WDM Network용 Polymer 광소자

ETRI
박 사 한 선 규

개 요

ETRI

- ■ 광통신 개요
- ■ WDM 광통신 소자
- ■ Polymer 광통신 소자 연구 동향
- ■ 수동/열광학 폴리머 광소자 (ETRI)
    - ● **AWG**
    - ● **tunable filter**
- ■ 요약

1. 광통신 개요

1.1 통신/정보처리 기술의 발전단계

1950 1980 2010

Electron	Photon
TDM	WDM
Analog	Digital
Voice	Data

Photon has higher carrier speed

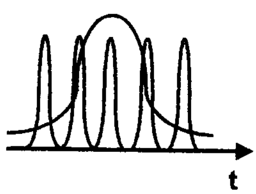
Photon has a unique property......more wavelength --> more information

Digital process --> clean and higher information

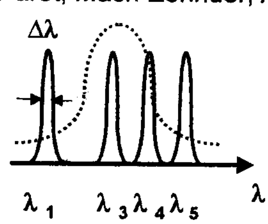
Voice : Data 1:1 --> 1:20 (2010)

1.2 WDM 광통신

- differrent wavelength not interfere each other
- ultrafast time tech. ⇨ multi wavelength tech.
- Low speed data controll ⇨ Low cost electronics
- High capacity data controll (>T bit/s)
- ❦●✸ .... data ✸
- multiwavelength tech ..... Prism, Fabry-Parot, Mach-Zehnder, AWG



TDM
(time division multiplexing)



WDM
(wavelength division demultiplexing)

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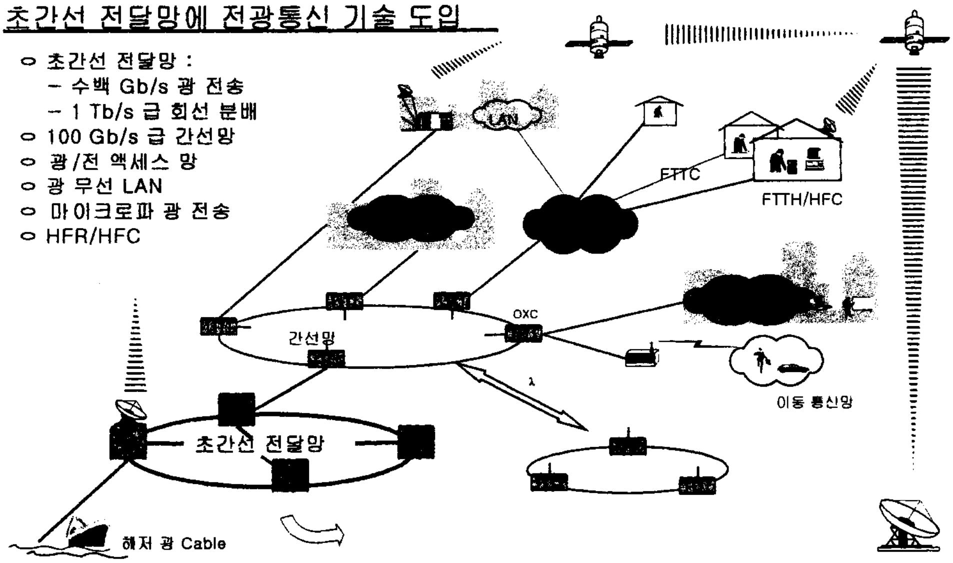
초간선 전달망에 전광통신 기술 도입

- 초간선 전달망 :
  - 수백 Gb/s 광 전송
  - 1 Tb/s 급 회선 분배
- 100 Gb/s 급 간선망
- 광/전 액세스 망
- 광 무선 LAN
- 마이크로파 광 전송
- HFR/HFC



2. WDM 광통신 소자

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2.1 WDM 광통신 핵심소자

- 단위 광소자
  - 광원, 광검출기, 광섬유, 고속 광변조기, OXC용 광스위치, 고속 광스위치, (가변)광감쇄기, 광세기분할기
  - 파장다중/역다중기, 파장필터, 파장가변필터
  - 광증폭기, 전광 기능기($\chi^{(3)}$)
- 집적 광소자
  - **ADM(Add/Drop Multiplexer),** 파장선택기 , 파장변환기, 3R(Re-amplification, Re-shaping, Re-timing) 재생기

