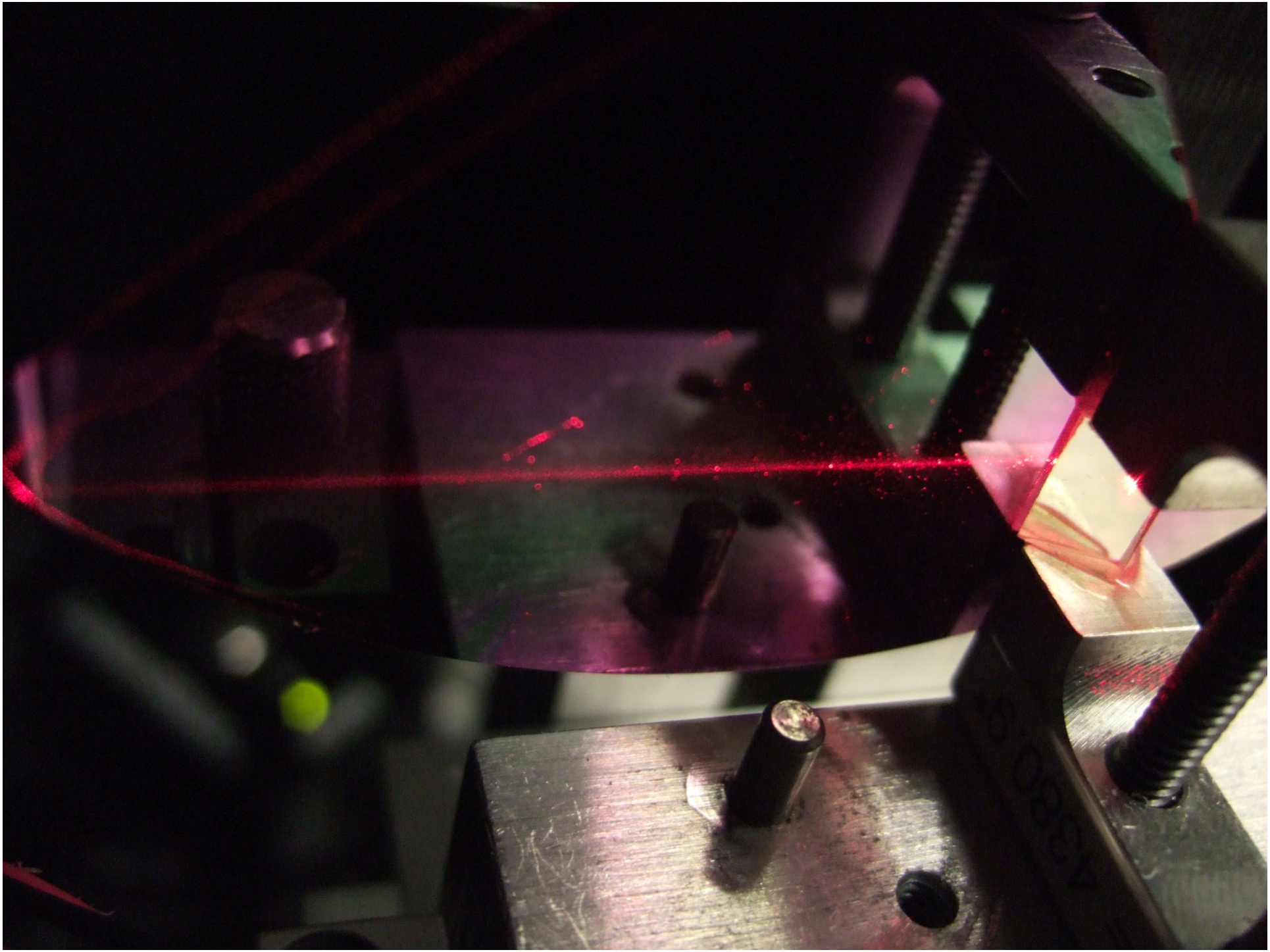


Impact of Sputtering Parameters on TiO_2 Thin Films for Non-Linear Nanophotonics

François Parsy, Jonathan Bradley, Chris Evans, Katherine Phillips, Ruwan Senaratne, Erwin Marti, and Eric Mazur

Mazur Group
School of Engineering and Applied Sciences
Harvard University

Outline

State of the art

Deposition process

Results

Outline

State of the art

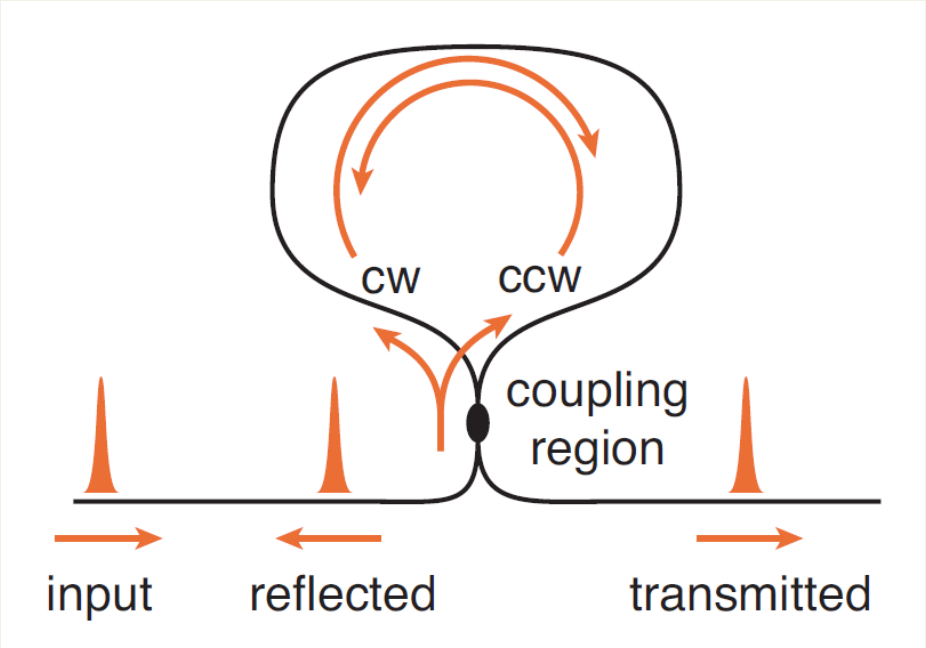
Deposition process

Results

State of the art

- Kerr effect

$$n = n_0 + n_2 I$$



Sagnac interferometer

M. Jinno, Journal of Quantum Electronics, **28**, **4**, 1992
Geoffrey Svacha thesis, Mazur Group, 2008

State of the art

- Kerr effect

$$n = n_0 + n_2 I$$

- Non-linear materials
  - SiO_2
  - Chalcogenides
  - AlGaAs and GaAs
  - TiO_2

State of the art

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n_0	n_2 (10^{-13} esu)	λ (μm)	E_g (eV)
1.45	0.85	1.06	8.9

Adair et. al., *Phys Rev B.* **39**, 1989

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Takana et al., Journal of non-crystalline solids, **198-200,** 1996
Ta'eed, Optics Express, **15**, 2007

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PLK Wa, *IEEE*, ***vol. 2***, 1994

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2.48	55.8	1.06	3.3

Adair et. al., *Phys Rev B.* **39**, 1989

Goals

- Reproducible deposition process
- High refractive index
- Low linear losses : < 1dB/cm

