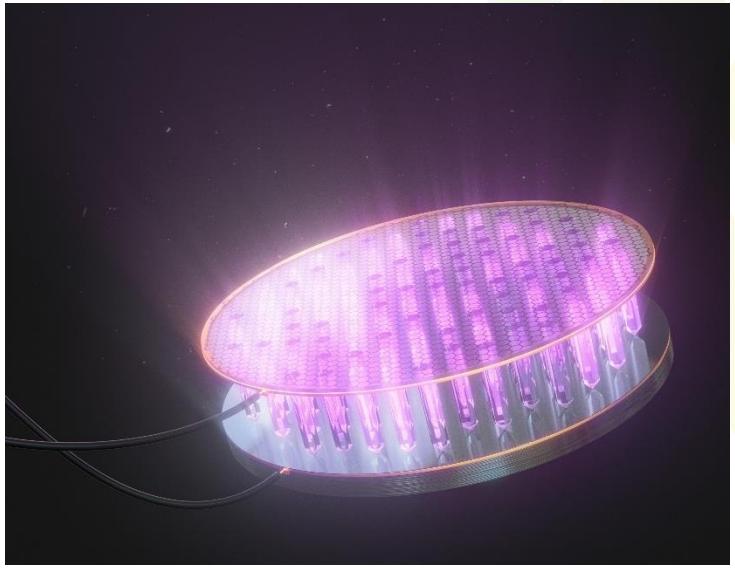
Etching AlGaN alloys using ICP-RIE

Leidulv Vigen

NNUM Copenhagen 7.-8. May 2019

- Active user of NTNU Nanolab for ~5 years
- CrayoNano
- Developing processes



Water disinfection

UVC LEDs can be used to instantly kill bacteria and microorganisms in water without affecting smell, taste and minerals.

Air purification

UVC LEDs are highly effective against many pathogens and have the potential for reducing the spread of airborne infections

Environmental monitoring

UVC is ideal to monitor hydrocarbons in water, ozone and water/wastewater monitoring

Food processing

UVC light diminishes the risk from pathogens, which often remain even after surfaces have been cleaned with disinfectants, e.g. listeria

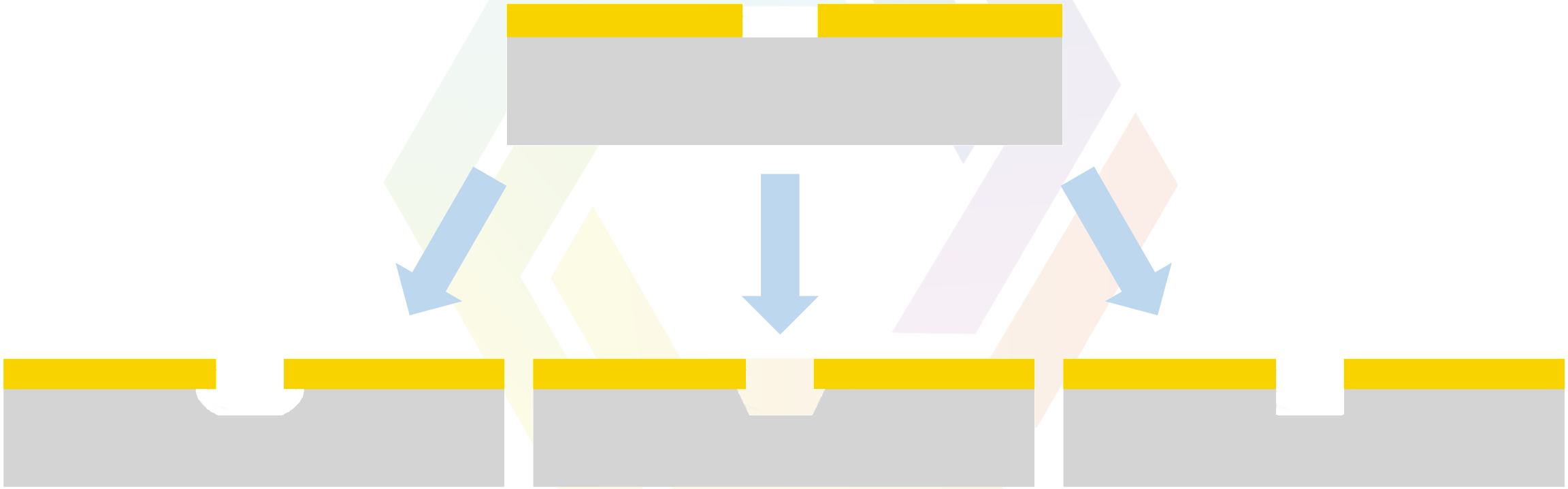
Life sciences

UVC light is essential in molecular spectroscopy used in dialysis, DNA measurements, protein research and liquid chromatography

