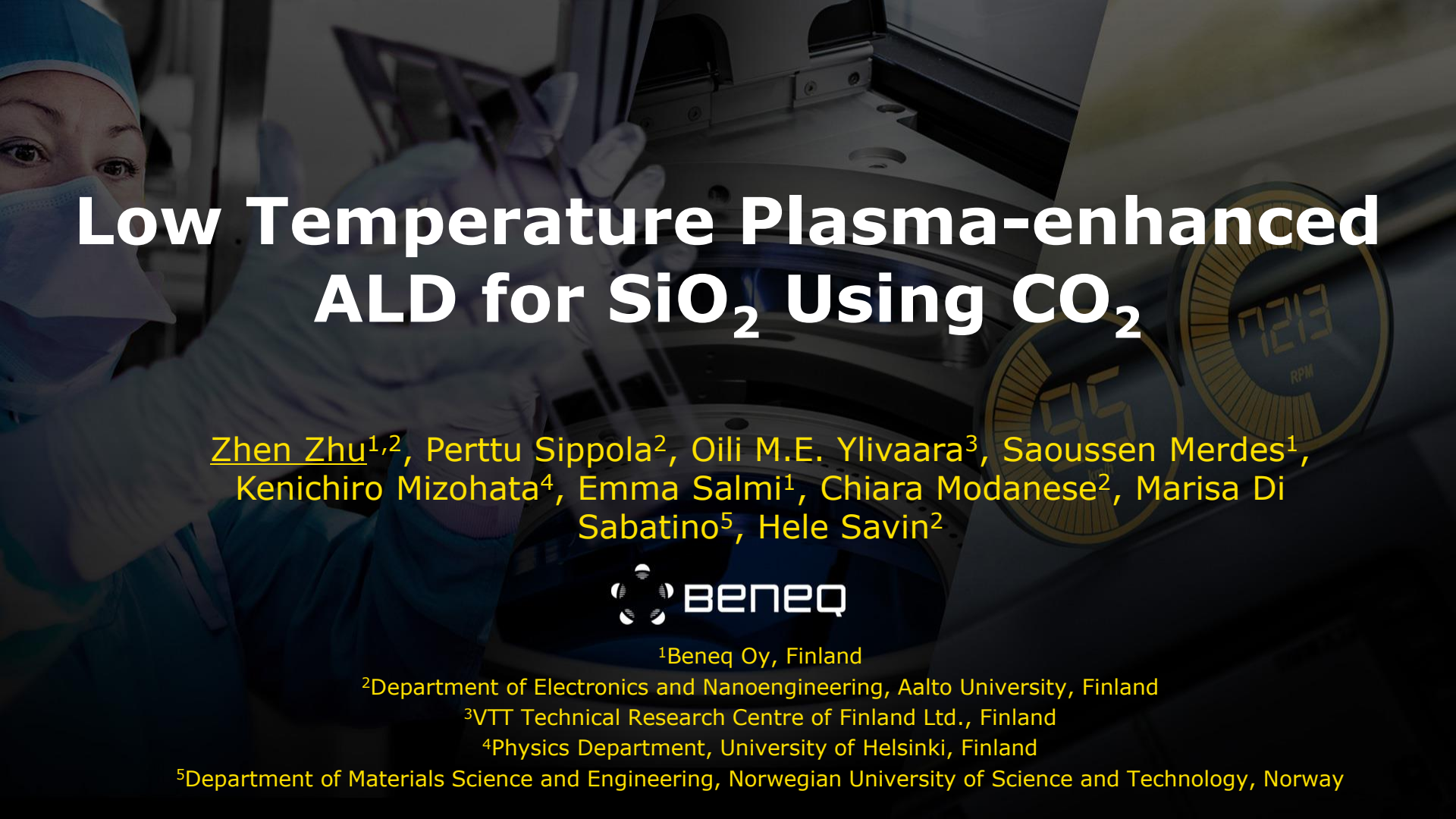

# Low Temperature Plasma-enhanced ALD for $SiO_2$ Using $CO_2$


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# Outline

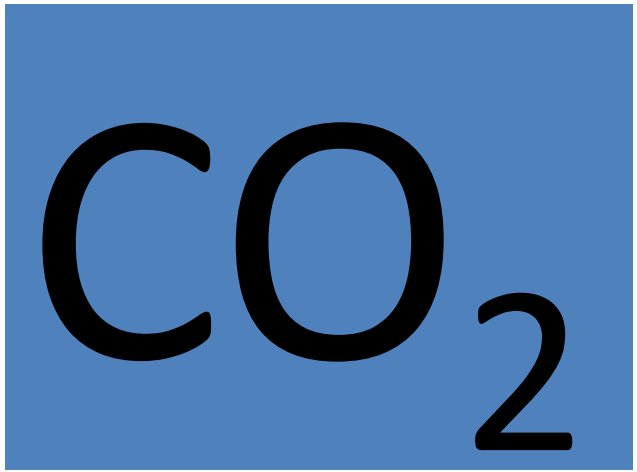
- Motivation
- Methods
- Results
  - Film Growth
  - Film Characterization
- Conclusions

# Motivation

## Thermal sensitive materials

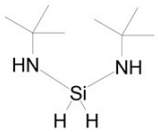
## Moisture/oxygen sensitive materials

- Deposition temperature of ALD $SiO_2$