Outline

State of the art

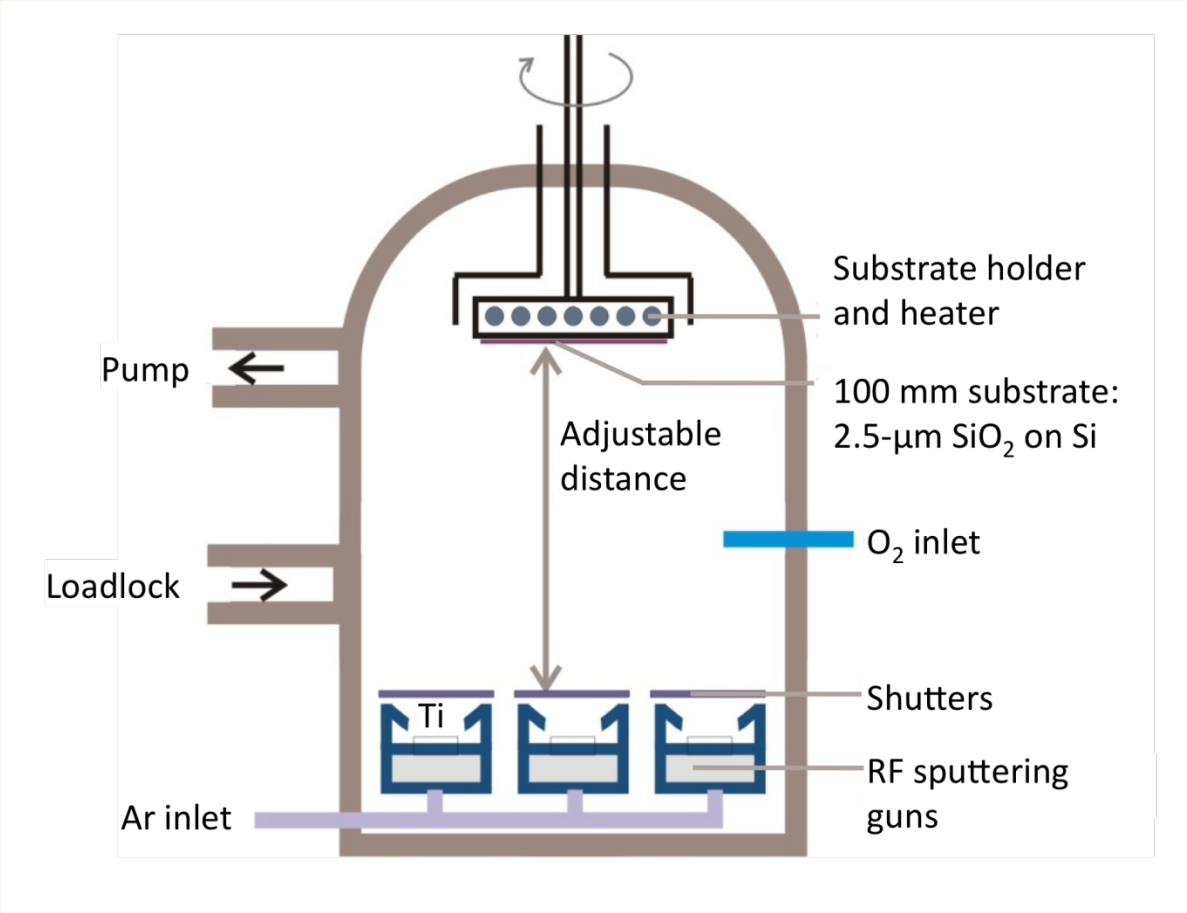
Deposition process

Results

Deposition

RF-Sputtering System

Deposition



Working Principle

Deposition

Parameter	Unit	Range
Temperature	[°C]	20 – 600
Plasma Genetator Power	[W]	100 – 200
Pressure	[mTorr]	2 – 5
Total Flow	[sccm]	40 – 60
O_2 Partial Flow	[%]	2 – 33

Outline

State of the art

Deposition process

Results

Results

Parameter	Charaterization Method
Composition	X-ray Photoelectron Spectroscopy
Phase	Raman Spectroscopy
Structure	Scanning Electron Microscopy
Thickness, Refractive Index	Ellipsometry, Prism Coupling
Linear Losses	Prism Coupling

Composition

- Different Titanium Oxides

Oxide	Titanium atomic %
TiO_3	25
TiO_2	33.3
Ti_3O_5	37.5
Ti_2O_3	40
TiO	50

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- Different Titanium Oxides

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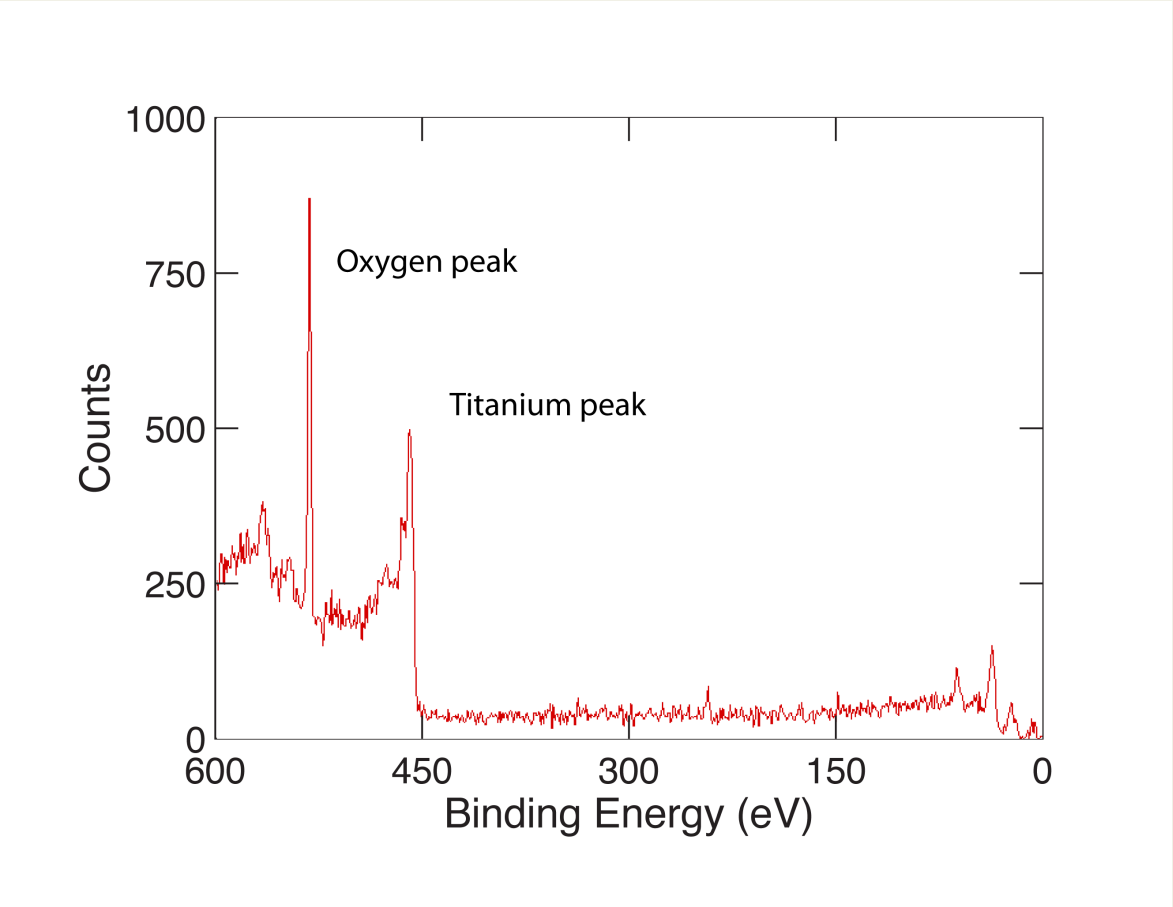
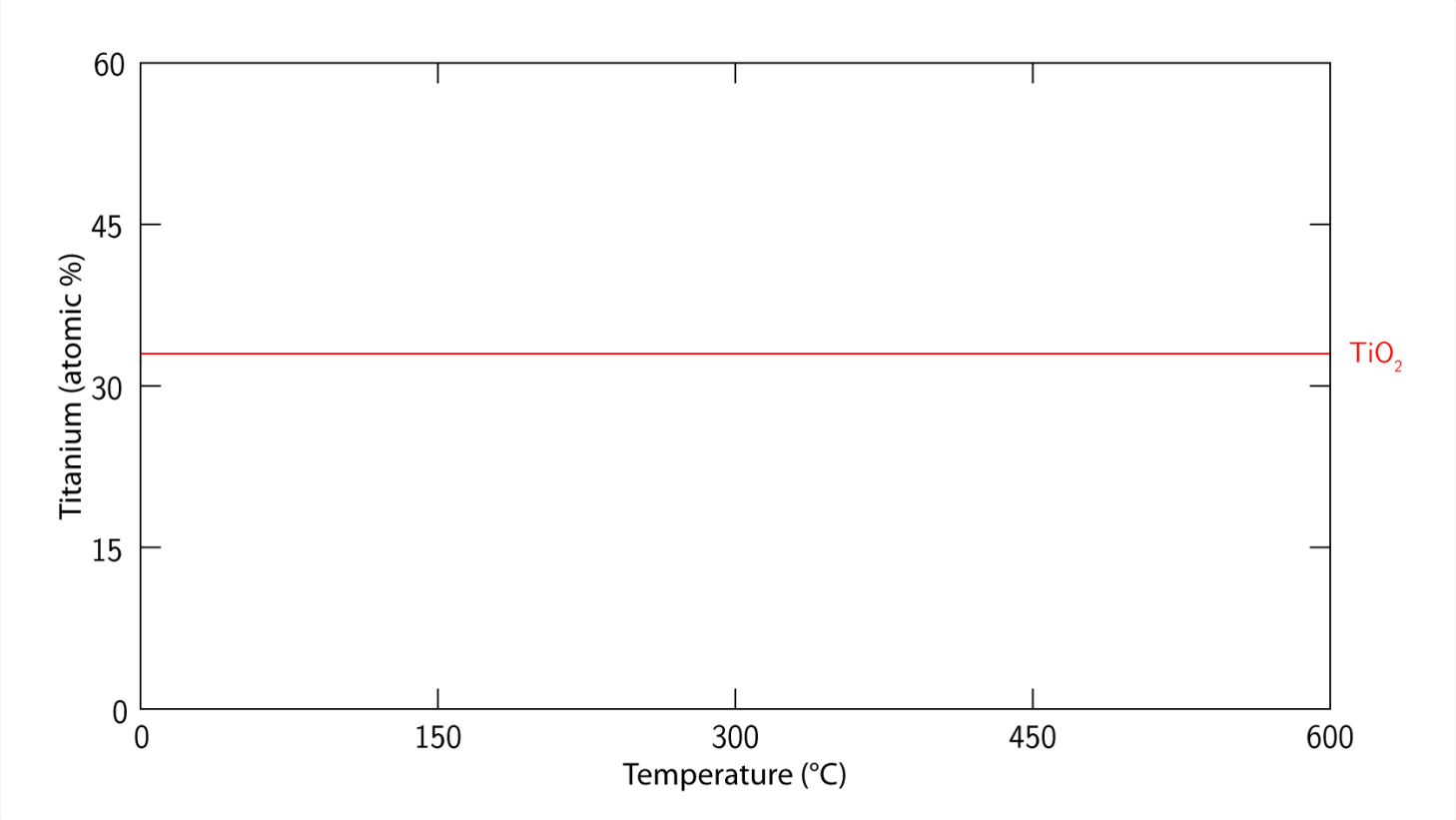
Composition



