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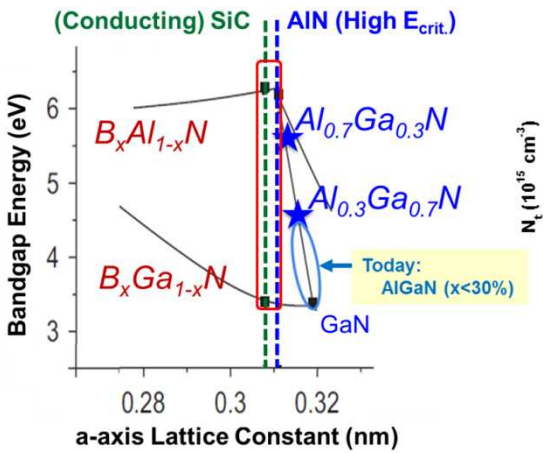

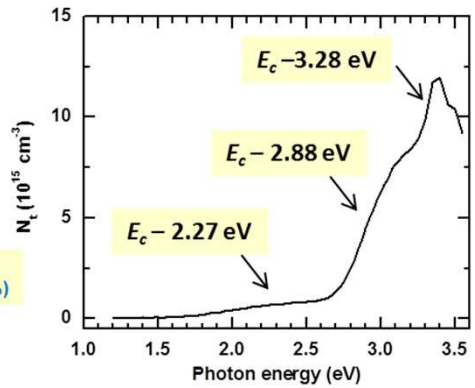

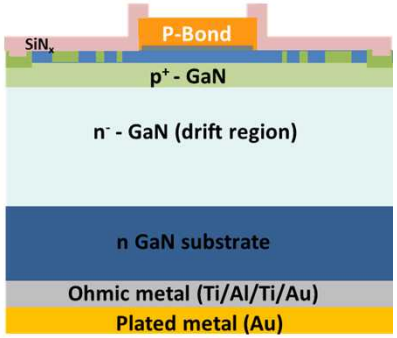

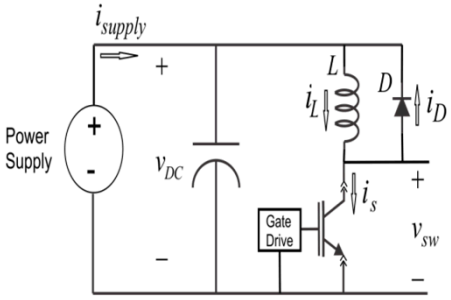

Advanced UWBG heterostructure characterization

A. M. Armstrong, T. Ohta

U.S. DEPARTMENT OF ENERGY
National Nuclear Security Administration

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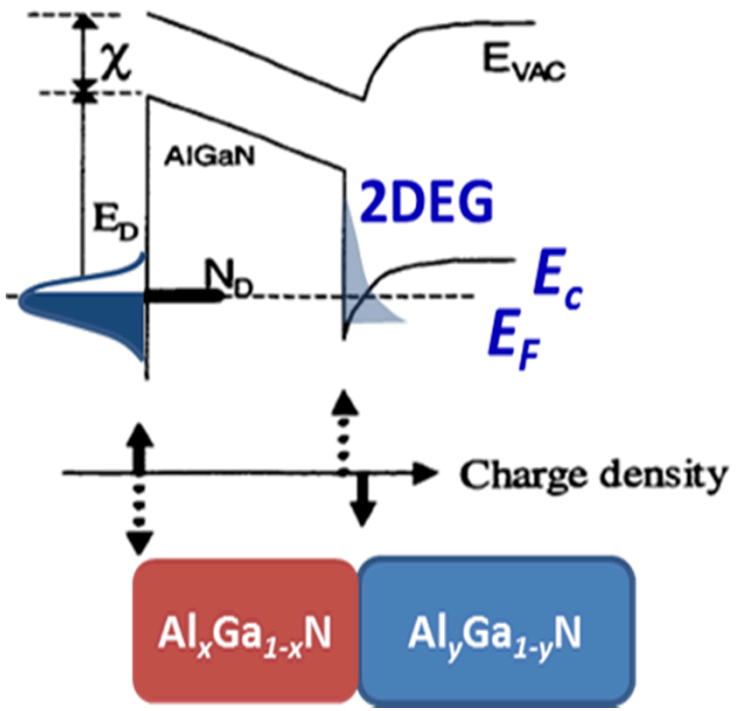
