In-situ Etching of β-Ga_2O_3 Using *tert*-Butyl Chloride in an MOCVD System

Henry Bowman[a]

[a]*Carleton College Department of Physics and Astronomy. Contact: bowmanh@carleton.edu.*

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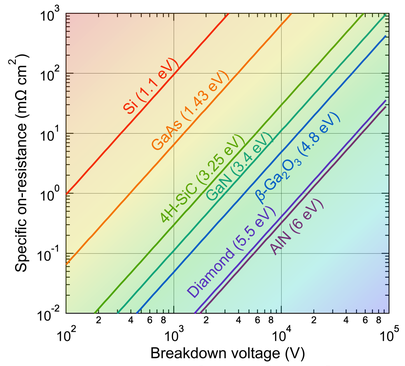
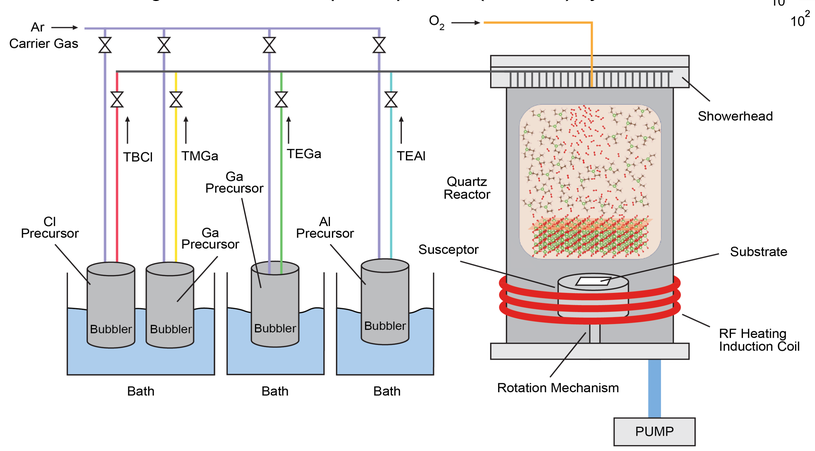
Why β-Ga_2O_3? Why TBCl Etching?

- Ultra-wide band gap of ~4.9 eV yields high breakdown voltage, superior **Baliga's figure of merit** compared to competing materials (e.g., SiC, GaN)
- Applications in power electronics, solar-blind UV photodetectors, and point-of-load voltage converters
- Rapid progress in research spurred by development of high-quality native *β*-Ga_2O_3 substrates
- **MOCVD** produces high-mobility epitaxial films



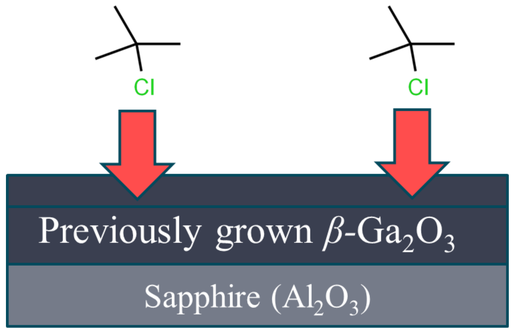
Metal Organic Chemical Vapor Deposition (**MOCVD**) system



- Use of ***tert*-butyl chloride (TBCl) precursor** allows for ***in-situ* etching of *β*-Ga_2O_3**
- *In-situ* etching may enable selective-area etching and regrowth towards **improved ohmic contacts** in *β*-Ga_2O_3 power electronics

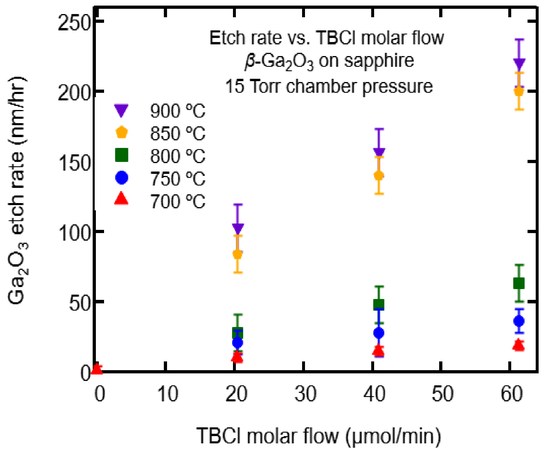
How is Etching Controlled?

