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Tunable refractive index titania silica hybrid sol-gel thin films

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Motivation

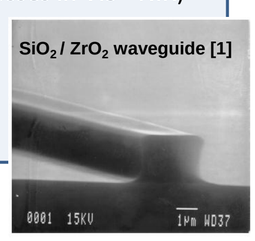
Advantages:

- Sol-gel synthesis close to room temperatures (apart from densification)
- Availability of highly purified precursors
- Controlled doping of different precursors (silica, titania, zirconia based etc.)
- Good optical properties: (variable refractive index (1.45 – 2.45), low material losses in VIS - NIR)
- Photolithography compatibility: Wet etch, dry etch & resist based
- Lower processing costs (relative to vacuum based technologies e.g. MBE, CVD)

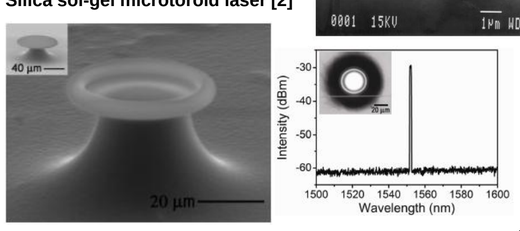
Disadvantages:

- Metal precursors are extremely moisture sensitive
- Drying process can introduce cracking
- Need high temperature baking to remove additional reagents

SiO_2 / ZrO_2 waveguide [1]



Silica sol-gel microtoroid laser [2]

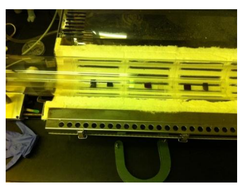


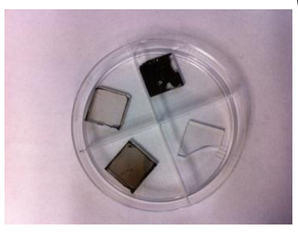
Synthesis and Characterization

Titanium - *n* – butoxide (*metal organic precursor*) + Benzoyl Acetone (*chelating agent*) + Ethanol [equal molar ratio] [3]

↓ *Mix in a glove bag for 3 hours in a N_2 environment*

Filter with 0.2 μm PTFE filter and spin coat at 2000 rpm, 45 sec, dwell time

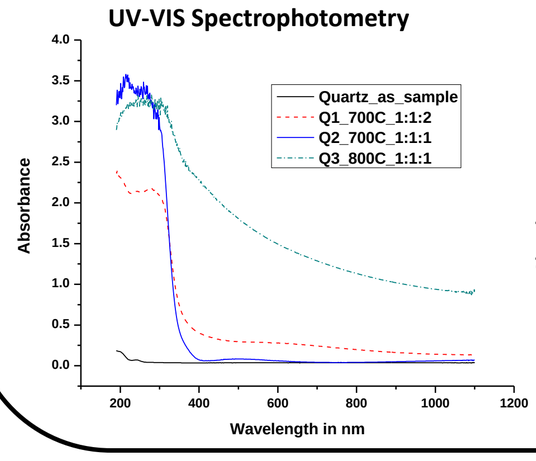




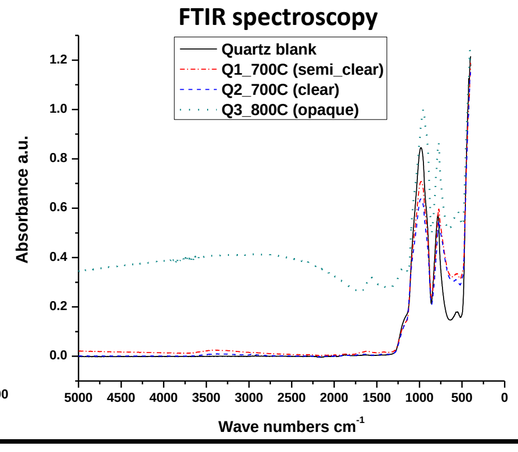
Spin coat and bake films on Quartz, Silica and Silicon substrates

