


# ALD systems and processes @ SENTECH Instruments GmbH

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# Agenda

1. Company Introduction
2. SENTECH-ALD-Systems
3. Process Results
   - **Plasma Processes**
   - **In-situ Ellipsometry**
4. Summary and Outlook

# The Company

Private company founded in 1990
- New building since 2010
- 60 employees (~ 25 % R & D)
- ISO 9001 certificated

Business fields:
- Thin Film Metrology &
- Plasma Process Technology

More than 1,500 metrology tools
- and 300 plasma tools in the field

SENTECH‘s strengths:
- Application support
- Broad range of products
- High quality of products
- Service

Turn over 2012:  10 Mio Euro



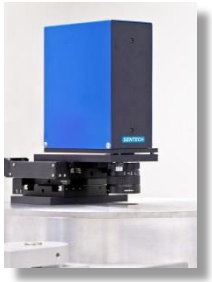



# Thin Film Metrology







Instruments:

- Reflectometers
- Laser ellipsometers
- Spectroscopic ellipsometers (deep UV–MIR)
- in-situ measurement tools




**For more information, please visit us in hall 1 / stand 1436**




# Plasma Process Technology

**Plasma ALD**



**Plasma deposition**





**Cluster tool**

- RIE, ICP-RIE
- PECVD, ICPECVD
- Cluster tools
- ALD / PEALD
- SENTECH laser end point monitor




**Plasma etching**

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# SI ALD systems

## SI ALD LL







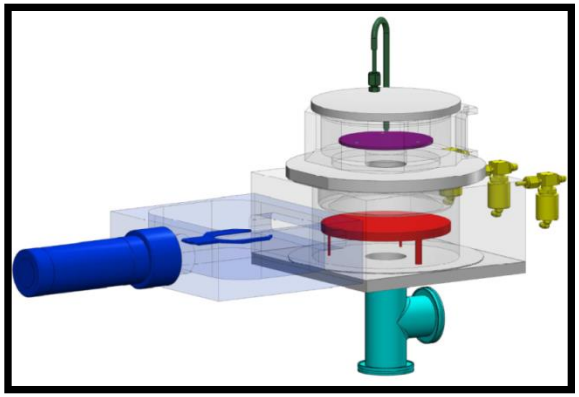
## SI ALD

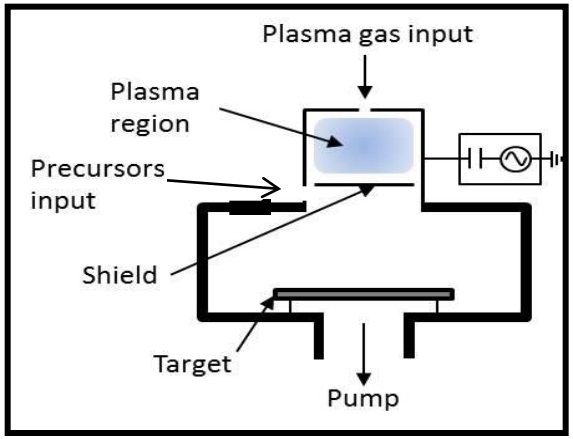





# Reactor chamber and plasma source

- **Reactor chamber** — Temperature: up to 150 °C; Showerhead mode
- **Precursor line** — Temperature: up to 200 °C; 3-Port ALD-valve; Stop valve
- **Plasma source** — True remote CCP-source; isolation valve






➡ **Plasma source can be separated from the system**




# System and options

- **Substrate size** up to 8“
- **Substrate temperature** up to 500 °C
- **Precursor lines** up to 4 separate inlets
  - More precursors with common inlet
  - Direct draw or bubble line
- **Gas lines** up to 7
- **In-situ diagnostic** SENTECH ellipsometer
  QMS, …
- **More options** TMP with isolation valve
  Ozone line
  Glove box
  …

