

Defect processes enabled by single-ion strikes on power devices – A comparative study of GaN, AlN, SiC, and Ga₂O₃

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1. UPDATE ON **CARRIER CAPTURE BY DEFECTS**



Laura Nichols



Xiao-Guang Zhang
and his group, U of FL



Ron Schrimpf
On Ph.D. Committee

- Project completed (fully DFT calculations)
 - Paper under review at Physical Review B (revised version)
 - Dallin Niels (Max Fischetti) to shepherd the future of the code
 - Two-day workshop 11/1-2 at VU (Andy O'Hara, Xiao Shen participating)

2. UPDATE ON **HYDROGEN RELEASE FROM DEFECTS BY HOT ELECTRONS**



Laura Nichols



Xiao-Guang Zhang
and his group, U of FL



Max Fischetti



Dallin Nielsen

Theory (fully DFT). Extension of
carrier-capture code completed



Monte Carlo Device
Simulations

Proof-of-principle calculations on p-type GaN device

3. PROJECT ON **SINGLE-EVENT DISPLACEMENT DAMAGE** IN SILICON



Grant Mayberry



James Trippe
(ISDE)



Ron Schrimpf

Poster #23

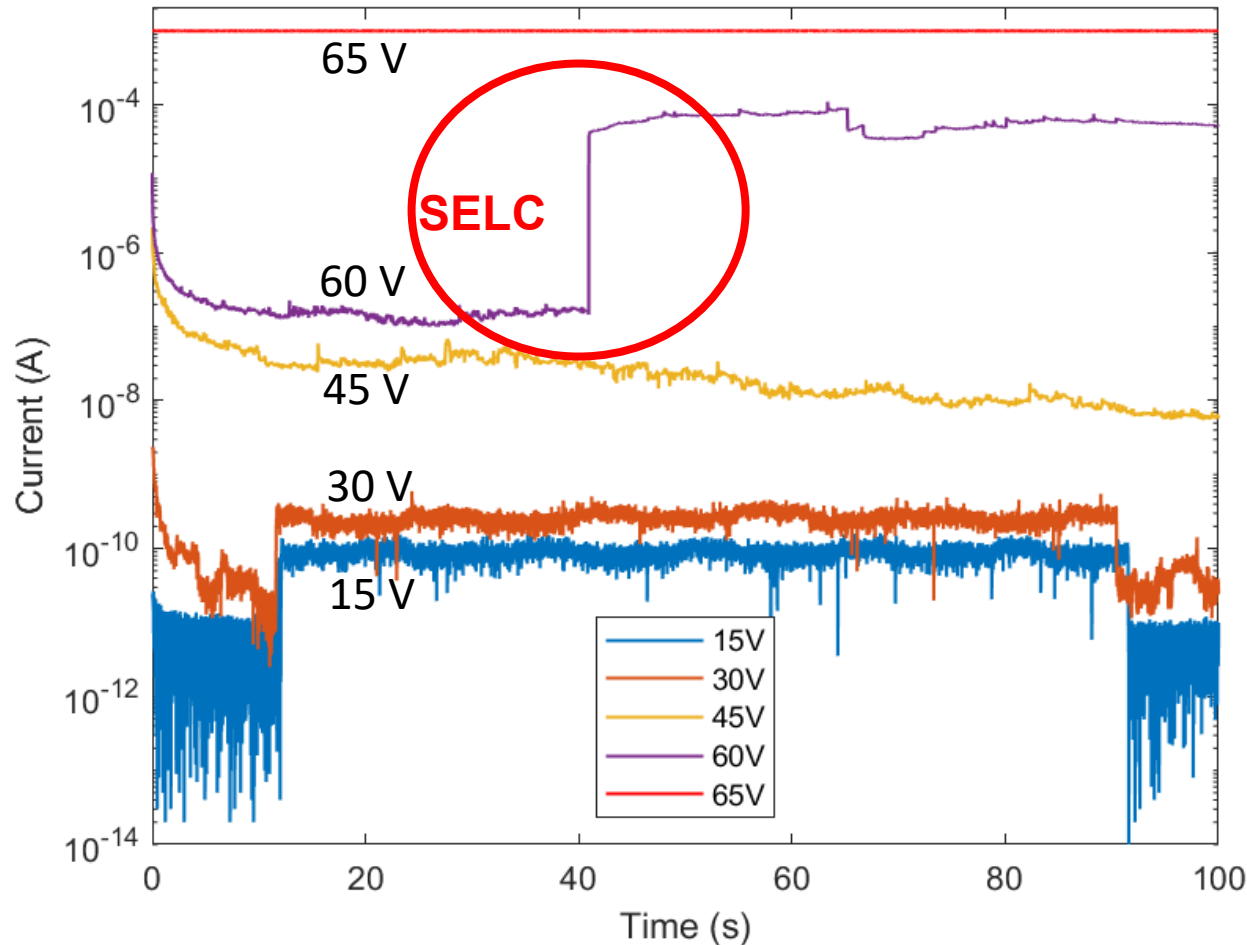
Defect processes enabled by single-ion strikes on power devices – A comparative study of GaN, AlN, SiC, and Ga₂O₃

Haardik Pandey, Grant Mayberry, Demos Negash, Scooter Ball, Ron Schrimpf, Dan Fleetwood



Single Event Leakage Current (**SELC**)