- RACE 57종 개발
- ACTS 54종 개발

2.2 광소자의 물질별 특성

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물질 / 특성	LiNbO3	반도체	실리카	폴리머
•기능	EO, TO	EO, OO	EO, TO	EO, TO, OO
•대역폭(GHz)	높음(< 40)	중간(< 10)	낮음(< 1)	매우높음(>100)
•광손실(dB/cm)	낮음(< 0.5)	높음(< 0.5)	매우낮음(< 0.01)	낮음(< 0.05, <1)
•이득	가능성 검증	있음	가능	가능성 검증
•공정(단계)	단순(<10)	복잡(~수십)	단순(<10)	단순(<10)
•편광의존성	있음	있음	있음	물질에 의존
•패키징	용이함	힘듬	용이함	용이함
•안정성	비교적안정함	안정함	매우안정함	비교적안정함
•경제성	나쁨	나쁨	좋음	매우좋음
종 합	완성단계 확장성?	소형화유리 이득기능	저손실 광집적화 유리	다소자집속가능 대용량화유리

3. 폴리머 광통신 소자 연구개발 현황

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•Historically : 1970년대 $\chi^{(3)}$ --> 1980대 $\chi^{(2)}$ --> 1990년대 $\chi^{(1)}$

현재 : 수동 및 열광학 소자를 중심으로 연구 및 일부 상품화(AKZO)
향후 : 수동소자, EO 효과를 이용한 고속 소자, 광증폭 소자 , 집적 소자

•미국 :
DARP : 광증폭, interconnection
POINT, : 광 interconnection - Allied Signal, AMP,
NIST : ATP(Advanced Technology Programs) : $10M

•일본 : NTT, Hitachi를 중심으로 광소자 기능 구현에 초점

•유럽 : RACE 및 ACTS project 에서 광소자의 기능 구현
AKZO :광증폭

•국내 : ETRI, KAIST, 삼성, LG 등에서 소자화 연구

최근에 폴리머 광소자의 가능성을 확인하여 매우 활발히 연구 진행중임.

3.1 수동 및 열광학소자 연구 동향

• 수동소자 : - splitter - AWG 필터 • 열광학소자 : - 광스위치 - 파장 가변 필터 - Add/Drop 필터 - 가변 광감쇄기	•수동소자 : - 삼성(1x32), JDS - NTT(1x32), ETRI(1x16) • 열광학소자 : - AKZO*(1X2, 2X2, 1X4, 1X8), KAIST - ETRI, - Allied Signal, ETRI - LG, ETRI, JDS

*AKZO 와 Allied Signal의 광소자 관련 부분은 JDS fitel 사로 합병됨

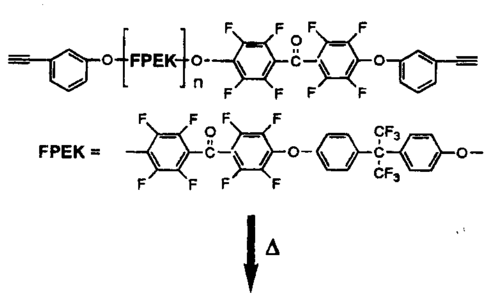
4. 수동/열광학 폴리머 광소자 (ETRI)

4.1 광저손실 물질 :

4.1.1 Fluorinated Poly(arylene ether)s and Poly(ether ketone)s for LLPOW

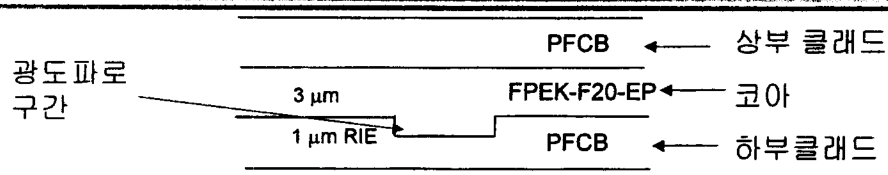
Low Optical Propagation Loss. High Thermal Stability.
Good Chemical Resistance. Good Cleaving Properties.
Lower Birefringence. Lower Curing Temperature.