**SI ALD LL with SENTECH In situ ellipsometer**






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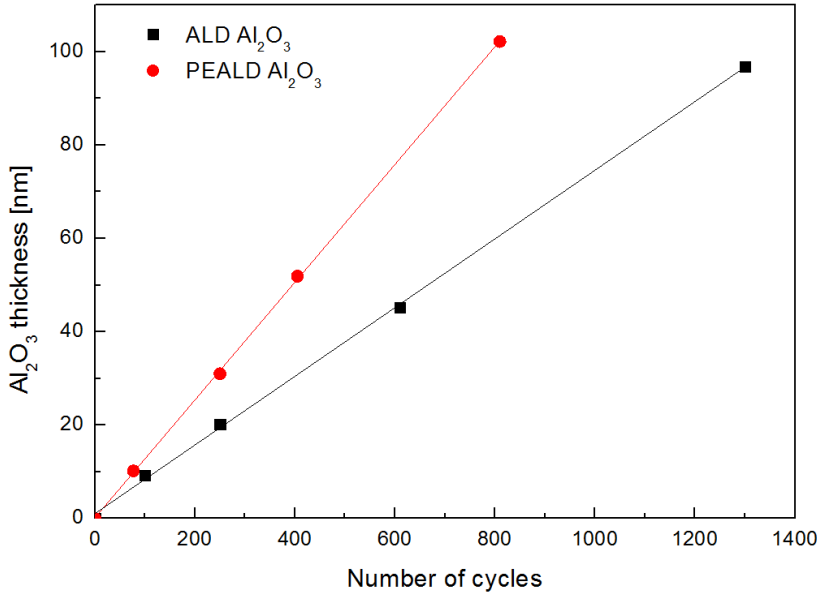

# Selected processes

- **Thermal deposition:**
  - $Al_2O_3$: @ 200, 100°C
  - ZnO: @ 200°C
  - $ZrO_2$: @ 200°C
  - …
- **Plasma enhanced deposition:**
  - $Al_2O_3$: @ 200°C … 27°C
  - $SiO_2$: @ 200°C
  - $TiO_2$: @ 200 °C
  - AlN: @ 250°C
  - Pt: @ 200°C
  - …






# ALD and PEALD $Al_2O_3$ in SI ALD LL



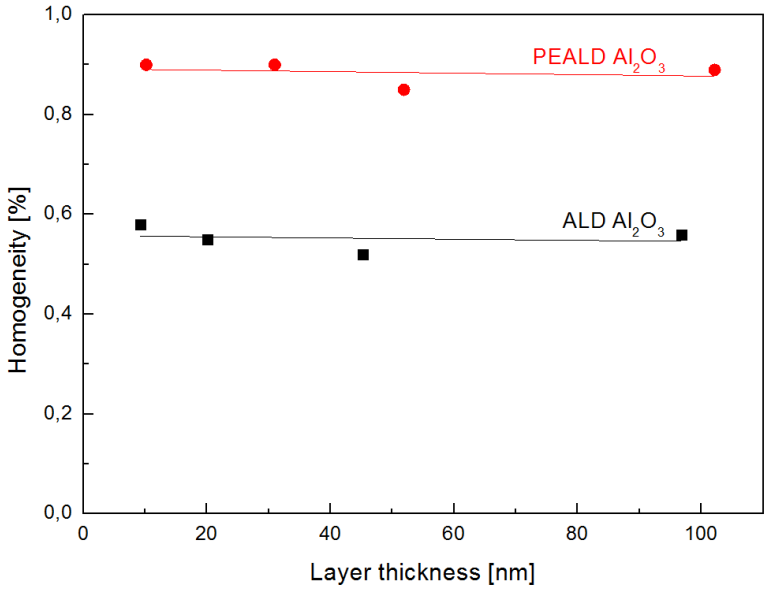

- $Al_2O_3$ film thickness shows linear dependence on the number of cycles in ALD and PEALD.
- PEALD provides a higher growth rate of 1,2 Å/cycle compared to ALD. The growth rate in ALD amounts 0,8 Å/cycle.

| Process parameter | ALD | PEALD |
|---|---|---|
| Substrate temperature (°C) | 200 | 200 |
| Process pressure (Pa) | 12 | 20 |
| Plasma power (W) | 0 | 100 |
| Growth rate (Å/Cycle) | 0,8 | 1,2 |

