C3NiT - Janzén

Kompetenscentrum

Centre for III-nitride technology

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Structure characterization of nitrogen-polar GaN on AlN/SiC epitaxy

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Nitrogen-polar III-nitride epitaxy

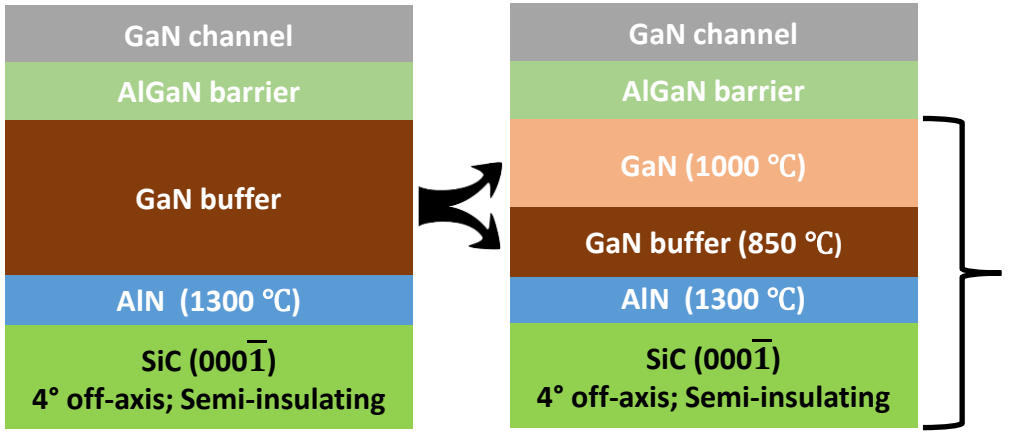
Background:

- Nitrogen-polar (N-polar) high electron mobility transistors (HEMTs) based on Al(Ga)N epitaxy offer superior characteristics over Al-polar Al(Ga)N for high-frequency operations e.g high-data-rate wireless communications and high-resolution radar imaging.
  - N-polar GaN on AlN epitaxy requires high-temperature AlN off-axis growth.
  - High temperature AlN
    → GaN dislocations and step bunching → surface roughness
    → no two-dimensional electron gas (2DEG) interface.

AIM: Two-step GaN growth

- ✓ Maintain N-polarity across SiC/AlN, AlN/GaN, GaN/GaN interfaces.
- ✓ Reduce surface roughness and dislocations to enable 2DEG

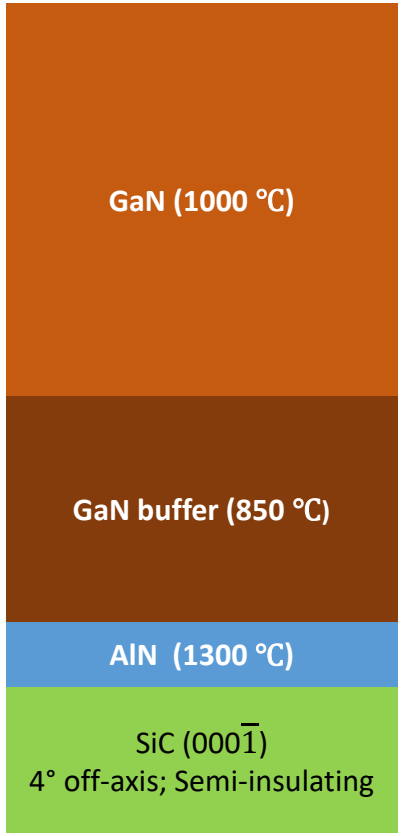
HEMT heterostructure cross-section models

