Technical Information of

ZPU12-RI & ZPU13-RI

(UV curable acrylate polymers)

Application

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, star coupler, etc.)
- Thermo-optic waveguide devices (switch, variable optical attenuator, etc.)
- WDM related devices (AWG, router, interleaver, etc.)
- Hybrid waveguides for silica and glass waveguides
- Optical interconnection
- Multi-mode waveguide devices

Features

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These coating resins have 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 through the blending of standard polymer solutions. To achieve the best film quality, a nitrogen environment is required during the UV exposure.

- UV curable type (solvent free)
- Low optical propagation loss
- High environmental stability
- Continuous and precision 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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Standard Item		ZPU12-RI		ZPU13-RI	
		450	470	430	450
Liquid	Viscosity (cps @25 ^{o}C)	200~300		50~150	
	Filtration	0.1 ~ 0.2 μm absolute PTFE filter			
	UV-exposure	> 2500 mJ/cm^2 (160 ^{o}C/30 min, post baking)			
	Propagation loss (measured from planer waveguide)	**0.35 dB/cm @ 1.55 μm**			
		0.06 dB/cm @ 1.30 μm			
	Refractive Index @ 1.55 μm	1.4500	1.4700	1.4300	1.4500
	Birefringence ($n_{TE} - n_{TM}$)	0.001 ± 0.0003		0.0007 ± 0.0003	
	Refractive index uniformity	**<0.00012**			
	Thermo-optic coefficient	- 1.5 ~ -2.2 x 10^{-4} / ^{o}C			
Film	CTE (ppm/^{o}C, by TMA)	200~300		300~400	
	Glass Transition Temp. (Tg)	Not detectable			
	Degradation Temp. (1 wt%)	300 ± 20 ^{o}C			
	Surface roughness (AFM)	**< 0.35 nm at 8 μm thickness**			
	Film thickness	< 25 μm per coating (multi-coating available)			

Continuous Control of Refractive Index

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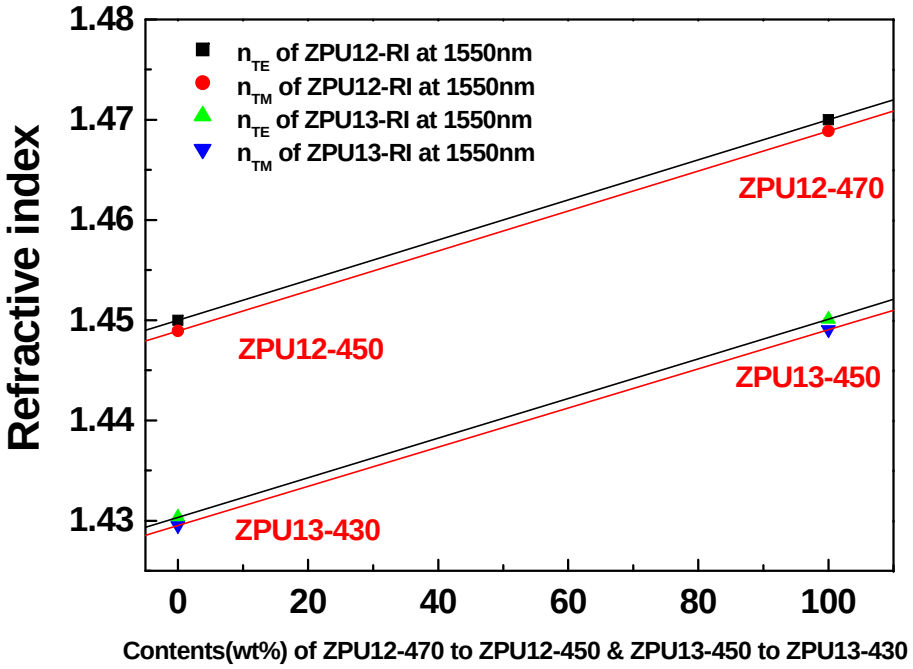
The precision control of refractive index can be achieved by simple blending of two polymers. The blended polymers exhibit intermediate properties of those of original polymers according to blending ratio.



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%)

