Junction Evaluation using Electron Beam Induced Current (EBIC)

Gary Mount

Mike Salmon

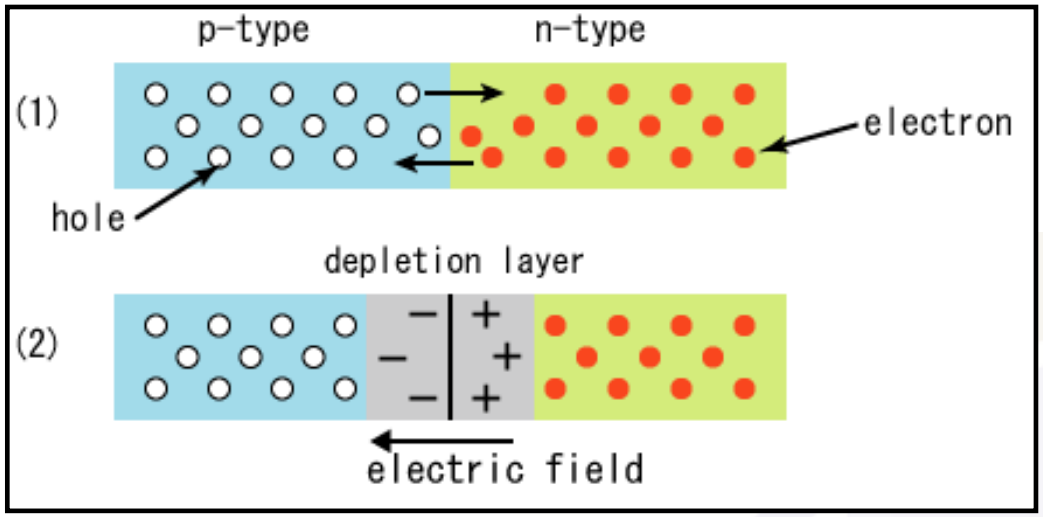
Introduction

- EBIC only works if there is an electrical junction.
- An electron beam is injected into a sample, electron-hole pairs are formed, but they are only separated causing current to flow in the presence of an electric field, such as that caused by a p-n junction.
- The strength of the signal depends on the quality of the junction.
- EBIC can be done using a standard SEM or with considerable effort, in a TEM.

Introduction

- EBIC is a useful tool for the evaluation of electrical junction performance uniformity.
- EBIC is a useful tool for finding the location of an electrical junction.
- It is very useful for large area junctions such as:
  - LED
  - Solar Cells
- EBIC combined with other analytical tools can find layer and crystal structure defects.

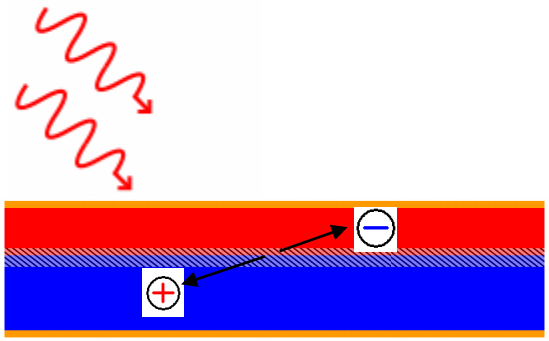
p-n Junction Fundamentals



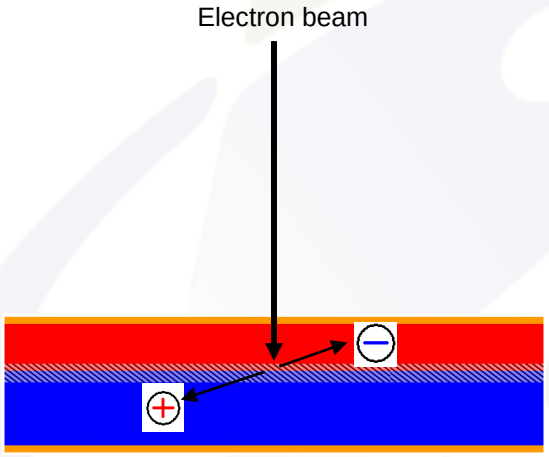
Current Generation

- Electron-Hole pair generation
- Can be generated by a photon (OBIC)
- Can be generated by an electron (EBIC)

Solar Cell



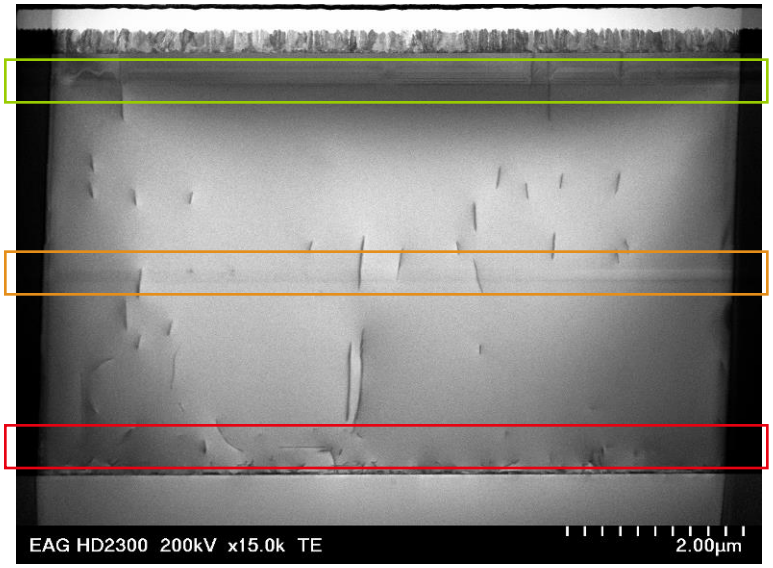
EBIC



Why EBIC?

- Layer structure and crystal structure defect evaluation is traditionally done by random selection.
- EBIC provides information on where to look.

