

# Atomic Layer Deposition of Zinc Oxide

EE 412, FALL 2014

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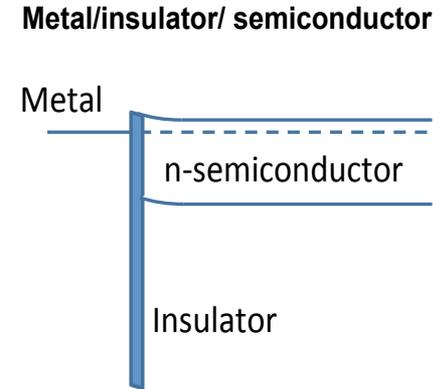
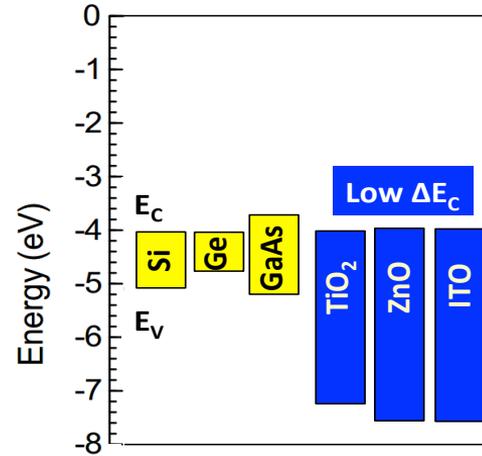
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## Why ZnO?

- Wide-bandgap semiconductor
- Piezoelectric
- Can be very highly doped
  - Oxygen vacancies
  - Aluminum
- MIS selective contacts
  - Small barrier for electrons
  - Large barrier for holes



## Project objectives

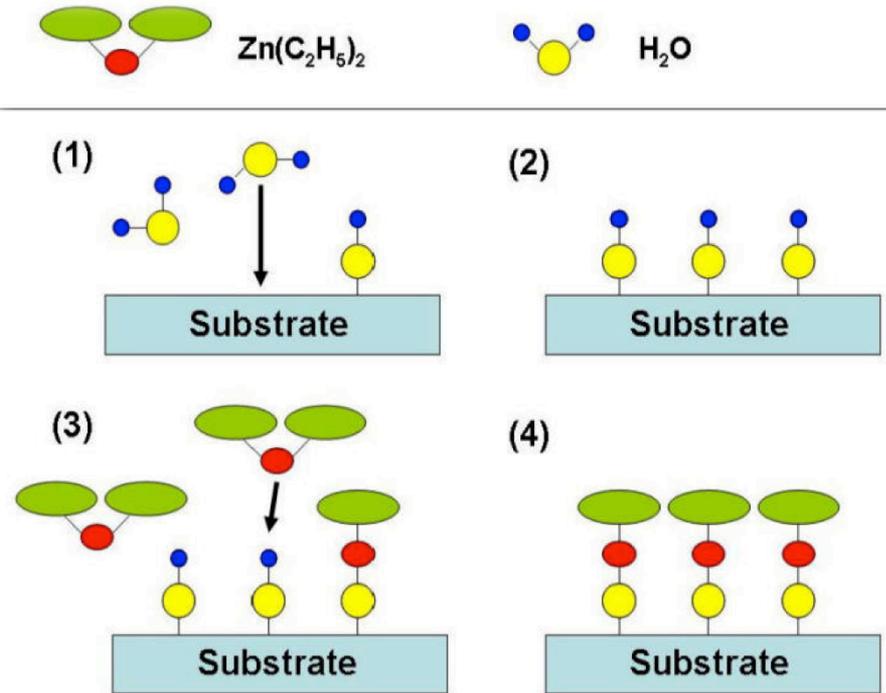
- Reliable and controlled growth of ZnO using ALD
- Variable film quality by changing growth temperature
  - Film stoichiometry
  - Resistivity
  - Growth rate

## What is ALD?

Atomic layer deposition: a powerful tool for thin film deposition

- Precise thickness control (nanometer scale)
- Pinhole-free
- Totally conformal coating on any shape and geometry
- High repeatability