  - 200 °C or more
  - <100°C
    - Catalyzed ALD
    - Plasma-enhanced ALD
    - Precusor development
- Commonly used oxidants
  - Water-based
  - $O_2$-based

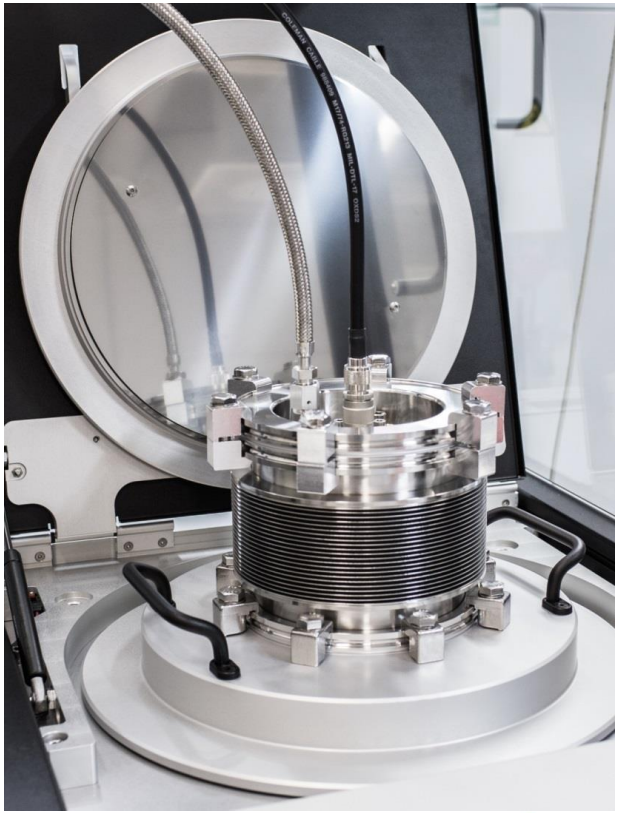


# Methods

- Deposition
  - TFS 200 with remote plasma option (capacitively coupled 13,56 MHz RF source)
  - Precursors:
    - BTBAS [bis(tertiary-butylamino)silane; $C_8H_{22}N_2Si$]
    - $CO_2$ plasma