Example: Commercial GaN LED



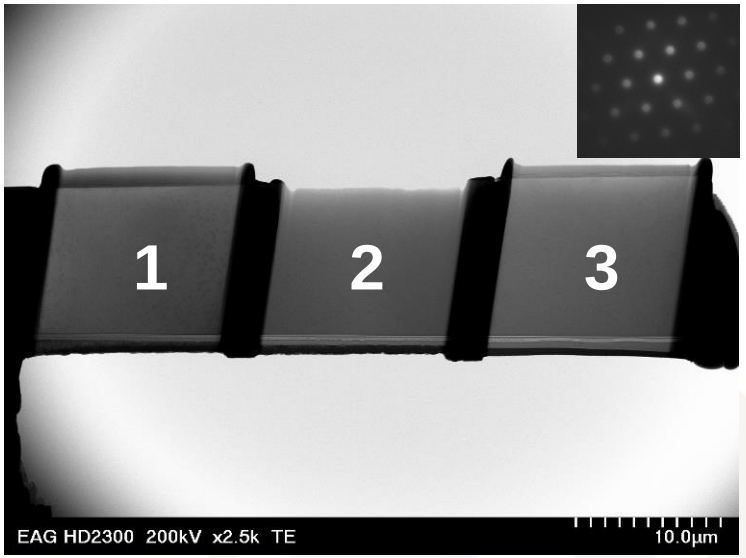
1

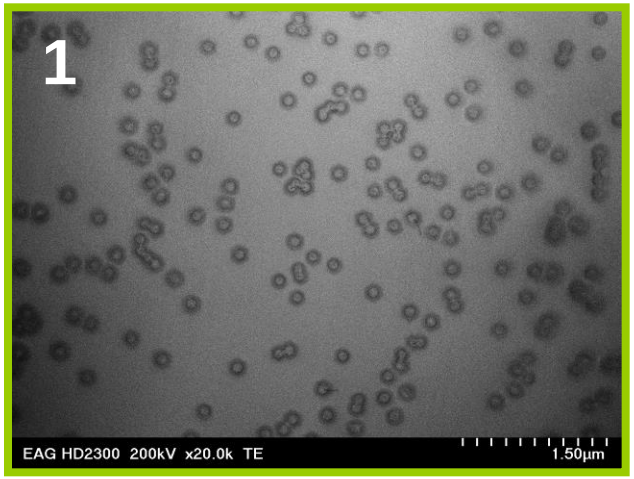
← XS

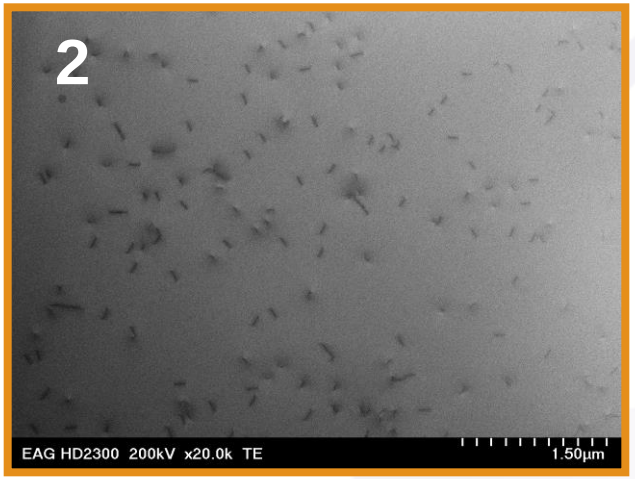
2

PV →

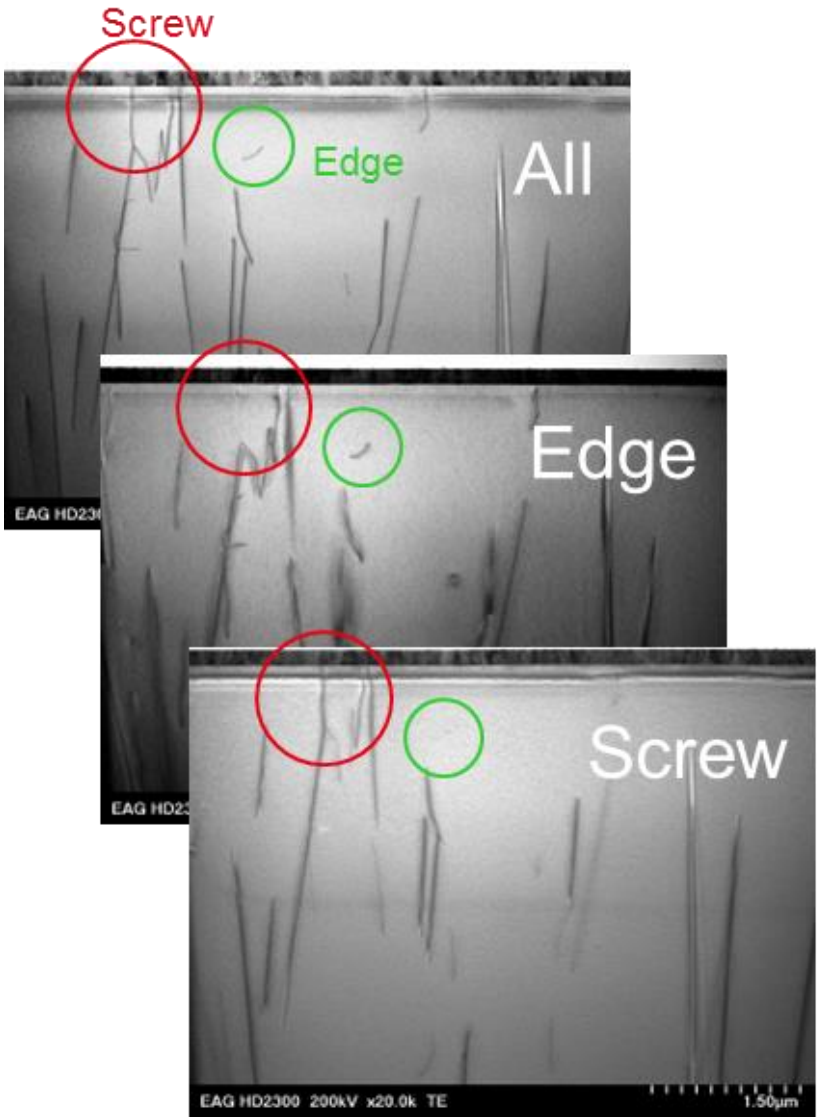
3





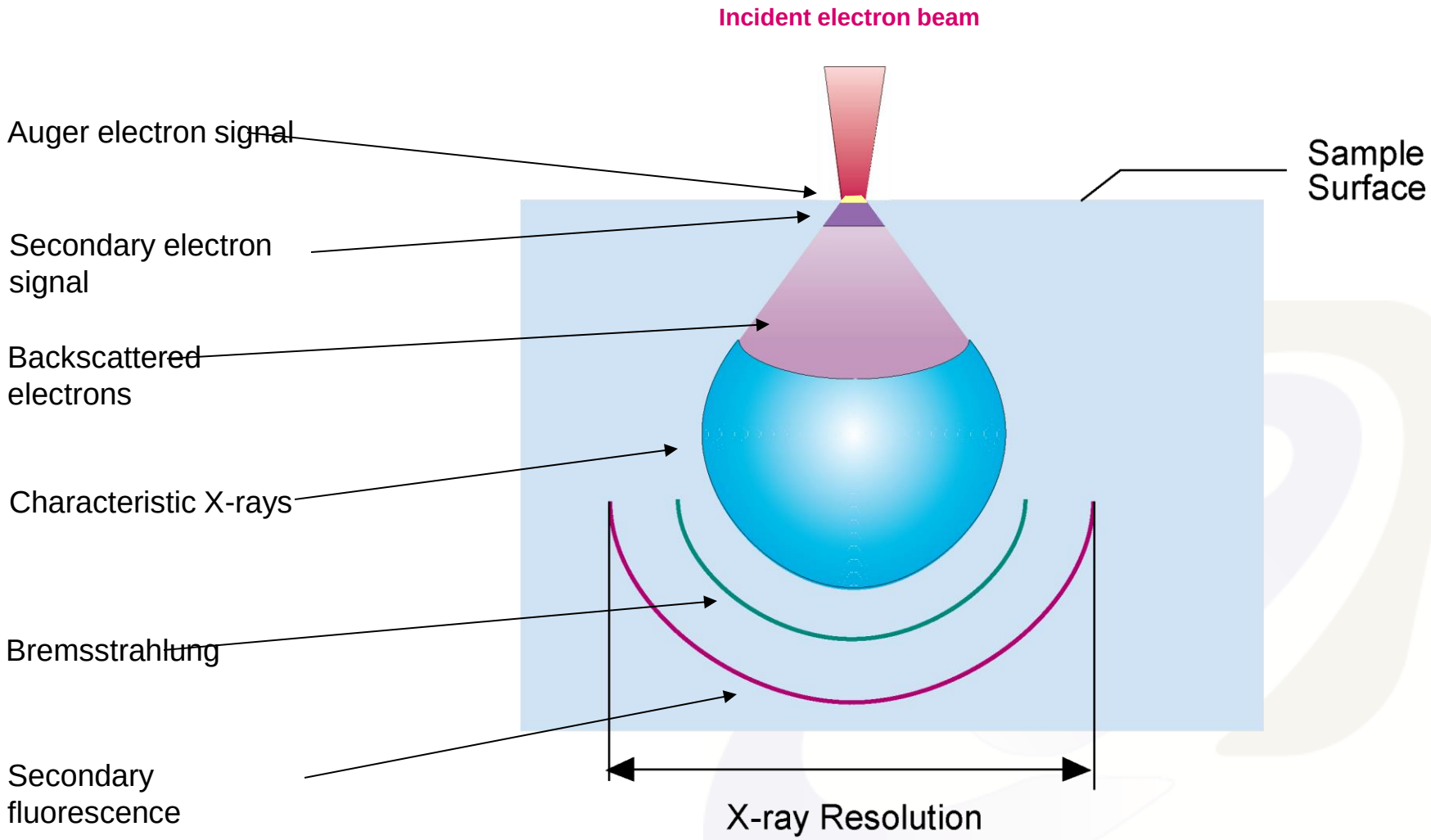