### Flow-through traveling wave setup



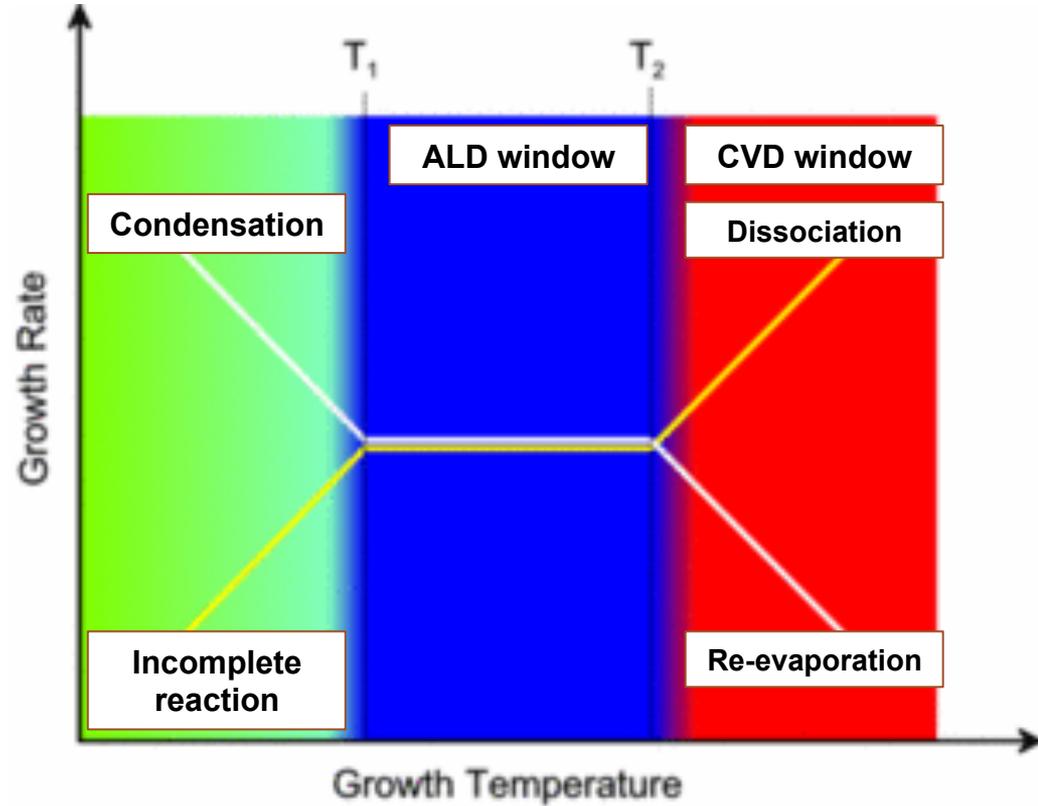
# ALD window

Typical process conditions:

- Pressure range: 0.1-10 mbar
- Temperature: 50-500 °C

ZnO ALD on Si:

- 130-170 °C
- Precursors:  $\text{Zn}(\text{C}_2\text{H}_5)_2$  &  $\text{H}_2\text{O}$