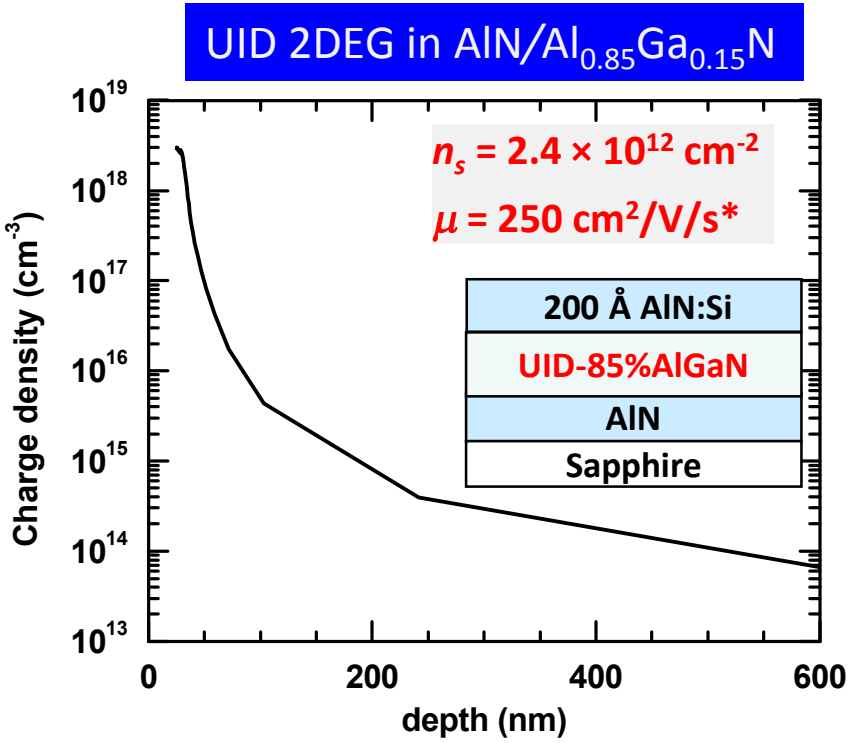
Understand AlGaN spontaneous two-dimensional electron gas formation

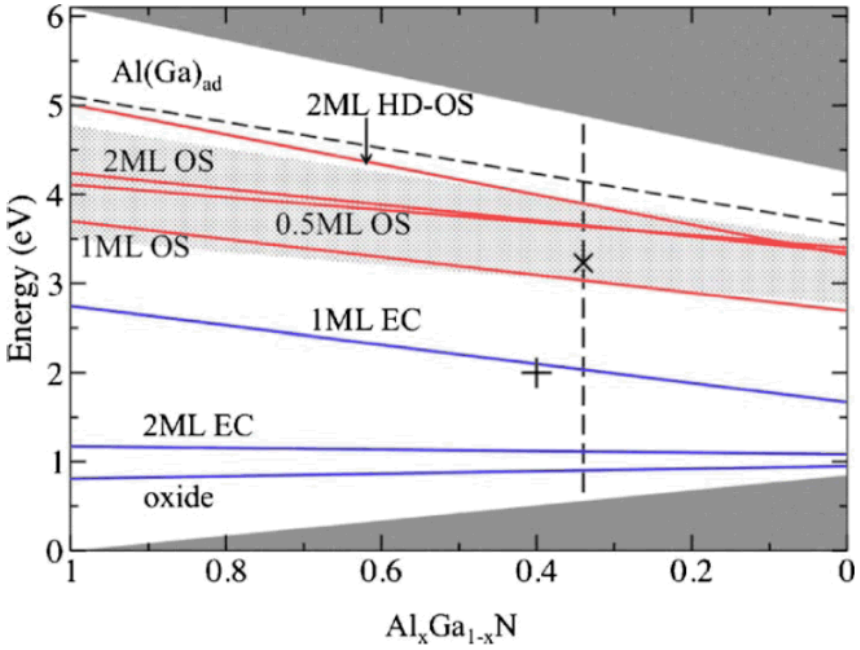




- First demonstration of two-dimensional electron gas (2DEG) in unintentionally doped (UID) $Al_yGa_{1-y}N/Al_xGa_{1-x}N$ HEMT $y > x > 0.6$
- Apply advanced surface science to AlN/AlGaN to definitively determine physical source of 2DEG