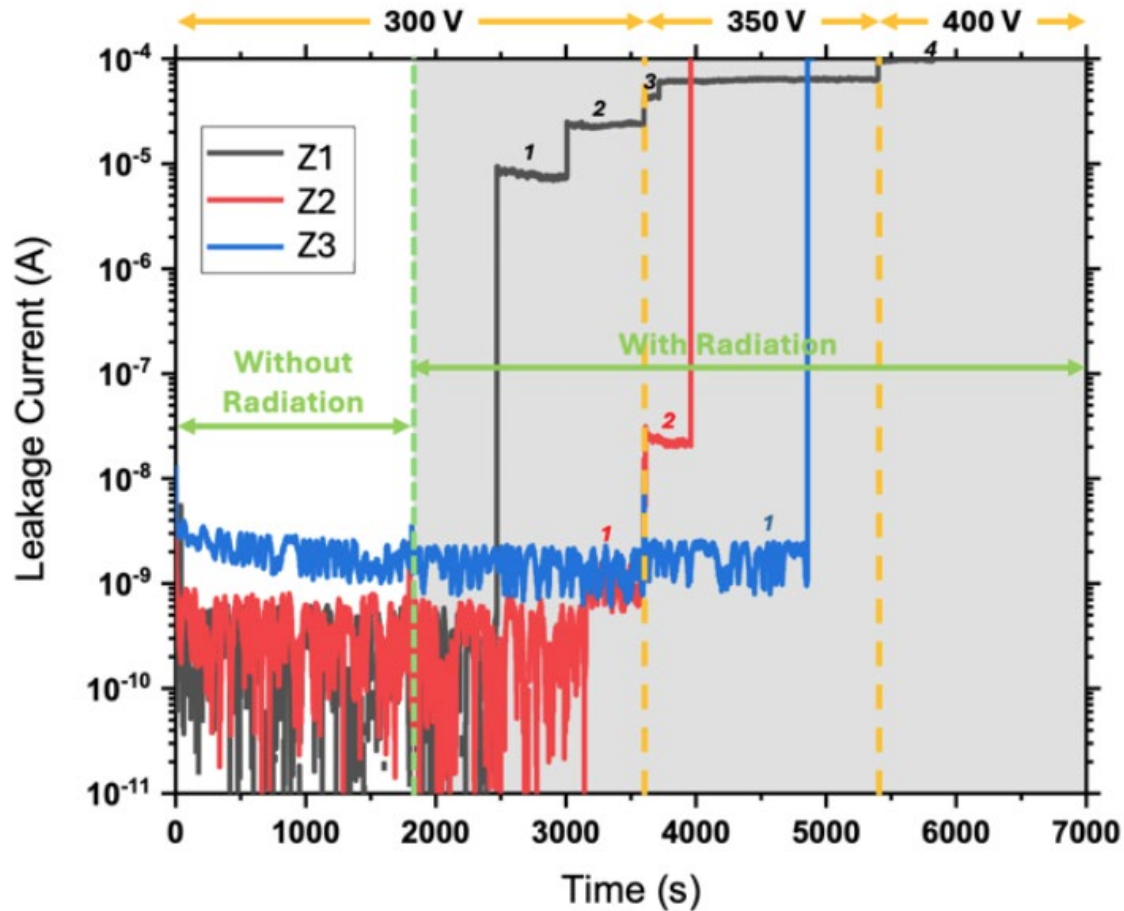
Ga_2O_3 Schottky diode



- Single-ion strike
- Sharp current increase
- Followed by steady current
- “Electron plasma wire” along ion path
- Formation of stable, conducting, defect nanowires
- At 65 V: Single Event Burnout (**SEB**) (device is shorted)

Single Event Leakage Current (**SELC**)

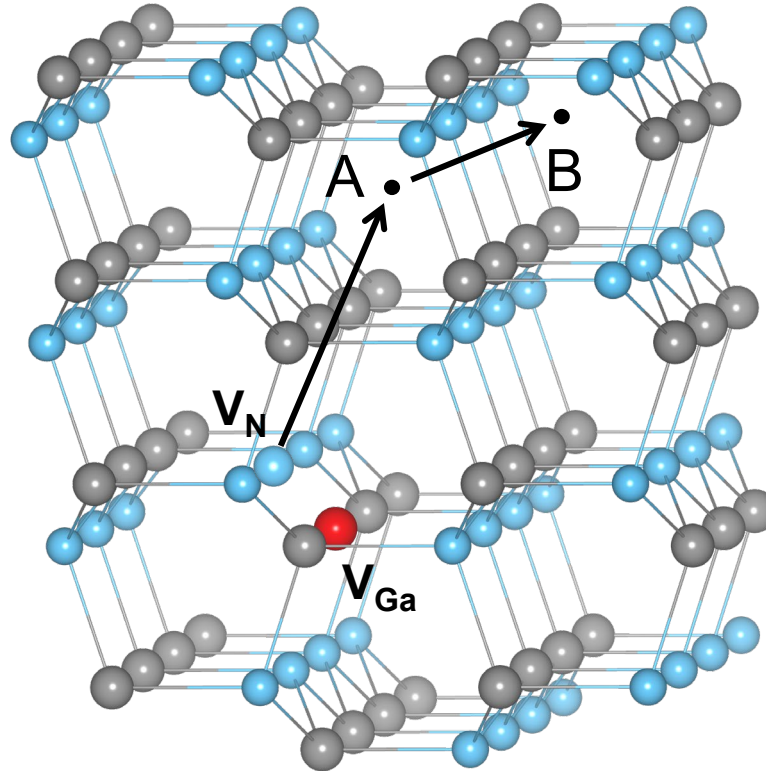
GaN PIN diode



- Single ion strike
- Sharp current increase
- Followed by steady current
- “Electron plasma wire” along ion path
- Formation of conducting, stable, defect nanowires
- Single Event Burnout (SEB)
(device is shorted)

