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Development of Atomic Layer Etching (ALEt) for GaN-based materials

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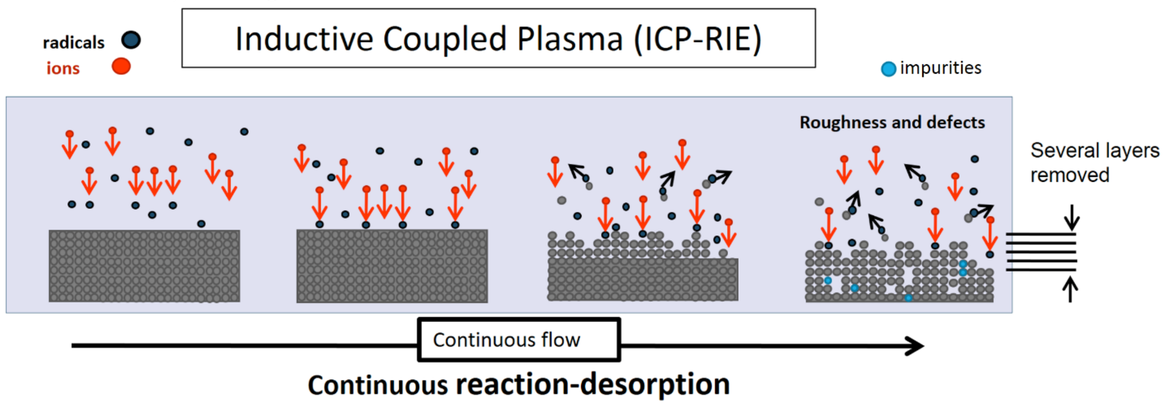
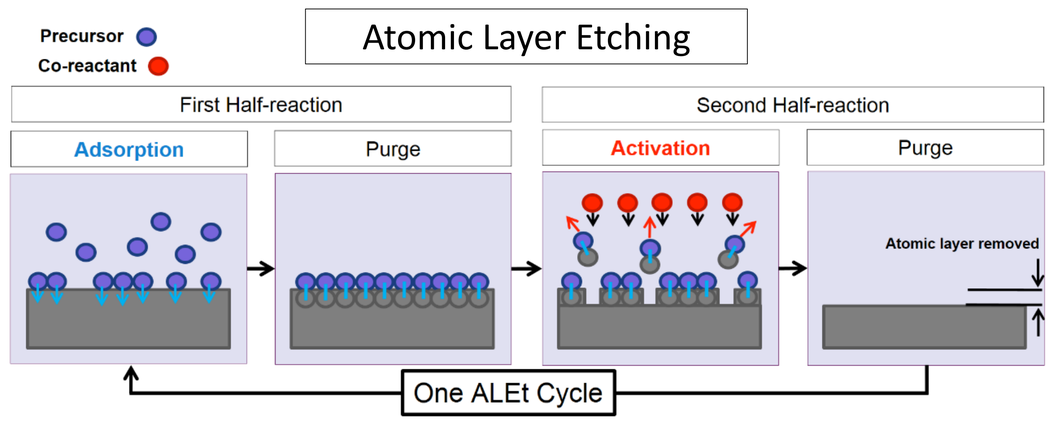
1. What is Atomic Layer Etching (ALEt)?

Conventional Dry Etching process for GaN-based materials





Advantages:
- Fast and deep etching
- Separate controlled of Plasma density (neutrals, radicals, ions), Ionic Fluxes and Ions Energies

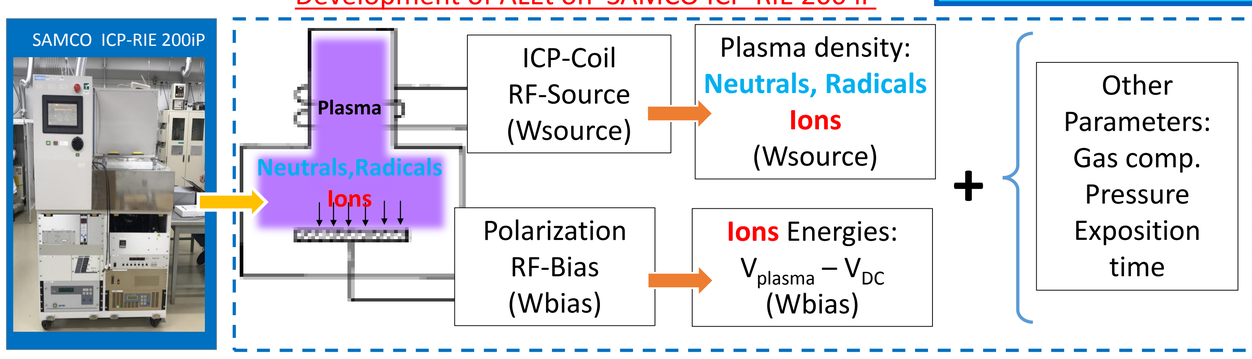
Limitations:
- Simultaneous effect of chemistry and ionic bombardment
- Difficult to control Surface States (morphology and composition)