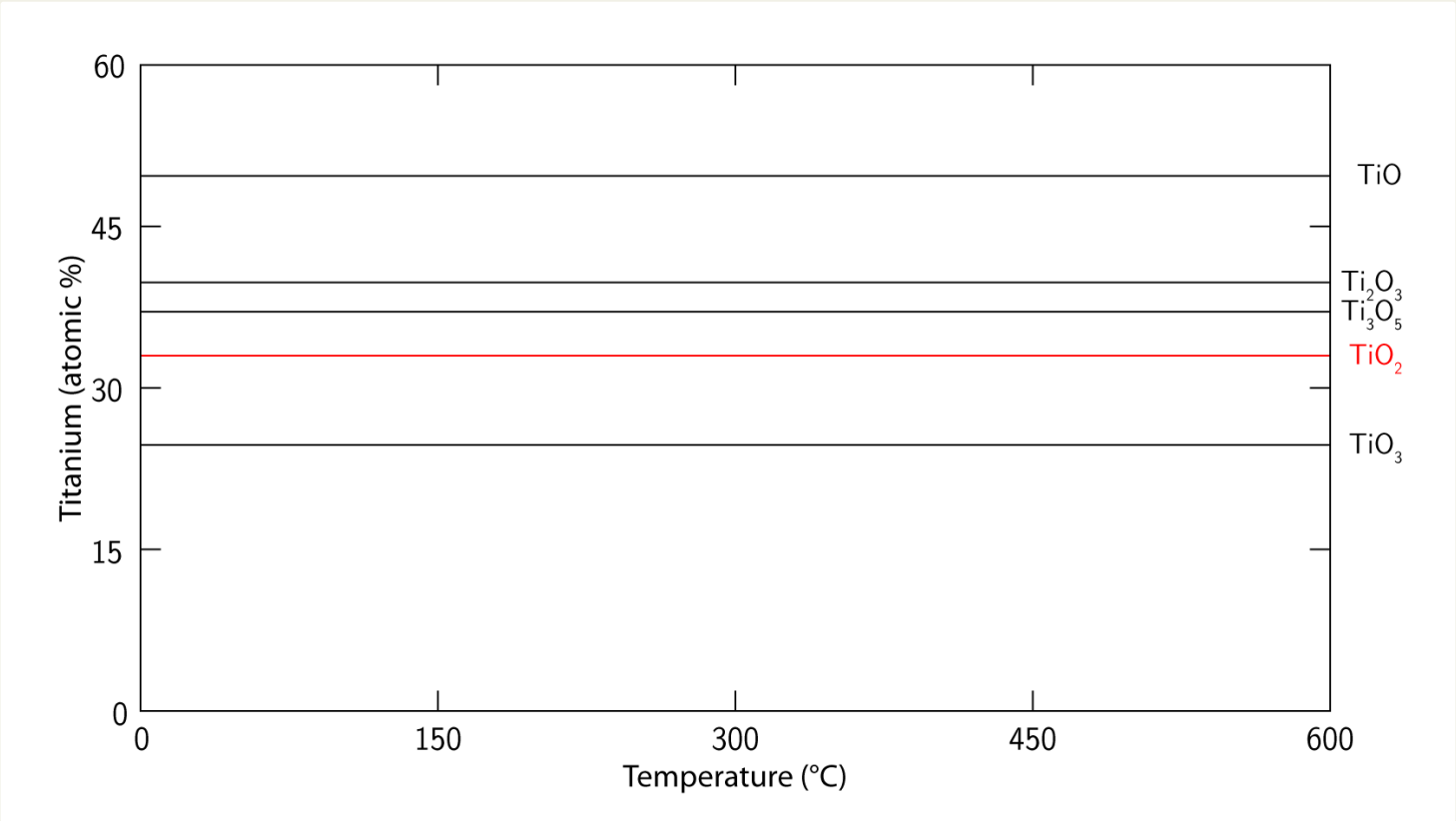
X-Ray Photoelectron Spectroscopy Measurement

Composition



Analysis of the results

Composition



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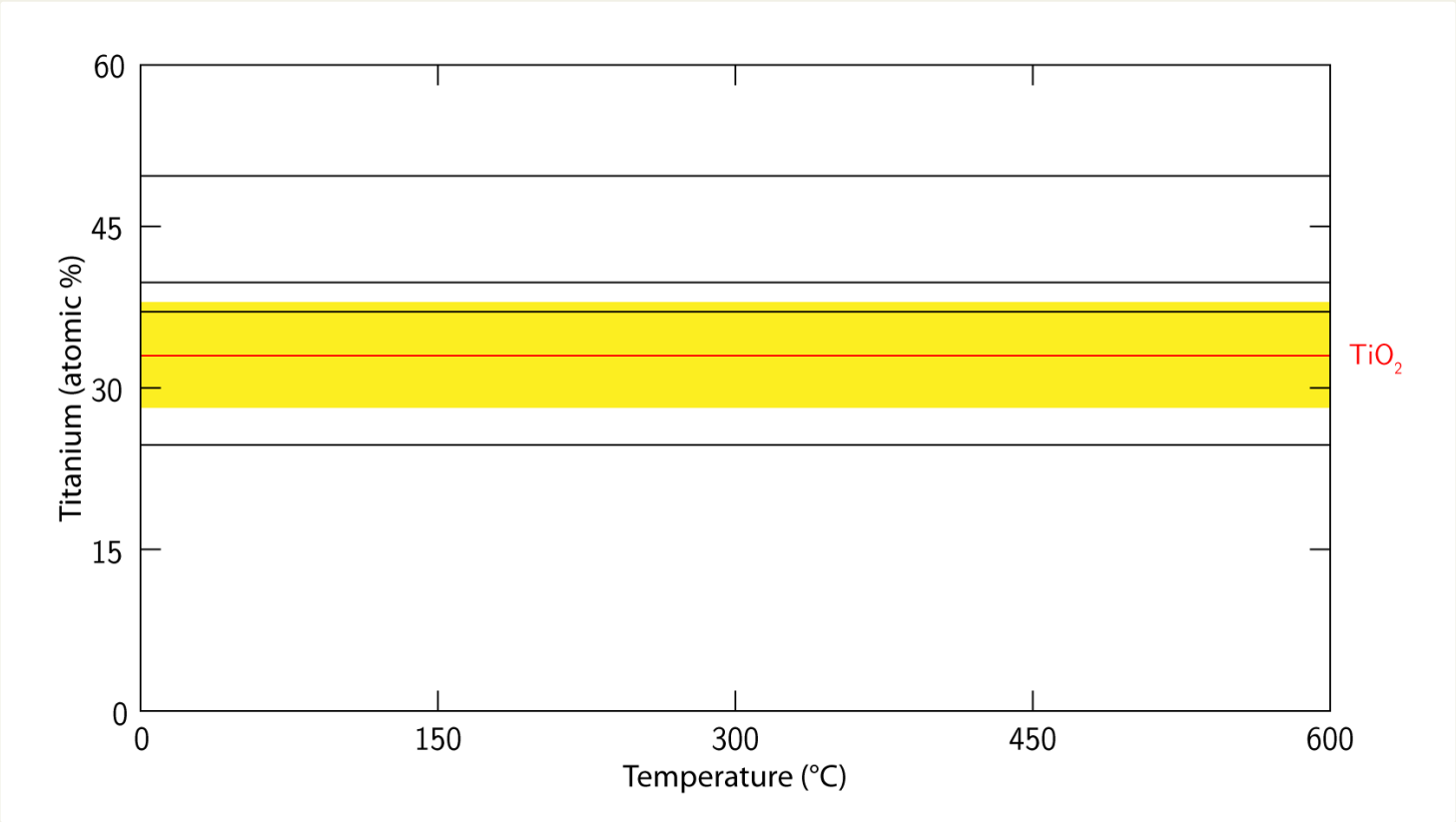