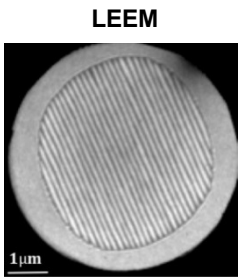
Understand AlGaN spontaneous two-dimensional electron gas formation

Understand and control electronic properties of UWBG Al(Ga)N surface

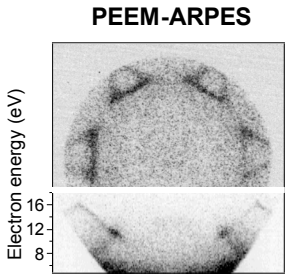


1. Miao et al. J. Appl. Phys. 107 123713 (2010).

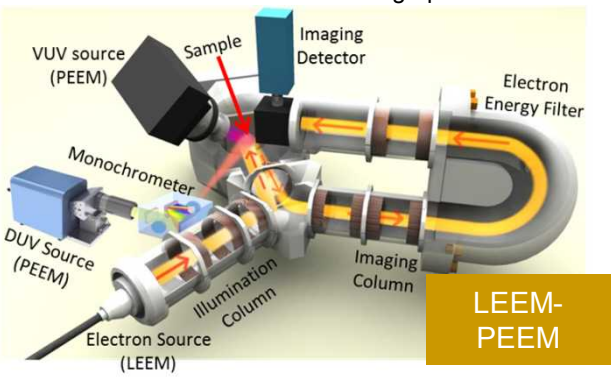
LEEM-PEEM surface characterization



Step morphology on Si(001)



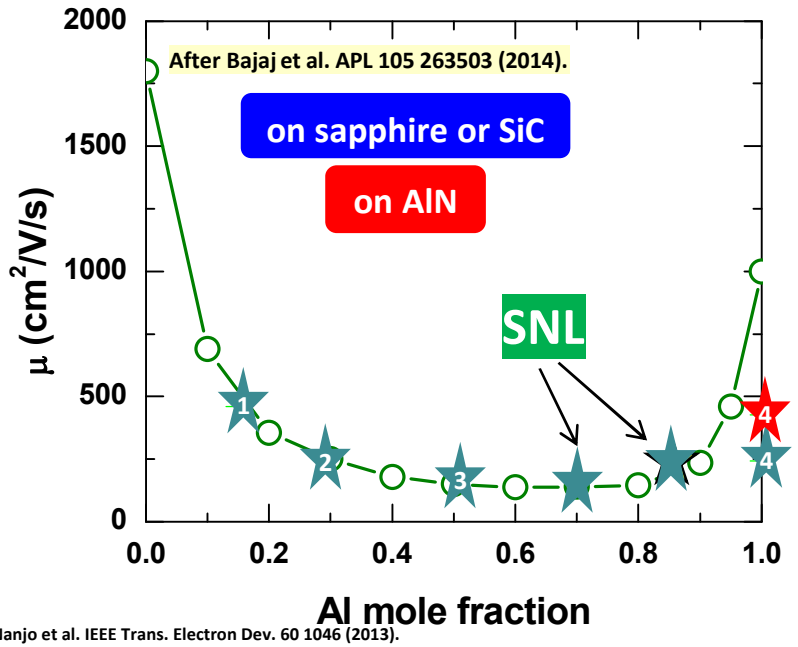
Valence band dispersion of graphene



- Use LEEM-PEEM to correlate Al(Ga)N surface structure, chemistry, & electronic properties at sub-μm length scale
- Study as a function of growth conditions, oxidation, and post-growth thermal treatment

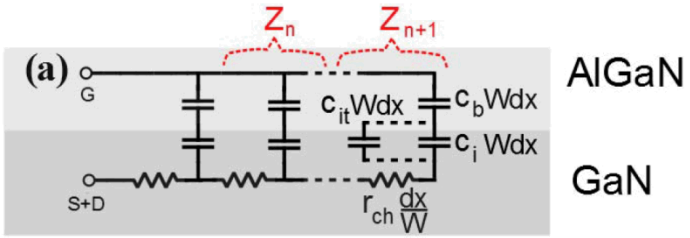
Characterize UWBG AlGaN heterostructures with AWE/Bristol

AlGaN μ *vs.* Al mole fraction



1. Nanjo et al. IEEE Trans. Electron Dev. 60 1046 (2013).
2. Hashimoto et al. SEI Tech. Rev. 71 83 (2010).
3. Hashimoto et al. PSS A 209 501 (2012).
4. Taniyusa et al. APL 89 182112 (2006).