$=1/(2\times10^{-4})\times(1.4550-1.45)=25$

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

Dispersion of Refractive Index

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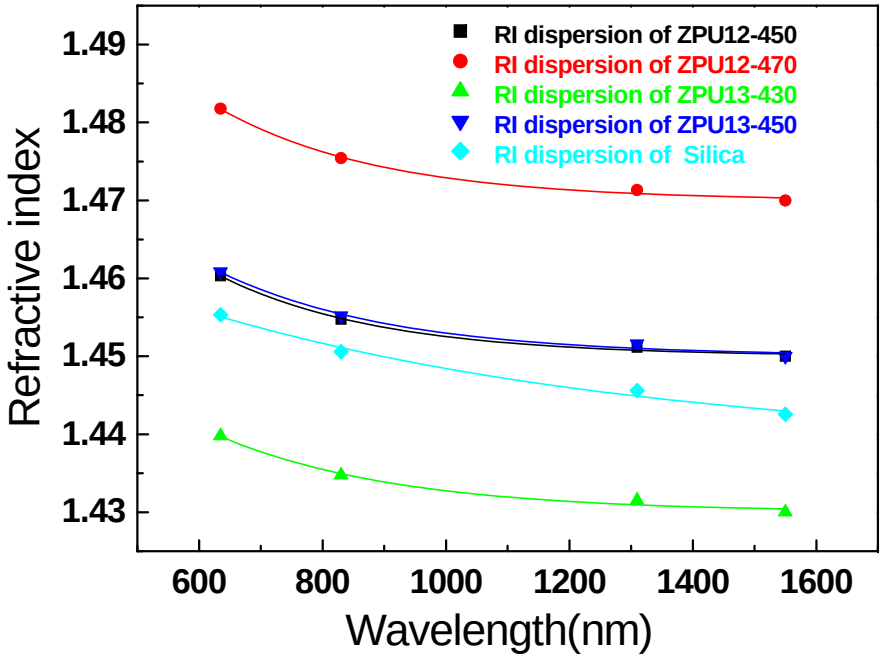
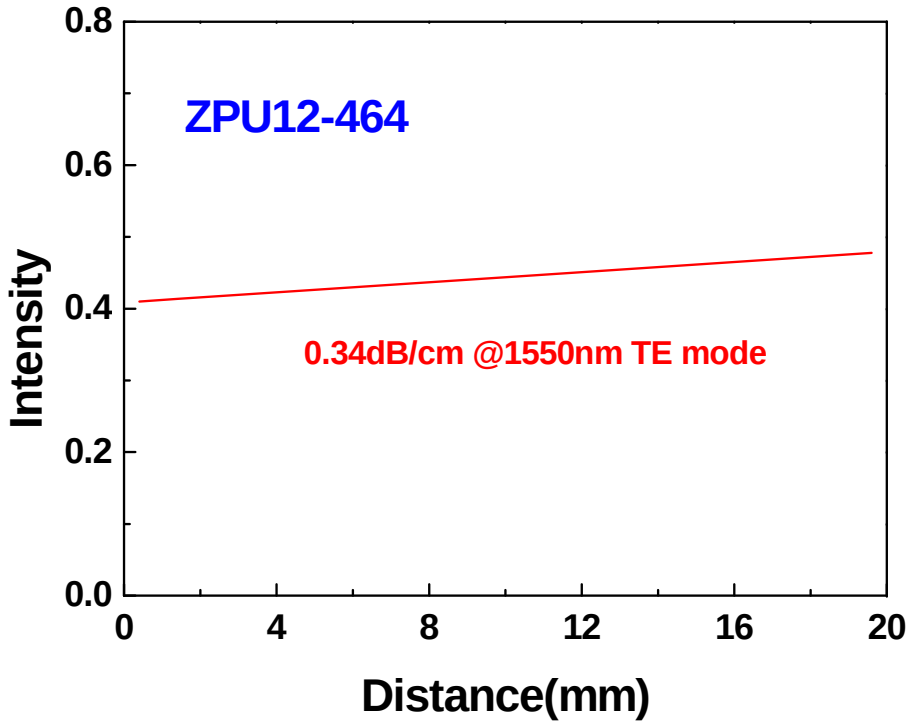


Sample name	dn / dλ (10^{-6} nm^{-1})		
	830nm	1310nm	1550nm
ZPU12-450	-9.2	-5.7	-4.0
ZPU12-470	-11.1	-6.6	-4.6
ZPU13-430	-8.0	-6.9	-6.4
ZPU13-450	-7.1	-6.4	-6.1

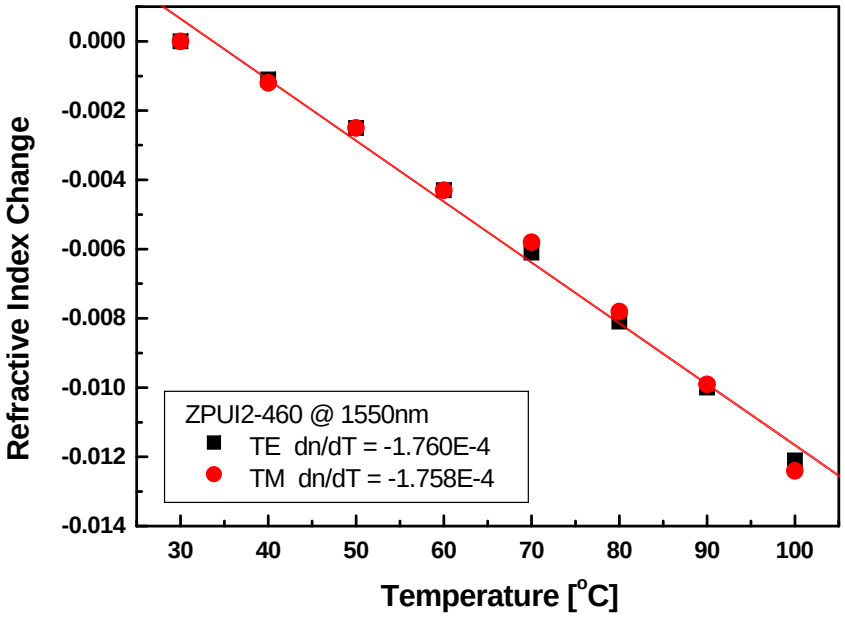
Optical Loss (slab waveguide)

