Electrical property mapping of ZnO:Al films with micro four-point-probe technique

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**Motivation**

Demonstrating the advantages of a micro-four-point probe setup for mapping electrical properties of transparent conductive films:
1. High spatial resolution
2. Non-destructive
3. Compatible with in-line processes
4. No sample preparation for Hall measurement
5. Error suppression by combining measurements from 7 probes

**Sheet resistance measurement**

![Graph showing sheet resistance measurement](image)

Probes with smaller pitch are more sensitive to local variations and reduce correlation effects.

**Hall measurement**

- Measure $V_B$ and $V_B'$ close to an insulating boundary.
- Determine Hall mobility and carrier density.

![Diagram of Hall measurement setup](image)

**On a ~1 cm scale:**
- Resistivity decreases due to increase in both carrier density and mobility.
- Carrier density and mobility vary in antiphase (measurement noise).

**On a ~100 µm scale:**
- Resitivity decreases due to increase in both carrier density and mobility.

**Burstein-Moss effect mapping:**

\[ \Delta E_c = \text{const} \left( \frac{1}{m_d} + \frac{1}{m_e} \right) n^{2/3} \]

\[ \Delta E_c': \text{ (optical band gap of } \text{ZnO:Al) } - (\text{band gap of undoped } \text{ZnO}) \]

\( n \): carrier density

**Thin film measurements**

- Optical mapping (ellipsometry) to determine film thickness.
- Band gap measurement to determine optical mapping.

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