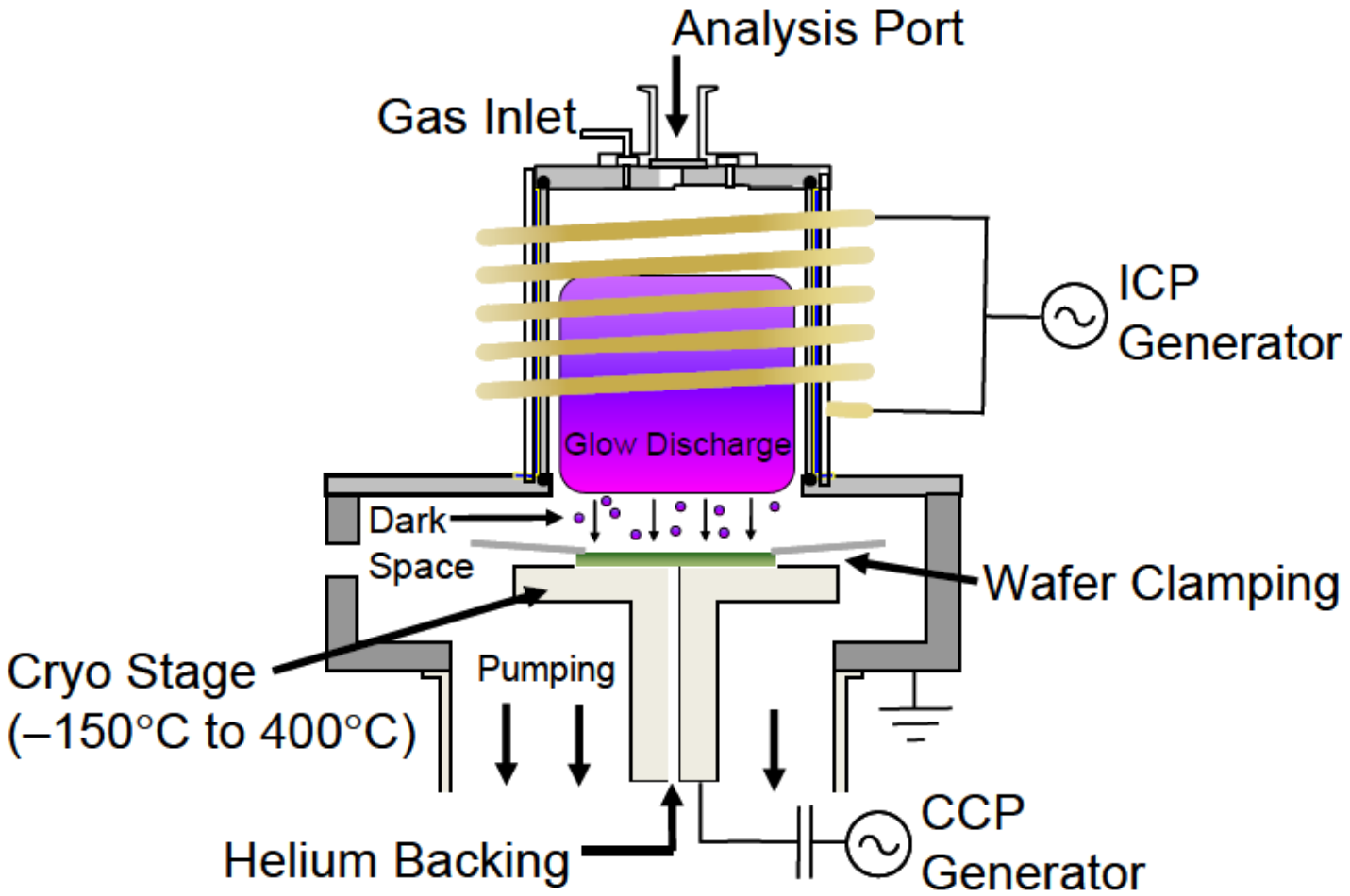
Presentation structure

- ICP-RIE basics
- Effects of different parameters
- General considerations
- Challenges encountered when etching AlGaN and solutions