Vacuum and Air bake at temperatures between 700 ^{0}C and 1050 ^{0}C

UV-VIS Spectrophotometry



FTIR spectroscopy



Thin film characterization

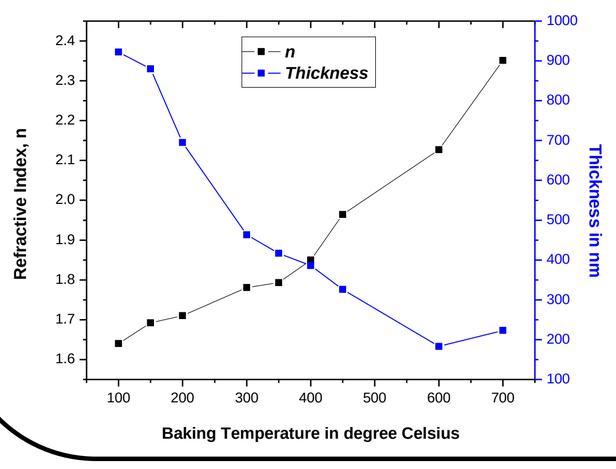
TITANIA PRECURSOR
Titanium Butoxide (TiBut)
Benzoyl Acetone (BzAc)
Ethanol (EtOH)
Molar Ratios
TiBut : BzAc : EtOH :: 1 :1 : 1

+

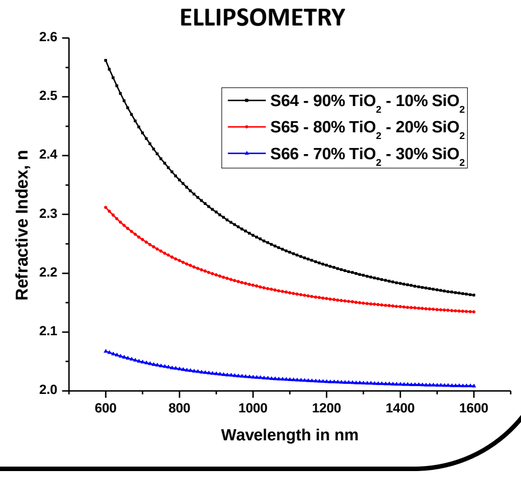
SILICA PRECURSOR
Methyl acryloxy propyl trimethoxy silane (MAPTMS)
0.01 M Hydrochloric Acid (HCl)
DI water (H_2O)
Molar Ratios
TiBut: MAPTMS: HCl: H_2O :: 1: 1: 0.75: 1

Volume ratio TiO_2: SiO_2	Thickness 7 hour vacuum 700 ^{0}C bake + 5 hour air rebake 1020 ^{0}C
90 % - 10 %	~ 503 nm
80 % - 20 %	~ 552 nm
70 % - 30 %	~ 682 nm (Max. ~1. 5 μm)

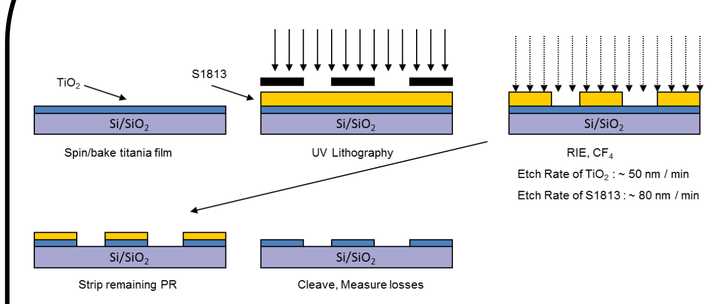
Refractive Index (@ 1550 nm), thickness *vs* baking temperature