Rapid Typing of Dislocations



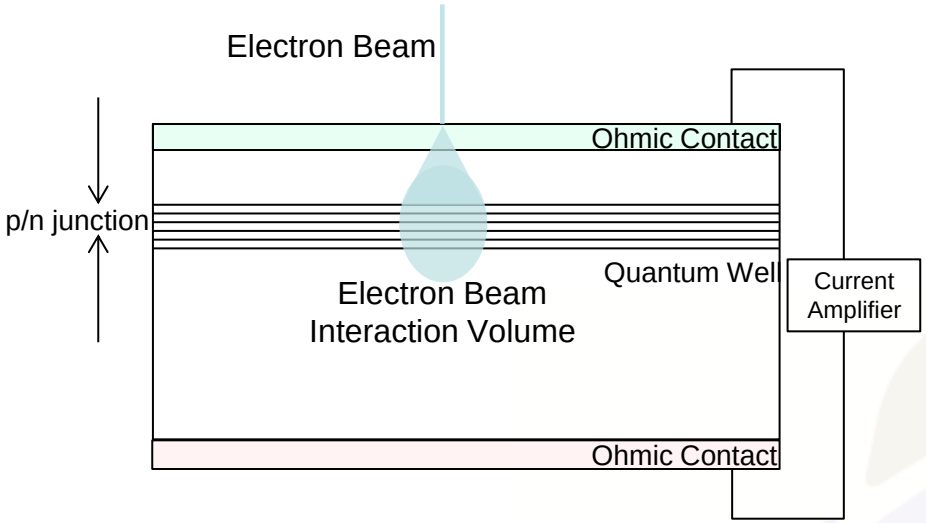
- The character of dislocations can be quickly determined using STEM imaging.
- By utilizing specific sample tilts, threading dislocations can be identified as having screw, edge, or mixed character.