Isotropic vs anisotropic profile

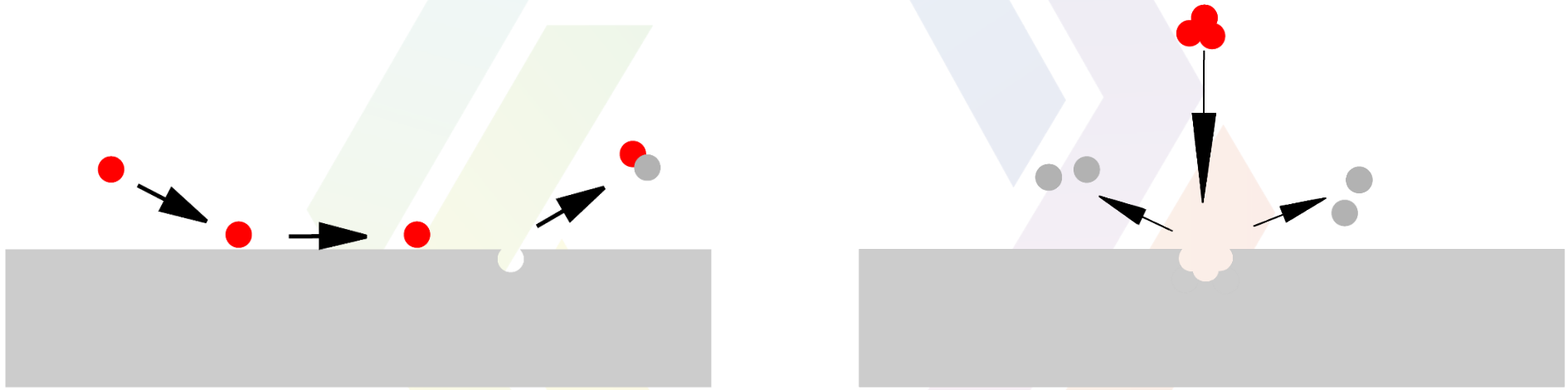


ICP-RIE basics



Source: Shearn *et al.*

ICP-RIE etching mechanics



Chemical

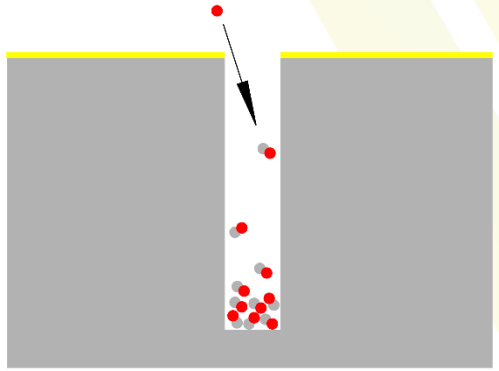
Physical

Parameters

Parameter	Effect on chamber environment	Effect on etch
ICP power	Ion density in plasma, table bias (slightly)	Affects physcial and chemical etch rates
Rf (CCP) power	Table bias, Incident energy of ions, ion flux	Affects physical etch rate and selectivity
Gas flow	Residence time of reactants and etching products	Affects chemical etching rate and etch rate uniformity
Chamber pressure	Amount of particles, mean free path, ion angular distribution, recombination of reactants	Affects physcial and chemical etch rate, and affects anisotropy
Table temperature	Higher initial sample energy	Likelihood of spontanous desorption of etch products