GaN prototype

● Ga ● N



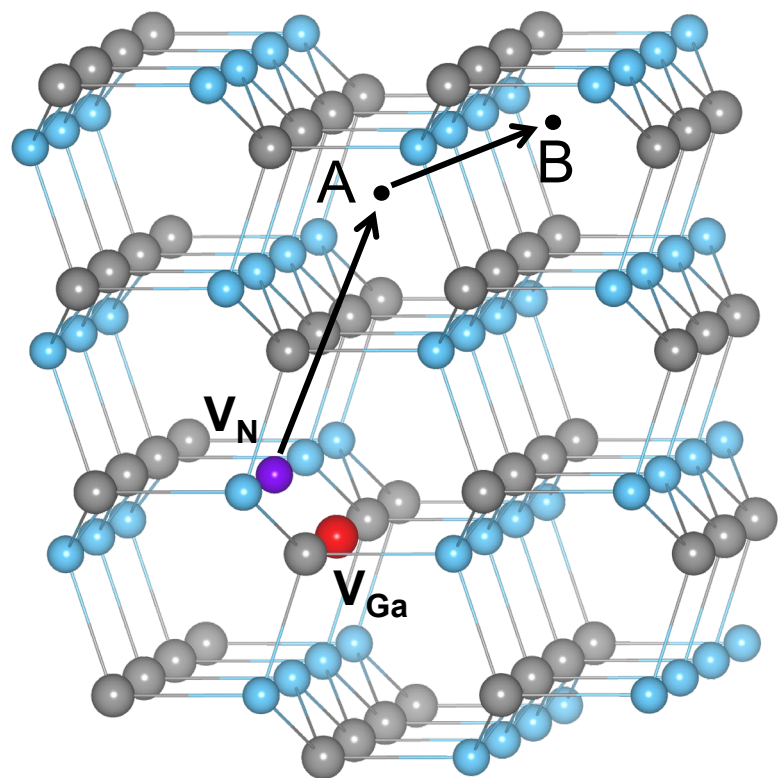
● V_{Ga}

- Ga vacancy generated by striking ion

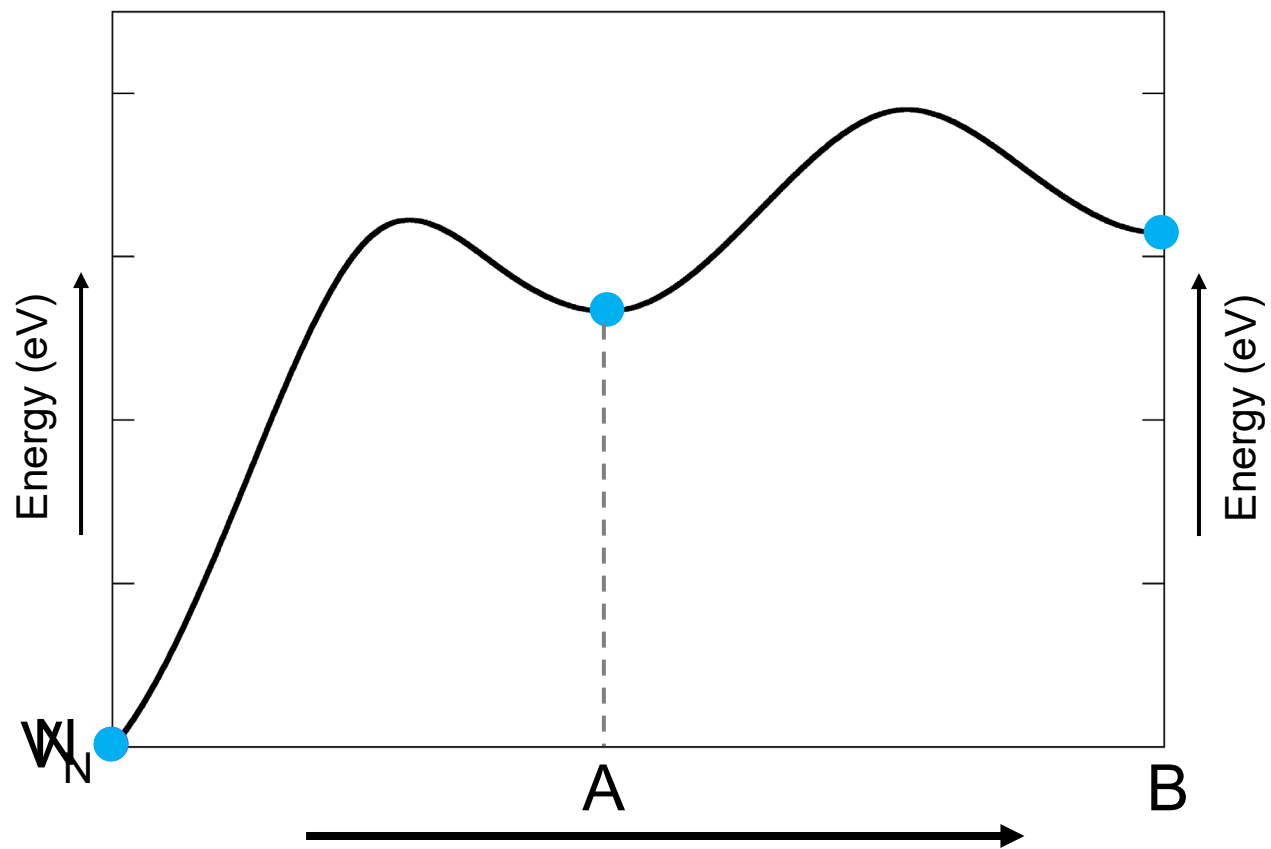
● V_N

- N vacancy generated by heat along ion path

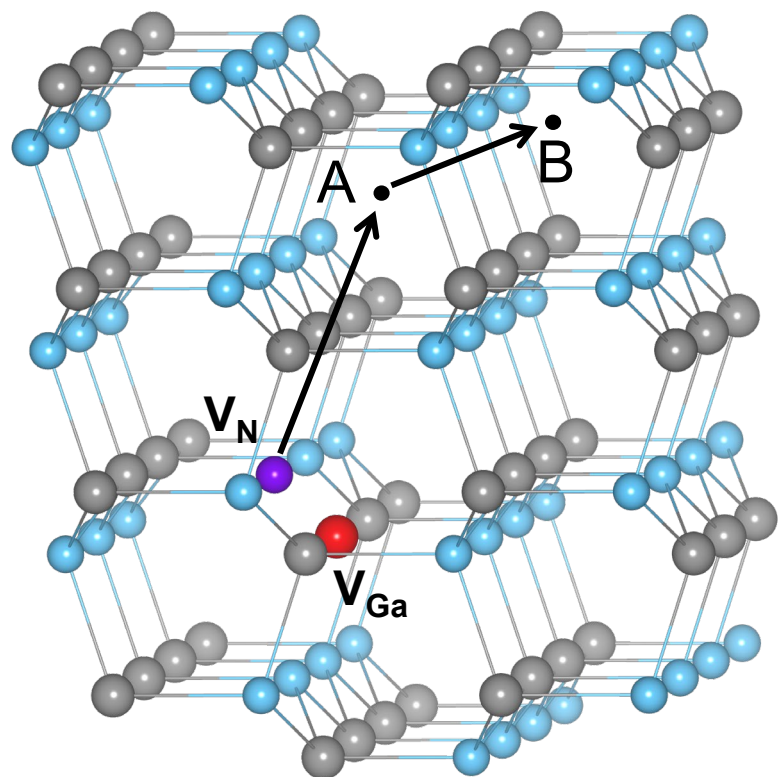
$V_{\text{Ga}} - V_{\text{N}}$ pair formation