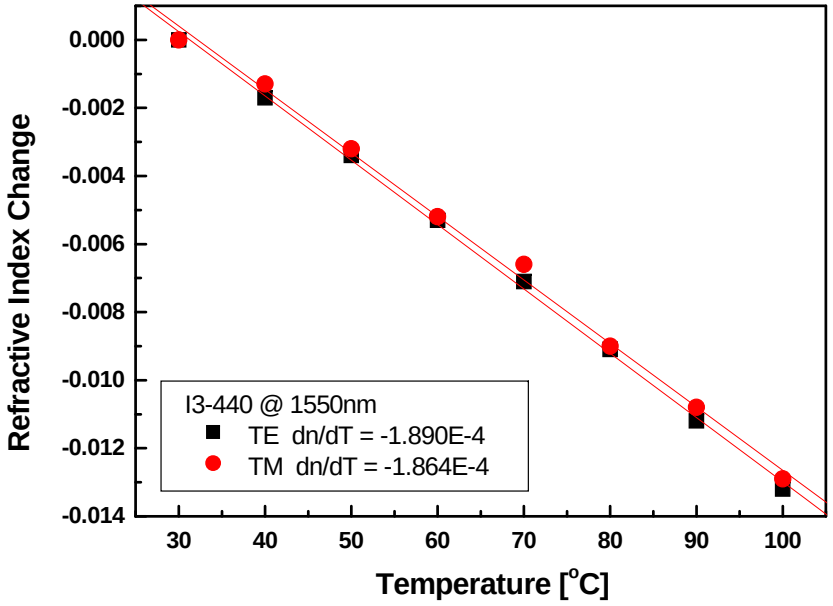


Sample name	Loss (dB/cm)		
	830nm	1310nm	1550nm
ZPU12&13-RI	<0.055	< 0.06	< 0.35

***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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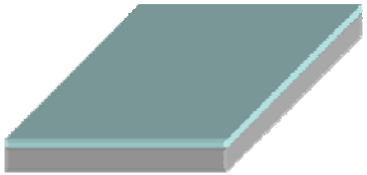
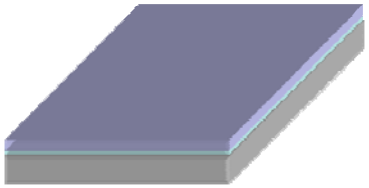
1. Adhesion Promoter treatment



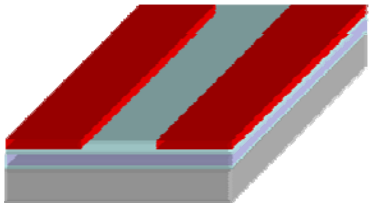
ZAP1020 drop
Spin coating : 3000rpm/30sec
Baking : 110 ºC/3min (hotplate)

2. Spin coating of under clad

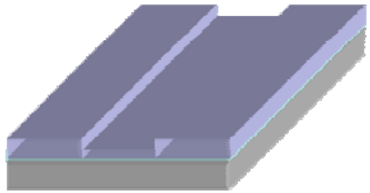


Clad resin drop
Spin coating : rpm/ sec
UV exposure :
12~14 mW/cm^2 for 3 min

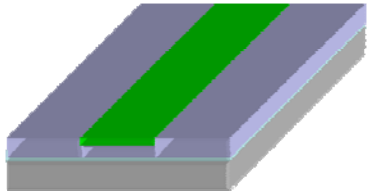
3. Resist masking process



4. Dry etching & mask remove

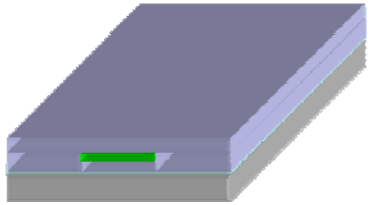


5. Spin coating of core layer & dry etching



Core resin drop
Spin coating : rpm/ sec
UV exposure :
12~14 mW/cm^2 for 3 min

6. Spin coating of upper clad



Clad resin drop
Spin coating : rpm/ sec
UV exposure :
12~14 mW/cm^2 for 3 min
Baking : 160 ºC/30 min (oven)

Film Forming Procedure

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

Surface Treatment

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

- Dispense 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 to 5 minutes.