# Methodology



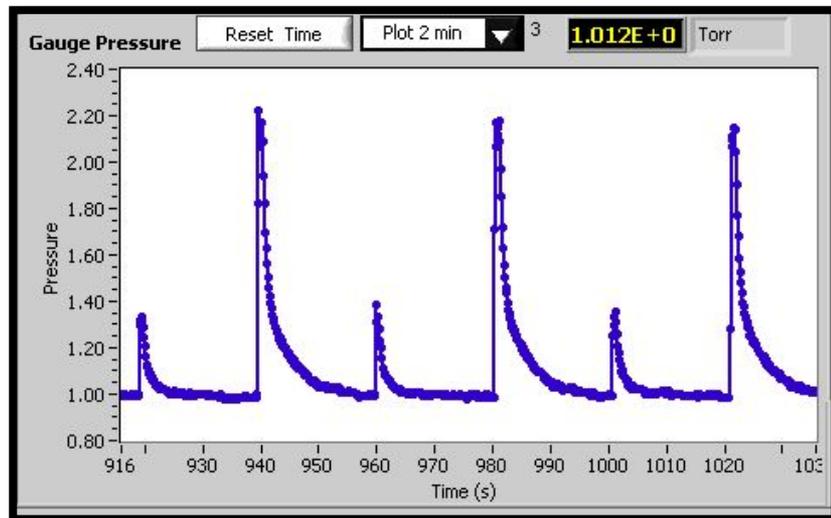
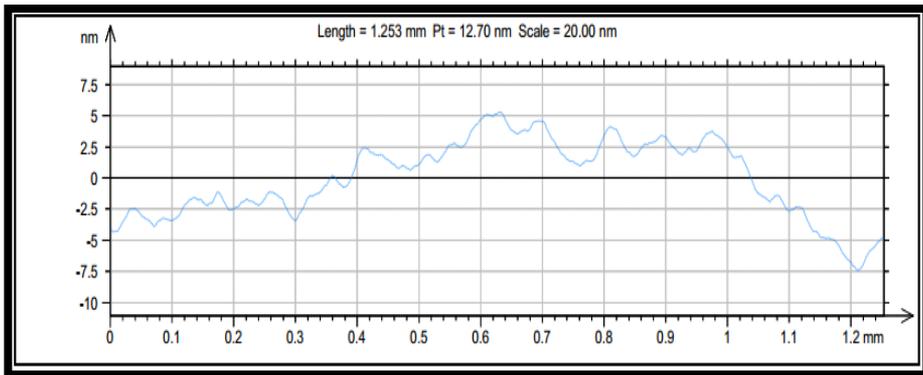
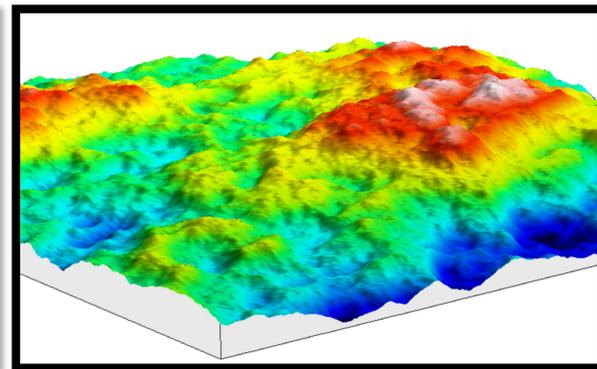
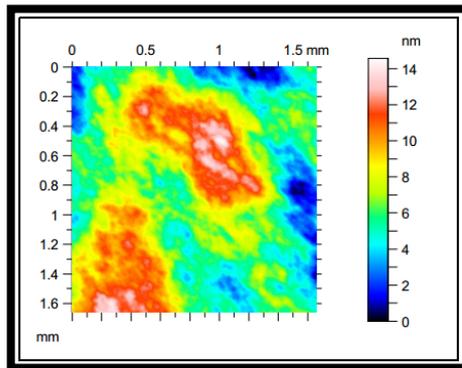
**300 nm SiO<sub>2</sub> as the insulating layer**

