

Plasma-Enhanced CVD of ZnO With Varying Doping Levels on Different Substrates



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Introduction

precursor synthesis

layer deposition
and characterisation

back-end

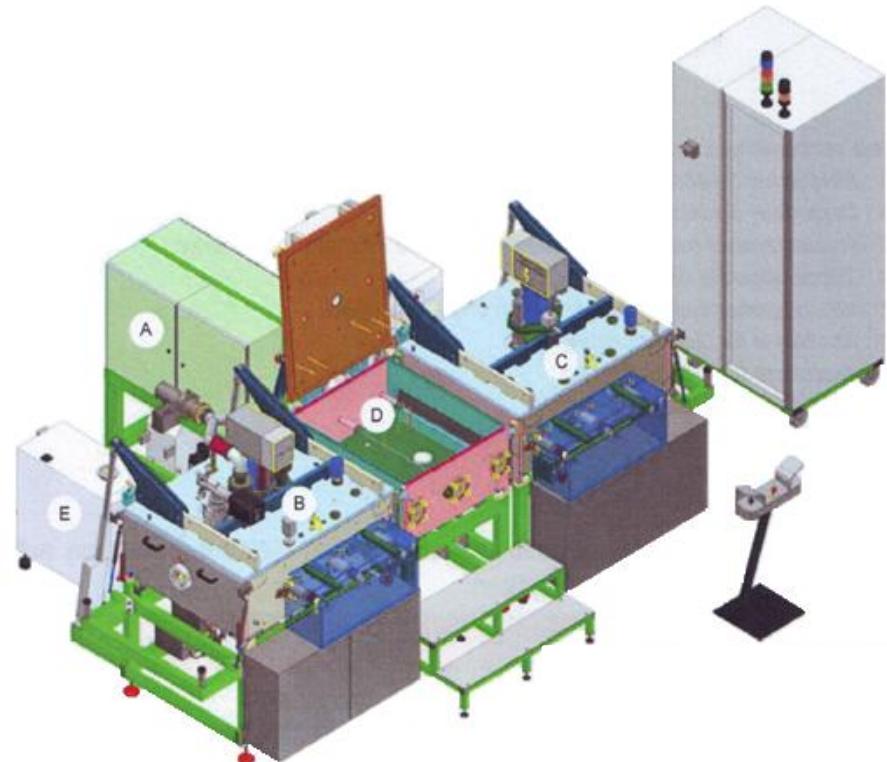
solar cell



characterisation of thin films

- structural
- optical
- electrical

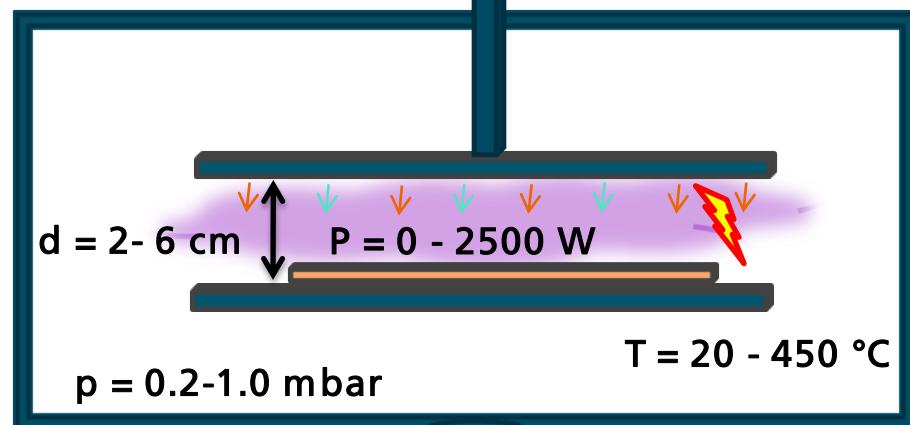
PECVD Equipment



- A gas system and bubbler
- B process chamber 1
- C process chamber 2
- D load lock
- E process pumps