Energy landscape for N removal



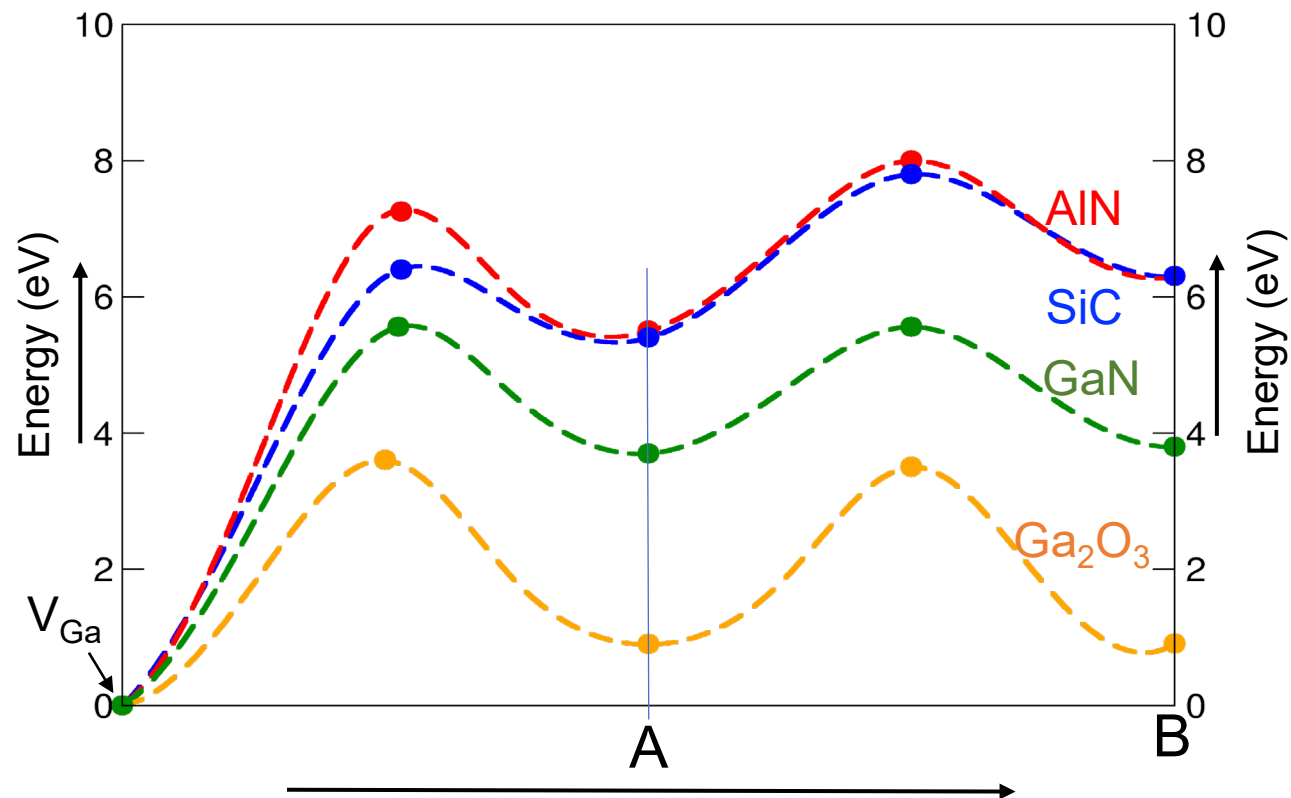
$V_{\text{Ga}} - V_{\text{N}}$ pair formation



● V_{Ga} ● V_{N}

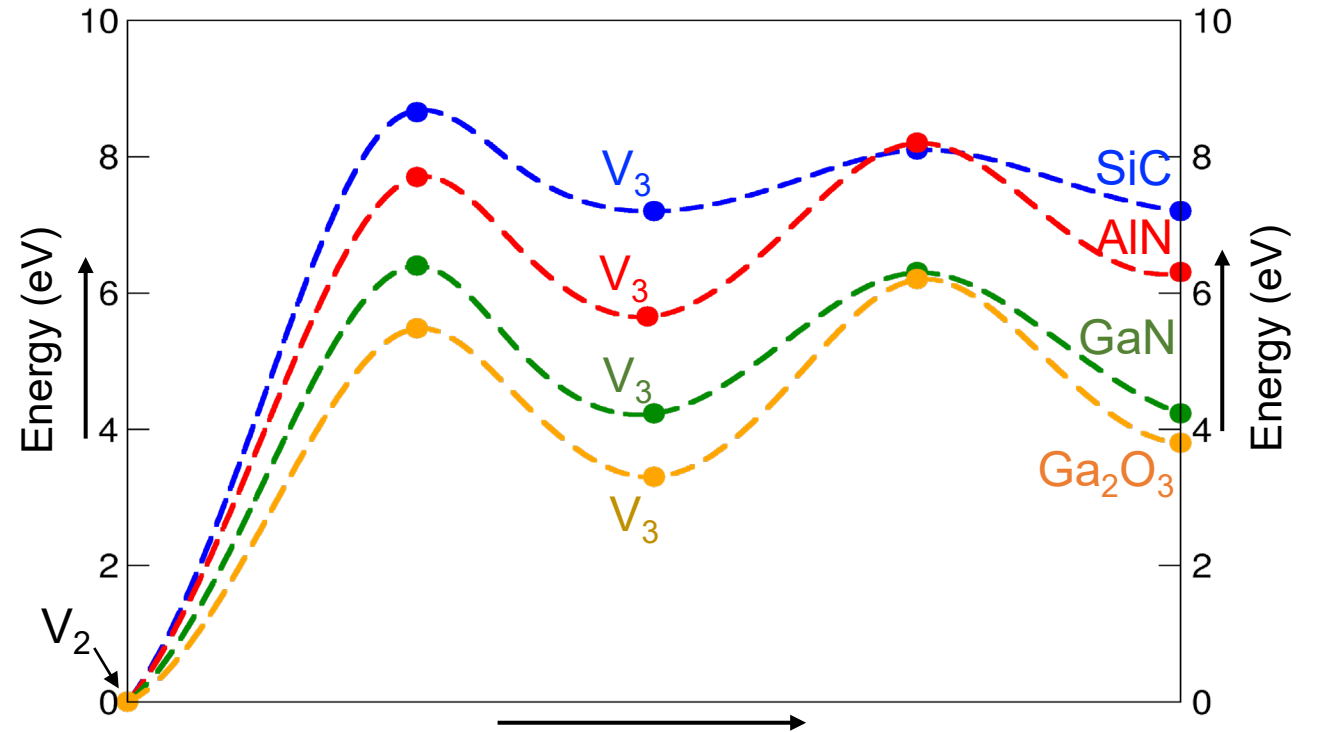
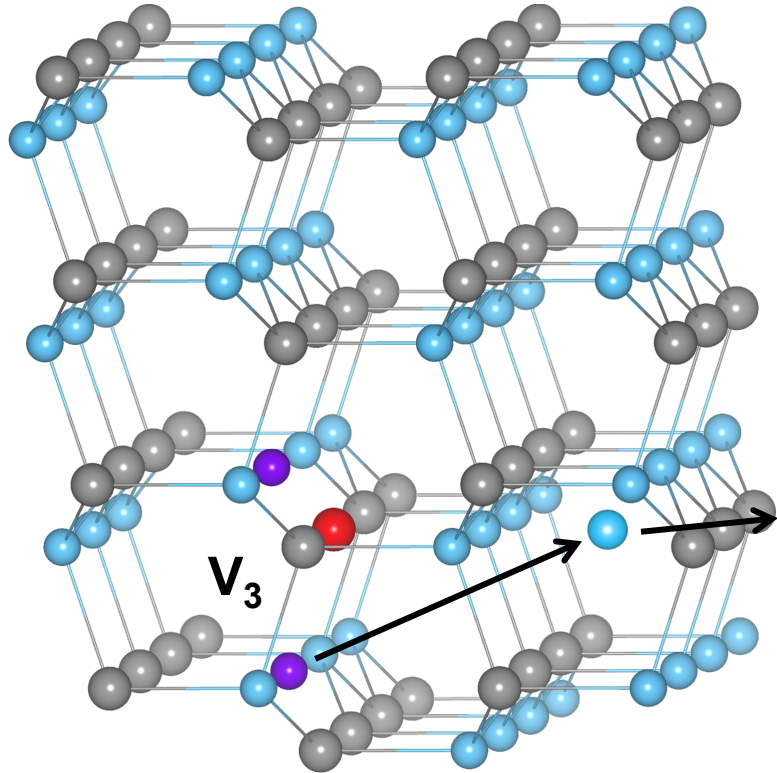
● Ga ● N