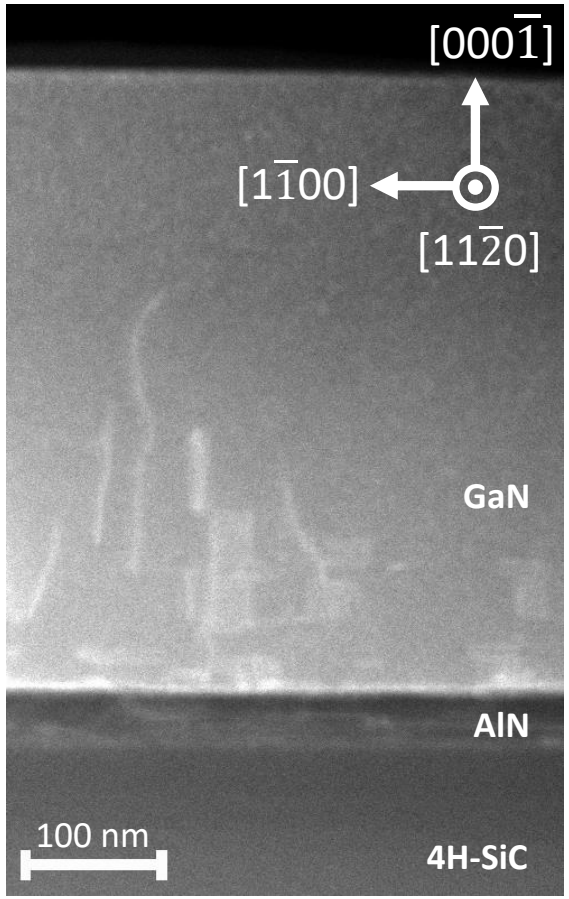


Scanning transmission electron microscopy (STEM)

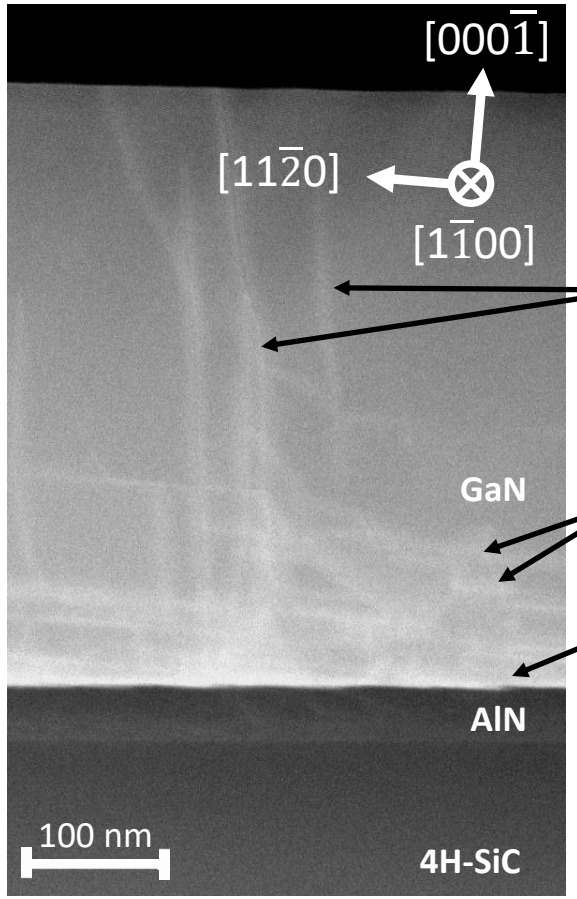
Structure characterization - Transmission electron microscopy (TEM)

- ✓ **Dislocations are significantly reduced in the upper GaN region**
- ✓ **Surface roughness reduced**