$$\begin{aligned}V_{Ar} &= 0 - 1390 \text{ sccm} \\V_{O_2} &= 0 - 990 \text{ sccm} \\V_{B2H6} &= 0 - 10 \text{ sccm}\end{aligned}$$

$$V_{DEZ} = 0 - 110 \text{ sccm}$$



Characterisation of ZnO Thin Films

structural and
morphological
characterisation

transmission

sheet resistance

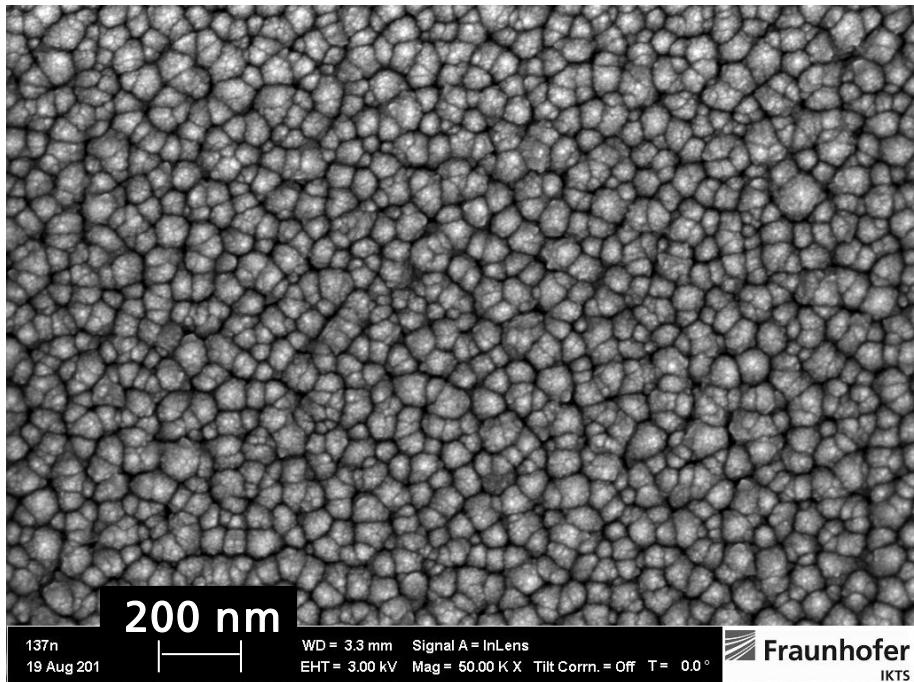
FESEM
XRD

UV-Vis-IR
spectroscopy

Hall-measurement
CV-measurement