Advantages:
- Separation: Chemistry (precursor)/ionic bombardment (co-reactant)
- Etch rate controlled by Numb. of cycles
- Different plasma (or gases): for chemistry and ionic bombardment

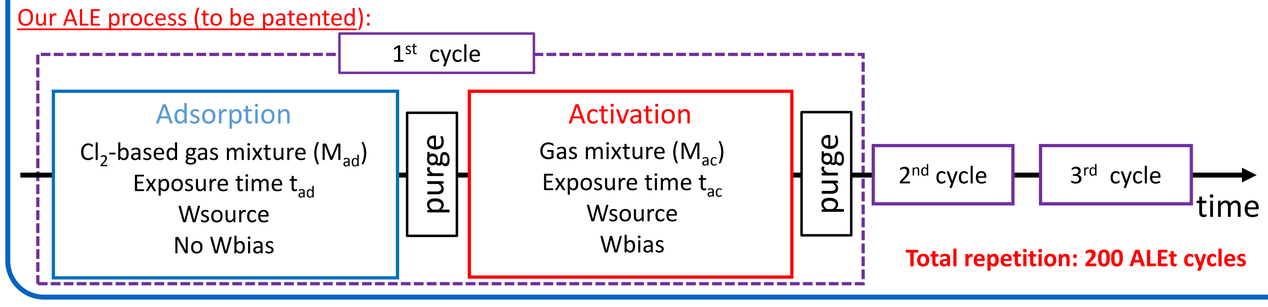
Challenges:
- Keep the "self-limiting" feature
- Slow: Etch profile defined by Numb. of cycles (< 1nm/cycle)
- Monitoring of etched thickness

2. Experimental procedures

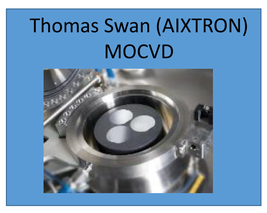
Development of ALEt on SAMCO ICP-RIE 200 iP

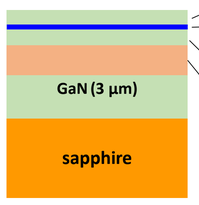


Our ALE process (to be patented):



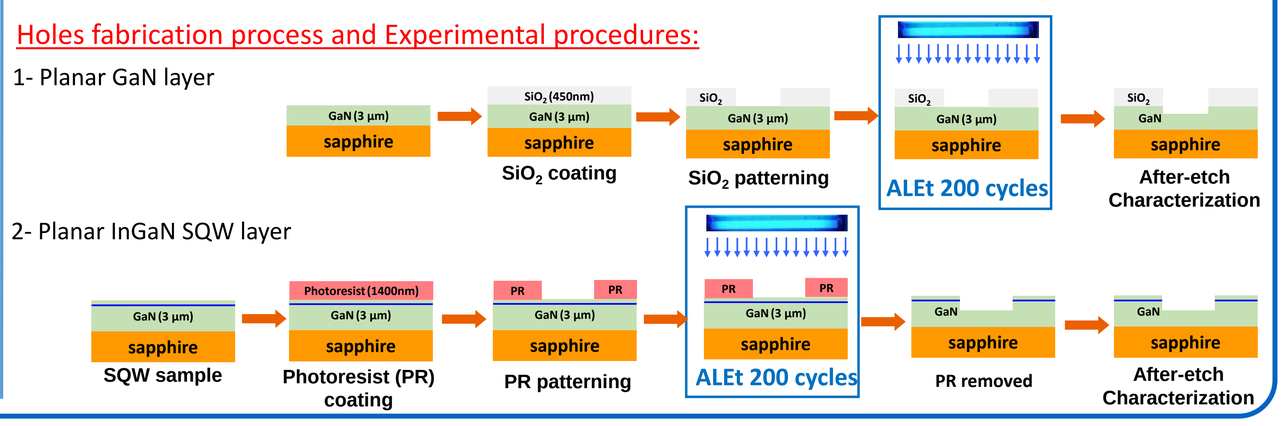
Deposition: GaN layers with embedded InGaN Single Quantum Well (SQW)