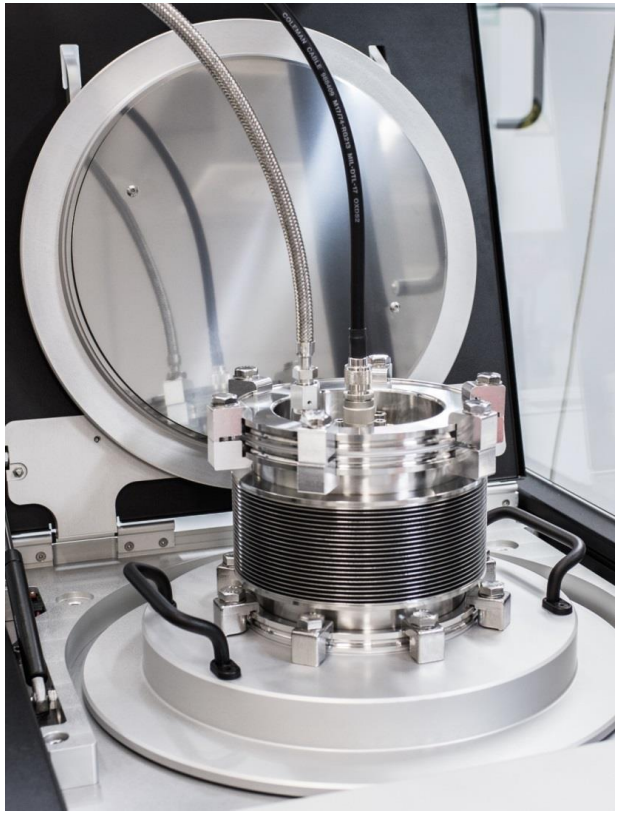



| Parameter | Range |
|---|---|
| Process temperature (˚C) | 90-200 |
| Plasma power (W) | 50 and 180 |
| BTBAS pulse time (s) | 0.05-0.5 |
| BTBAS purge time (s) | 0.5-3 |
| $CO_2$ plasma exposure time (s) | 1-15 |
| $CO_2$ plasma purge time (s) | 0.5-3 |



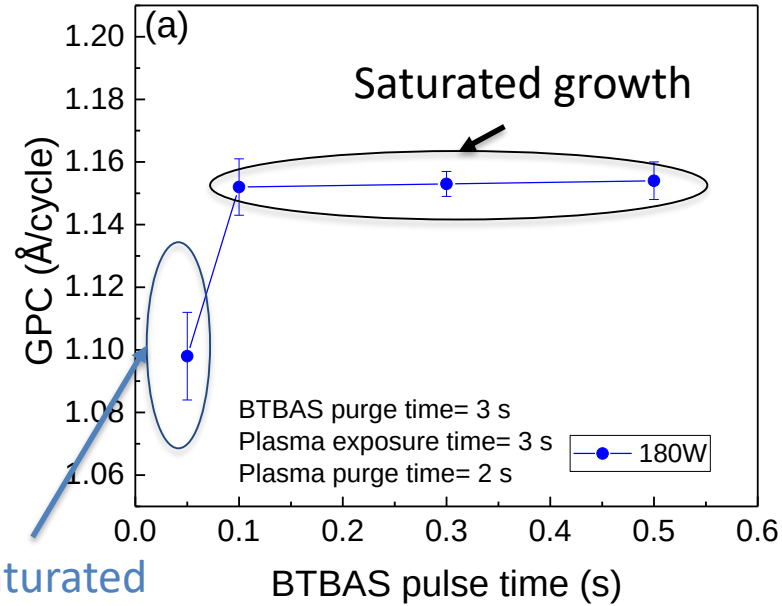
# Methods

- Characterization
  - Ellipsometry
  - Glow discharge optical emission spectroscopy (GDOES)
  - Time-of-flight elastic recoil detection analysis (TOF-ERDA)
  - X-ray reflectivity (XRR)
  - Wafer curvature measurement