Coating

ZPU12&13-RI series solutions are spin cast onto the substrate directly after the adhesion promoter application. The precise conditions used to deposit the resins will depend on the desired final film thickness. A typical application procedure is outlined below:

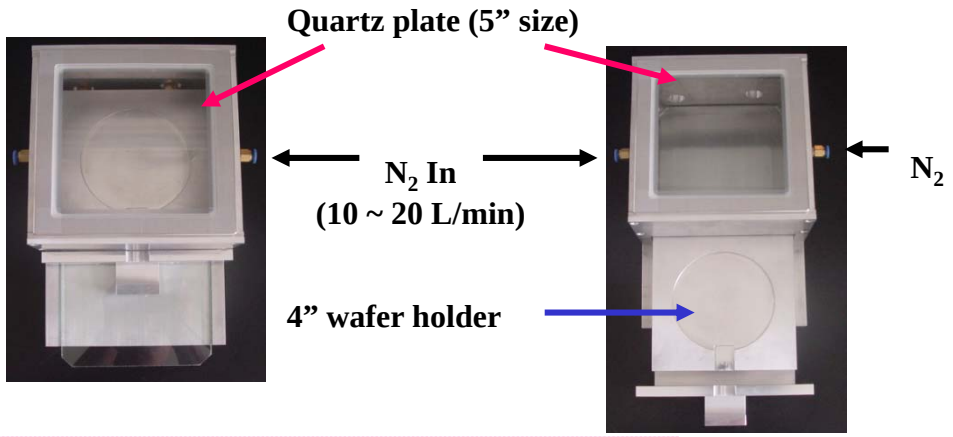
- Dispense resin: Dispense the polymer solution onto the center of the substrate (approximately 3~5 ml in case of 4-inch substrate).
- Spinning: Spin at 300~500rpm/5sec and then immediately increase spinning speed to 700~2500rpm/20~30sec to achieve the desired film thickness.

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

UV curing

After coating, the polymer film is cured to ensure stability during the subsequent processes such as multi-layer over coating, photolithography. The UV curing is performed in an UV light irradiation chamber with an optical intensity higher than 15 mW/cm^2 for 3 ~ 10 minutes. Curing of 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 ^{o}C is necessary for 30 ~ 60 min after the UV curing.

