

Availability

These solutions are available in clean plastic bottles at 100 g and 250 g.

Contact

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For further information, please feel free to contact us.

- **Address** 104-11 Moonji-Dong, Yusong-Gu, Daejon 305-380, South Korea
- **Phone** +82-42-868-6861
- **Fax** +82-42-868-6852
- **Website** www.chemoptics.co.kr
- **E-mail** sales@chemoptics.co.kr