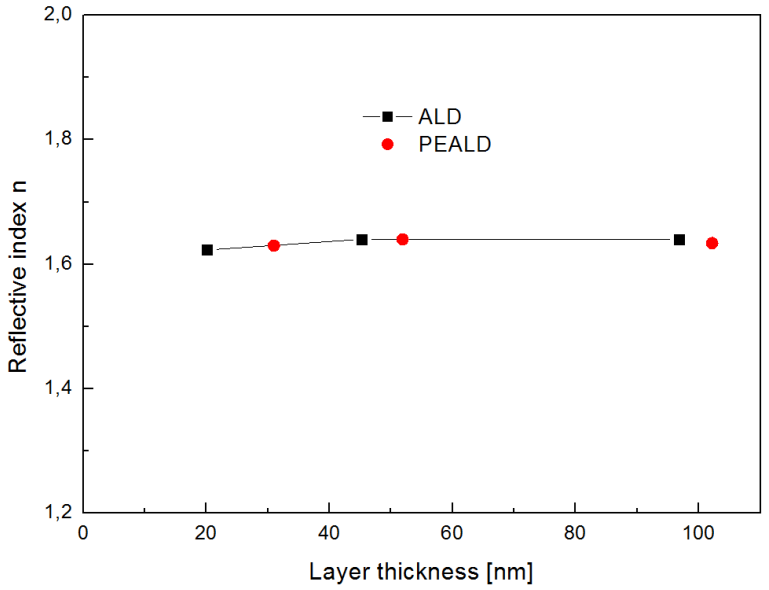



# ALD and PEALD $Al_2O_3$ in SI ALD LL

**Homogeneity**




**Refractive index**

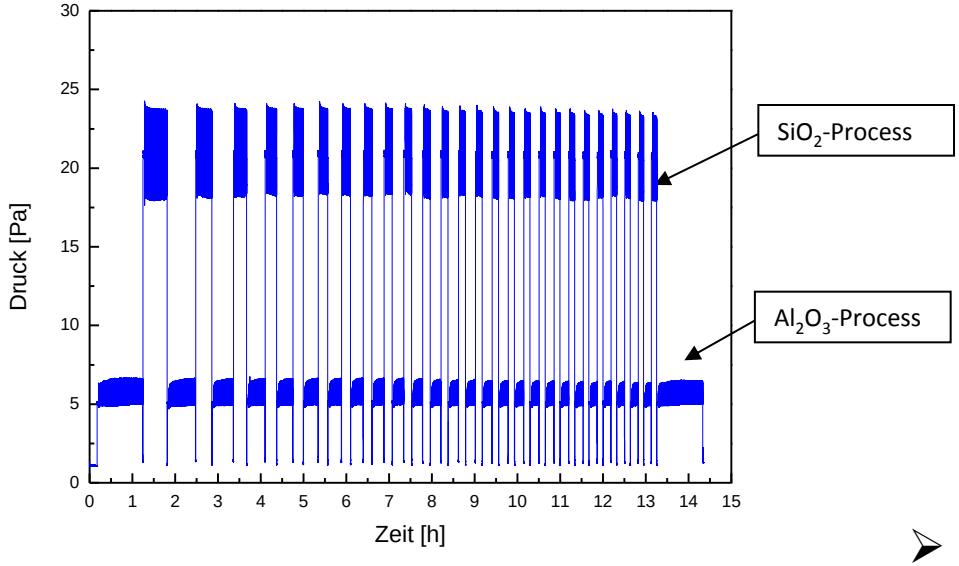



- ALD and PEALD $Al_2O_3$ films show very good homogeneity (range, not sigma!) of ± 0,6 % and ± 0,9 % on 4“ Si-wafer respectively.
- Refractive indexes (measured @ 632,8 nm wavelength) of ALD and PEALD $Al_2O_3$ films with the same thickness are identical.