E-beam Interaction with a Surface



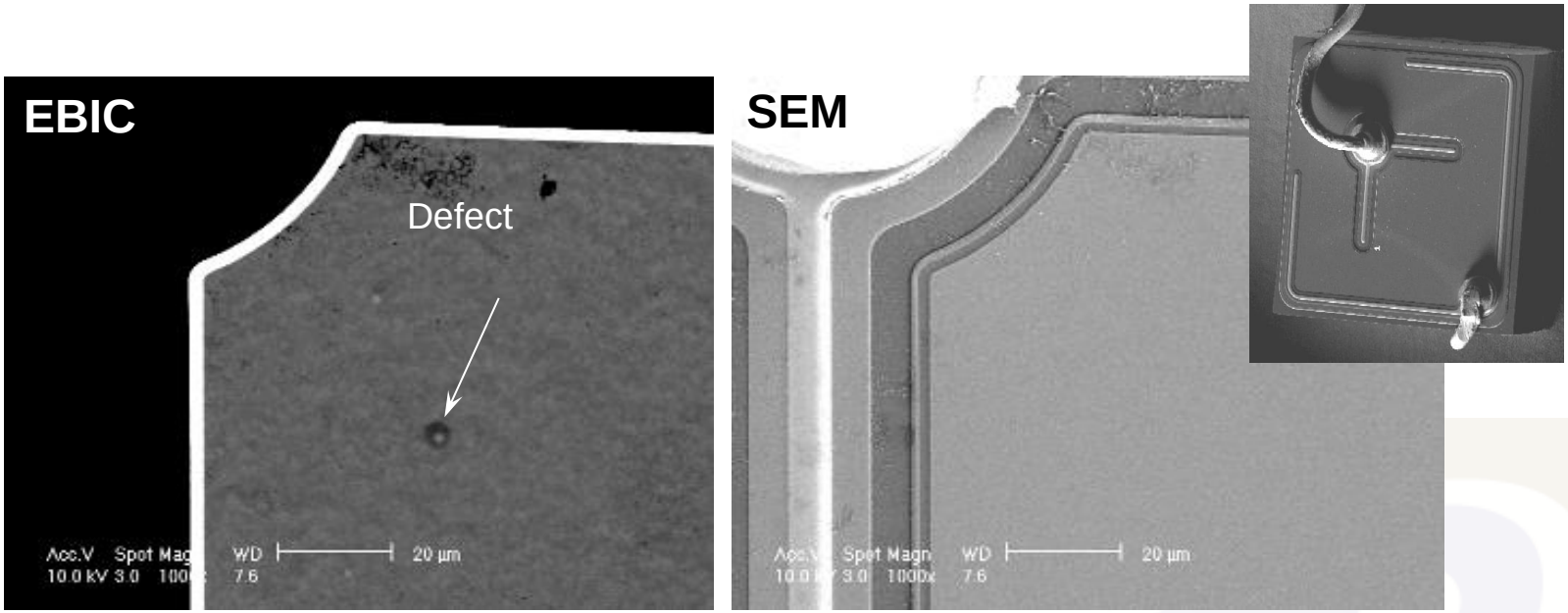
Plan View EBIC using SEM

- Plan-View



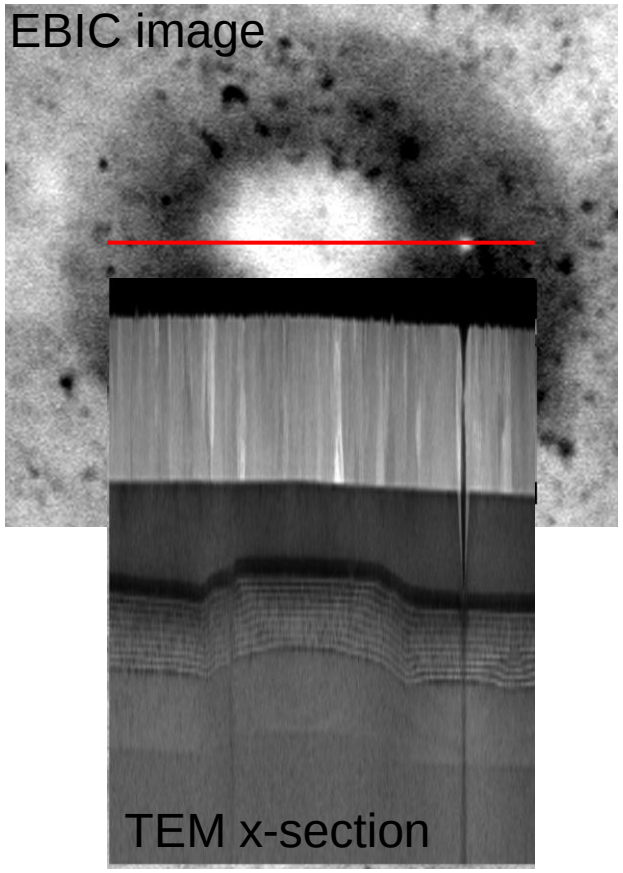
- Current flows when SEM electron beam penetrates p-n junction.
- Uniformity of current flow depends on uniformity of electrical junction.
- Contrast created by non-uniformities in junction.

Finding Defects using EBIC



- Electron Beam Induced Current (EBIC) imaging is compared with standard SEM imaging. An EBIC 'bright spot' reveals a defect that is not seen in standard SEM.
- The contrast at the Defect is caused by current changes in the p-n junction. Why?