**Three recipes:**  
**1. Over dosing**  
**2. Under dosing**  
**3. Good**

**Film characterization**

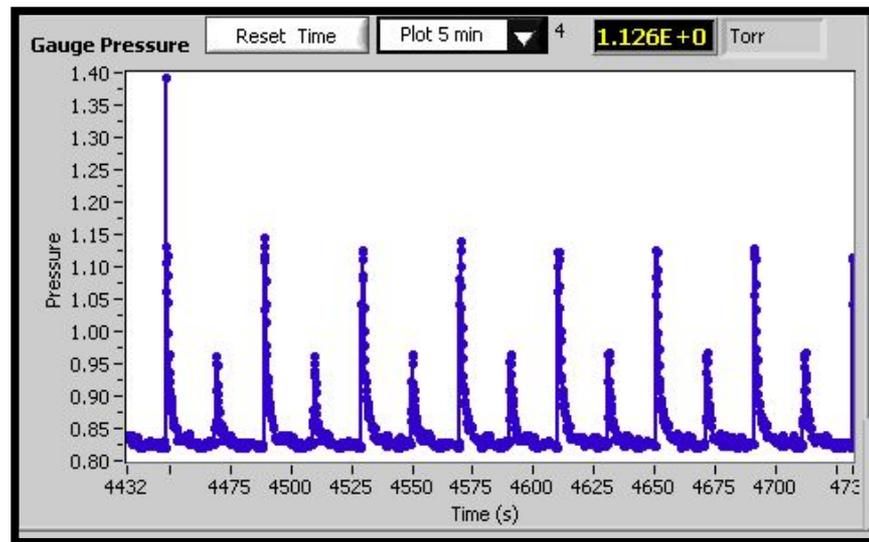
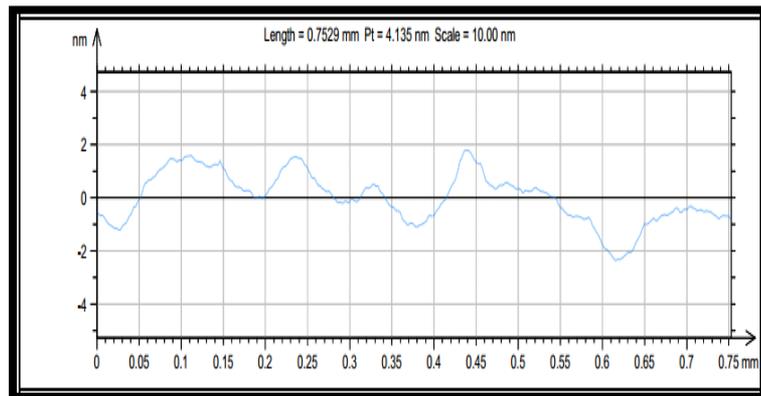
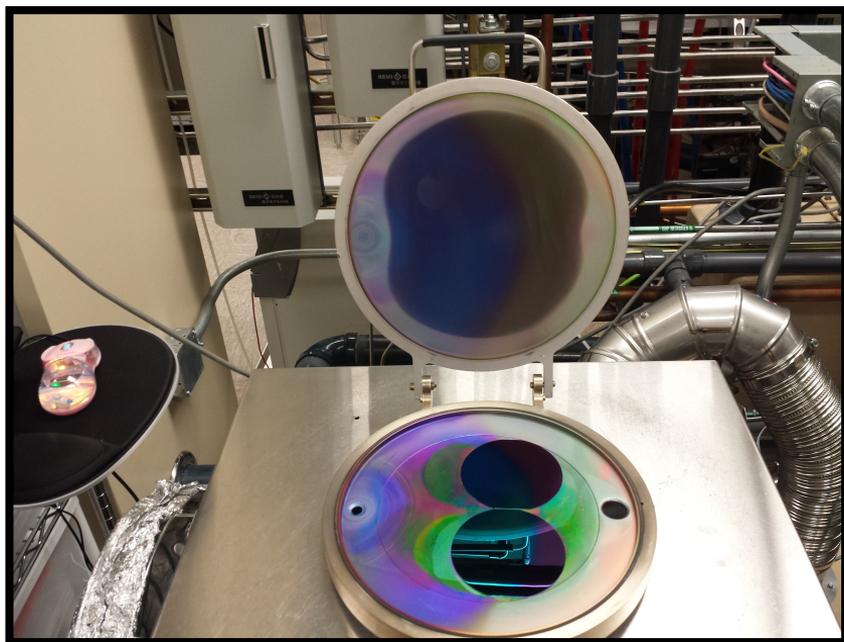
# Over dosing