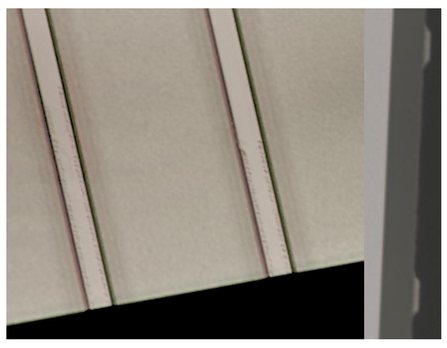


ELLIPSOMETRY

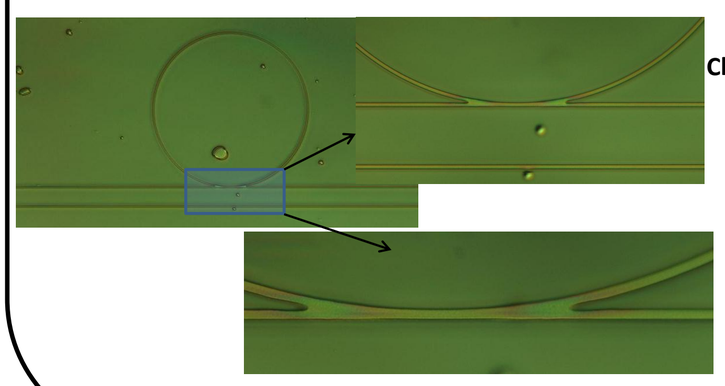


Device Fabrication

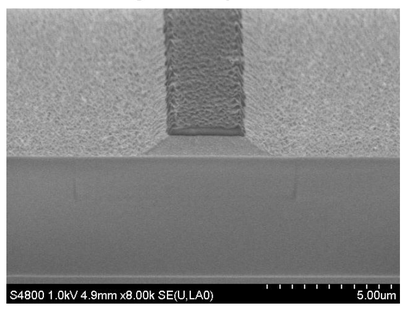




Cleaved waveguide top view and cross section



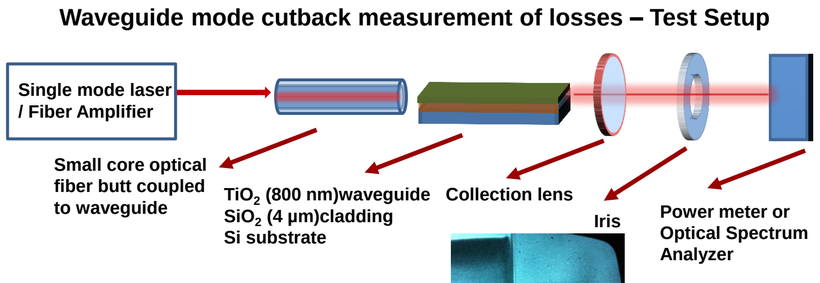
Micro ring resonator with MMI coupler



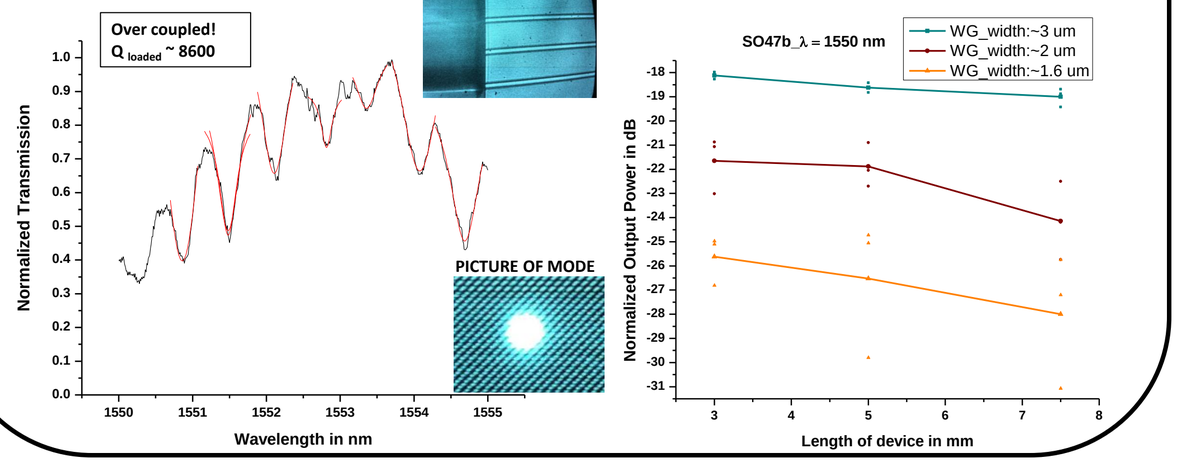
Cleaved waveguide with PR - SEM

Loss Measurements

Waveguide mode cutback measurement of losses – Test Setup



Waveguide width	Waveguide losses in dB/cm	
	1310 nm	1550 nm
~ 5 μm	~ 1.2	~ 2
~ 4 μm	~ 5.2	~ 5.5
~ 3 μm	~ 5.2	~ 5.5



Conclusion

- Synthesized, fabricated and characterized variable refractive index hybrid sol-gel films made of titania and silica sol-gel (Refractive Index between 1.6 and 2.5)
- Fabricated and characterized straight waveguides and micro ring resonators to obtain material losses (Scattering dominated, best values so far: 1-2 dB / cm)

Applications:

- Micro ring resonator based optical filters and waveguide Bragg grating filters
- Integrated optical coupling waveguides for Lithium Niobate/ Lithium Tantalate microdisks

Future Work:

- Improve etch recipe to minimize scattering losses and hence isolate material losses
- Demonstration of functional photonic devices like microring filters & waveguide Bragg gratings

References:

[1] Du X.M., Touam T., Degachi L., Guilbault J.L., Andrews M.P. and Najafi S.I., Optical Engineering, Vol. 37, No. 4, pp. 1101 – 1104 (1998)

[2] H.-S. Hsu, C. Cai and A. M. Armani, Optics Express, Vol. 17, No. 25, pp. 23265 - 23271(2009)

[3] B. Liu and S.-T. Ho, Journal of The Electrochemical Society, Vol. 155, pp. 57-60 (2008)

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