Energy landscape for “N” removal

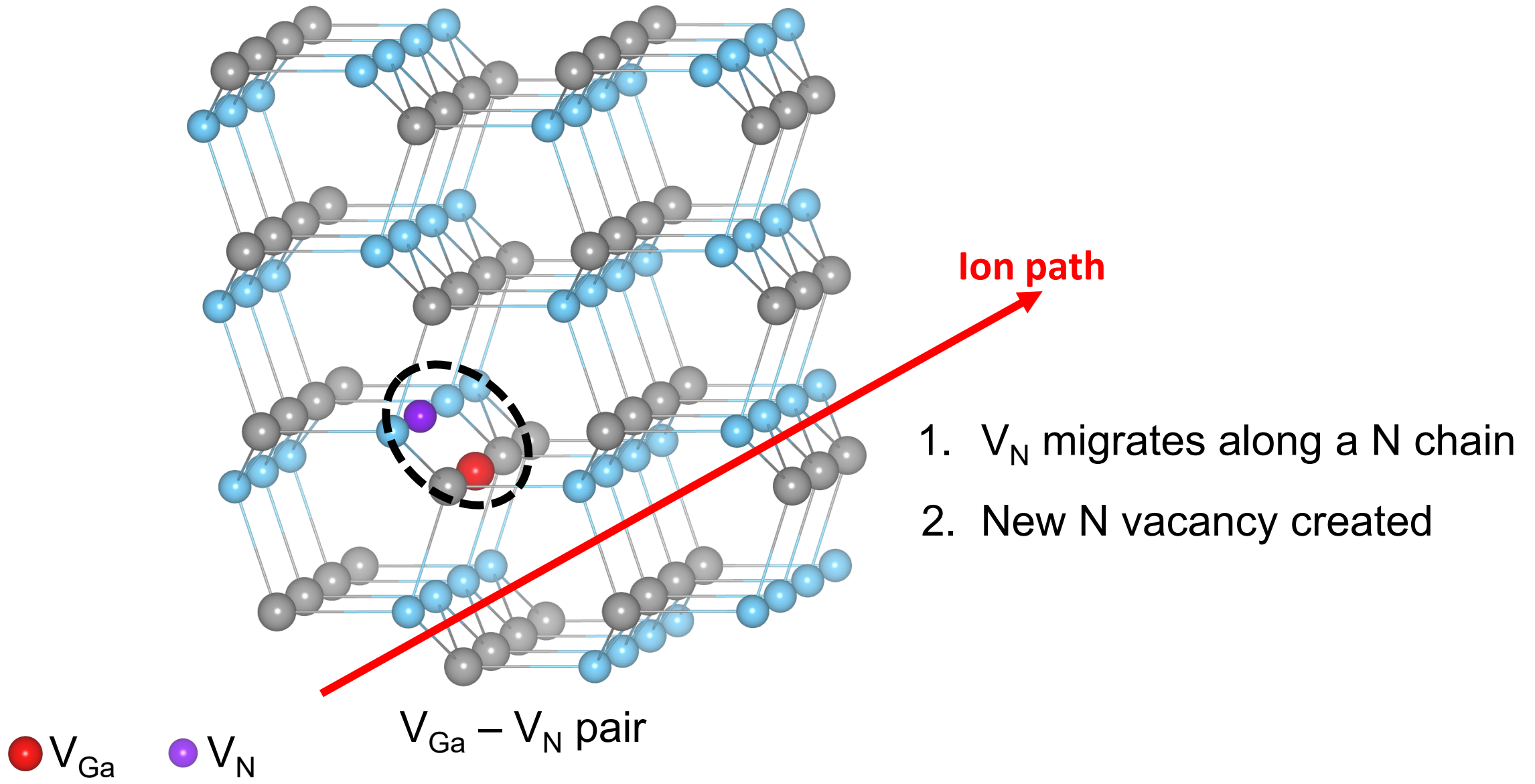


Energy barriers: AlN, SiC > GaN > Ga₂O₃

Void growth -- Trivacancy formation

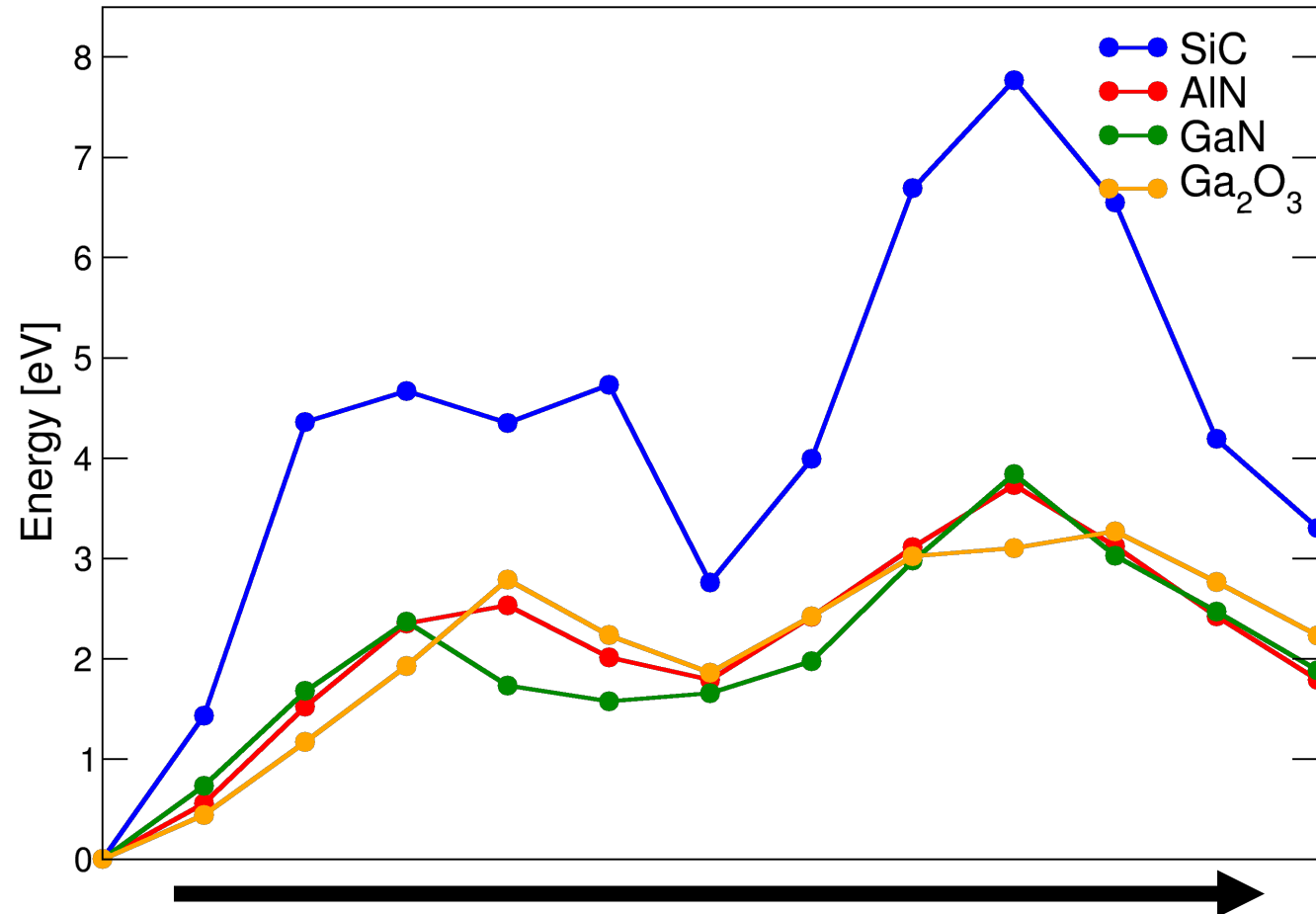