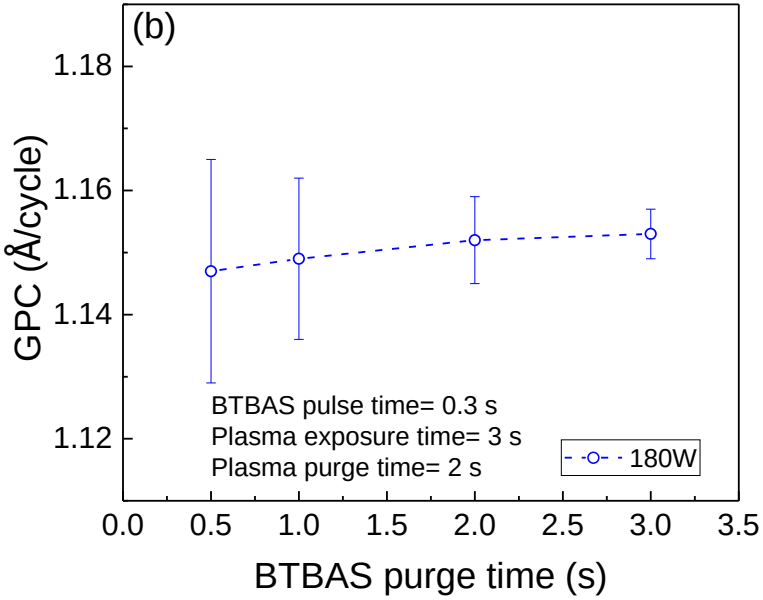


# Film Growth

- The effect of BTBAS

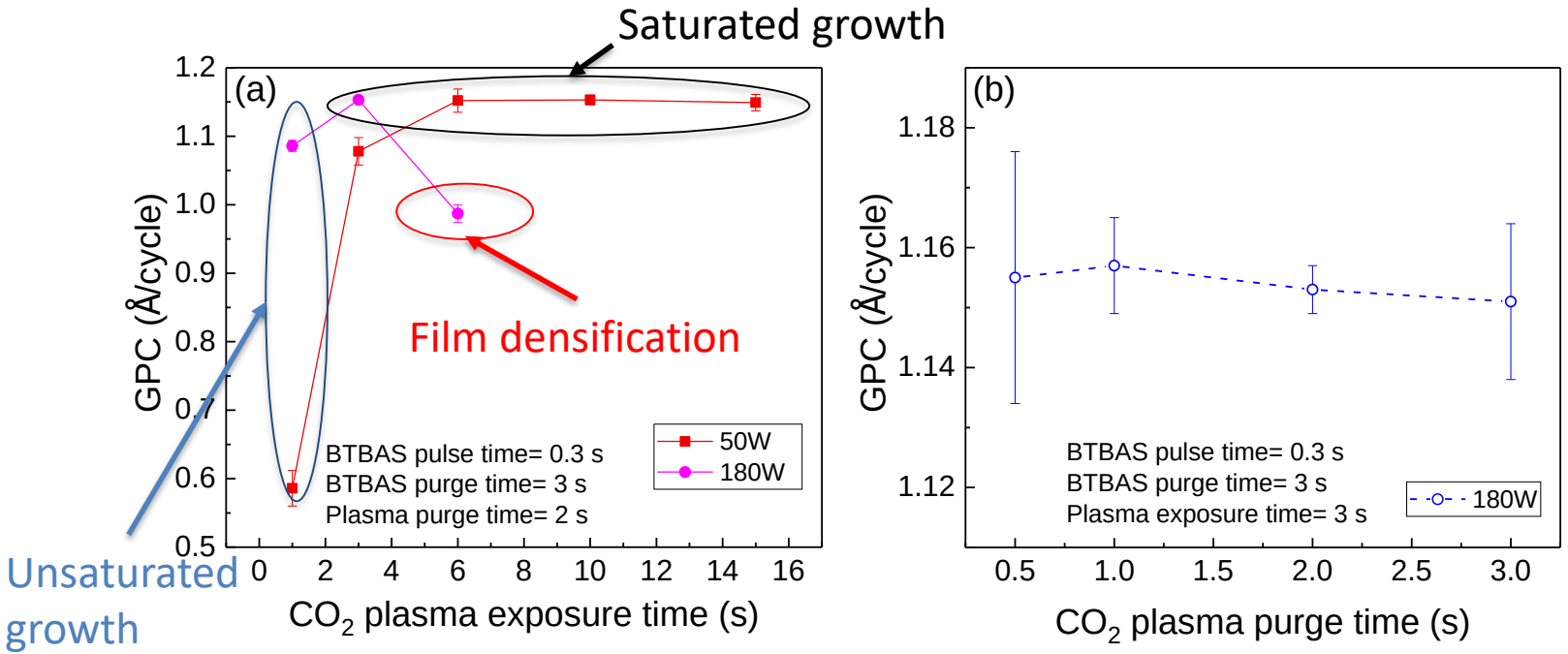



Unsaturated growth



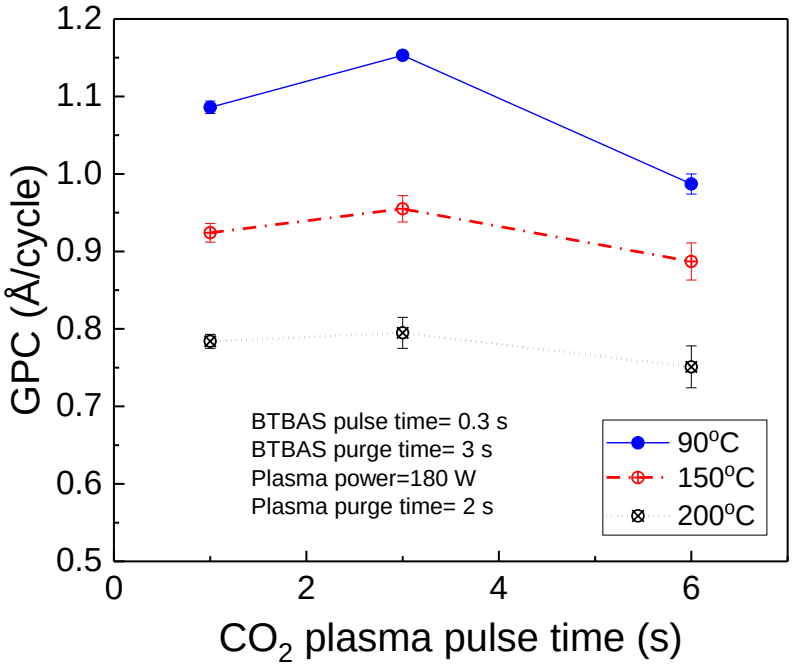