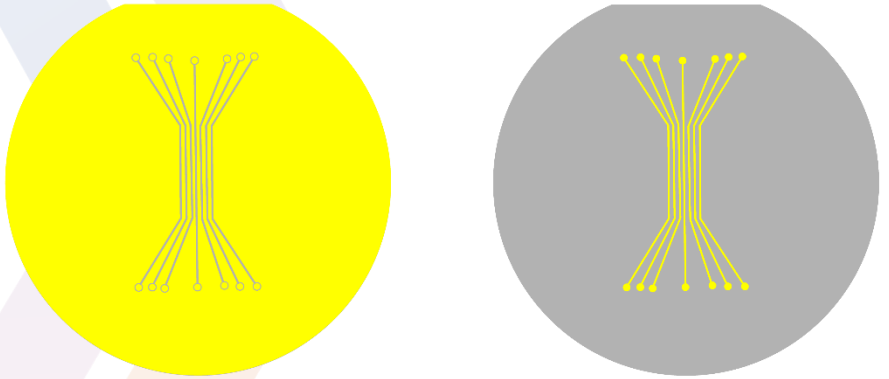
Considerations

- What is the purpose of the etch?
  - Speed
  - Precision
  - Profile
  - Roughness



Aspect ratio dependent etch lag

Exposed surface

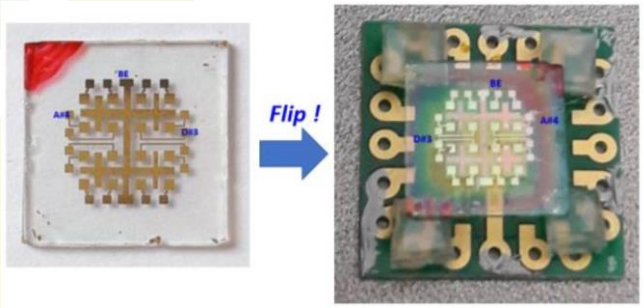


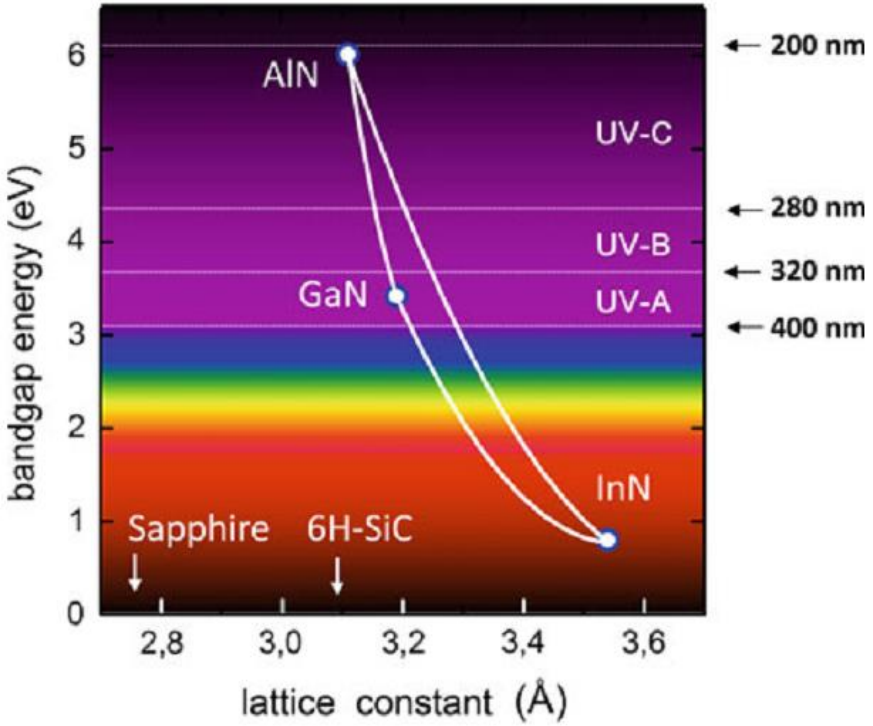
Chamber cleanliness

AlGaN

Alloy of AlN and GaN

Source: Panasonic





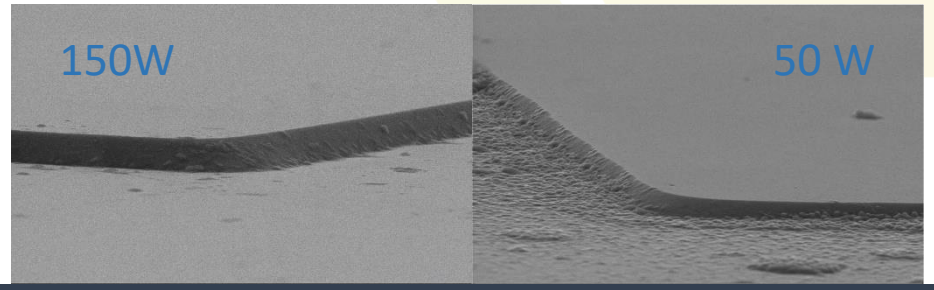
Material properties

- Hard
- Stable