- DEZ pulse time: 0.3s
- DEZ pulse height: 1.3-1.4 torr
- Severely overdosing



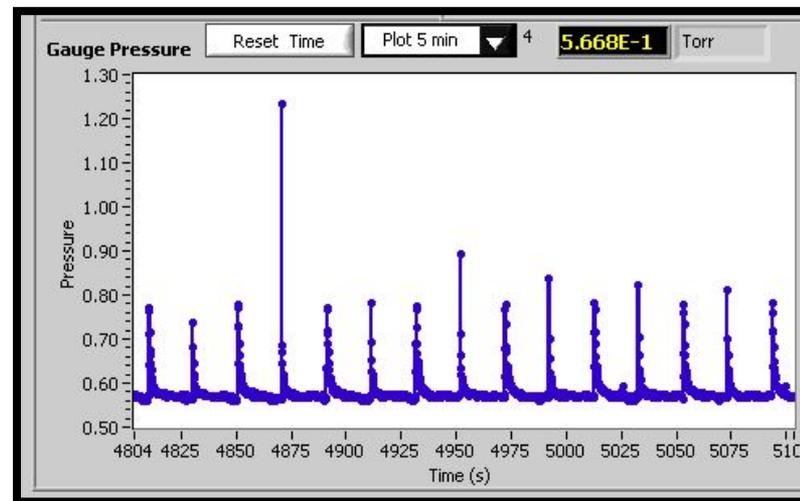
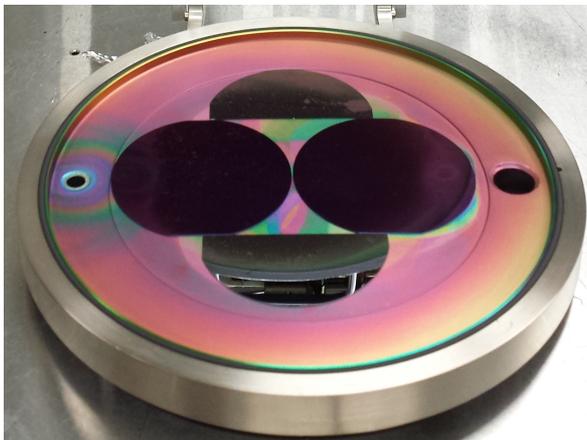
## Under dosing

- DEZ pulse time: 0.03s
- DEZ pulse height: 0.1-0.15 torr



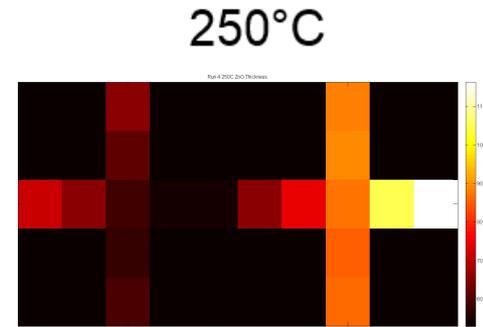
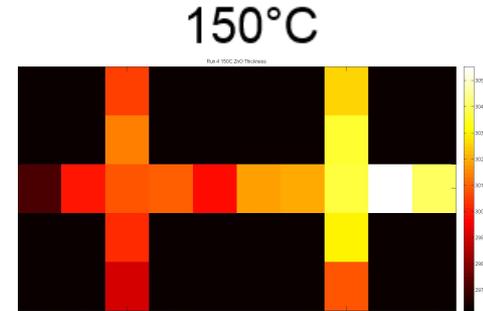
## Good recipe