90 °



4 ° off-axis cut

4H-SiC

Threading dislocations

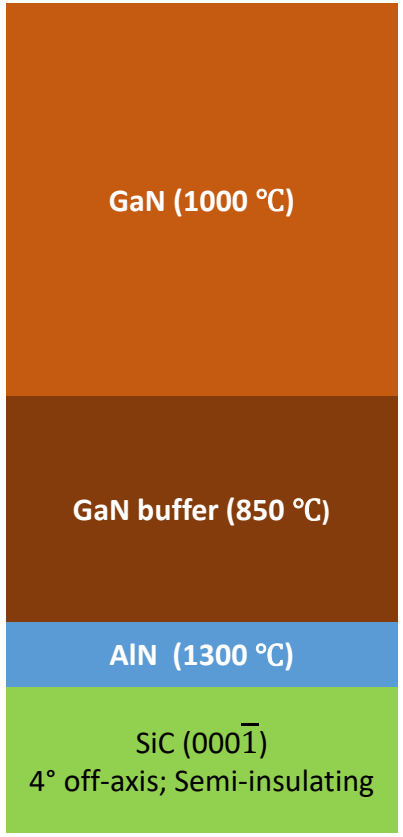
Stacking faults and in-plane dislocations along [11$\bar{2}$0]

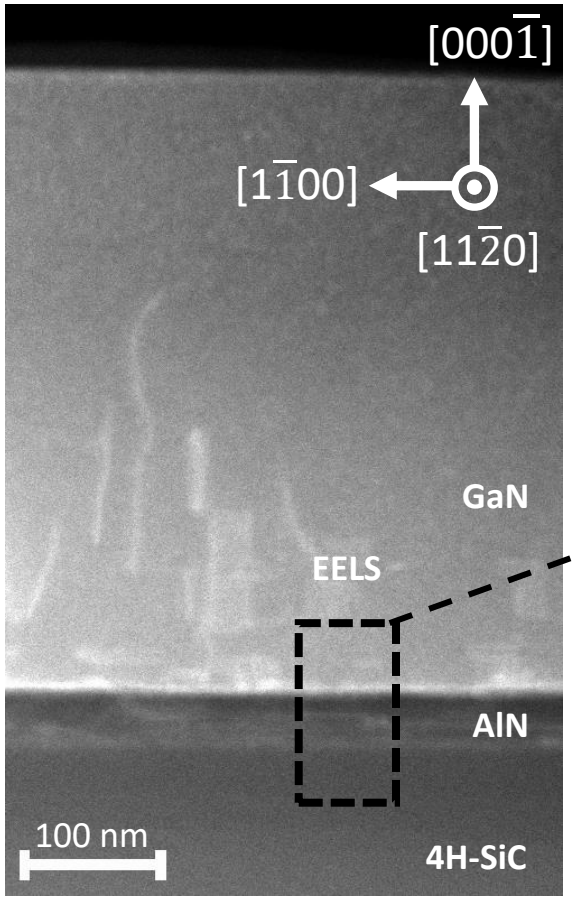
Nano steps

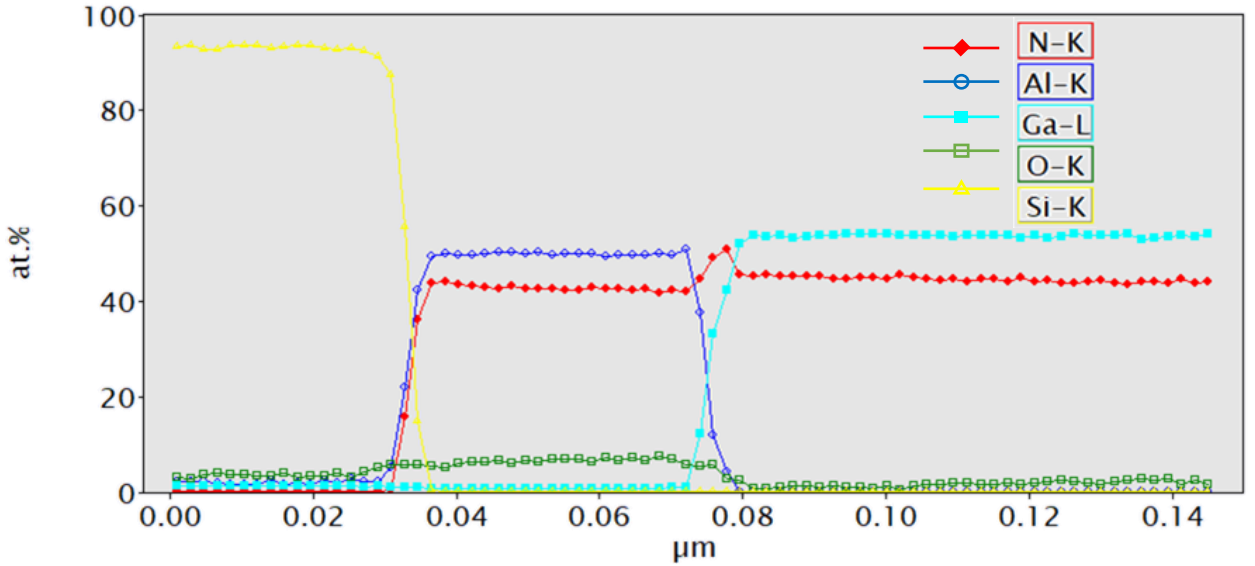
- **Some threading dislocations remain in the upper GaN region.**