AWE/Bristol *C-V-f* model for heterostructures



$$Z_{n+1} = \left(j\omega c W \Delta x + \frac{1}{Z_n} \right)^{-1} + r_{\mathrm{ch}} \frac{\Delta x}{W}$$

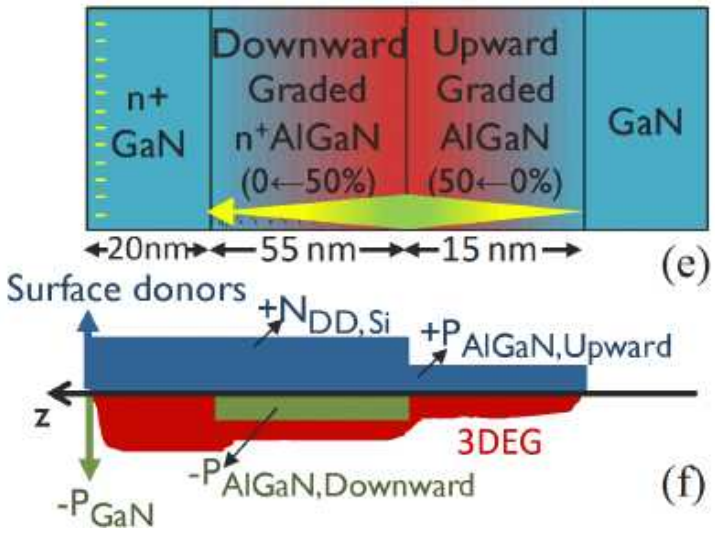
$$r_{\mathrm{ch}} = \frac{1}{\mu_0 n_i q}$$

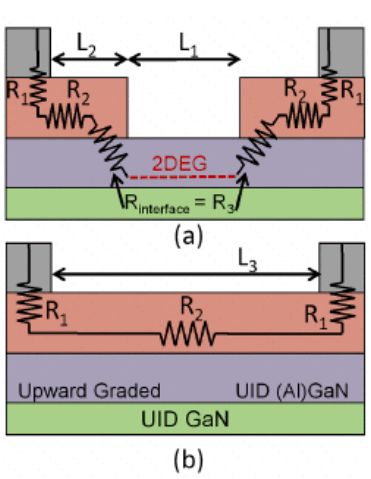
Waller *et al.*, IEEE TED 2464 62 2015

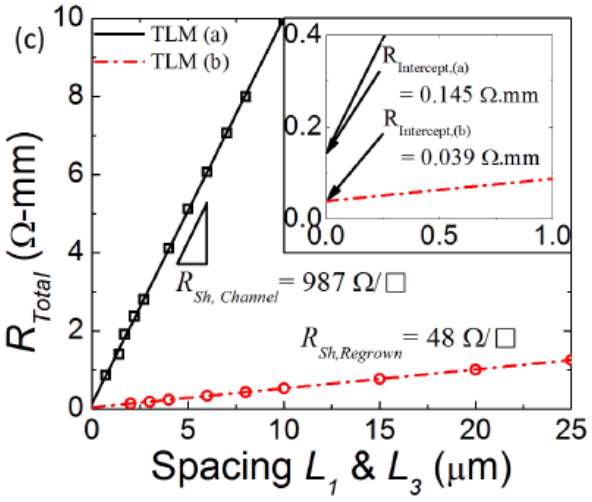
- Measuring μ is critical to establishing AlGaN HEMTs
  - Typically requires ohmic contacts
- SNL will work with AWE/Bristol to extract AlGaN heterostructure interface states and channel mobility from Schottky diodes

Reverse graded contacts with Ohio State

Potential path for re-growth free ohmic contacts







- Ohio State (Prof. Rajan) has demonstrated low resistance ohmic contacts to UWBG AlGaN
- SNL has provided graded AlGaN samples for contact re-growth by OSU
- Promising approach for a MESFET-type device