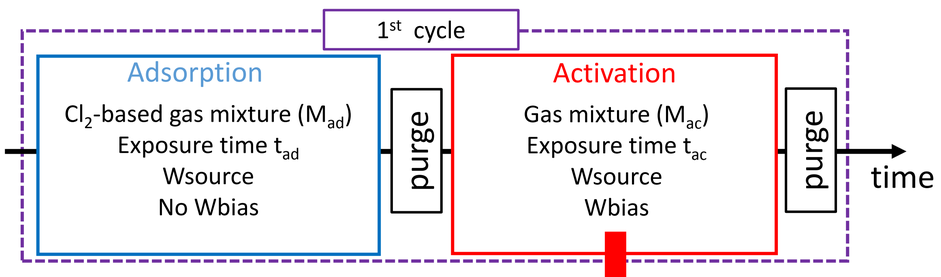


Capping layer: GaN (5 nm)
Single quantum well: InGaN with 18% In (2.75 nm; 750°C)
GaN (20 nm; 850°C)
Underlayer: InGaN with 3-5% In (50 nm; 750°C)

Holes fabrication process and Experimental procedures:



3. ALEt Etch rate as a function of Activation Bias



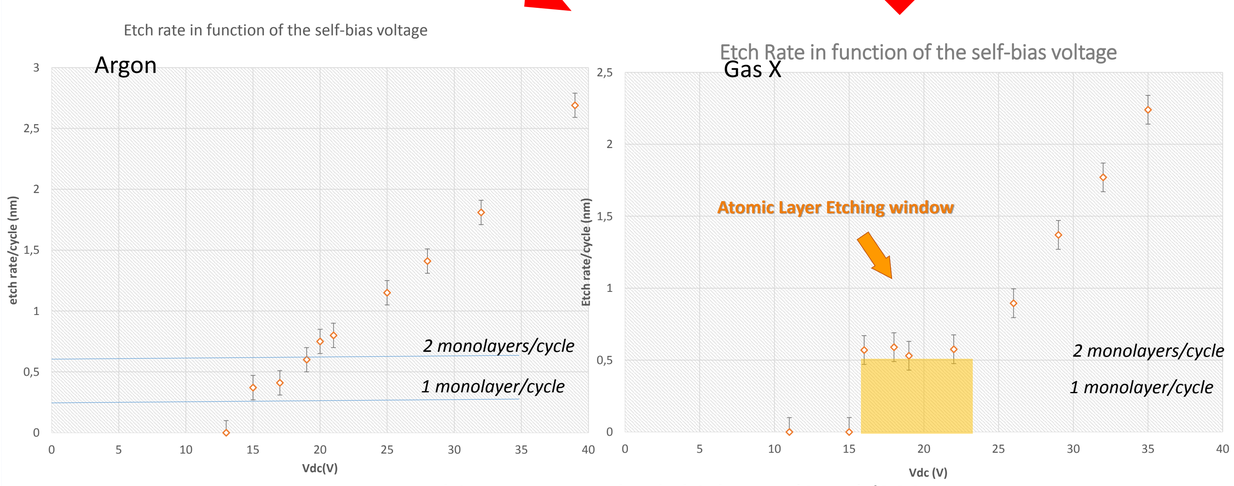
For undoped-GaN and GaN + embedded SQW GaN

200 ALE cycles

Effect of Wbias on ALE etching rate and (Self-bias voltage and ion energy)