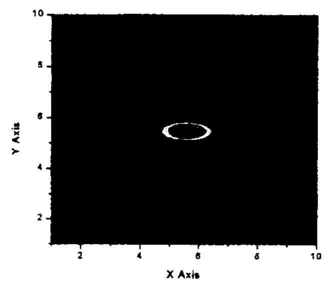
(FPEK-Fn-EP)



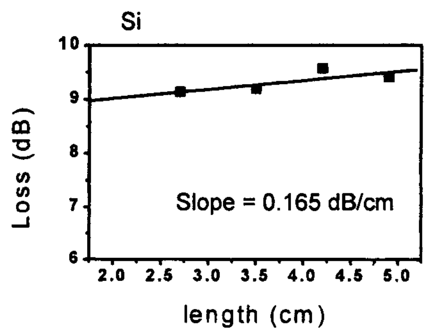
Thermally cured FPEK

4.1.2 FPEK 특성





출력단에서의 광모드



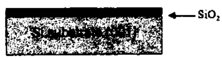
Cut-back method에 의한 광손실 측정

4.1.3 TO 폴리머 물질 국내외 개발 현황

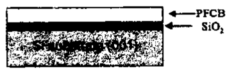
Institute	Materials	Thermal stability (°C)	Birefringence	Optical Loss (dB/cm) (material)
AlliedSignal	UV-currible Fluorinated acrylate	Td > 350 TGA	Δn =0.0008 @543.5 nm	0.03 @1.3 0.05 @1.55
NTT	Deuterated fluorino methacrylate	Tg = 100 DSC	Very small	0.084 @1.3
	Deuterated polysiloxane	Td > 400 TGA	Very small	0.17 @1.3 0.43 @1.55
	Perfluorinated Polyimides	Tg =309 DSC	Δn > 0.04	0.3 < @1.3
Akzo Nobel	Halogenated polymer	Td > 150	Very small	0.25 < @1.55
Dow Chem.	Perfluorocyclobutane (PFCB)	Tg = 400	Δn =0.0008	0.25 @1.3 0.20 @1.55
ETRI	Thermal curable fluorinated poly(arylene ether) (FPAE)	Td > 500	Δn =0.0034	0.20 < @1.55
Samsung	Fluoro chlorinated poly(arylene ether) (FCPAE)	Td > 400		0.20 < @1.55

4.1.4 Fabrication Procedure

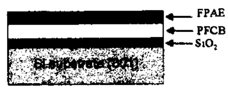
1. substrate



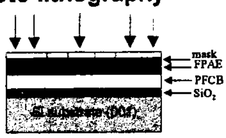
2. Spin coating of lower clad layer



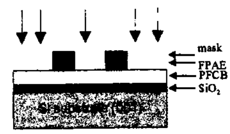
3. Spin coating of core layer



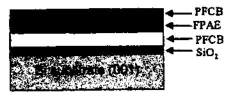
4. Photo lithography



5. RIE of core layer



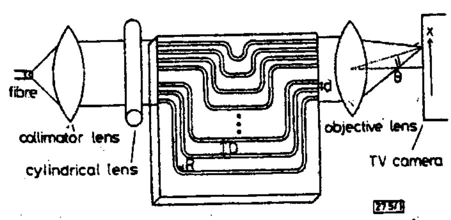
6. Spin coating of upper clad layer



7. Fiber coupling

8. Packaging/Stability

4.2 AWG(arrayed-waveguide grating)



Takahashi et al.

***Fig. 1** Proposed arrayed-waveguide grating and experimental set-up*
Length difference between adjacent channel waveguides is given by $\Delta L = 2(D - d)$