# Film Growth

- The effect of $CO_2$ plasma

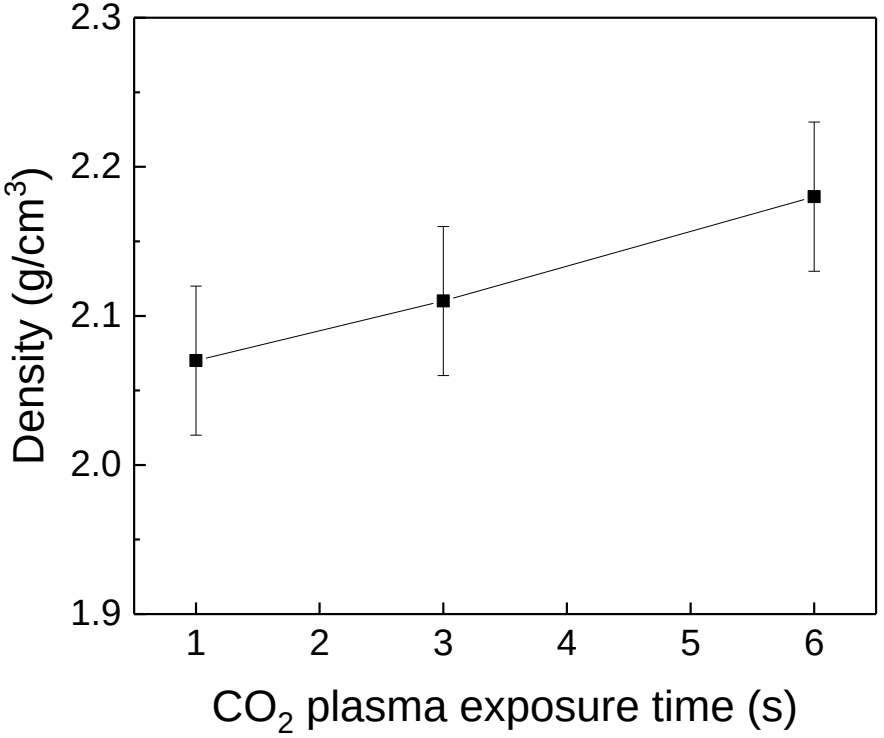


# Film Growth

- The effect of deposition temperature



# Film Characterization-density

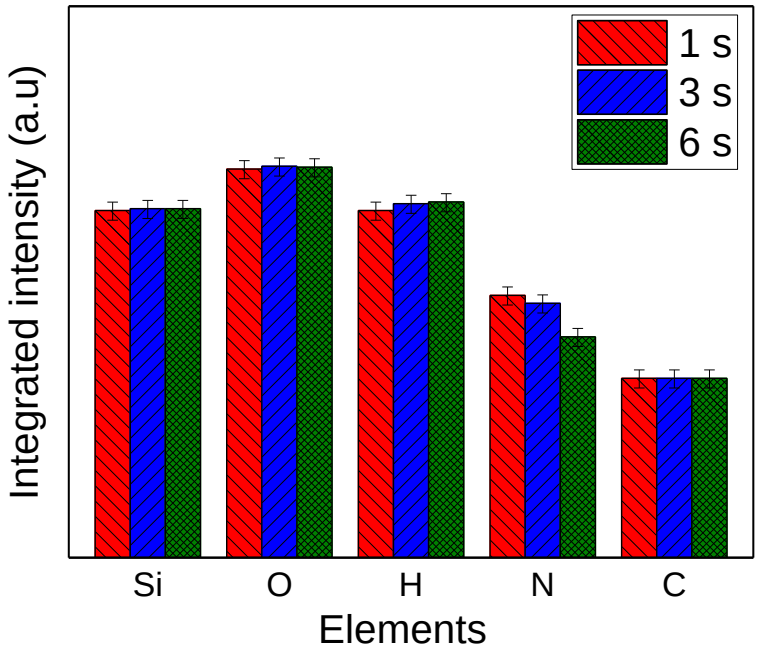



The film density of ~2.1 g/cm$^3$ is in a good agreement with values reported in earlier studies of $O_2$-based PEALD with a temperature range of 50-300 ˚C [1-3]