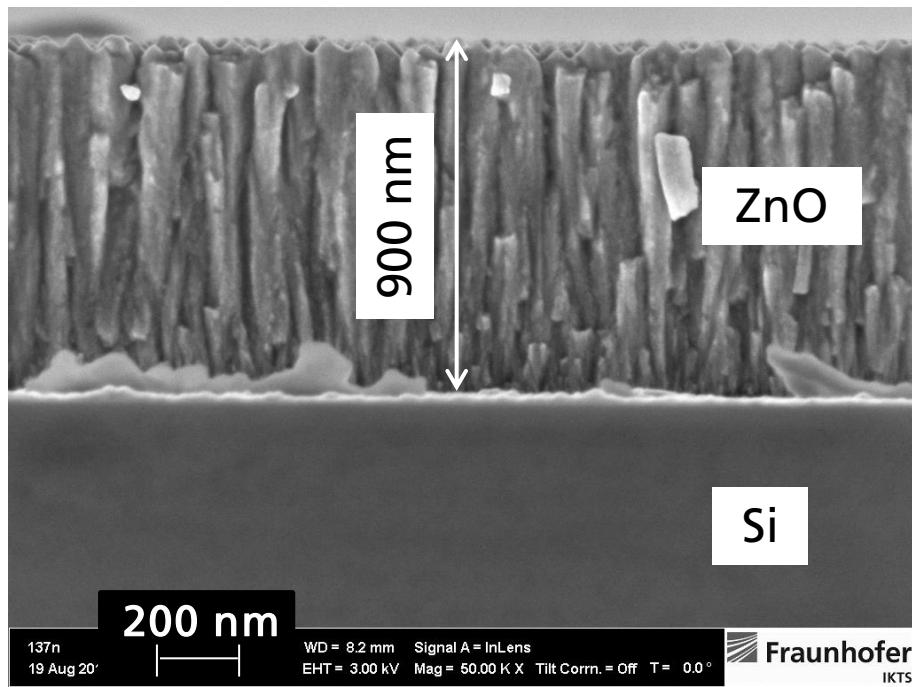
Characterisation - FESEM



cross section

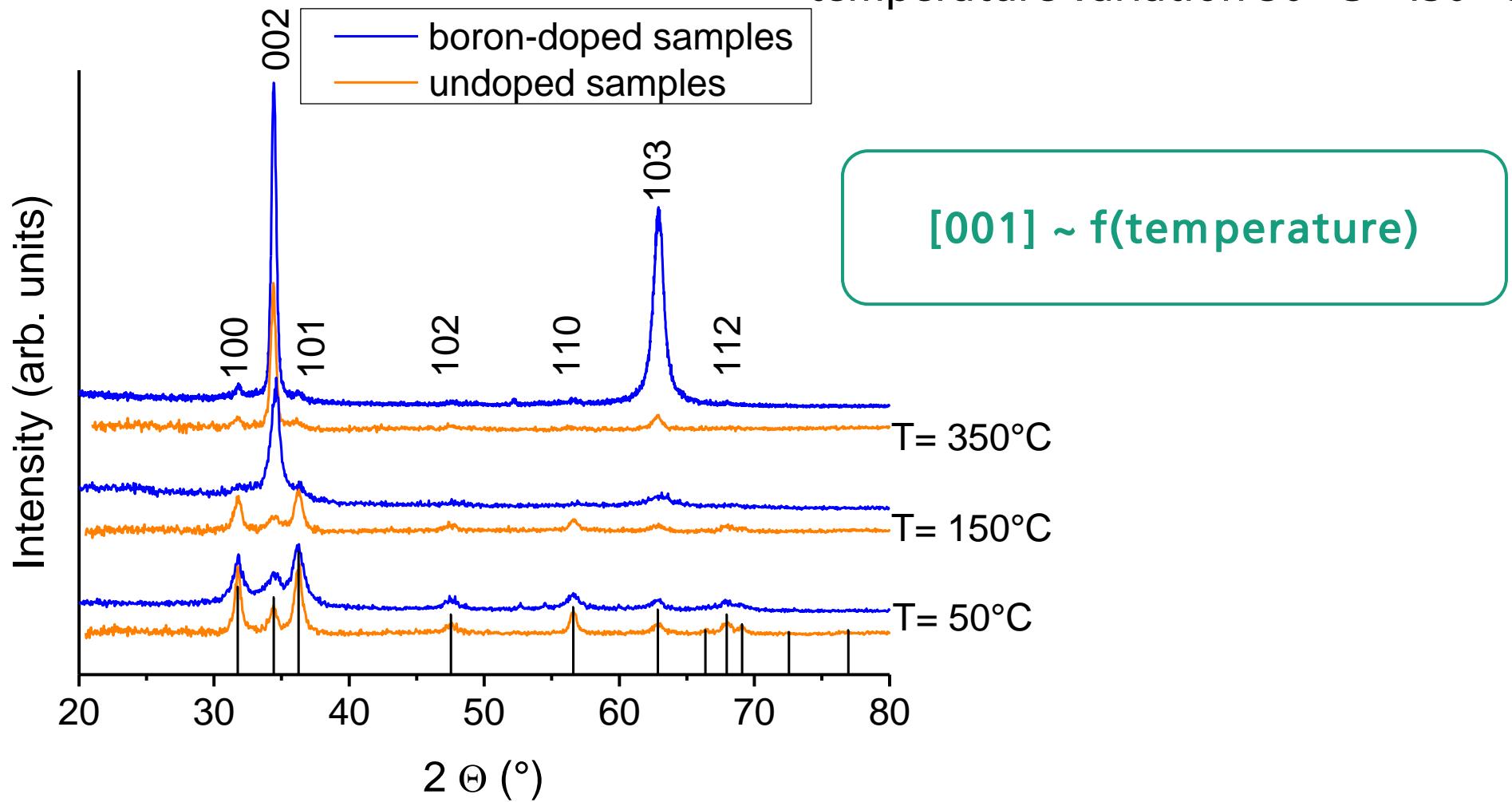
↑T → columnar grain growth

substrate temperature 350 °C
plasma power 50 W



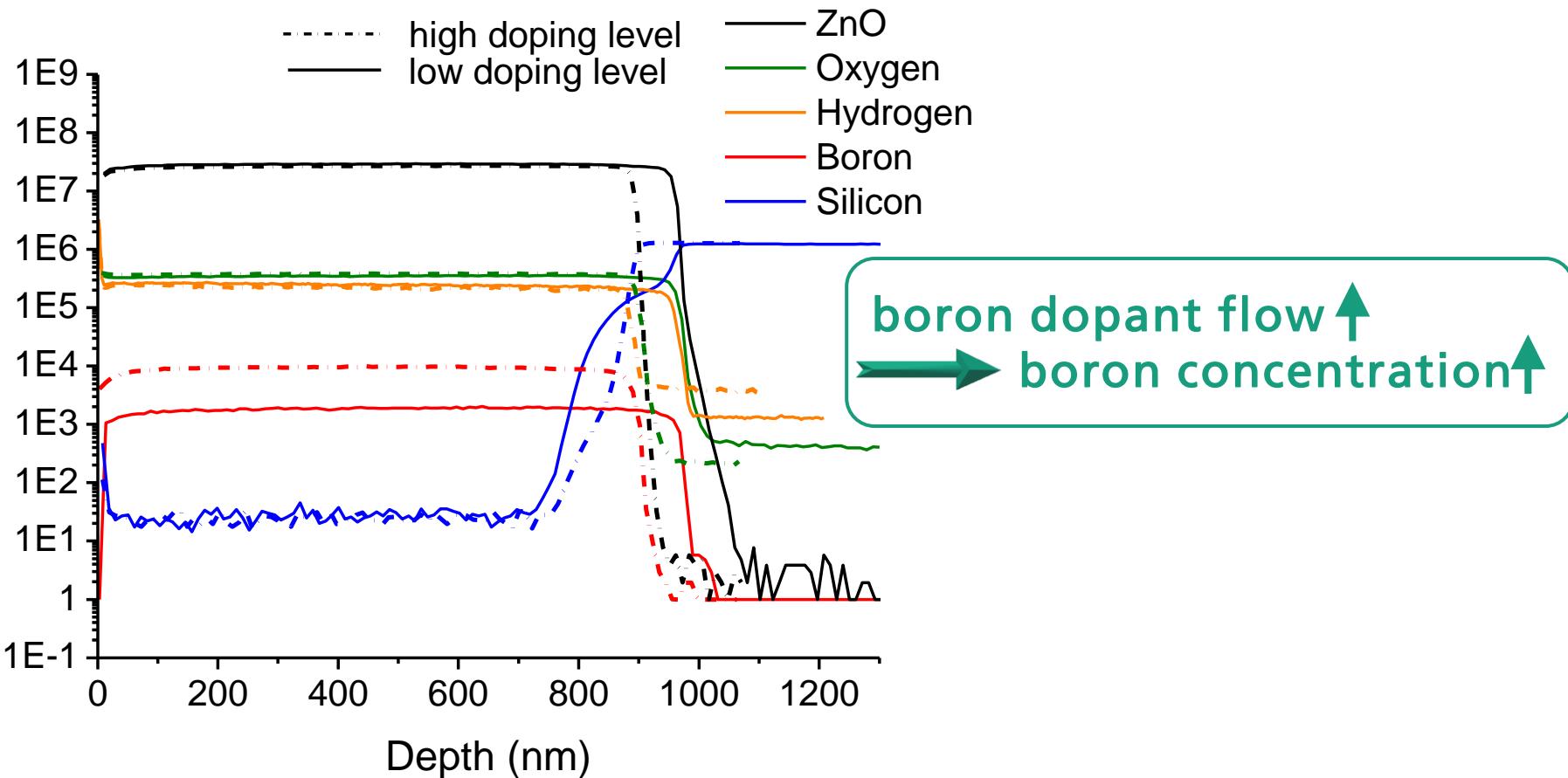
Characterisation - XRD

grazing incident 1°
temperature variation 50 °C - 450 °C



Characterisation- SIMS

substrate temperature 350 °C
plasma power 50 W