$$n_c \Delta L + n_s d \sin\theta = m\lambda$$

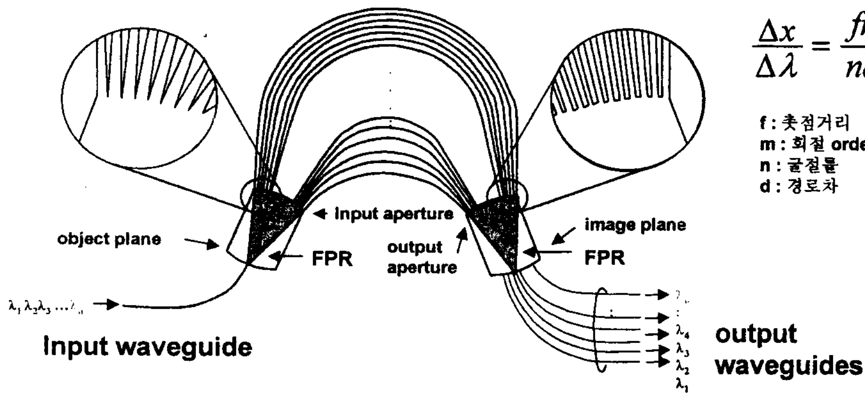
$$dx/d\lambda = fm/n_s d$$

$$\Delta \lambda = \lambda / Nm$$

m; diffraction order, N;channel no.,
n_c;refractive index of channel waveguide
n_s;refractive index of converging space

4.2.1 1xN AWG MUX/DEMUX

기능 : 입사광의 파장에 따라 다른 출력단으로 routing



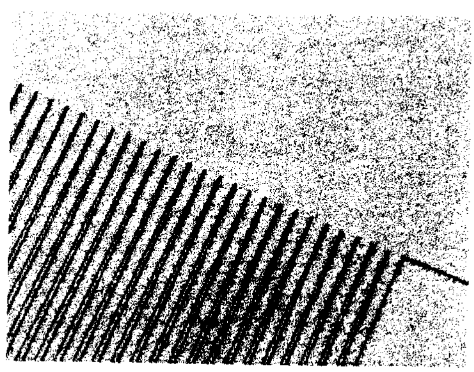
$$\frac{\Delta x}{\Delta \lambda} = \frac{fm}{nd}$$

f : 촛점거리
m : 회절 order
n : 굴절률
d : 경로차

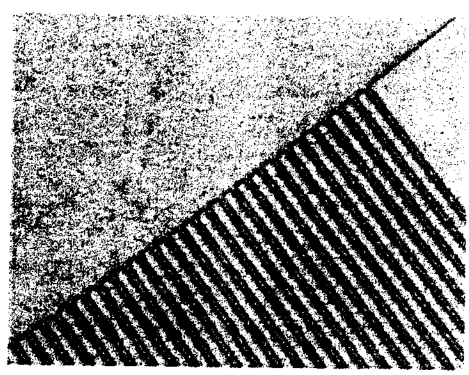
chip size : 60x26 mm²

4.2.2 Microscope of 1x8 demultiplexer

Input transition



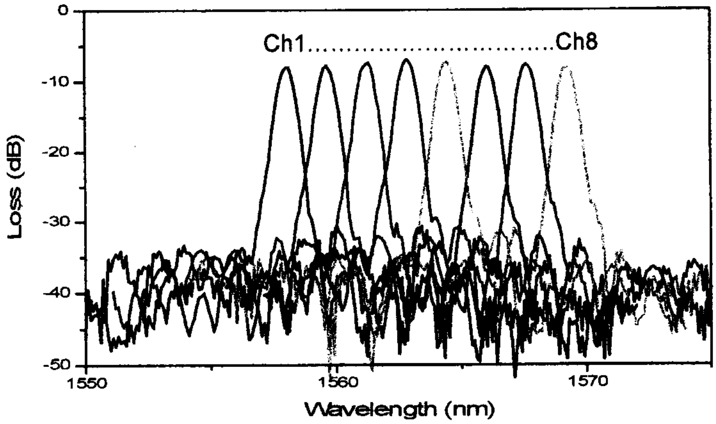
output transition



4.2.3 Measured loss spectra (TE mode)

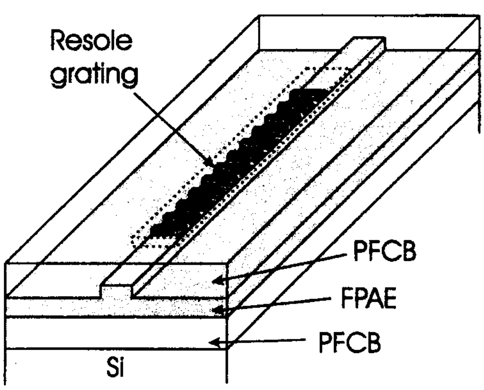
각 출력단에서의 파장에 따른 광출력

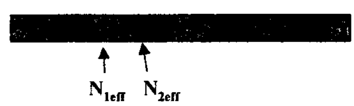
Loss = - 10 Log(I_{out}/I_{in})