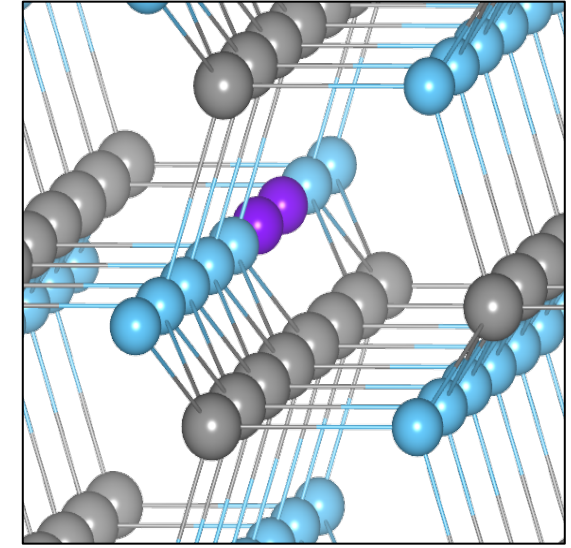
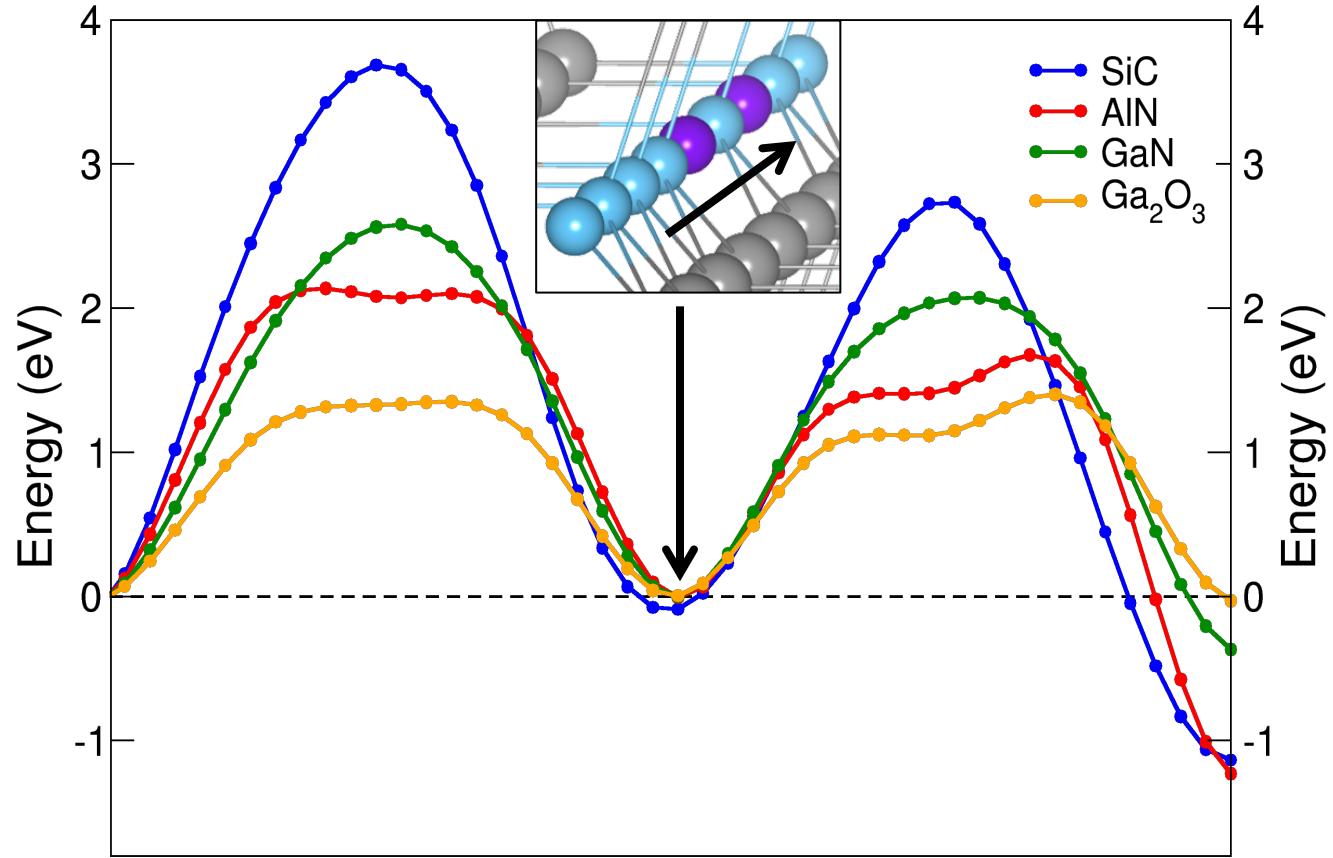
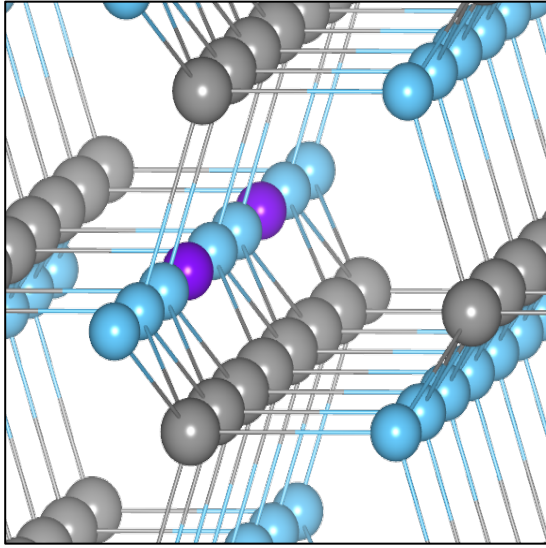
V_{Ga} SPOUT streams of V_{N} that form V_{N} chains