Characterisation of ZnO Thin Films

structural and morphological characterisation

transmission

sheet resistance

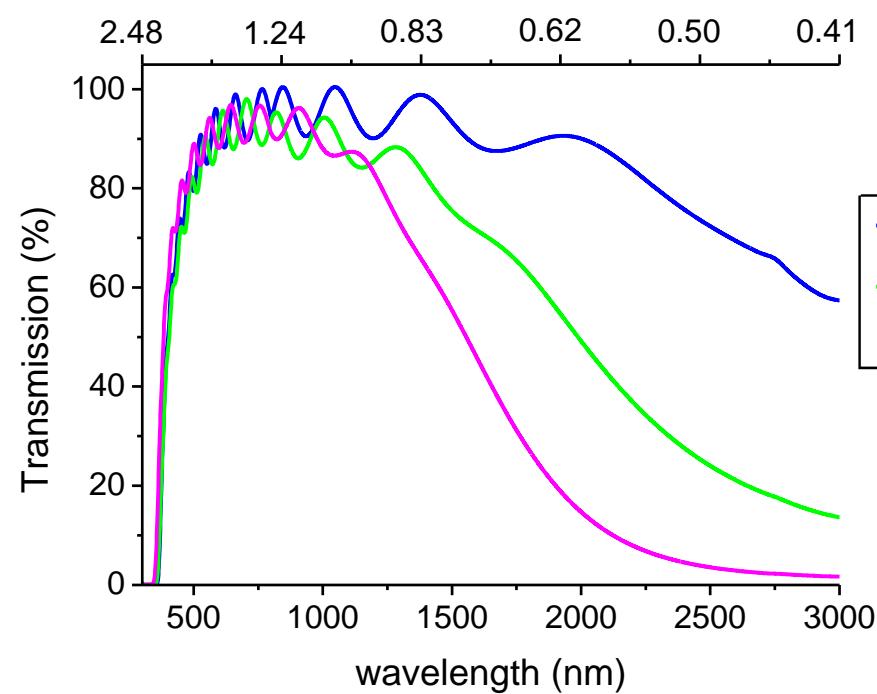
FESEM
XRD

UV-Vis-IR
spectroscopy

Hall-measurement
CV-measurement



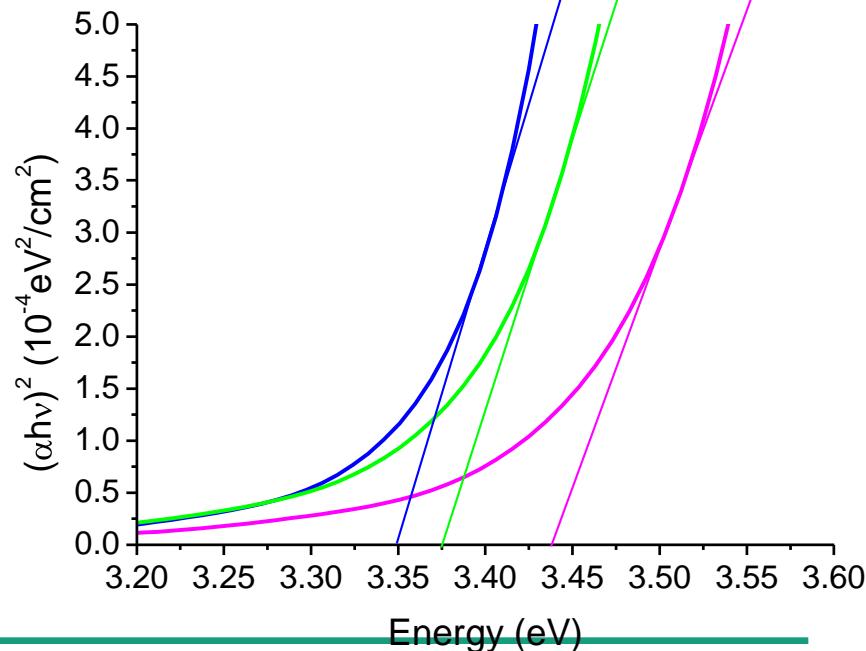
Characterisation - UV-VIS Spectroscopy



substrate temperature 350 °C
plasma power 50 W

| | |
|---------------------|------------------------|
| low doping level | film thickness 1090 nm |
| medium doping level | film thickness 1090 nm |
| high doping level | film thickness 900 nm |

transmission > 80 %
dopant concentration ↑
→ blue shift of band gap



Characterisation of ZnO Thin Films

structural and morphological characterisation

transmission

sheet resistance

FESEM
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UV-Vis-IR
spectroscopy