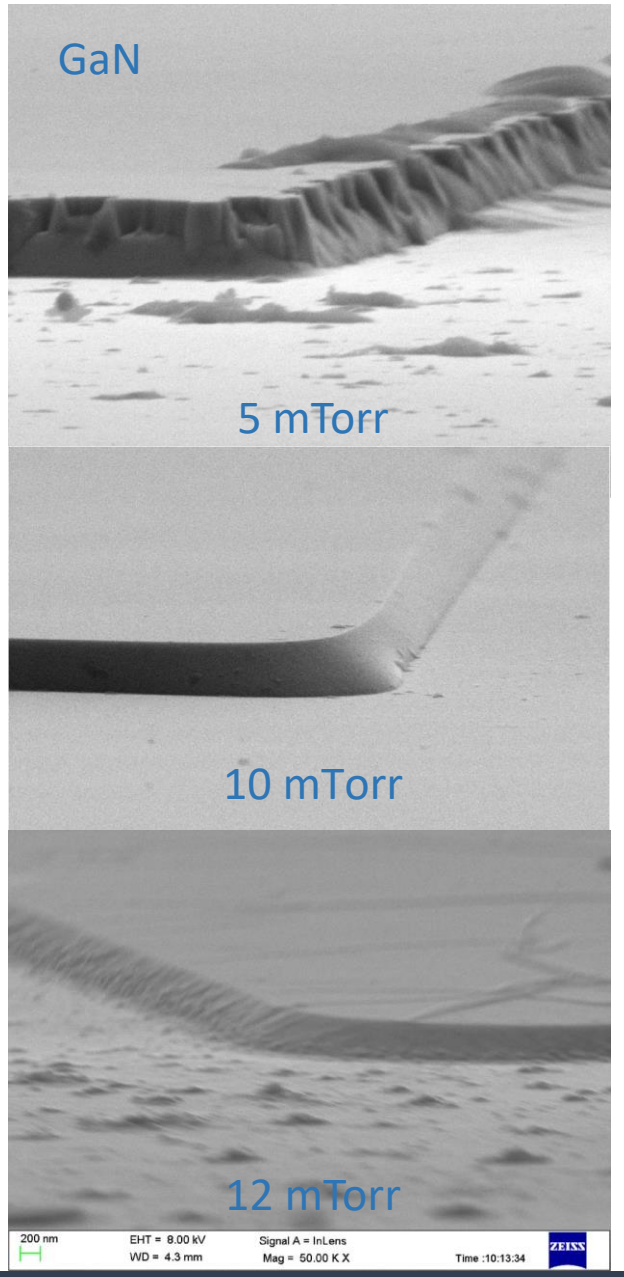
Etching AlGaN

- BCl_3/Cl_2 chemistry for AlGaN etching
  - $GaCl_x$ and $AlCl_x$
  - Cl ions contribute chemically, BCl ions contribute physically
  - Important with some BCl_3

- High bond strength and low etch product volatility
  - High sample bias is needed to break up GaN and AlN bonds and to desorb $GaCl_x$ and $AlCl_x$
  - Pressure and RF power
  - High Al-content AlGaN etch rate saturates at high RF power