- ***tert*-Butyl Chloride (TBCl)** is injected into the MOCVD chamber **to etch *β*-Ga_2O_3**



- **Heteroepitaxial** (grown on c-plane sapphire, shown above) **and homoepitaxial *β*-Ga_2O_3** (grown on (010) Fe-doped substrates) etched with TBCl

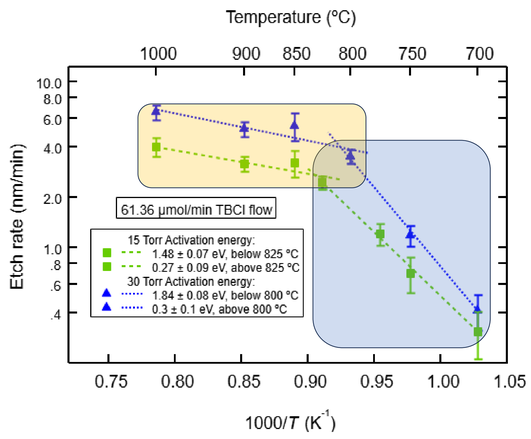
- Etch rate depends on TBCl molar flow and temperature (shown below)



- Etch rate increases with increasing TBCl flow and increasing temperature
- Etch rate also increases with increasing pressure (not shown)

Activation Energy and Mechanism of Etching

- **Activation energy** of etching **depends on temperature and pressure**



- Etching explained by two-step mechanism:

1. $(CH3)_3CCl$ (g) → iso-C_4H_8 (g) + HCl (g)

2. Ga_2O_3 (s) + 6HCl (g) = 2$GaCl_3$ (g) + 3H_2O (g)

Reaction 2 takes place on the *β*-Ga_2O_3 surface, all gaseous species are adsorbed

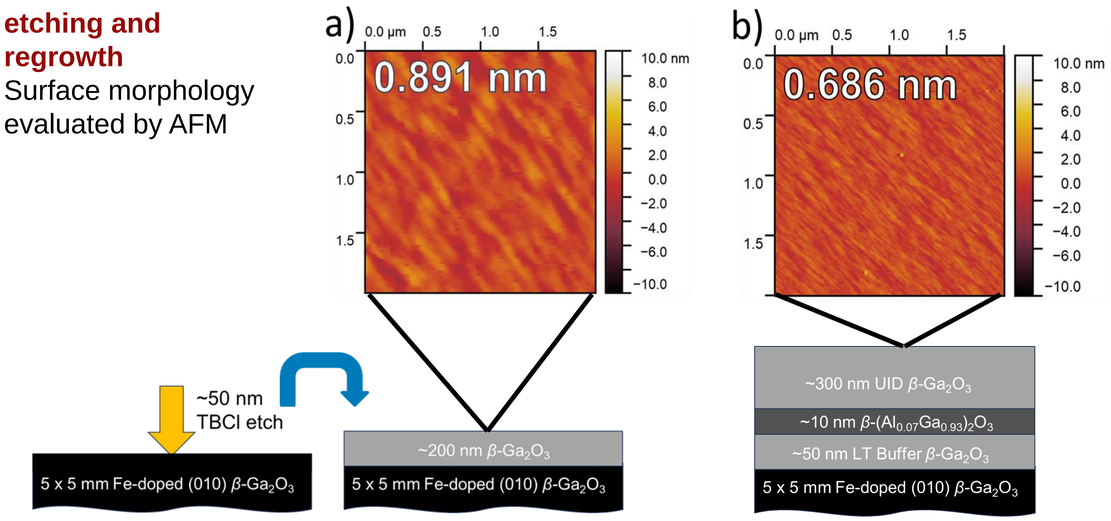
Low-temperature activation energy reflects the activation energy of reaction 1

High-temperature activation energy reflects the activation energy of reaction 2

Morphology of Etched Surfaces

- Homoepitaxial *β*-Ga_2O_3 etched to assess prospects for **selective-area etching and regrowth**
- Surface morphology evaluated by AFM

- Etching a *β*-Ga_2O_3 substrate and **regrowing yields sub-nm RMS roughness** (panel a), comparable to *β*-Ga_2O_3 grown on an unetched substrate (panel b)



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