Photograph of UV curing box

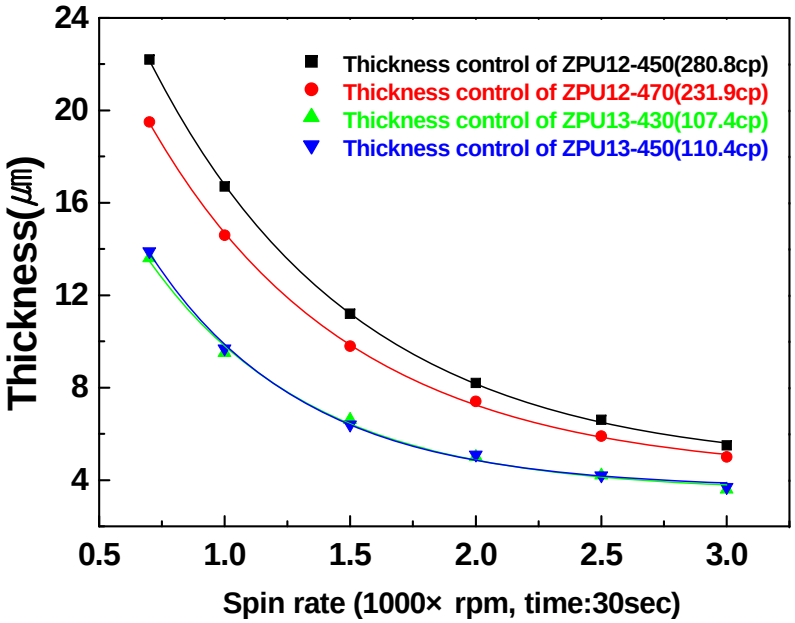


Curing box size : L x W x H = 150 x 150 x 100 mm

a) Closed curing box

b) Opened curing box

Film Thickness

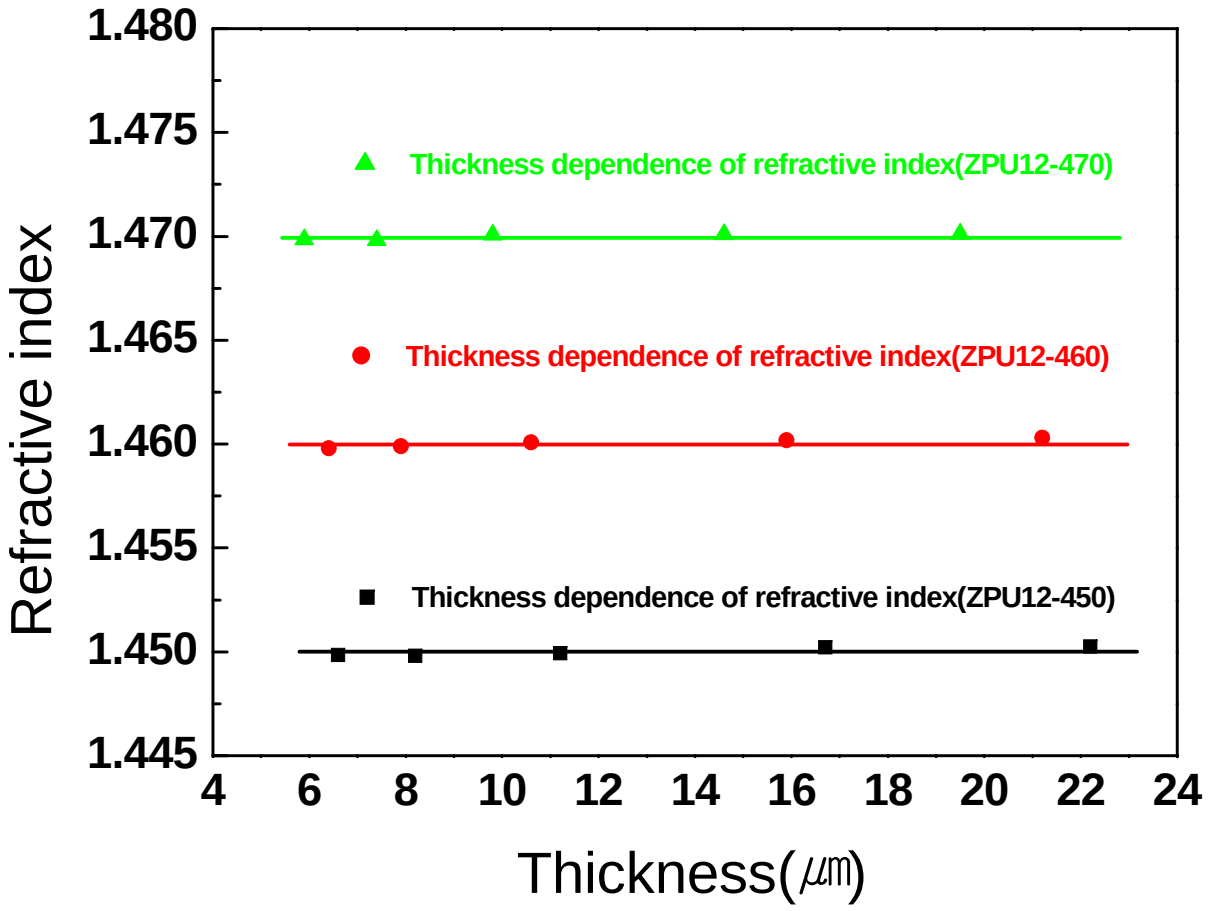


sample / Rate(rpm)	12-450 (㎛)	12-470 (㎛)	13-430 (㎛)	13-450 (㎛)
700	22.2	19.5	13.6	13.9
1000	16.7	14.6	9.5	9.7
1500	11.2	9.8	6.6	6.4
2000	8.2	7.4	5.0	5.1
2500	6.6	5.9	4.2	4.2
3000	5.5	5.0	3.6	3.7

Note: Film thickness depends on coater equipments and spinning procedures.

Measured by prism coupler.

Thickness dependence of refractive index



Film Uniformity (Refractive index & Thickness)

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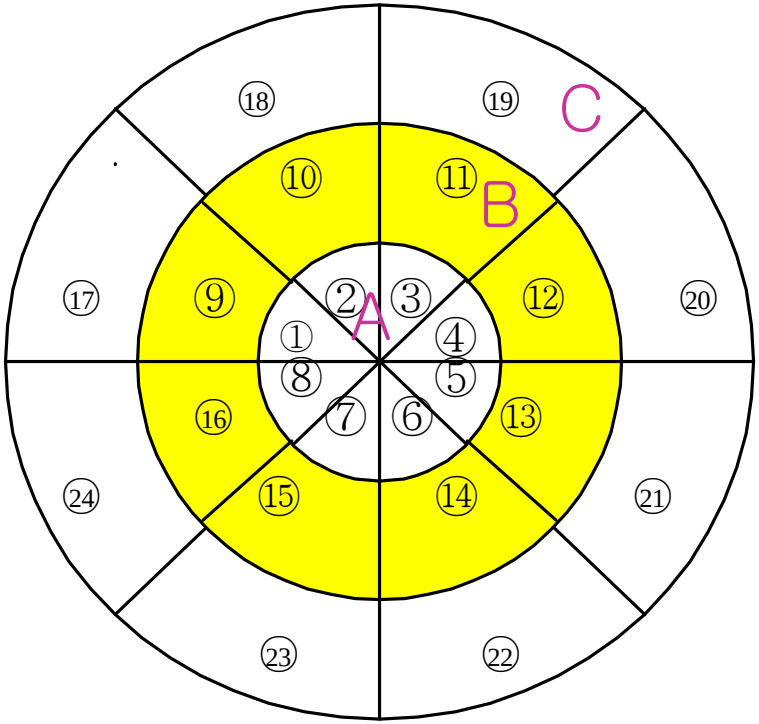
4” Si wafer



	Refractive index	Thickness (㎛)
A area (average)	1.46433	8.63
B area (average)	1.46419	8.64
C area (average)	1.46414	8.64
Total average	1.46422	8.64
Uniformity	**< 0.008 % (0.00012)**	**< 0.5% (0.04)**