Analysis of EBIC Discovered Defect



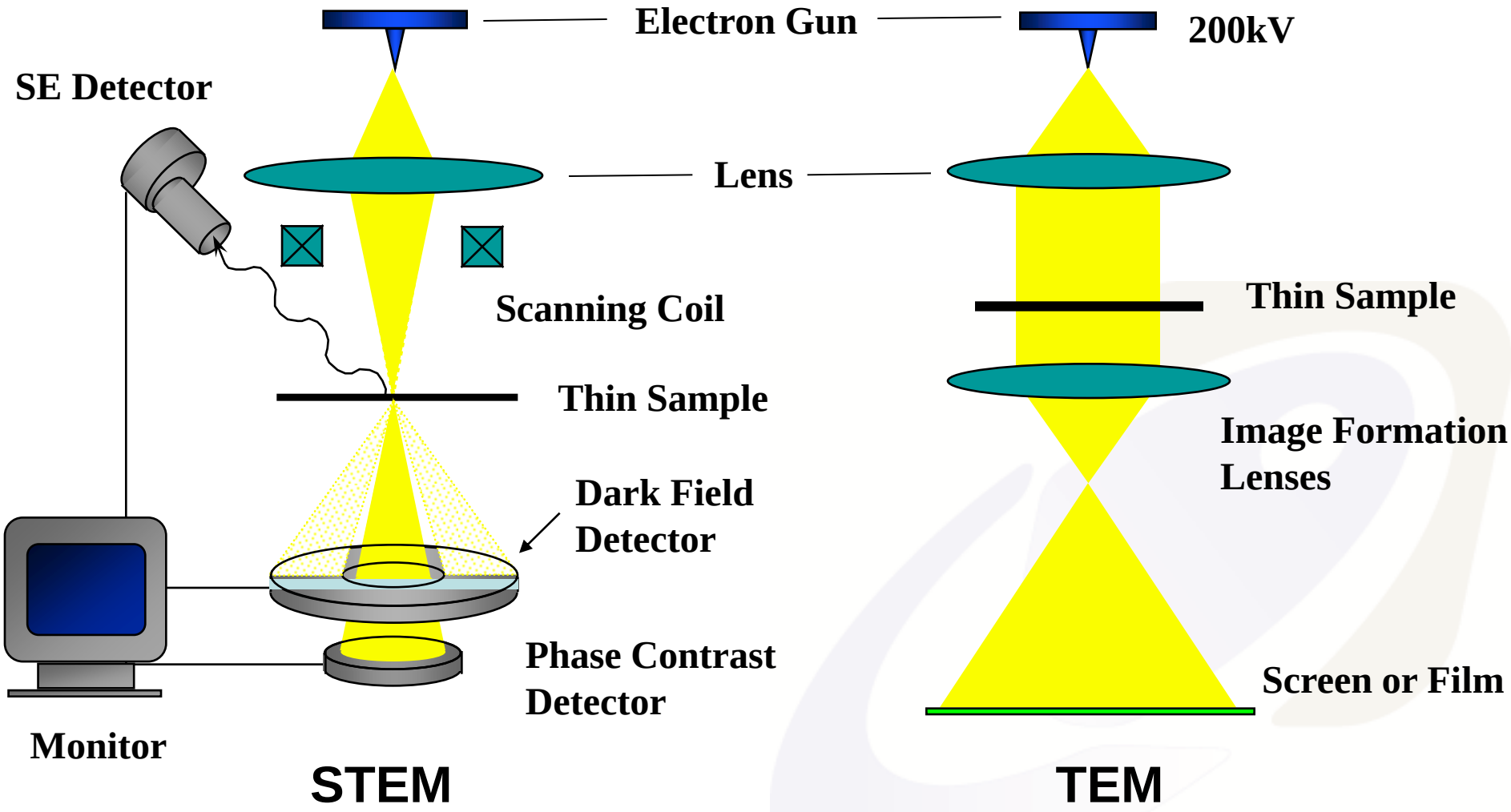
- Same defect as previous slide.
- Cross section prepared.
- Large EBIC bright spot correlates with quantum well structure.
- Small EBIC bright spot correlates with pit defect.

EBIC in the TEM

EBIC in the STEM

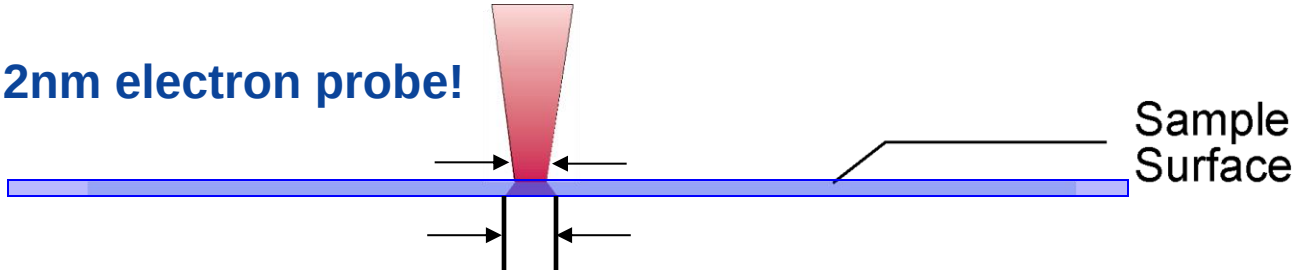
- Resolution in standard EBIC is limited by the electron beam interaction volume.
- EBIC in the STEM has the promise of much higher resolution.