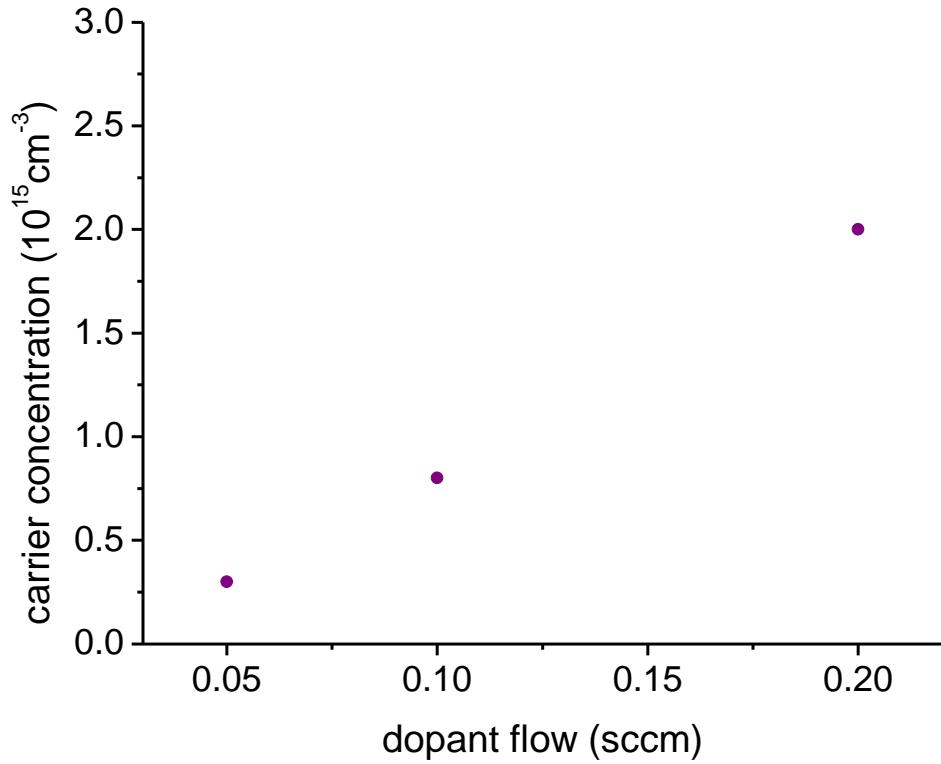
Hall-measurement
CV-measurement

Characterisation – Determination of Carrier Concentration

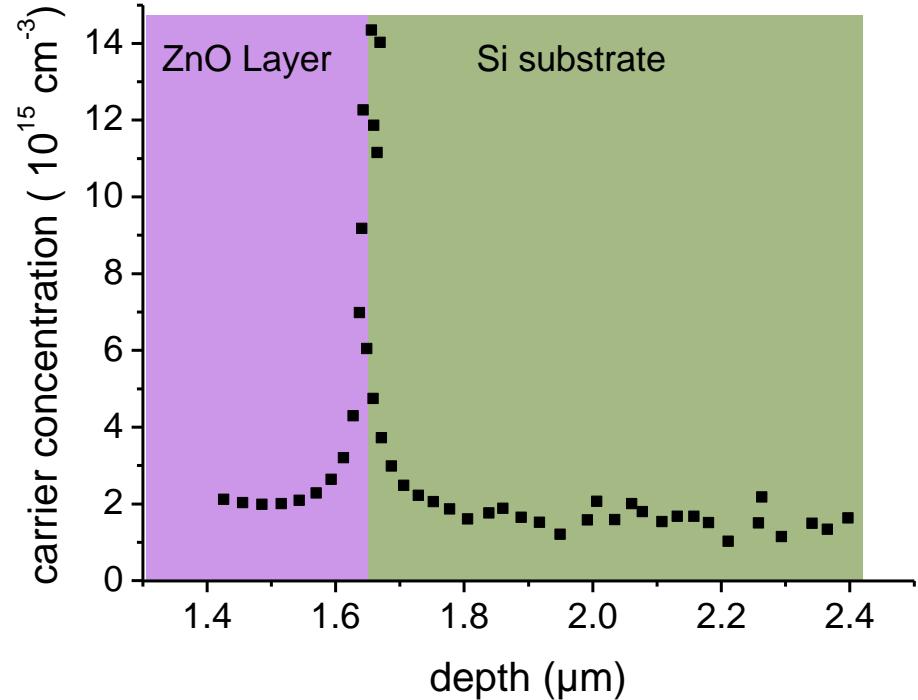
Hall measurements at room temperature in van-der-Pauw-configuration

| | carrier concentration (cm ⁻³) absorption edge (Burstein -Moss-shift) | carrier concentration (cm ⁻³) Drude model | carrier concentration (cm ⁻³) Hall measurements | carrier mobility (cm ² /Vs) |
|---------------------|---|--|--|--|
| low doping level | >5*10 ¹⁹ | 1.1*10 ²⁰ | | |
| medium doping level | >5.6*10 ¹⁹ | 3.7*10 ²⁰ | 9.8*10 ¹⁹ | 1.96 |
| high doping level | >1.3*10 ²⁰ | 6.5*10 ²⁰ | 1.8*10 ²⁰ | 2.34 |

Characterisation – Capacity Voltage Measurements



substrate temperature: 150 °C
plasma power: 50 W



boron dopant flow ↑
→ boron concentration ↑

Summary

- High carrier concentrations ($\sim 10^{20}$) achieved
- Boron incorporated in films
- Preferred orientation of films depending on substrate temperature
- Typical columnar growth at a temperature of $T = 350 \text{ } ^\circ\text{C}$
- ZnO layer deposition with PECVD equipment up to $50 \times 50 \text{ cm}^2$

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Thank you for your attention!