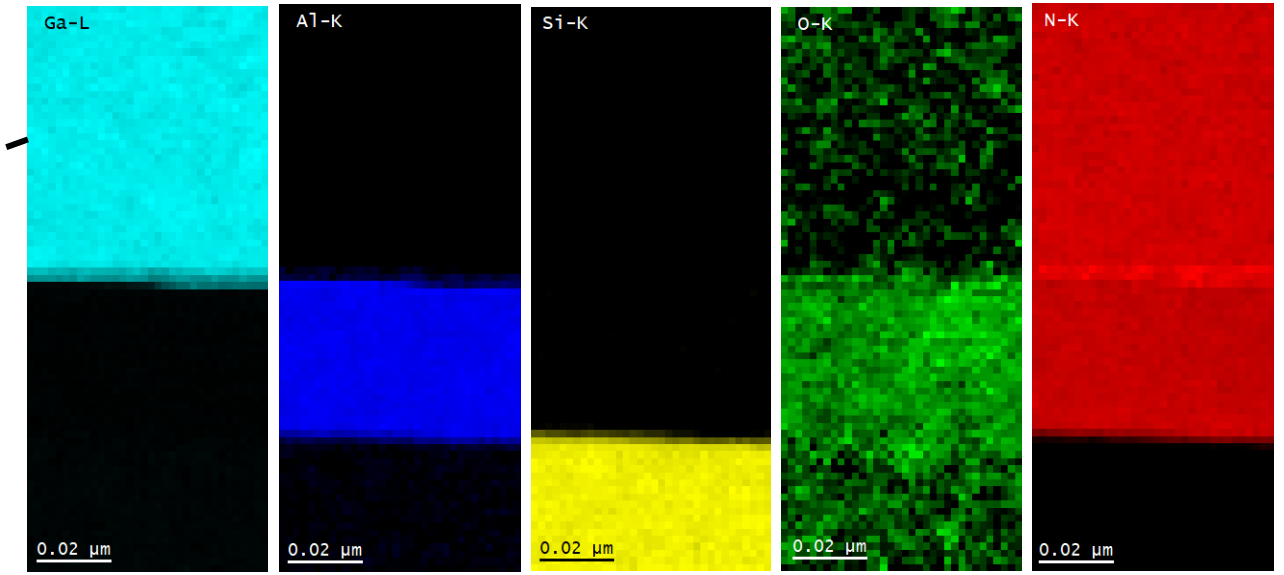
Structure characterization – Electron energy-loss spectroscopy (EELS)