ZPU12-RI & ZPU13-RI show the excellent uniformity of refractive index and film thickness
Measured by prism coupler & a-step surface profiler

Film surface roughness (AFM)

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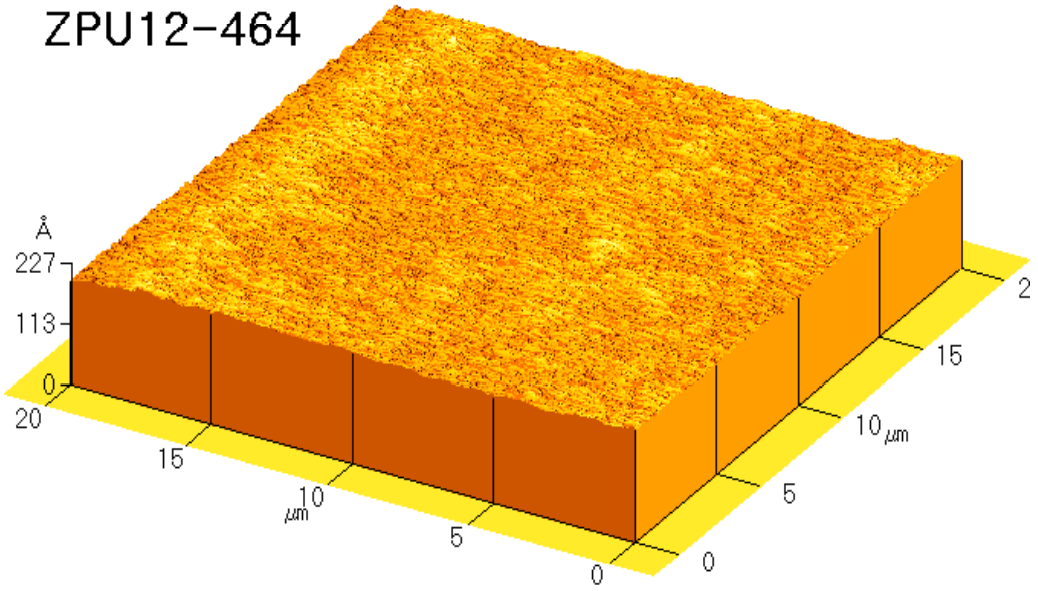
RMS Roughness: < 0.35 nm



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

Film stability :Pressure Cooker Test

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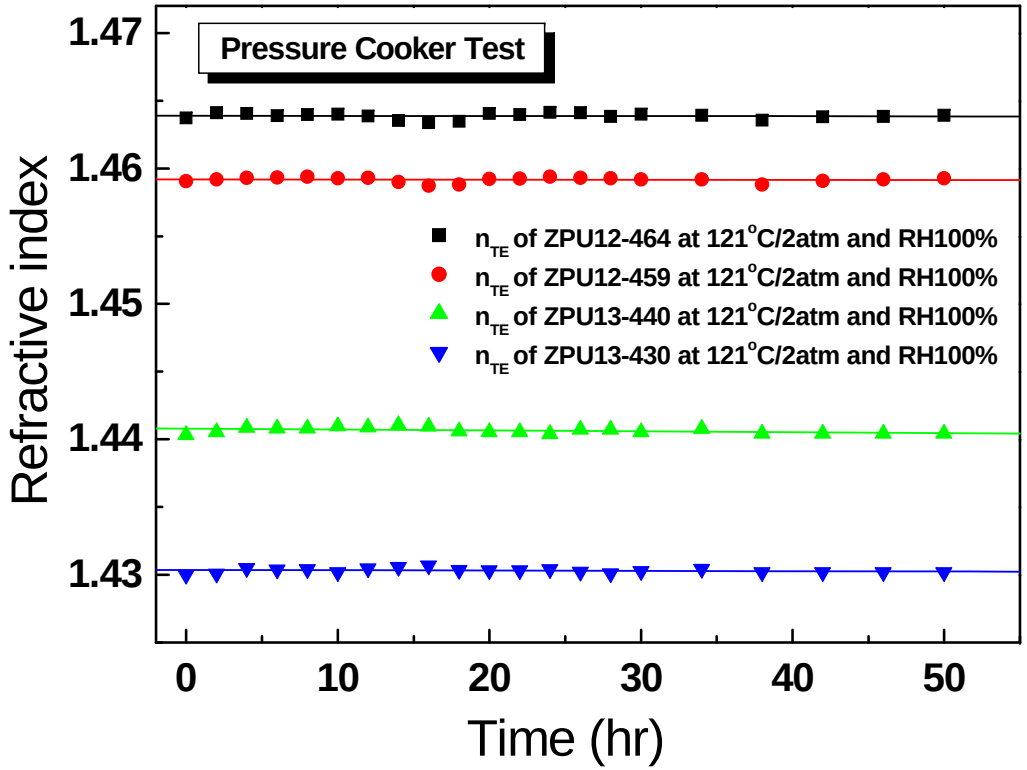

All of the samples were treated with adhesion promoter ZAP1020 between Si wafer and polymer film.