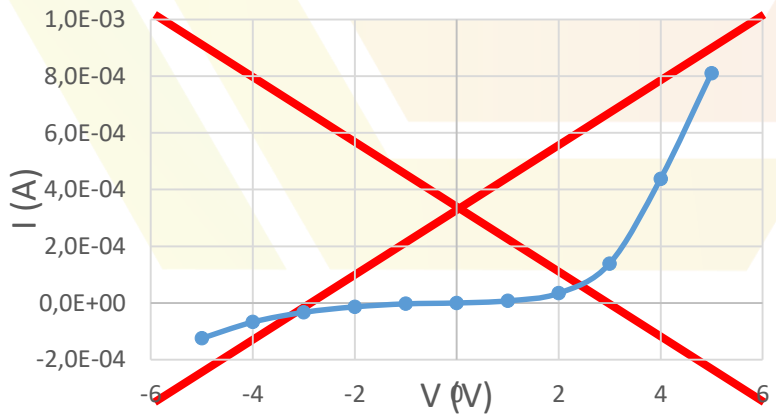
Source: Rawal *et al.*



Etching AlGaN

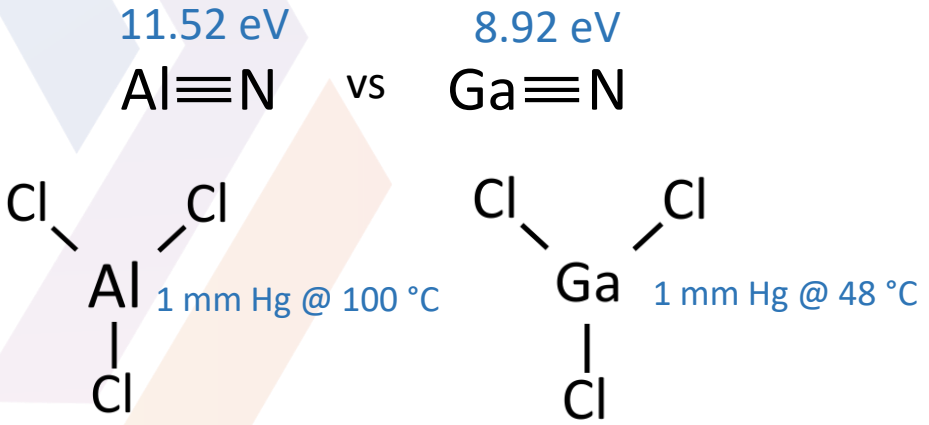
- Prone to oxidation
  - Increased surface oxidation with increasing Al composition
  - Etching delay
  - Micromasking

- Surface roughness can provide leakage paths in electronics



Etching AlGaN

- Roughness can be due to several factors
  - Higher bond energy for AlN vs GaN
  - Higher volatility for $GaCl_x$ vs $AlCl_x$
  - Aluminium oxide micromasking



- Patterning masks
  - Resist
  - ~~Silicon oxide~~
  - Silicon nitride
  - Metal

BCl_3/Cl_2	**9/36 sccm**
ICP power	1000 W
Rf power	100 W
Pressure	10 mTorr
Temperature	20 °C

References

[1] Michael Shearn, Xiankai Sun, M. David Henry, Amnon Yariv, and Axel Scherer. *Semiconductor Technologies*, chapter 5. InTech, April 2010.

[2] Liheng Zhang, Amit Verma, Huili (Grace) Xing and Debdeep Jena. *Jpn. J. Appl. Phys*, 2017, Vol. 56, No. 3.

[3] R.J. Westerman, D.J. Johnson, Y.S. Lee. "Characterization of a 10 µm/min chlorine-based ICP etch process for GaAs vias".

[4] Erica A. Douglas, Carlos A. Sanchez, Robert J. Kaplar, Andrew A. Allerman, and Albert G. Baca. *J. Vac. Sci. Technol. A*, 2017, Vol. 35.

[5] S. A. Smith, C. A. Wolden, M. D. Bremser, A. D. Hanser, R. F. Davis, and W. V. Lampert. *Appl. Phys. Lett.*, 1997, Vol. 71.

[6] Bo-Sheng Zheng, Po-Yu Chen, Chia-Jui Yu, Yung-Fu Chang, Chong-Long Ho, Meng-Chyi Wu, and Kuang-Chien Hsieh. *IEEE Electron Device Letters*, 2015, Vol. 36, No. 9.

[7] S. L. Lai, D. Johnson, and R. Westerman. *J. Vac. Sci. Technol. A*, 2006, Vol. 24.

[8] D. S. Rawal, Hitendra K. Malik, Vanita R. Agarwal, Ashok Kumar Kapoor, B. K. Sehgal, R. Muralidharan. *IEEE Trans. Plasma Sci.,* 2012, Vol. 40, No. 9.

[9] Amit P. Shah, Masihhur R. Laskar, A. Azizur Rahman, Maheshwar R. Gokhale, and Arnab Bhattacharya. *J. Vac. Sci. Technol. A*, 2013, Vol. 31.

Questions

Leidulv Vigen
leidulv.vigen@crayonano.com

www.crayonano.com