Compare STEM and TEM



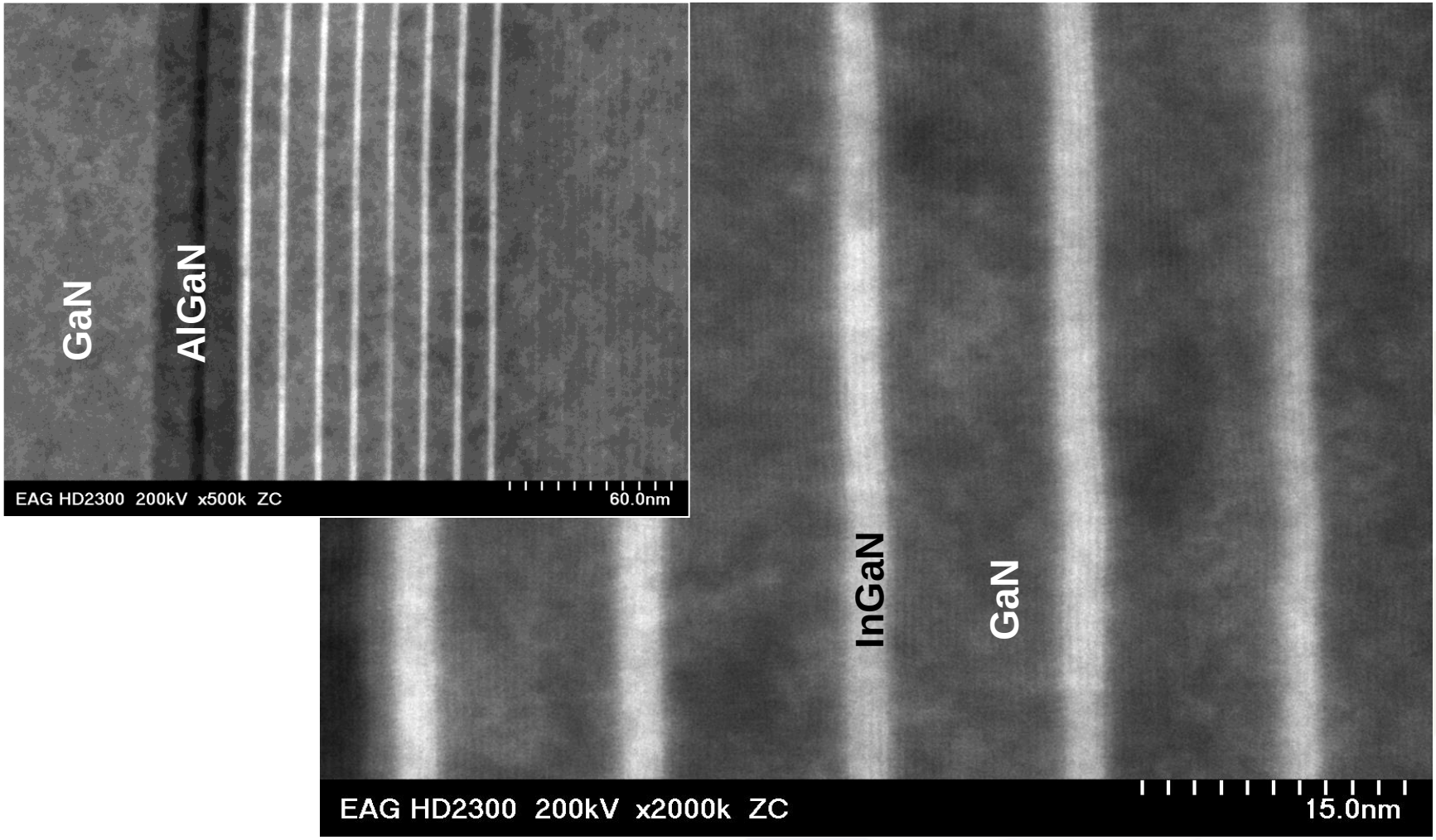
STEM Theory/Background

Thin Film Sample



EBIC Resolution

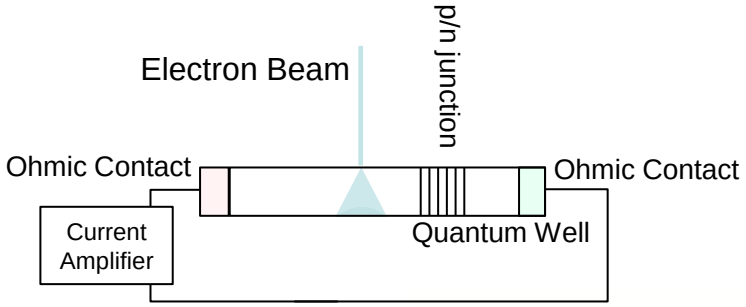
Z- Contrast Image of QW Structure



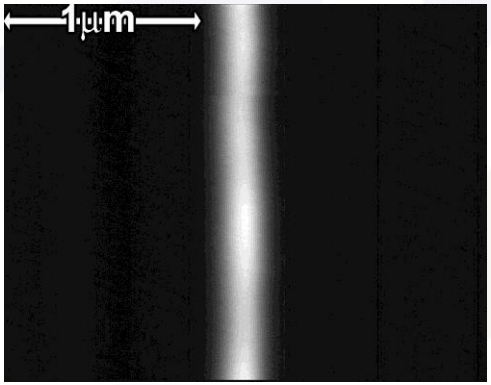
Z-contrast image, showing the GaN and AlGaN barrier layers and the InGaN quantum well. STEM has unique capabilities in providing Z-contrast images.

Cross-Section EBIC using STEM

- Cross-Section

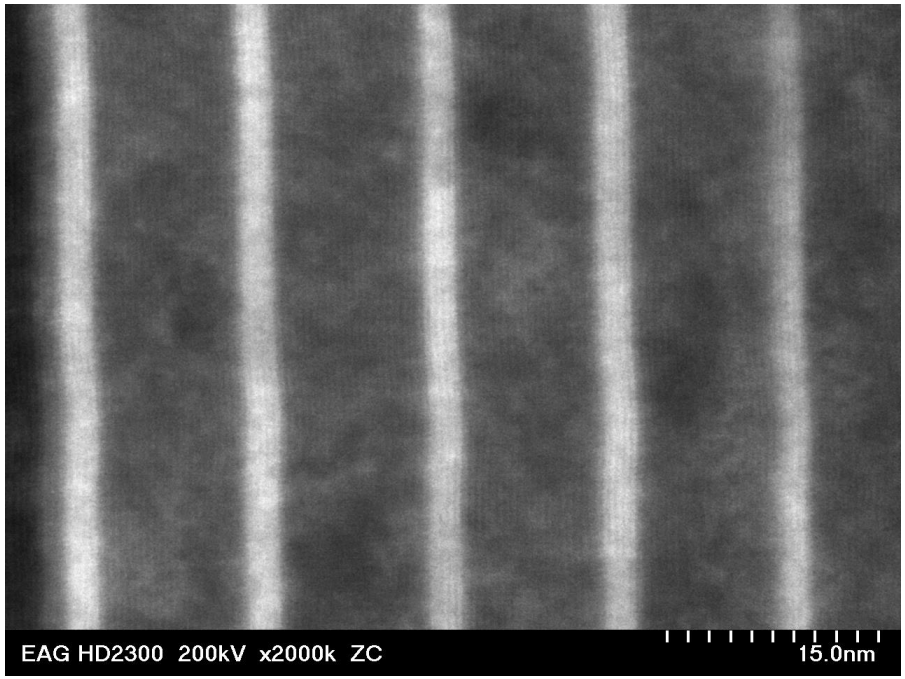


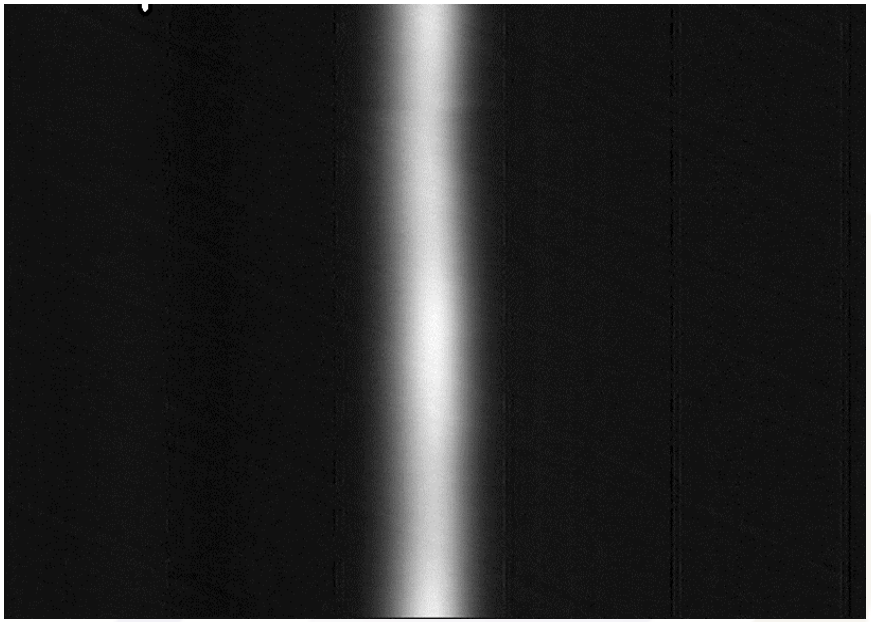
- EBIC imaging can be done on a thin cross-section prepared for STEM
- The electron beam scanned over a cross-section reveals the location of the p-n junction within the quantum well.