✓ **Sharp elemental transitions achieved**

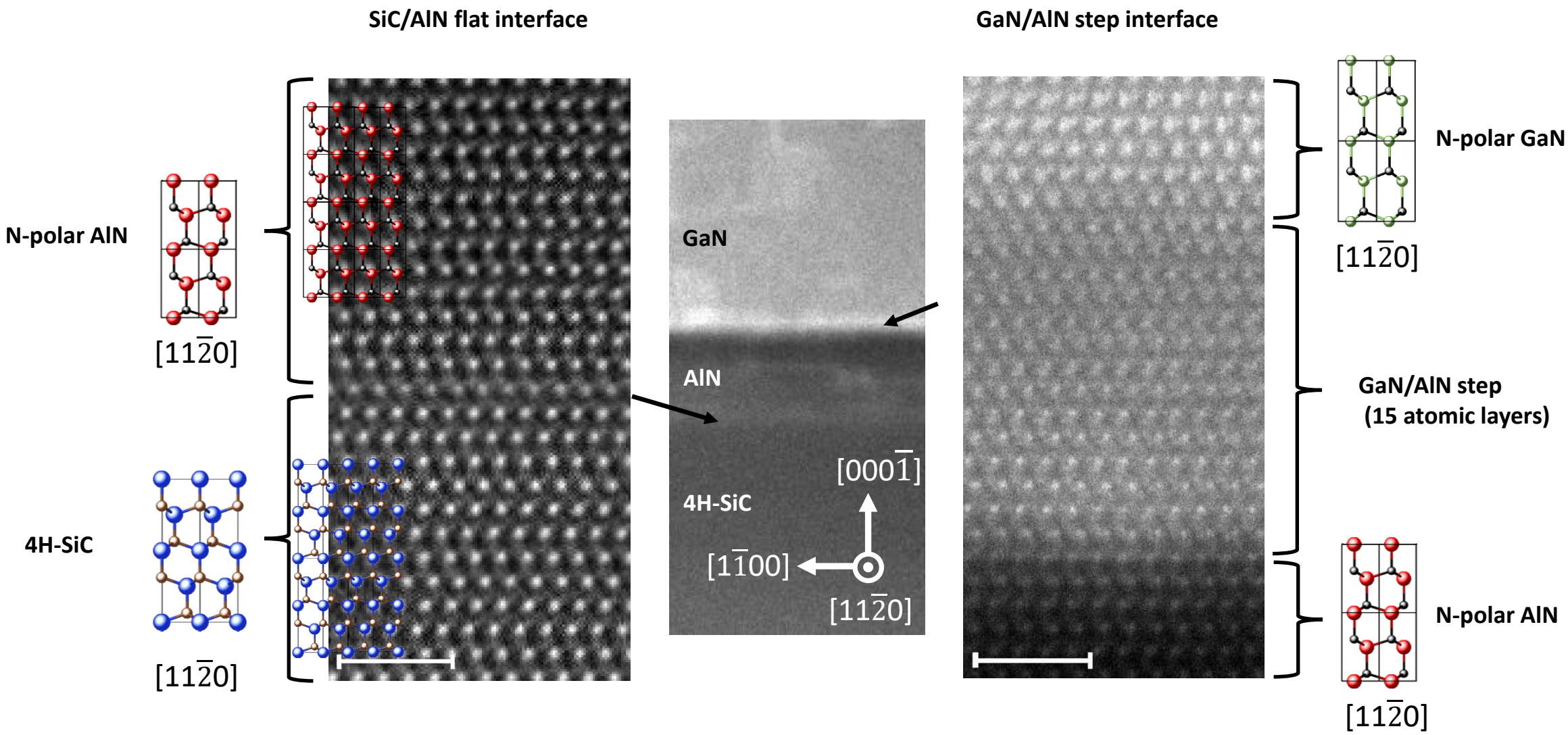




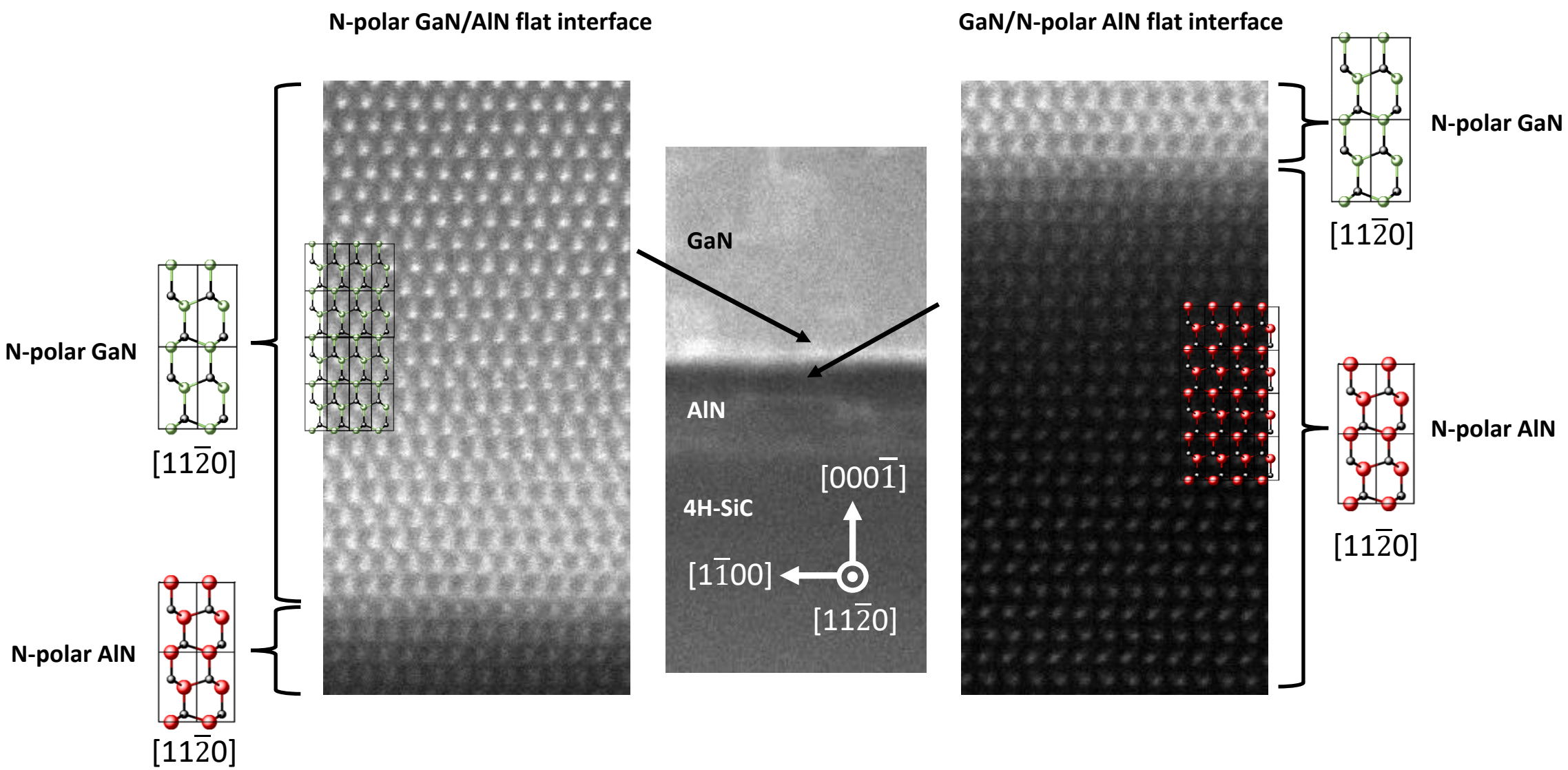




Atomic scale scanning TEM (STEM)



Atomic scale STEM



Summary

Two-step N-polar GaN growth can be achieved and results in:

- **Maintaining N-polarity across SiC/AlN, AlN/GaN, GaN/GaN interfaces.**
- **Reducing surface roughness and dislocations to enable 2DEG**

Next step, demonstrate 2DEG in N-polar AlGaN/GaN HEMT

N-polar GaN

N-polar AlN