Gallium vacancies SPOUT nitrogen-vacancy chains

Energy barriers for V_N migration away from V_{Ga}

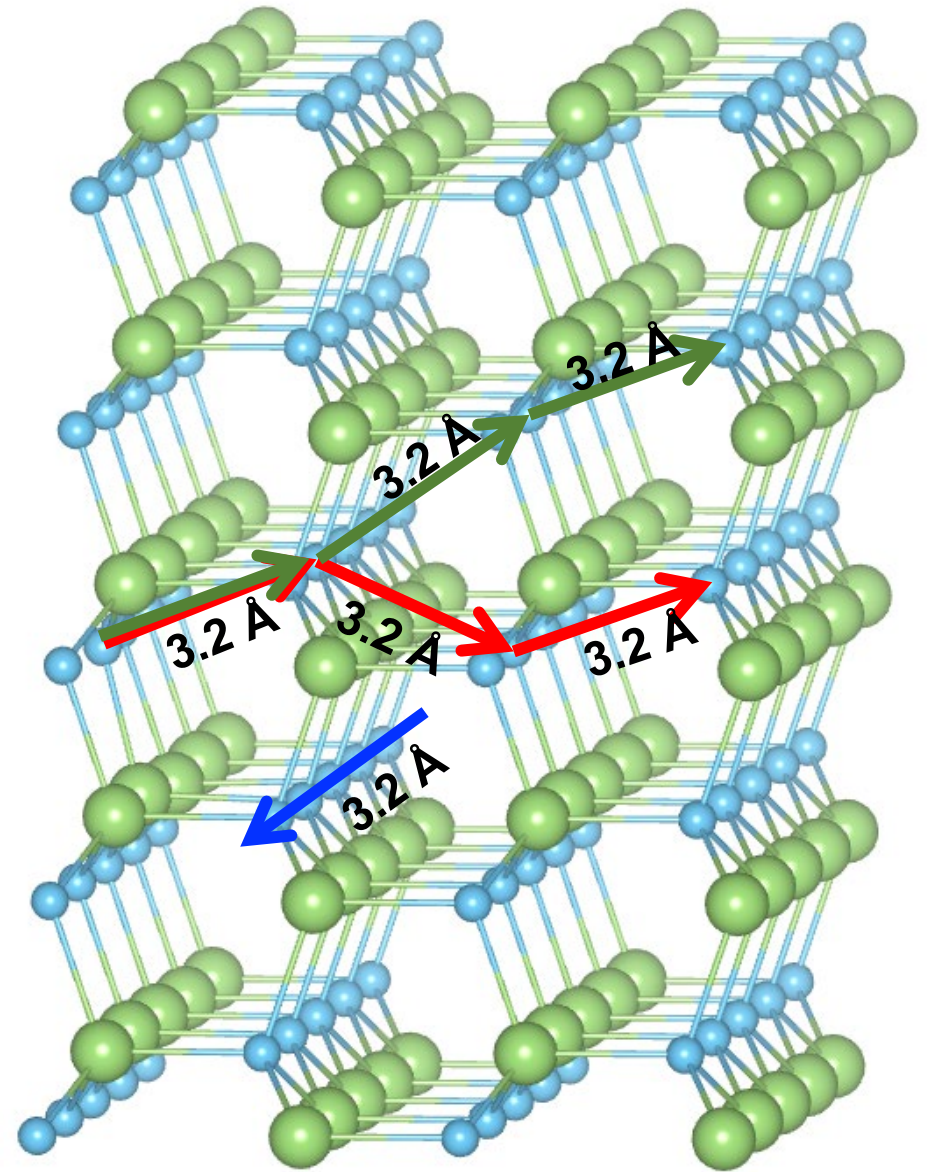
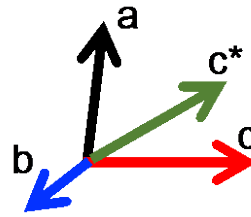