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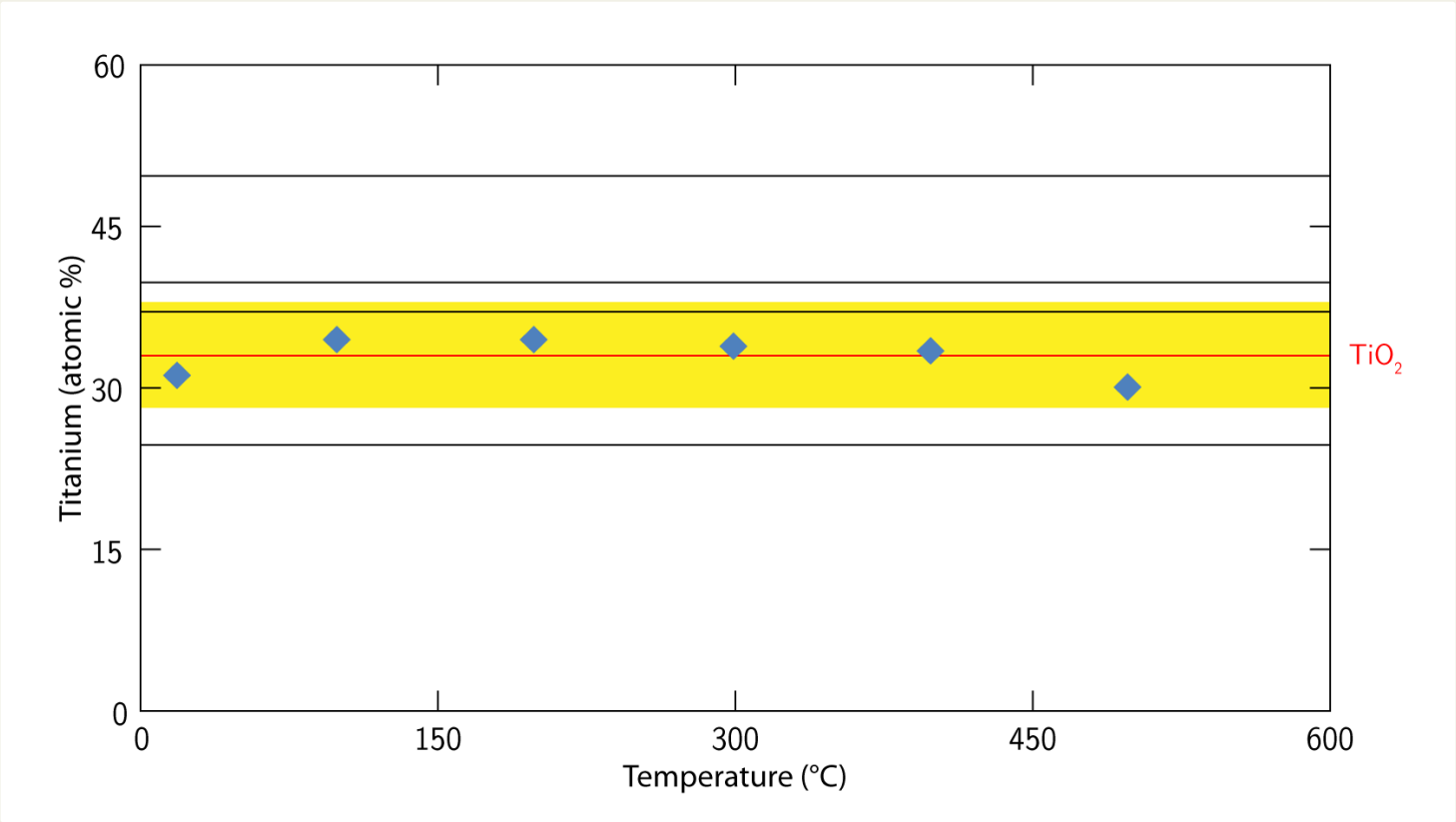

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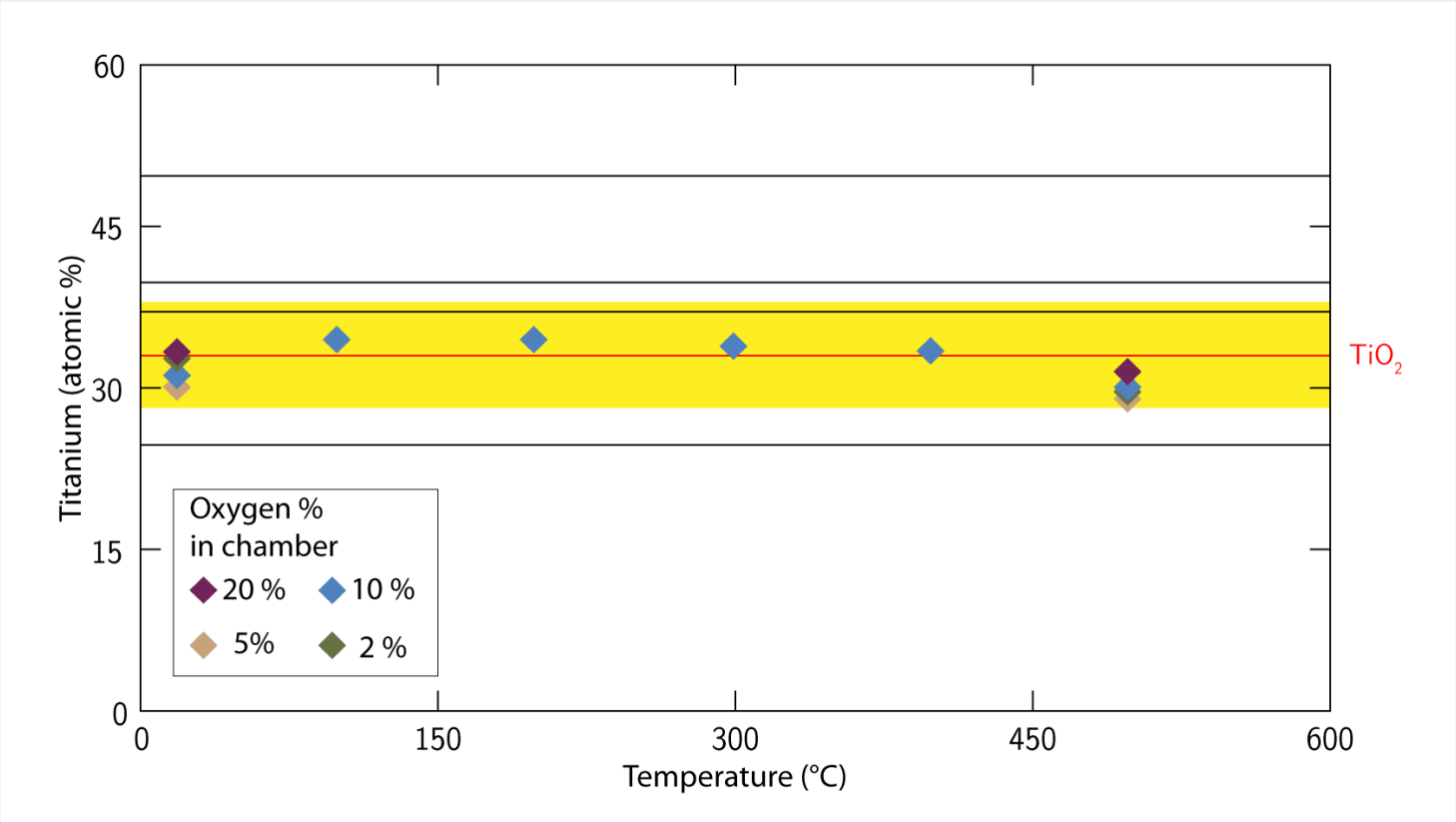
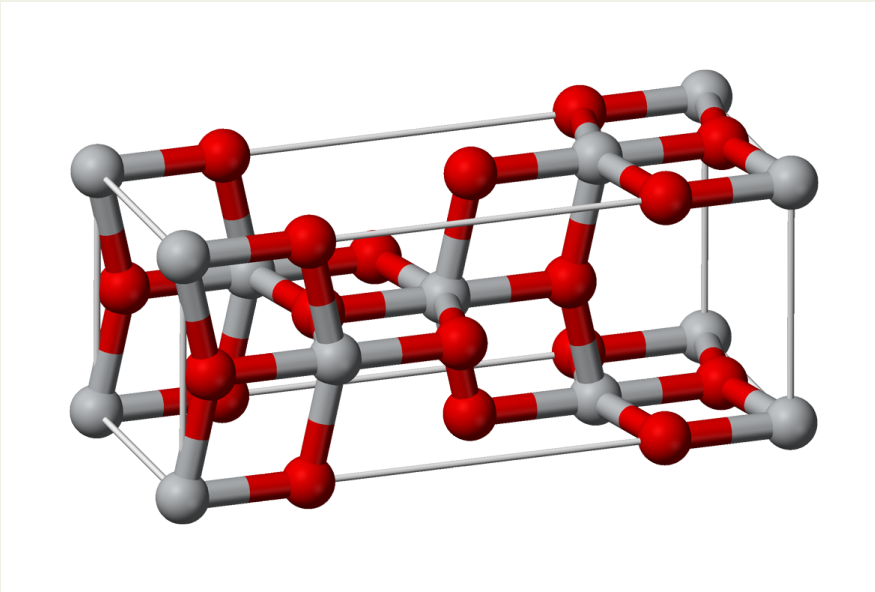