- DEZ pulse time: 0.06s
- DEZ pulse height: 0.15-0.2 torr



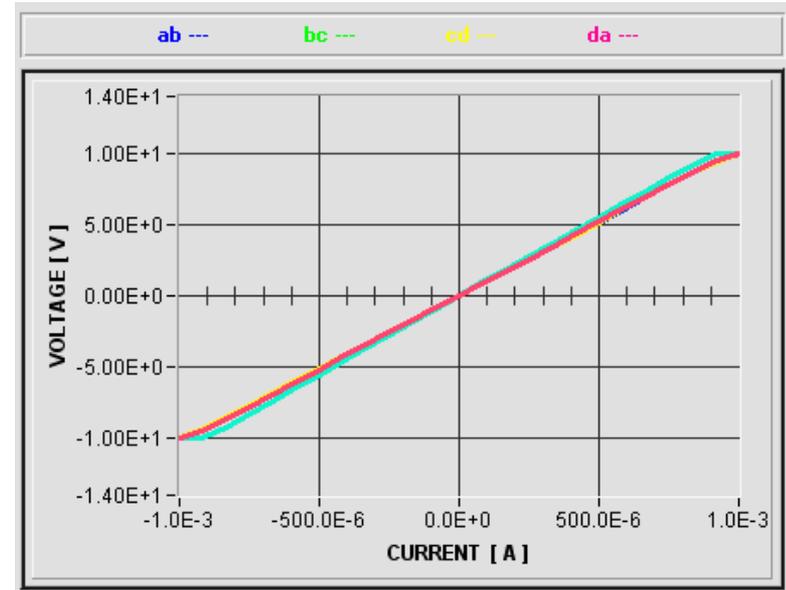
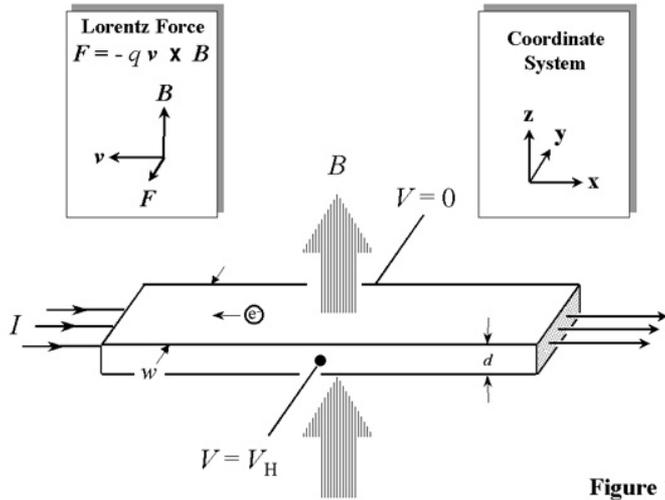
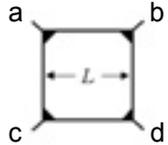
# ALD Uniformity

Temperature	Average (Å)	Standard Deviation (Å)	Deposition Rate (Å/cycle)