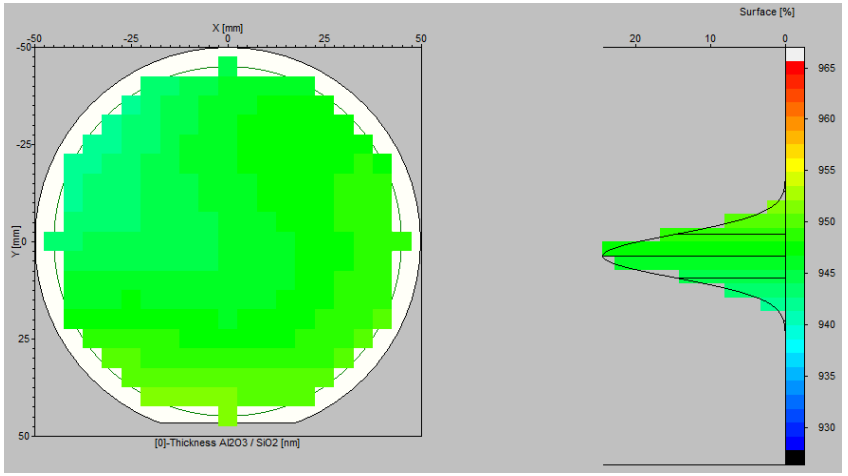



# Multilayer $Al_2O_3$ / $SiO_2$

- thermal ALD $Al_2O_3$ and PEALD $SiO_2$ alternately
- in total **44 layers :** 23 $Al_2O_3$-layers and 21 $SiO_2$-layers (~ 1 µm)
- deposition time: **~ 14 h**




Layer thickness (SENTECH Reflectometer: RM 2000)

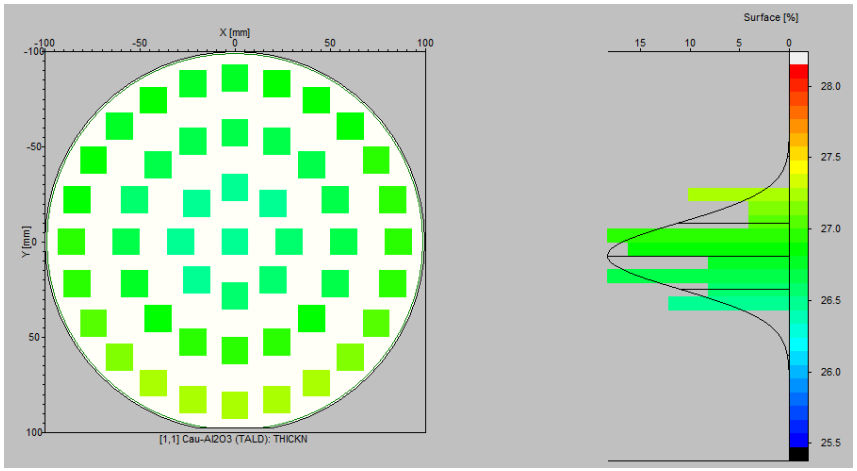



- Excellent homogeneity (± 0,6 %, 4″-Wafer)
- Very good agreement with expected film thickness




# PEALD on 8" Wafer

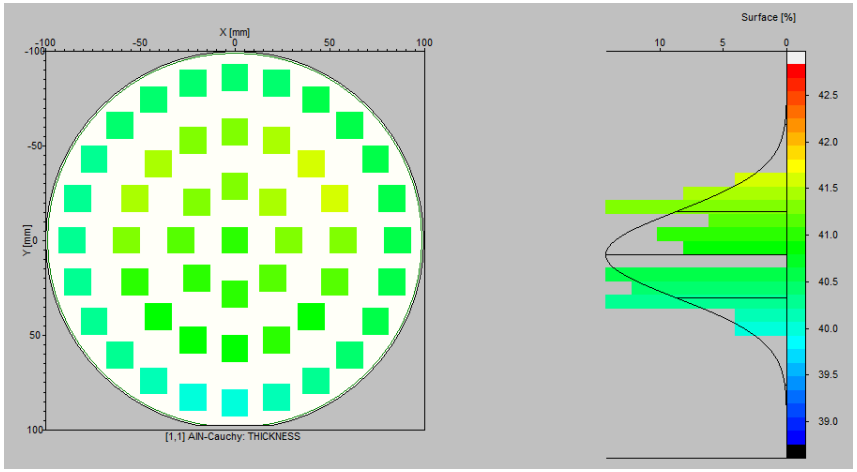
## **$Al_2O_3$:** TMA + $O_2$-Plasma




SENTECH Ellipsometer: SE 800

| | |
|---|---|
| **Layer thickness: 8” wafer (nm)** | 26,8 (**± 1,6%**) |
| **Growth rate (Å/cycle)** | 1,2 |
| **Substrate temperature (°C)** | 200 |
| **n (@632,8 nm)** | 1,642 (± 0,58%) |

## **AlN:** TMA + $NH_3$-Plasma




SENTECH Ellipsometer: SE 800

| | |
|---|---|
| **Layer thickness: 8” wafer (nm)** | 40,8 (**± 1,96%**) |
| **Growth rate (Å/cycle)** | 0,9 |
| **Substrate temperature (°C)** | 250 |
| **n (@632,8 nm)** | 1,933 (± 0,91%) |