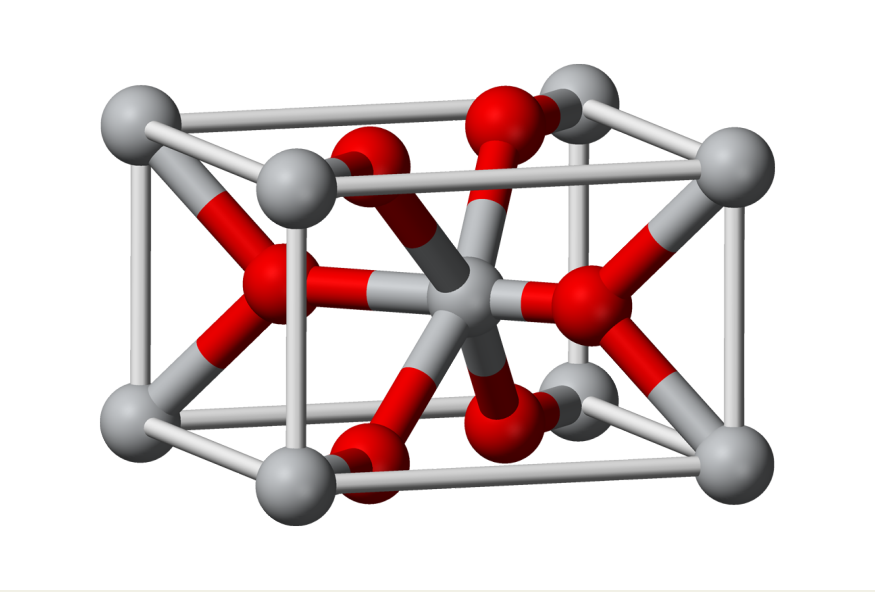
Analysis of the results

Phase

Different phases of TiO_2

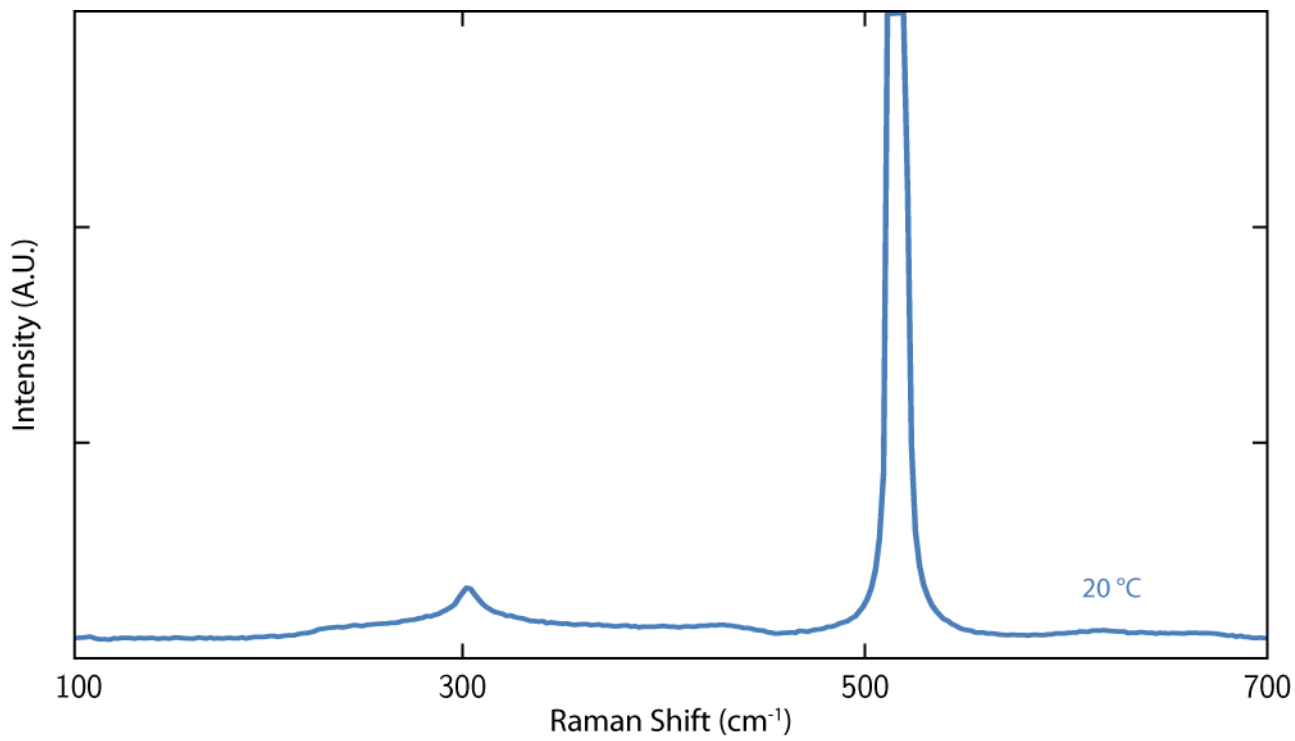


Anatase



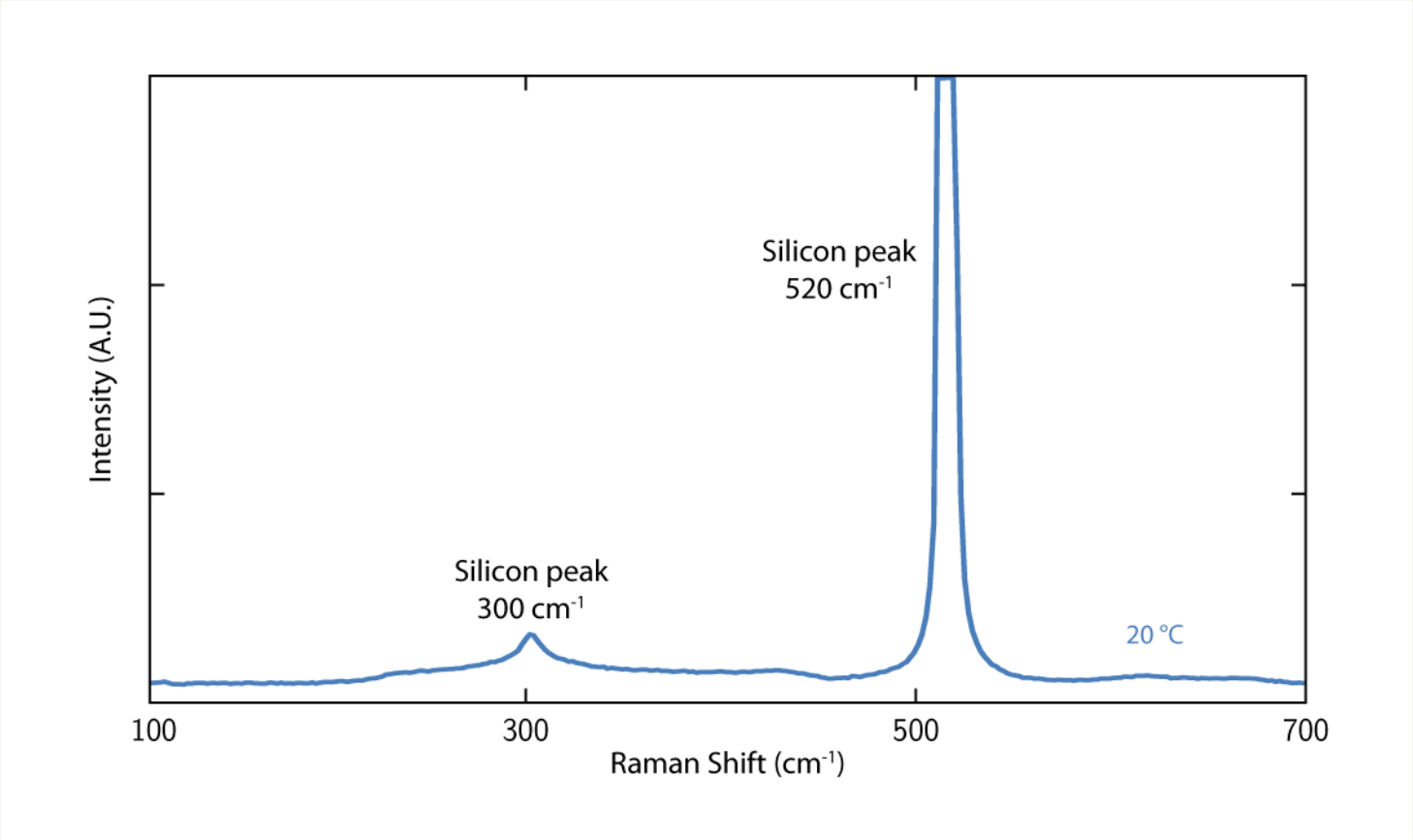
Rutile

Phase



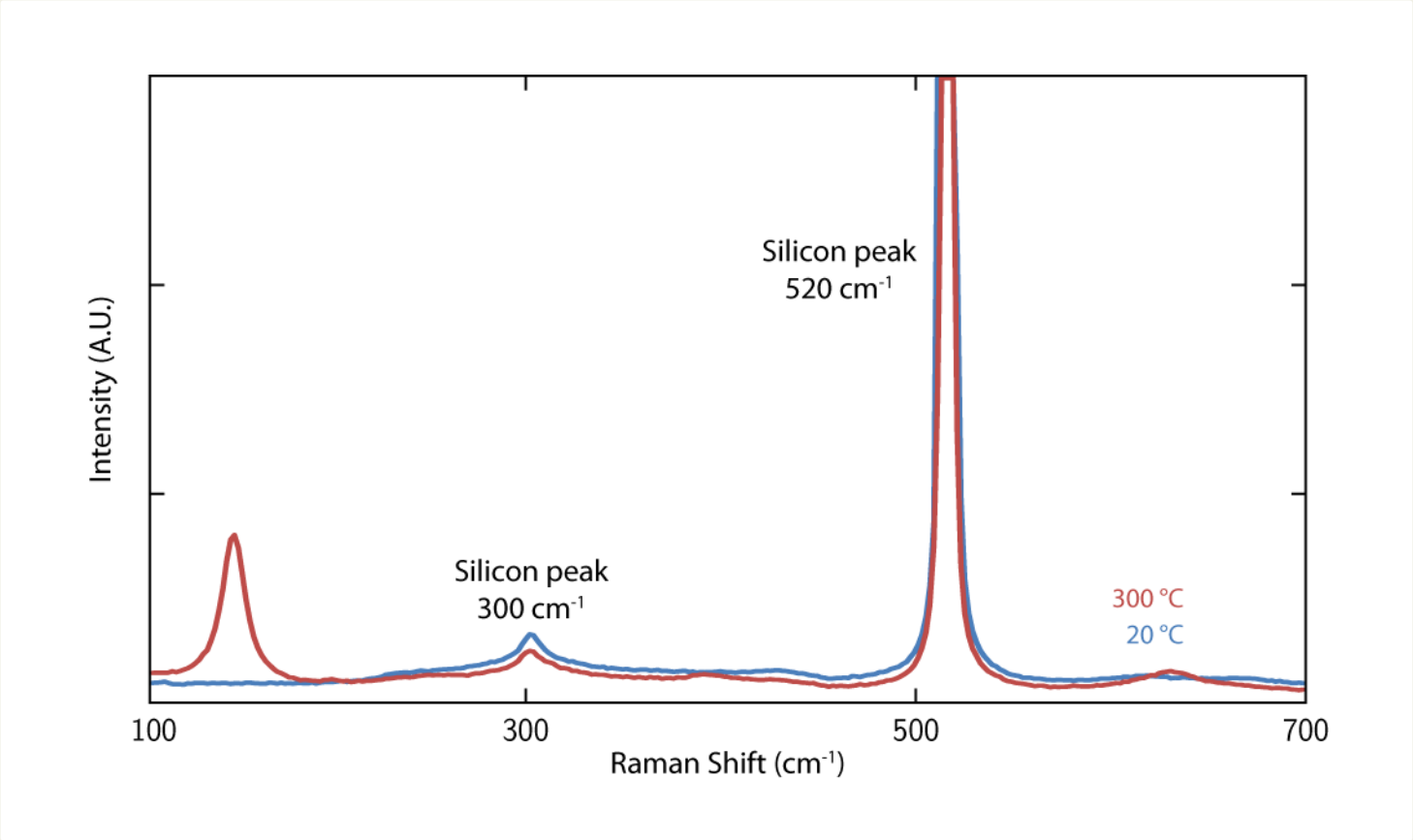
Raman Spectra

Phase