100°C	384.93	3.66	1.92
125°C	407.88	4.12	2.04
150°C	301.48	2.02	1.51
175°C	292.81	2.00	1.46
200°C	246.18	18.56	1.22
225°C	204.06	17.13	1.02
250°C	74.57	18.11	0.37



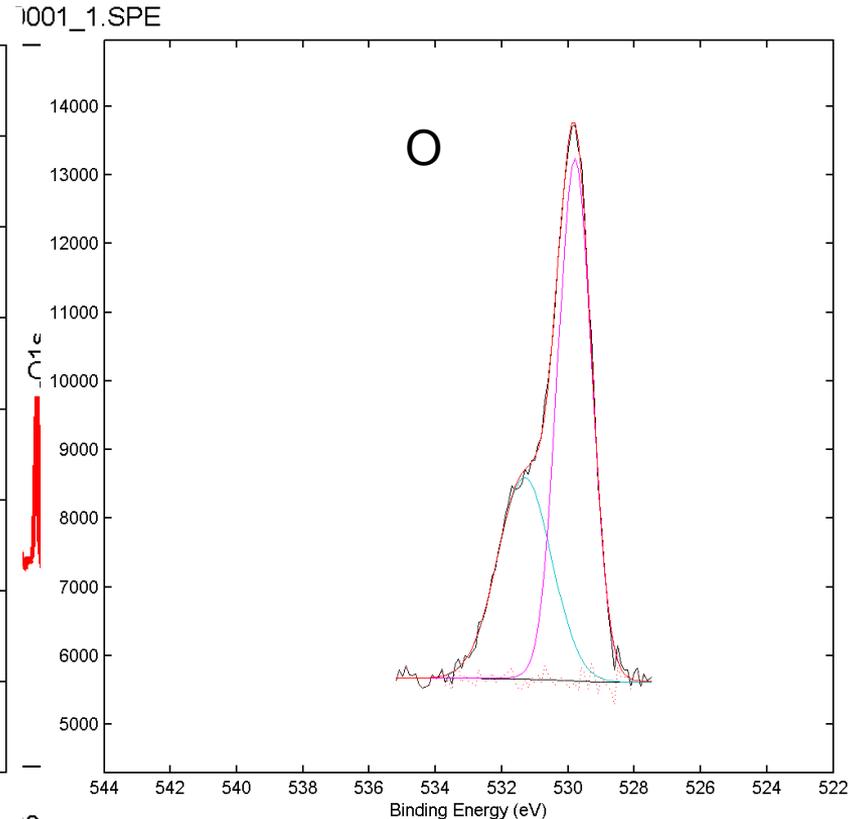
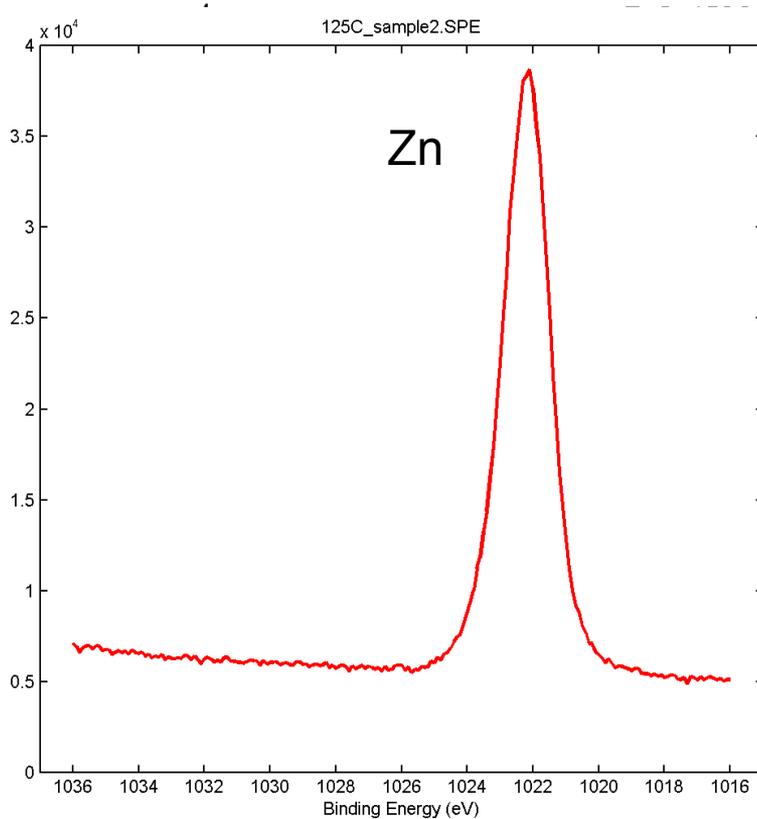
# Hall Measurement