# In-situ methods

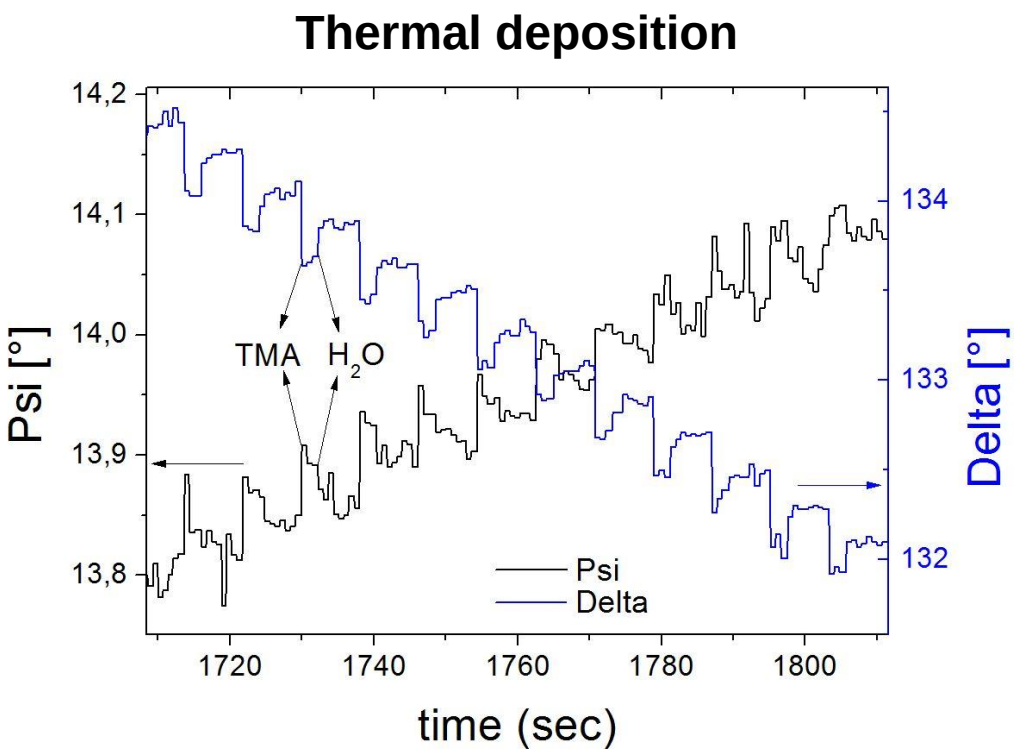



- in situ monitoring during ALD-processes require fast and sensitive methods
- different methods have been applied like **QCM, QMS, ellipsometry** ….
- **best suited for layer monitoring is ellipsometry** due to the high surface sensitivity
- ellipsometry does not influence the processs and measures directly the layer properties