Raman Spectra

Phase



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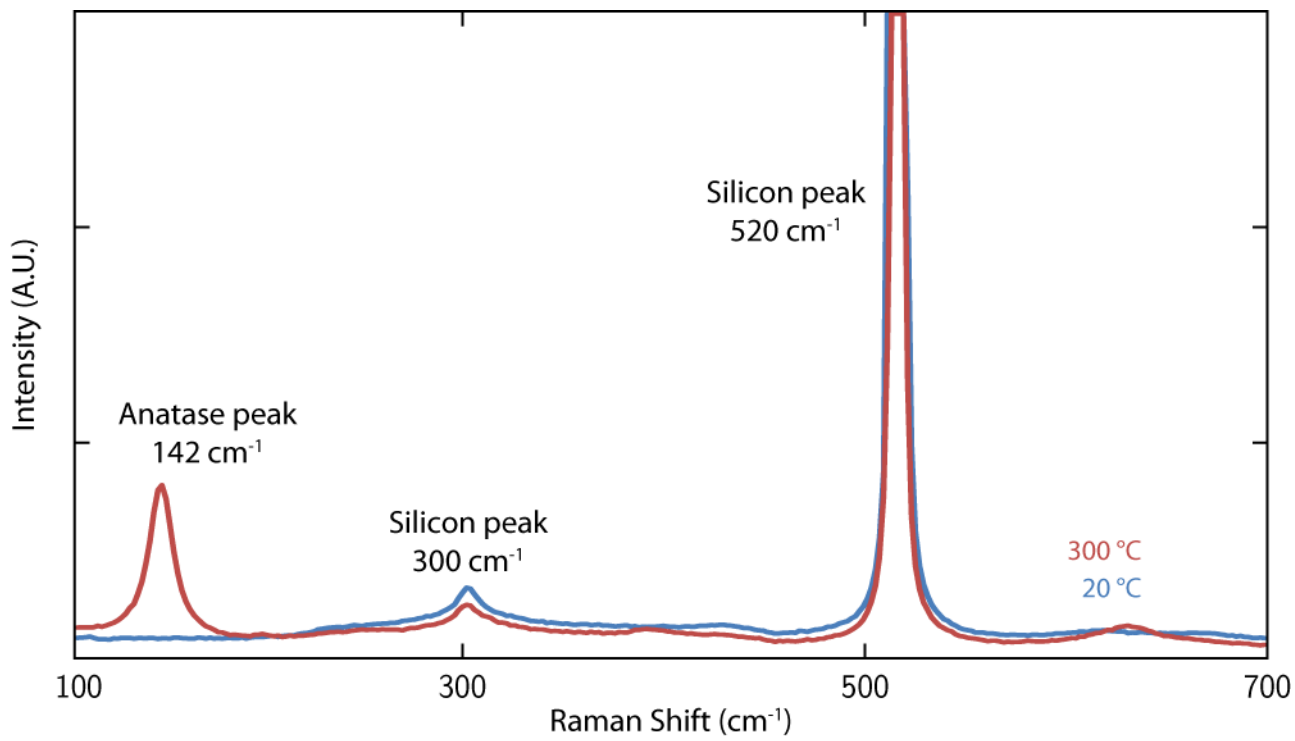
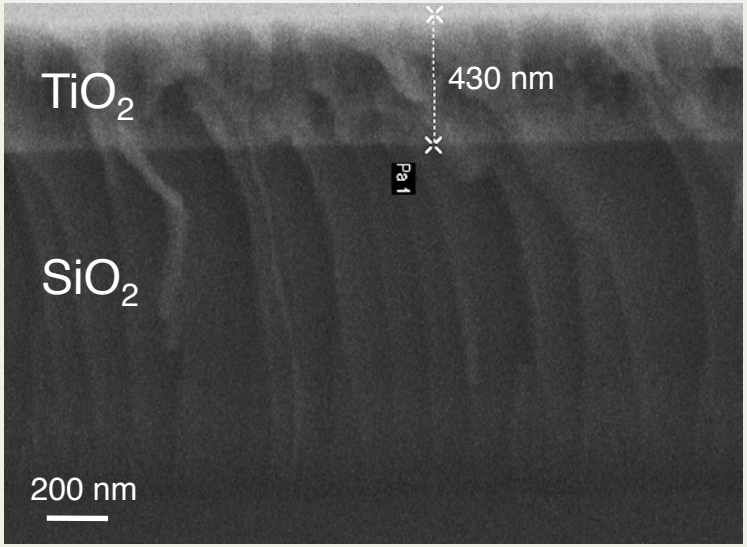


Raman Spectra

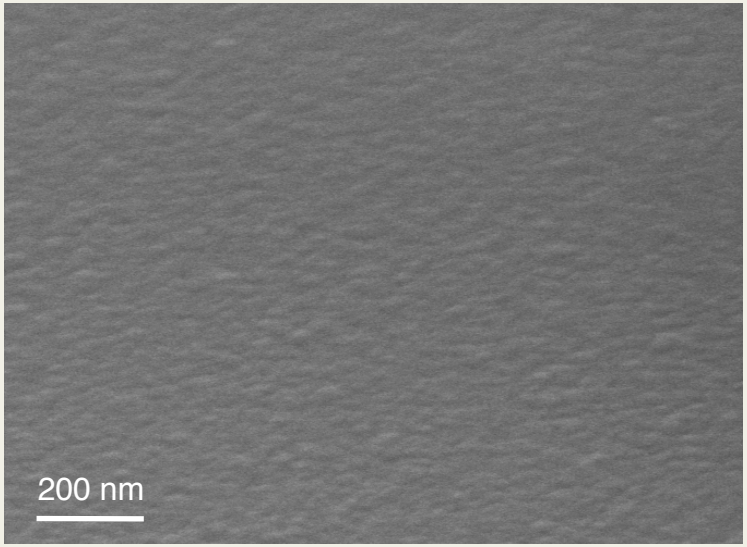
Ohsaka et. al., *Journal of Raman Spectroscopy* **7**, 1978.