Conditions

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

→

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

Film stability : High Temp. storage/dry heat

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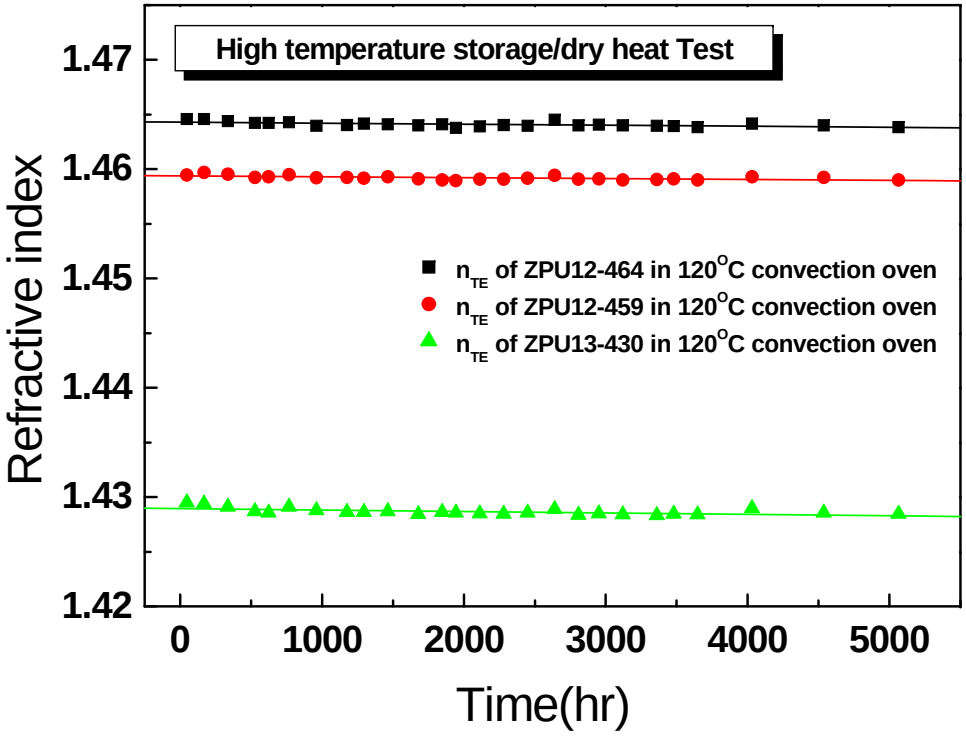
❖ Long-term refractive index stability

❖ Convection Oven



Conditions

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

→

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

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

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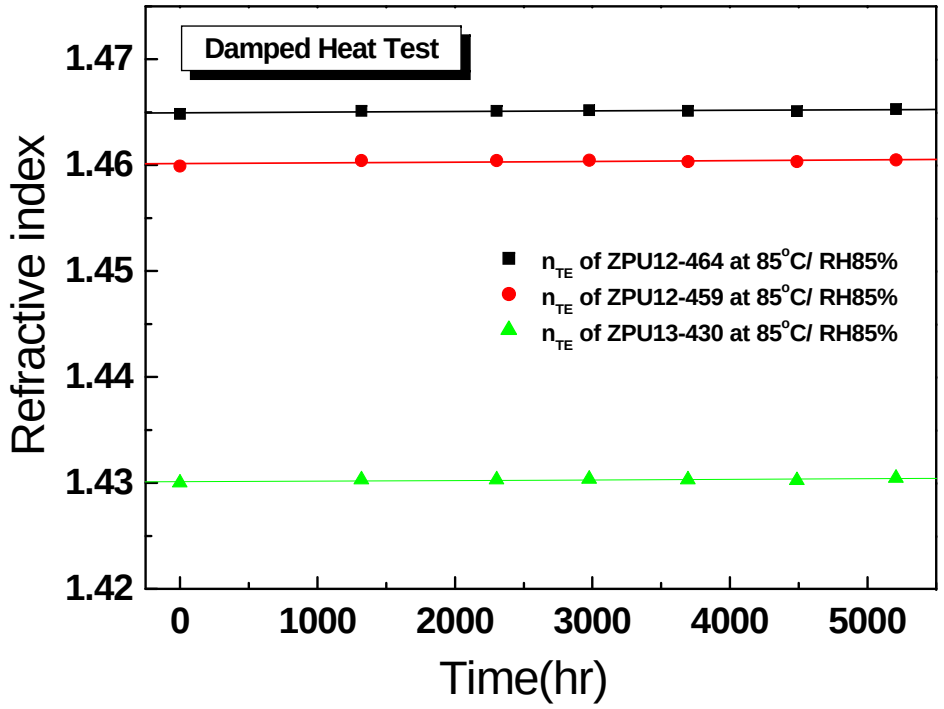