4.3 파장 가변 필터

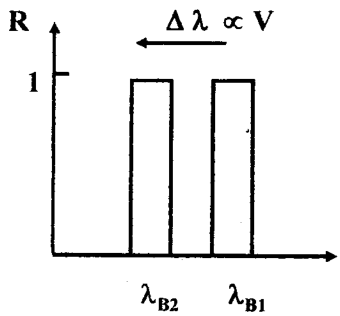
기능 : 열을 가해 폴리머의 굴절률 변환 원하는 파장을 반사시킴



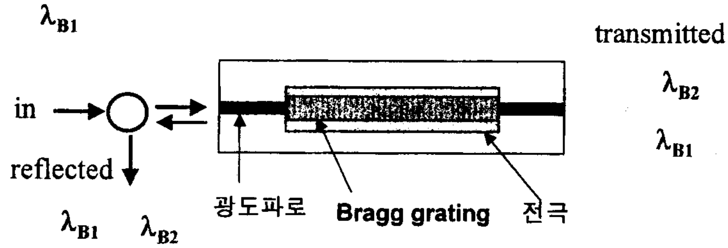


- $\lambda_B = n_{eff} \Lambda_{mask}$
- $\Delta N = N_{1eff} - N_{2eff}$
- 고굴절률 폴리머 회절격자
  (ΔN =0.001, 회절격자수=3000)
- 미세 패턴을 위한 위상 마스크
- 저손실 폴리머 도파로

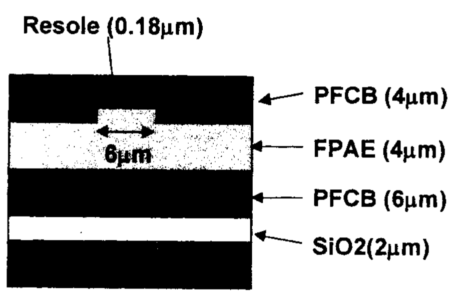
4.3.1 Mechanism



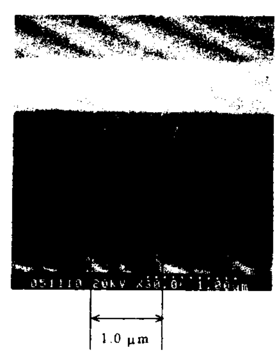
- •Apply current : Refractive index change due to thermo-optic effect
- •number of grating ↑ ..... R ↑
- •ΔN ↑ .... FWHM ↓
- •0.8 nm spacing, R=1



4.3.2 SEM Photograph of Polymeric Bragg Reflector



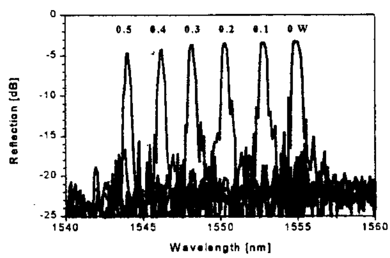
Schematic diagramof waveguide structure



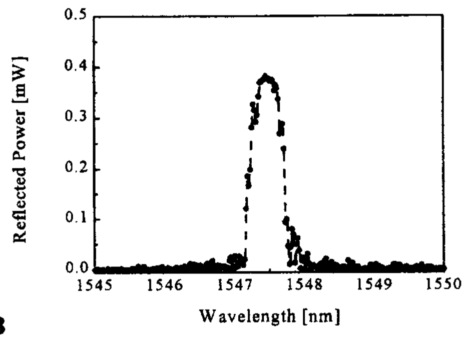
Sub-micron gratings fabricated by using a Phase Mask Technology

4.3.3 Polymeric Bragg Reflection Wavelength Filter

세계 최초의 **Bragg grating형 폴리머 파장 필터(신공정 사용)**



Bragg reflection efficiency : 30 dB
Tuning : 10 nm/0.5W



- **3-dB bandwidth : 0.6 nm**
- **Insertion loss : 3.7 dB**

5. 요약

- **We have shown application of low -loss polymer optical waveguide material**
  - Optical devices are fabricated
  - 1x8, 8x8, 1x16 AWG
  - Tunable Filter
- **Tested in the optical system**
- **Polymer is the most attractive material,**
  if loss comparable for that of silica