# In-situ ellipsometry of $Al_2O_3$ growth

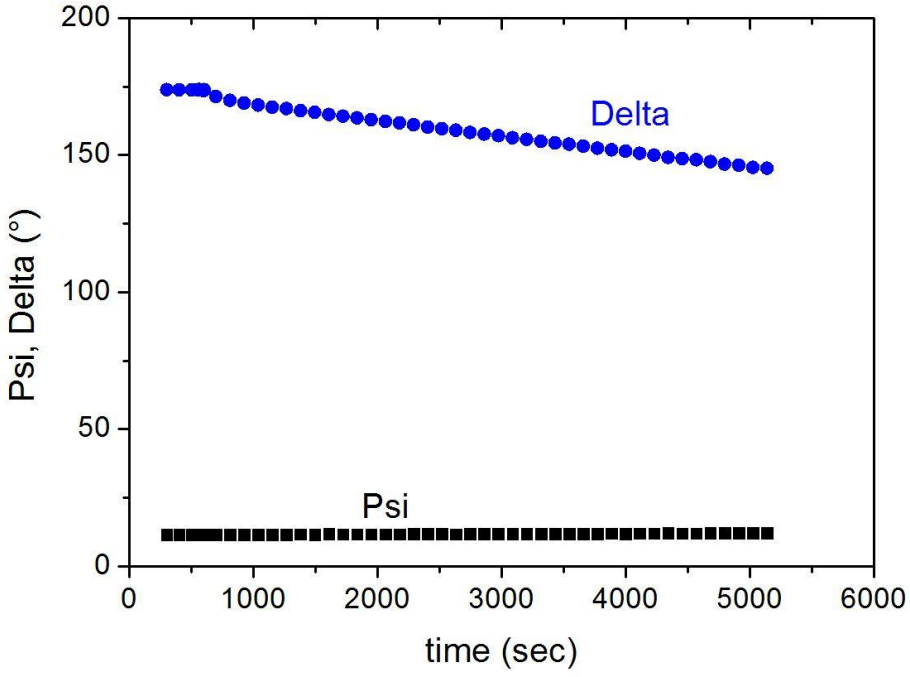


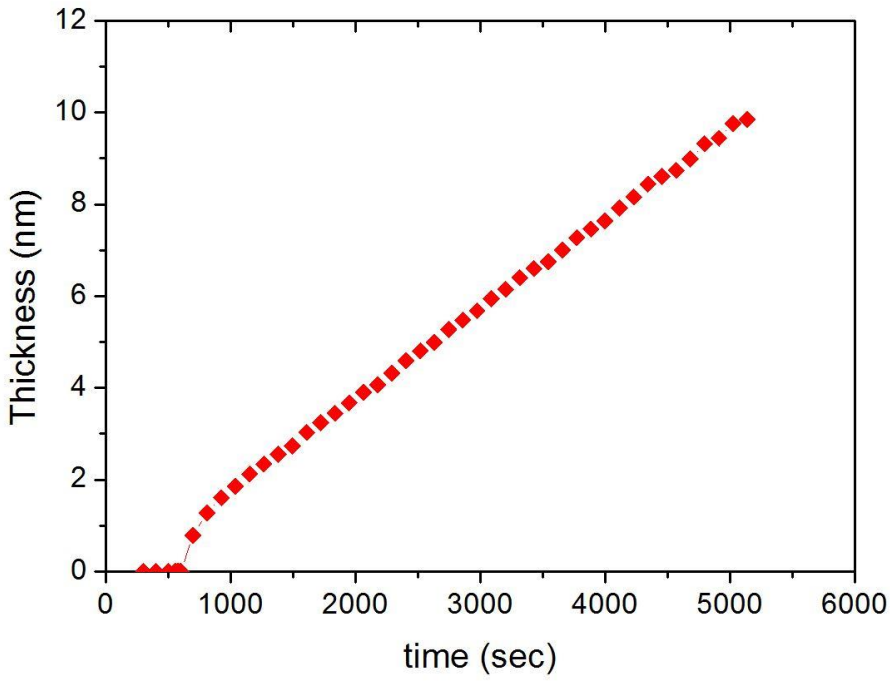




**growth monitoring extremely sensitive**
**even different steps in cycle visible**




# In-situ monitoring of PEALD-$TiO_2$



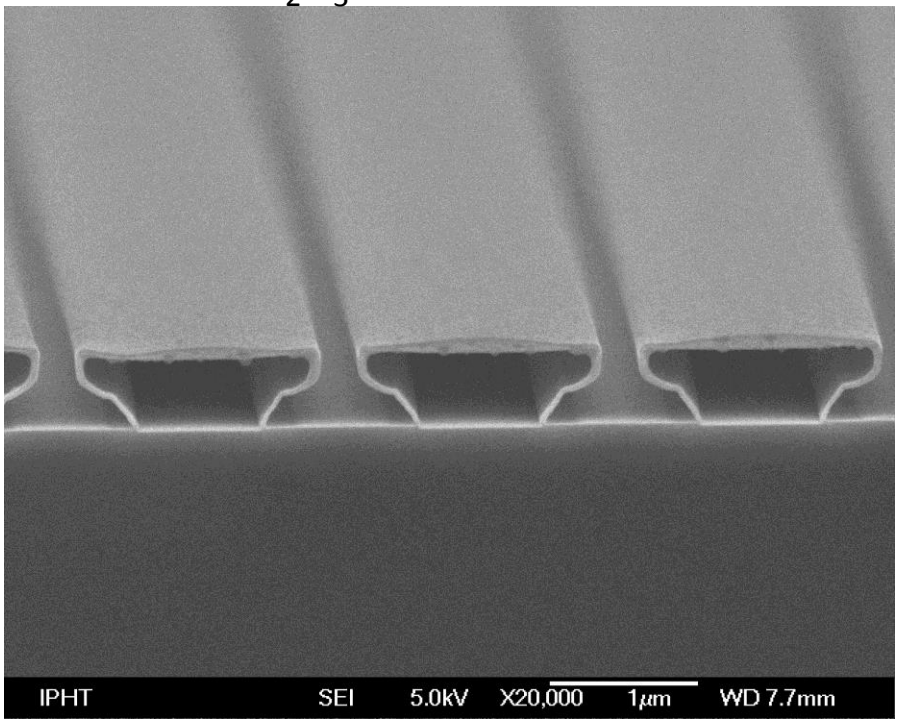




**In-situ end point detection possible on sub Å-scale**

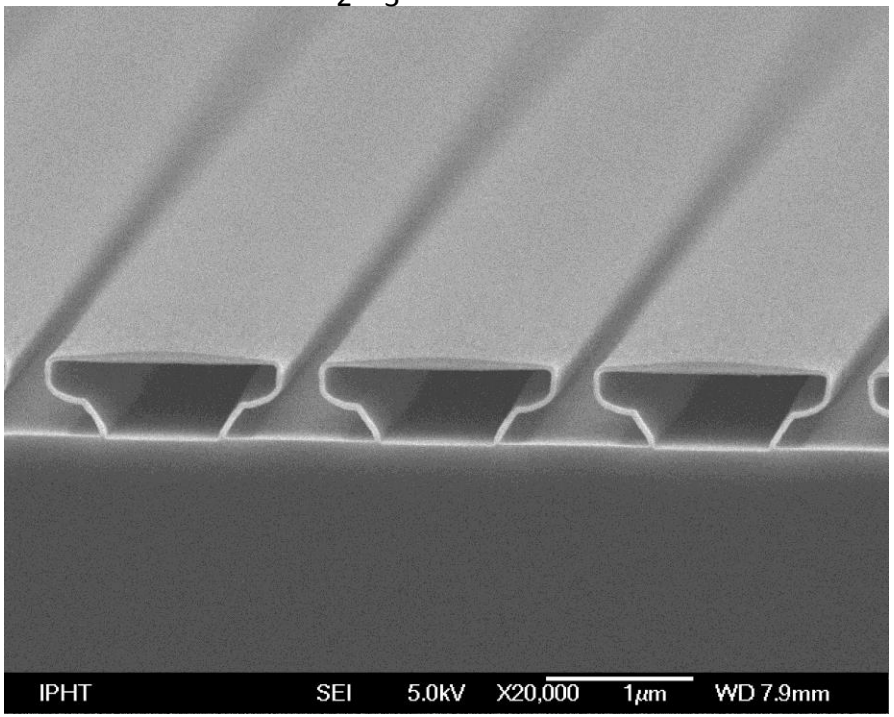



# Conformality

18 nm ALD-$Al_2O_3$ @ **80 °C**




21 nm PEALD-$Al_2O_3$ @ **80 °C**




1) 3D resist structures were prepared on Si-Wafers* and coated with ALD and PEALD $Al_2O_3$ at 80°C substrate temperature.
2) Prepared samples were treated with $O_2$-plasma to remove resist and examined with REM*.

→ Very good conformality to 3D structures

*) Thanks to Dr. Hübner, IPHT-Jena, Germany, for preparing the 3D structures and doing the REM-measurement.



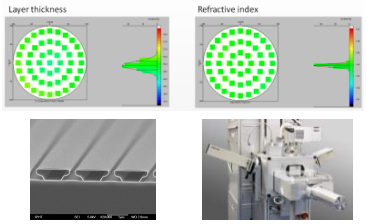

# Summary



Outstanding features of SI ALD-systems:

⇒ Flexible system configuration for a wide range of processes and applications

⇒ Rugged design and small footprint




Process results:

⇒ PEALD-Processes: excellent uniformity

⇒ SENTECH in-situ ellipsometry: very sensitive for monitoring of thin layer growth

## Outlook

- Further thermal and plasma enhanced processes and applications
- Nitride and metal deposition
- Coating of different substrates and structures
- Optimization of in-situ measurement for better process understanding




# Thank you for your attention.



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