M_{ac} = Ar

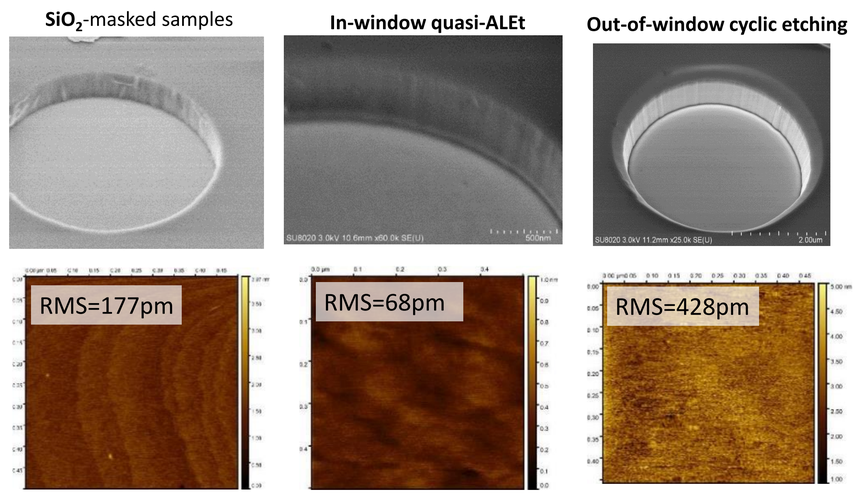
M_{ac} = X



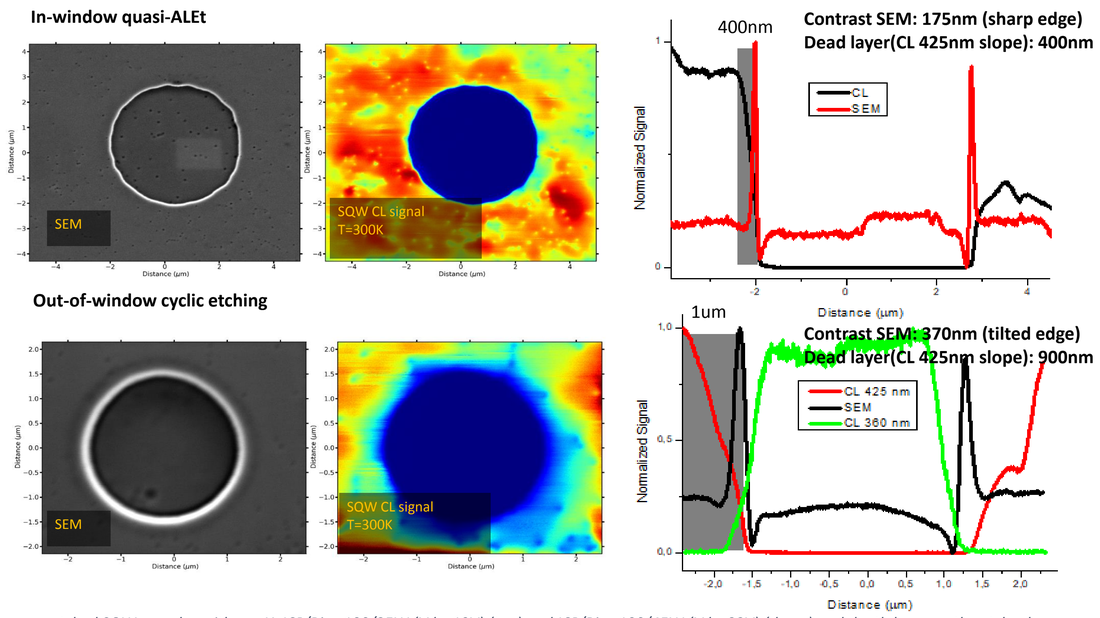
Etching rate = etched thickness (SEM)/200

Optimization of the Activation step:
The best Etch rate: near 2 monolayers/ cycle
Gas X have a better control of ALEt

4. Comparison of in- and out-of ALEt window etched samples

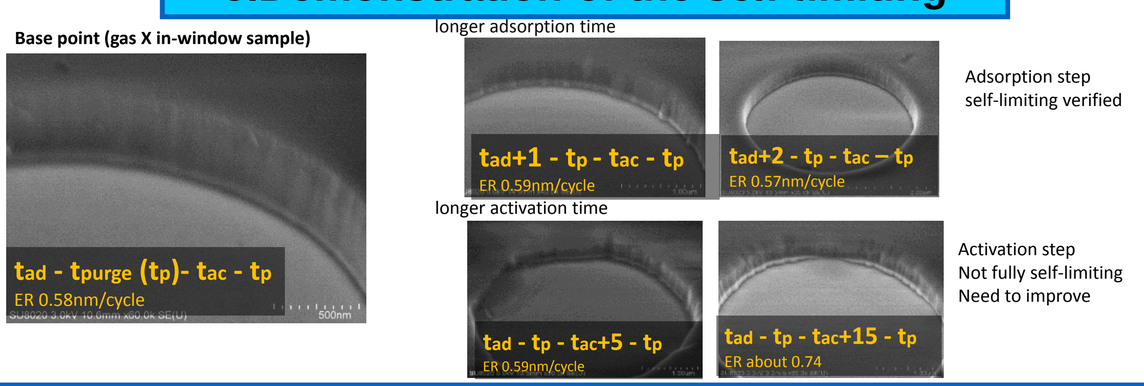


Cathodo-Luminescence of SQW samples : Estimation of deadlayer thickness



etched SQW samples with gas X: ICP/Bias 100/25W (Vdc=19V) (top) and ICP/Bias 100/45W (Vdc=32V) (down) and death layer on the etch edge

5.Demonstration of the self-limiting



6. Conclusions and perspectives

1. **Gas X has a better etch control on the ALEt process**
2. **Quasi ALEt has a better etch quality: sharp border; thinner dead layer**

Optimizations → real ALEt +limiting the dead layer
Improve the Activation step (take a Bias on the ALEt window→change the ICP power); change pressure in different steps, etc
verify other advanced properties →Apply to Electronic/optoelectronic device

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