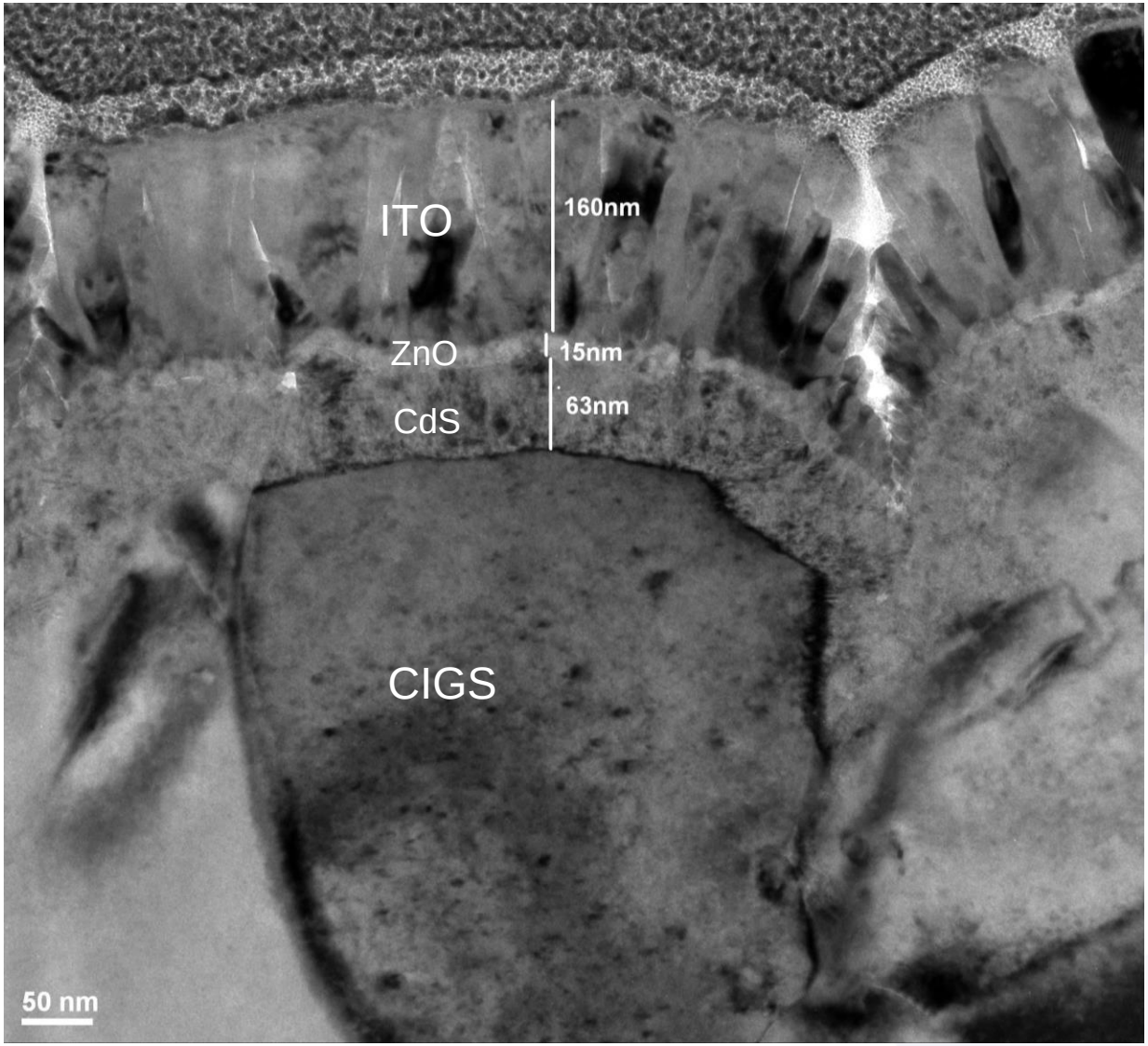
EBIC current only flows when the electron beam hits the p-n junction

Where is the p-n Junction?