Conditions

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

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

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

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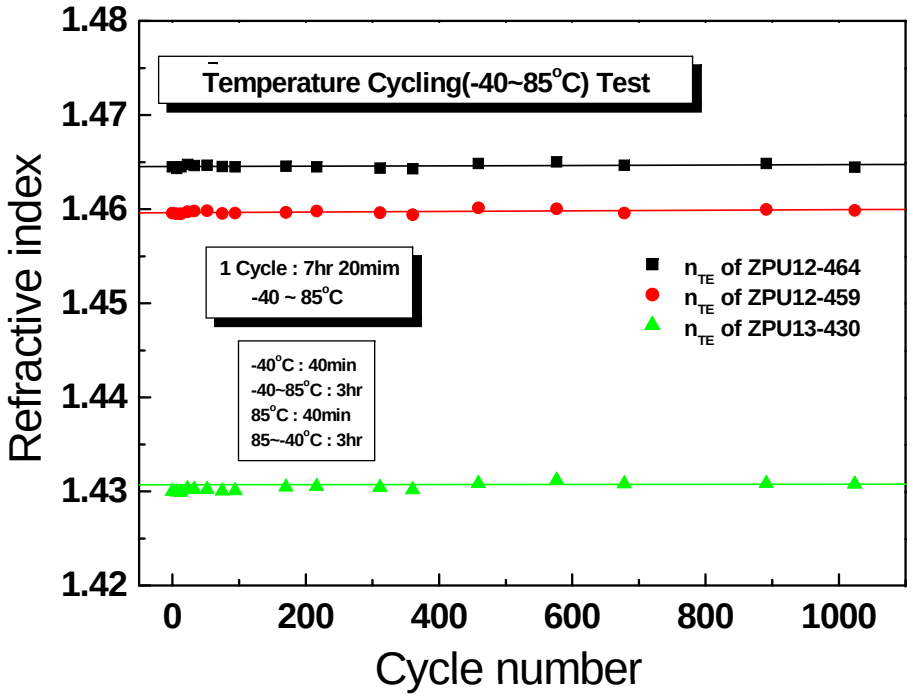
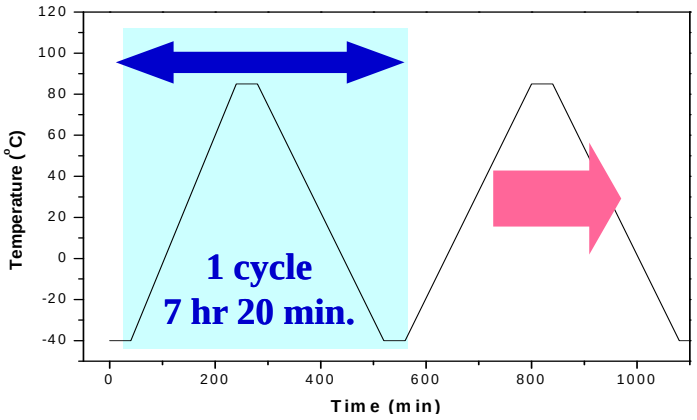




Conditions

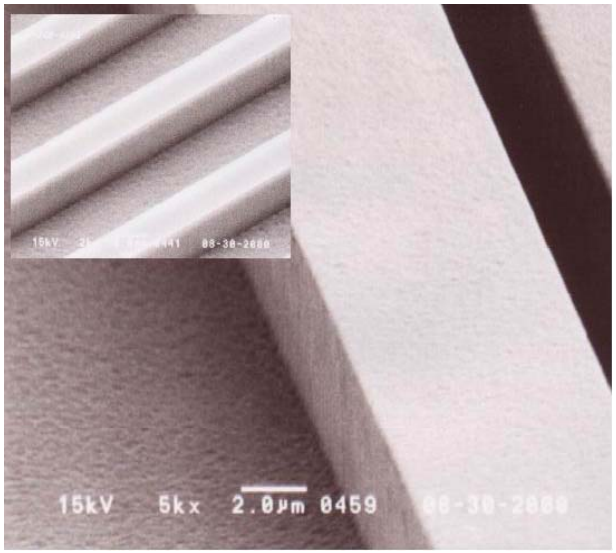
- Temp. cycle : -40 to 85 ºC (±2℃)
- 1 cycle : 7hr 20min

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

Dry Etching

Dry etching of the waveguides patterns on the film is accomplished by ICP or RIE in a 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. Commonly used etching masks are Au, SiO_2 and photoresist. The ultimate etching rate is a function of gas composition, system power, and chamber pressure.

Etching Mask	Metal
Etching gas :	O_2
Working pressure :	50 mtorr
Gas flow :	100 sccm
RF power :	150 W
Etching rate :	1.0 μm/min



SEM of patterned waveguide

Storage

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

Precaution

These solutuins may cause skin and eye irritation to a sensitive person. Avoid direct skin and eye contact. In case contact does occur, immediately wash the exposed area with water and then wash thoroughly with soap and water once again.

Availability

These solutions are available in clean PP bottles by 100 g and 250 g.

Contact

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