Structure

SEM Images

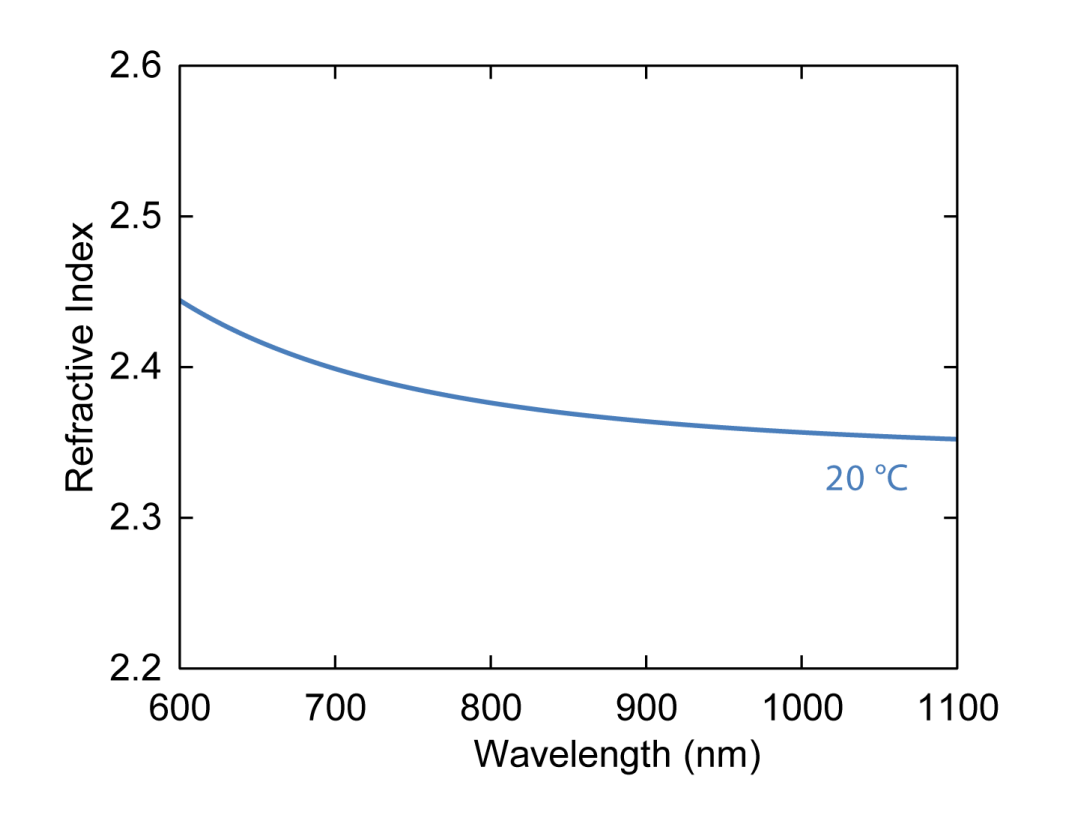


Cross-section



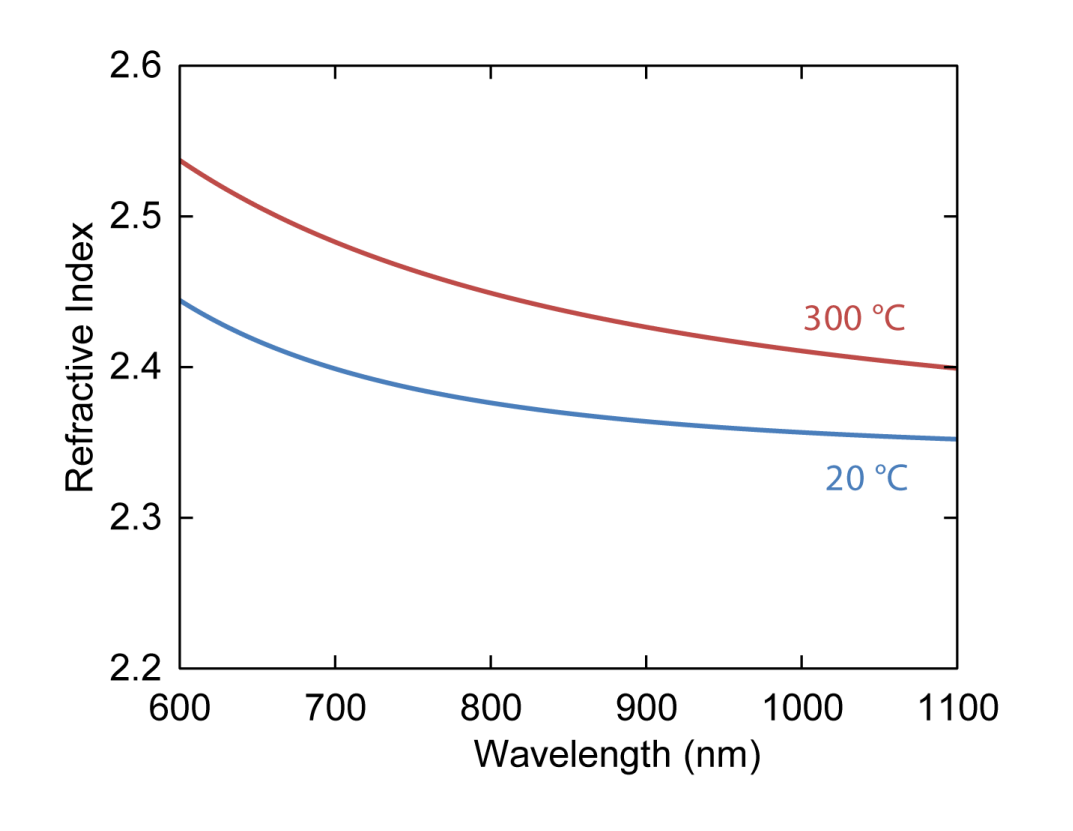
Surface

Index of Refraction



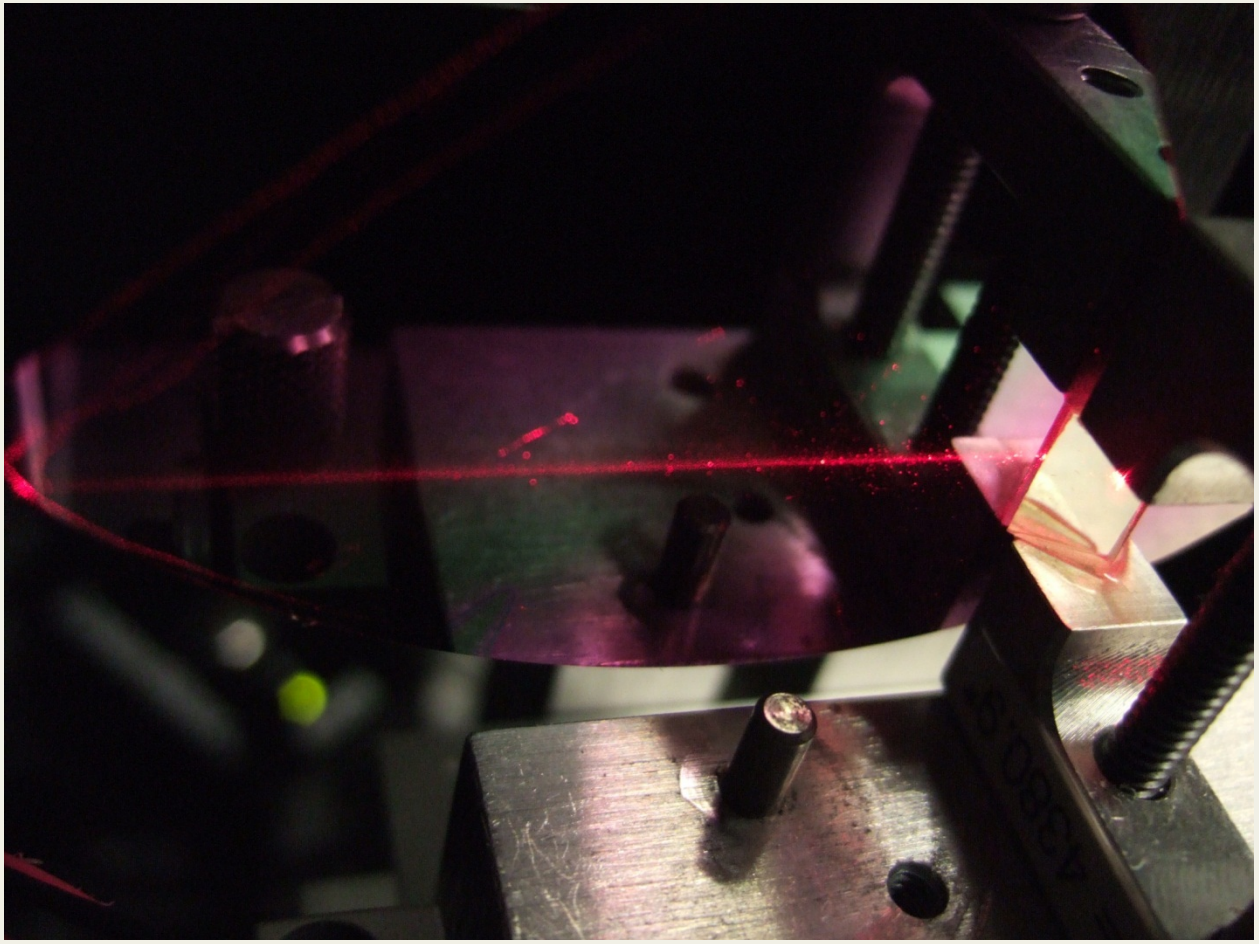
Dispersion curve

Index of Refraction



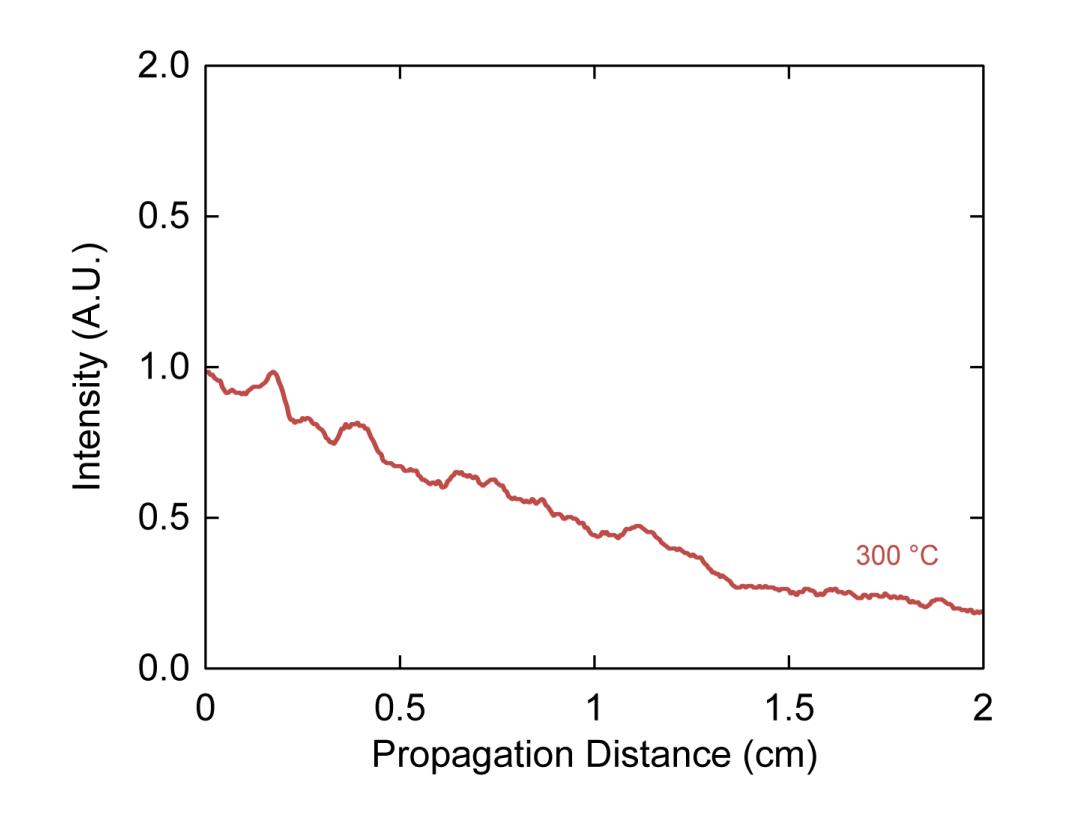
Dispersion curve

Linear Losses



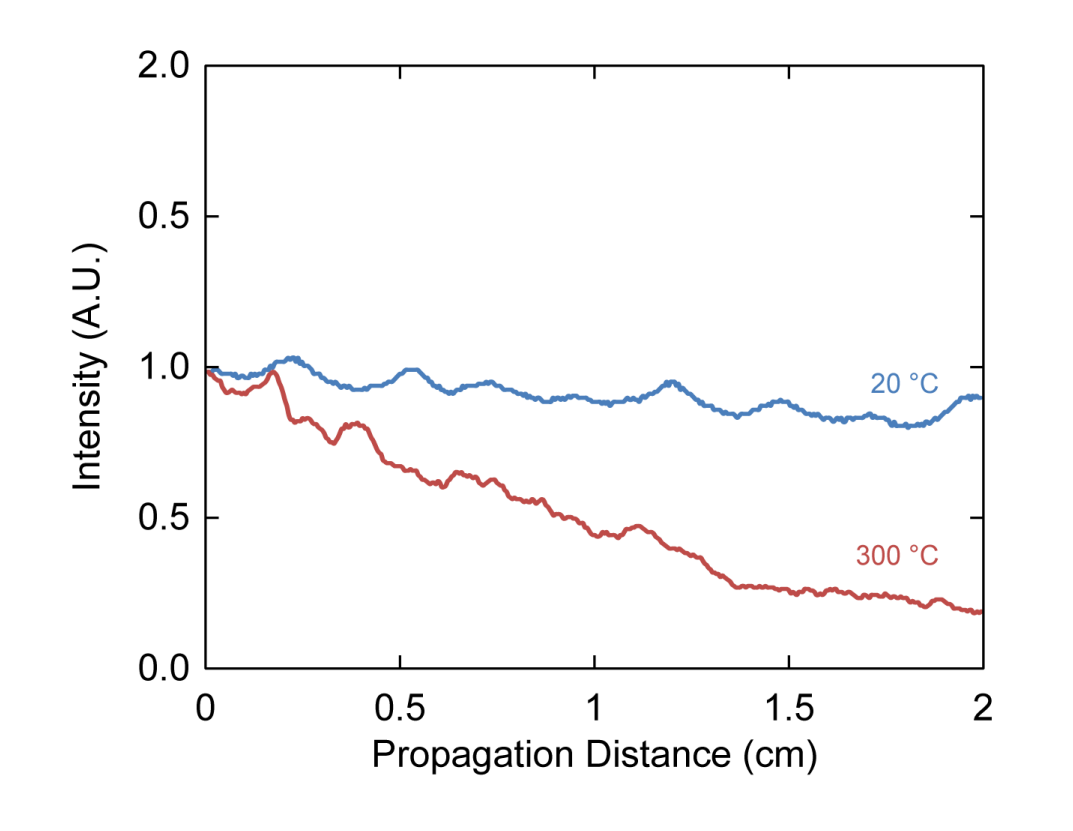
Prism Coupling Setup

Linear Losses



Prism Coupling Measurement

Linear Losses



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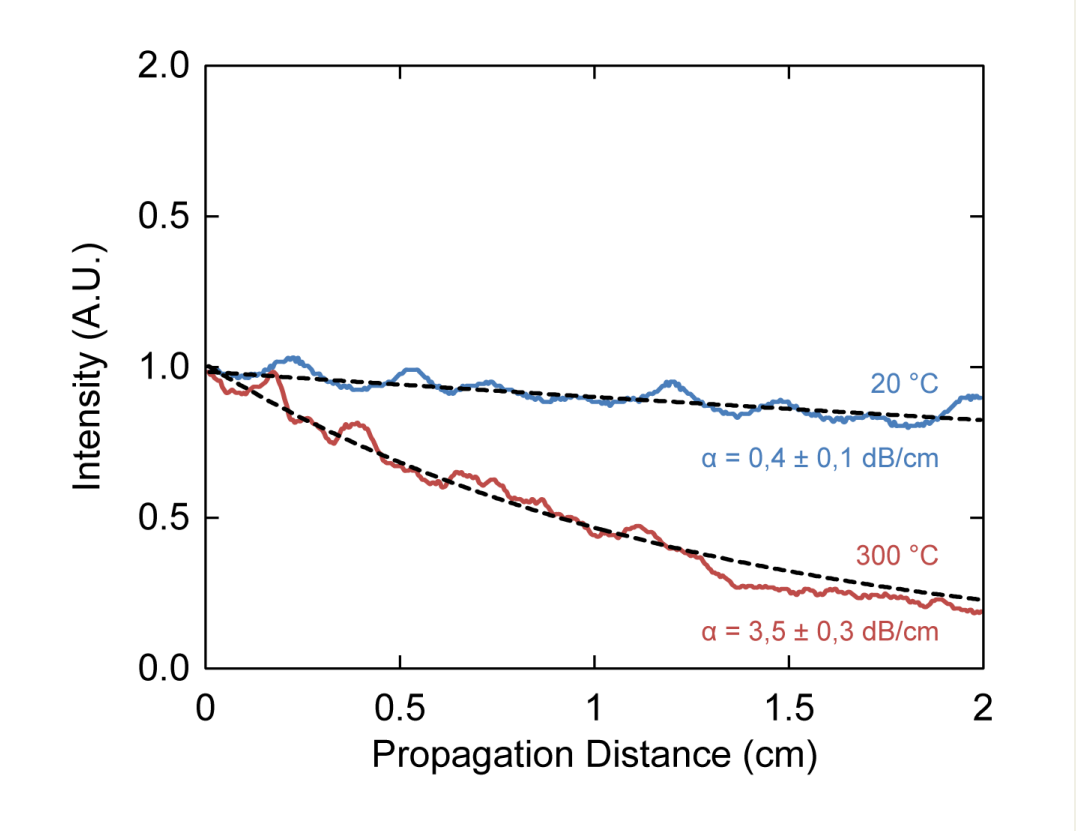

Prism Coupling Measurement

Conclusion

Deposited TiO_2, reproducible process

Linear losses: 0.4 $dB.cm^{-1}$

Refractive index: 2.34

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TiO_2 is a promising material
for non-linear integrated optics.

Conclusion

Non-linearity measurement in progress

Christopher Evans: Thursday at 2:35

Acknowledgements

National Science Foundation

Nanoscale Engineering and Science Center (NSEC)

Center for Nanoscale Systems (CNS)