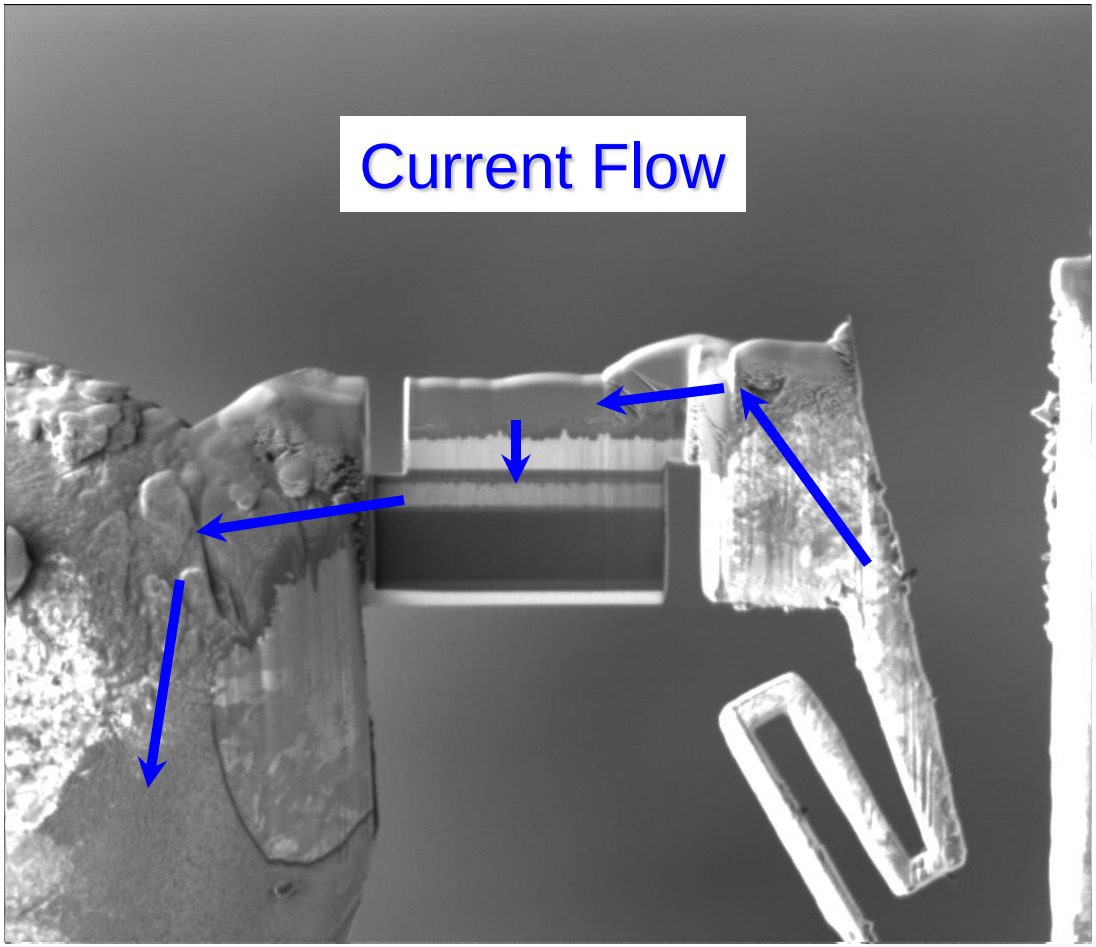


CIGS Layer Structure



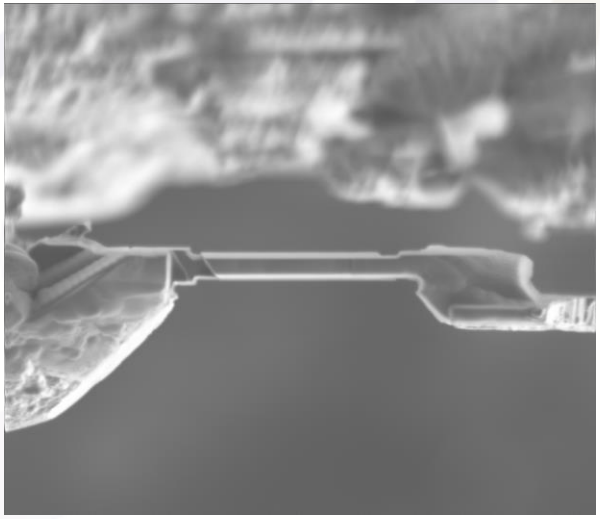
- TCO layers show columnar ITO grains, a very thin (15nm) ZnO layer, and CdS with no apparent grain structure.
- The layers appear conformal with the CIGS surface and have good layer uniformity.
- The 15nm ZnO layer cannot be seen by any other method.

TEM Sample Prep for EBIC

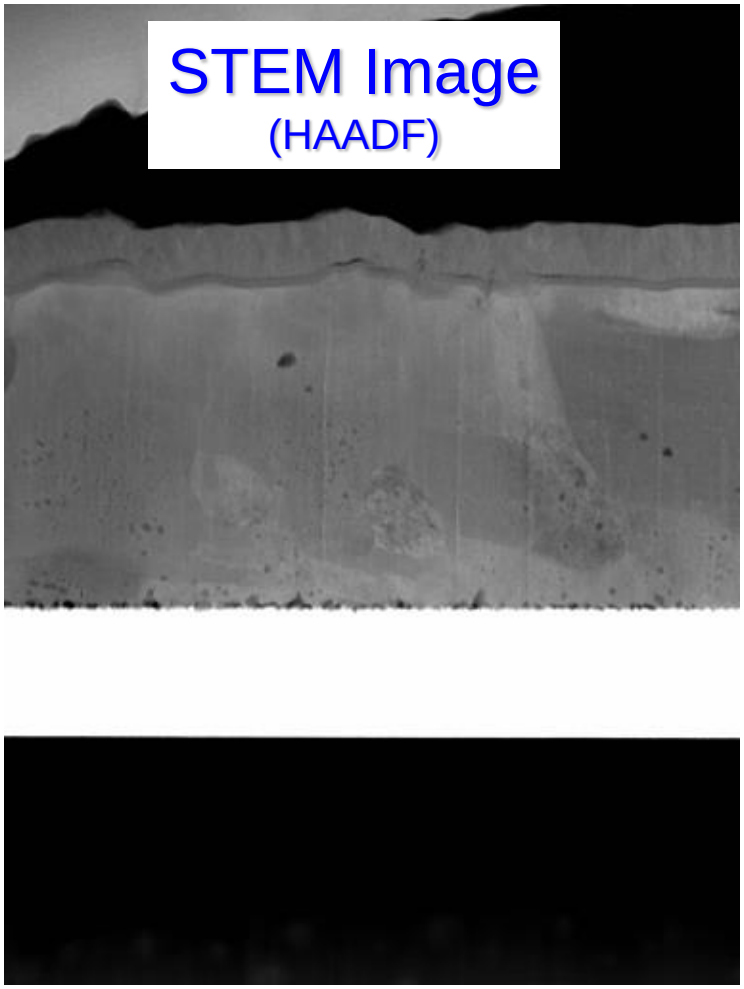


CIGS
Solar Cell

Top View



STEM and EBIC Images



EBIC Signal

Permission not granted to show data

Overlay of STEM and EBIC Images

Permission not granted to show data

Summary

- Sample type determines analysis
  - Plan-view (SEM)
  - Cross-section (STEM)
- Plan view EBIC can find defects under the surface.
- Cross-section EBIC shows junction location.
- STEM can greatly improve resolution limits.

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