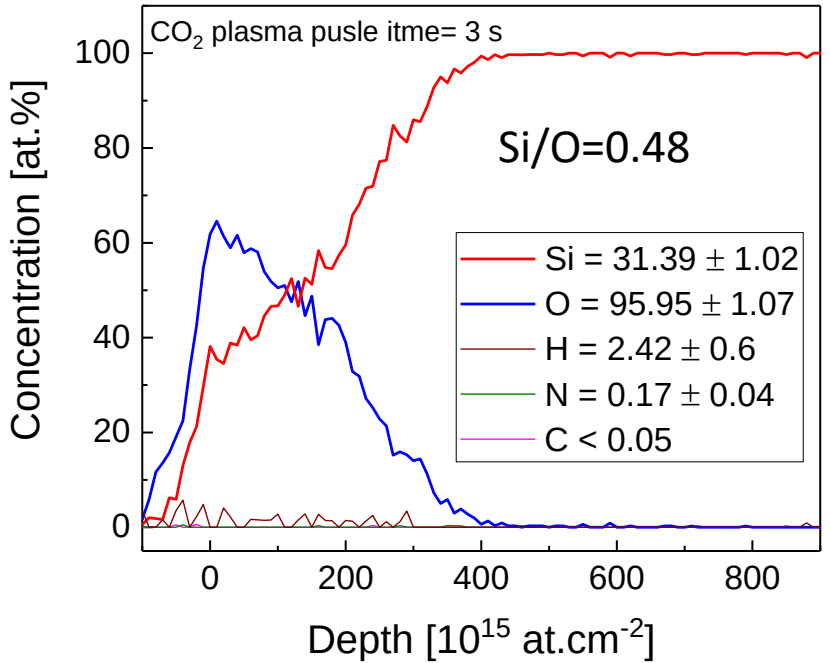

[1] Dingemans et al., J. Electrochem. Soc., 159, 2012
[2] Putkonen et al., Thin Solid Films, 558, 2014
[3] Shestaeva et al., Appl. Opt., 2017, 2017

# Film Characterization-composition

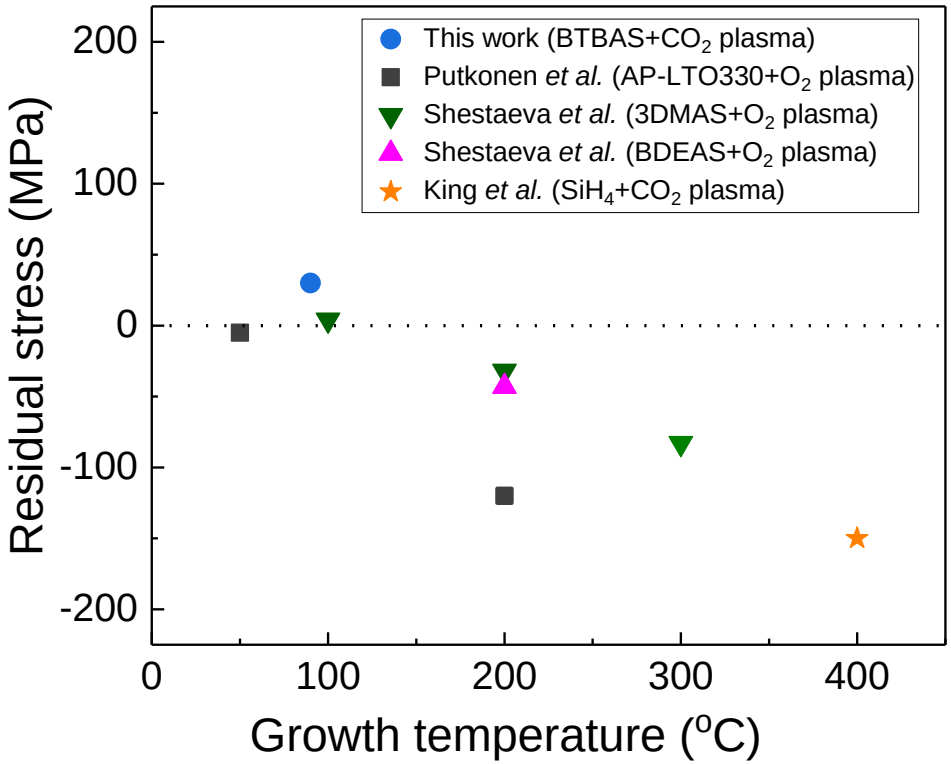
GDOES




TOF-ERDA



# Film Characterization-residual stress



# Conclusions

- $CO_2$ was confirmed as a promising oxidant for growing low temperature PEALD $SiO_2$ films.

- The films had a saturated GPC of 1.15 Å/cycle, a low level of impurities (~3 at.% for H, ~0.17 at.% for N and <0.05 at.% for C), a reasonable film density of ~2.1 $g/cm^{-3}$, and a low tensile residual stress of 30 Mpa.

- The evaluated pulse and purge times of precursors suggested a possibility for having the saturated growth with a very short cycle time of 4.1 s.

# From research to industry

PEALD for Single wafer

Beneq TFS 200


Beneq C2

PEALD for Batch

Beneq C3R


Thank you!
95
km/h
7213
RPM
BENEQ