- Uniform, conductive film
- Good Ohmic contact

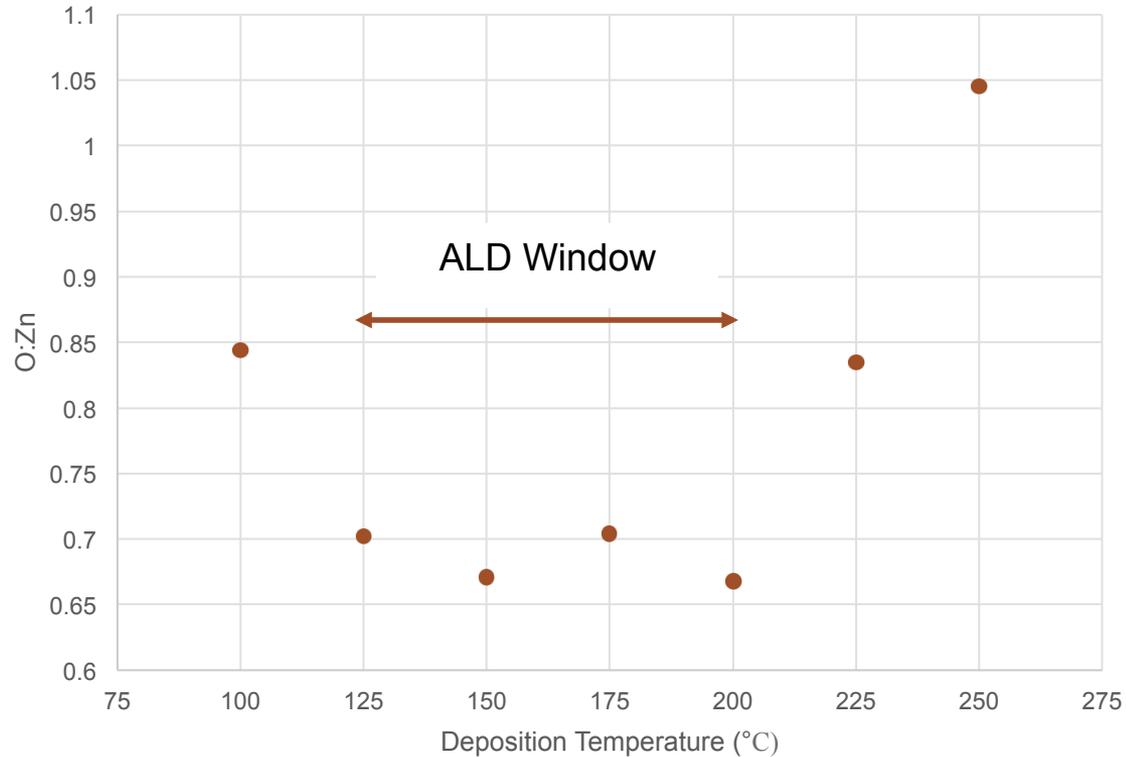




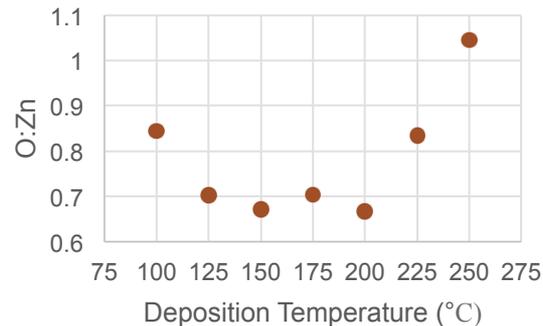
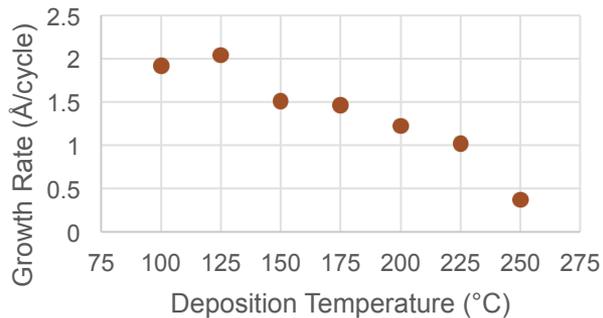
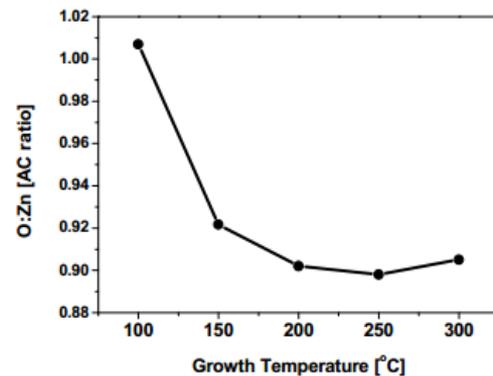
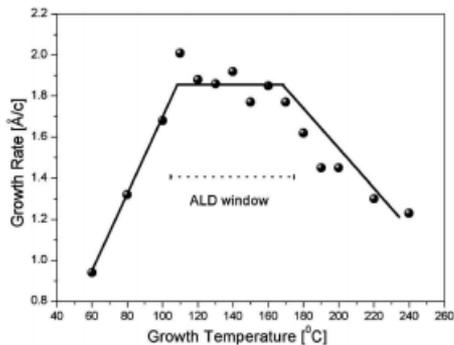
# XPS Film Characterization



# ALD ZnO<sub>x</sub> Stoichiometry



# Comparison to Literature



# Potential Problems

- Growth
  - Issues with old DEZ precursor
  - Inadvertent precursor heating
  - Contamination in Savannah
  - Pressure fluctuation
- Measurement
  - Contacts for Hall measurements
  - Woollam model and fitting

## Conclusion

- Developed standard ALD ZnO recipe
- ALD window similar to literature
- Controlled growth and good uniformity within ALD window
- Recipe requires further modification
  - O:Zn ratio does not follow reported trend
  - New precursor bottle will be used
  - Possibly try deposition in Fiji2
- Zinc contamination study ongoing