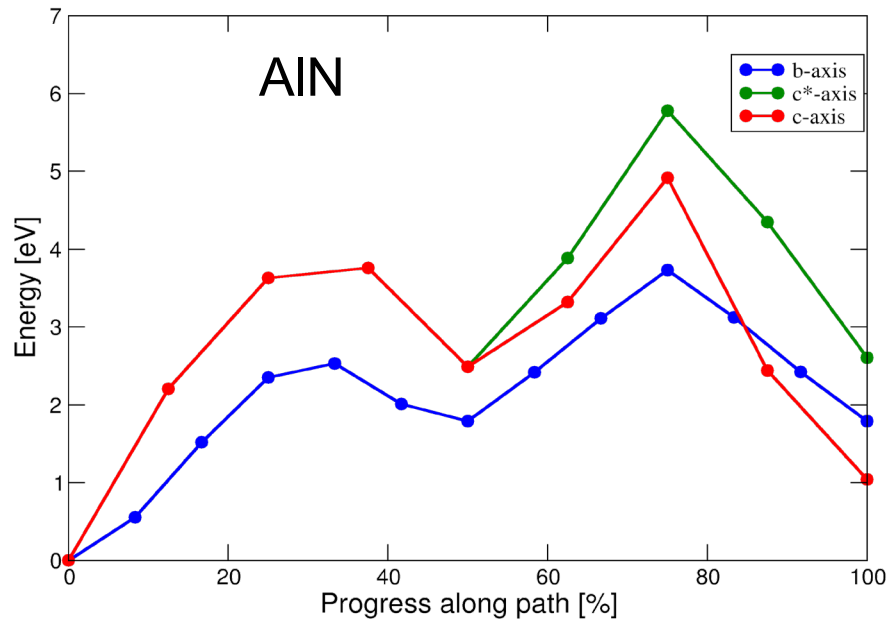
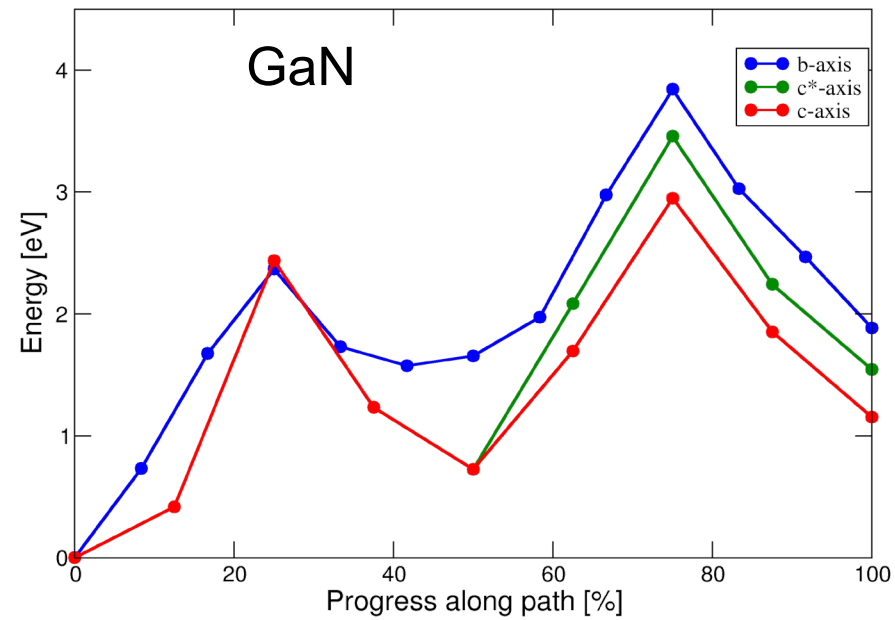




Two separated V_N forming a divacancy

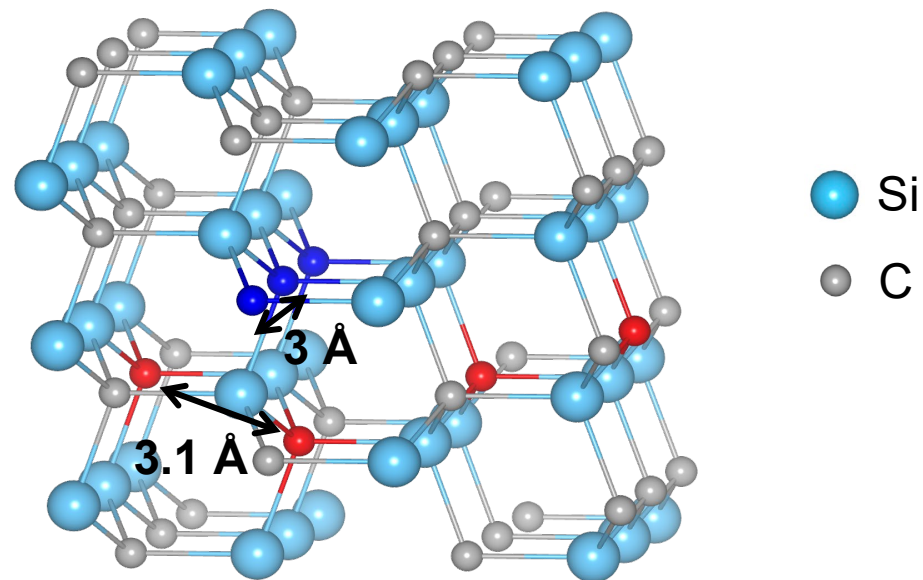
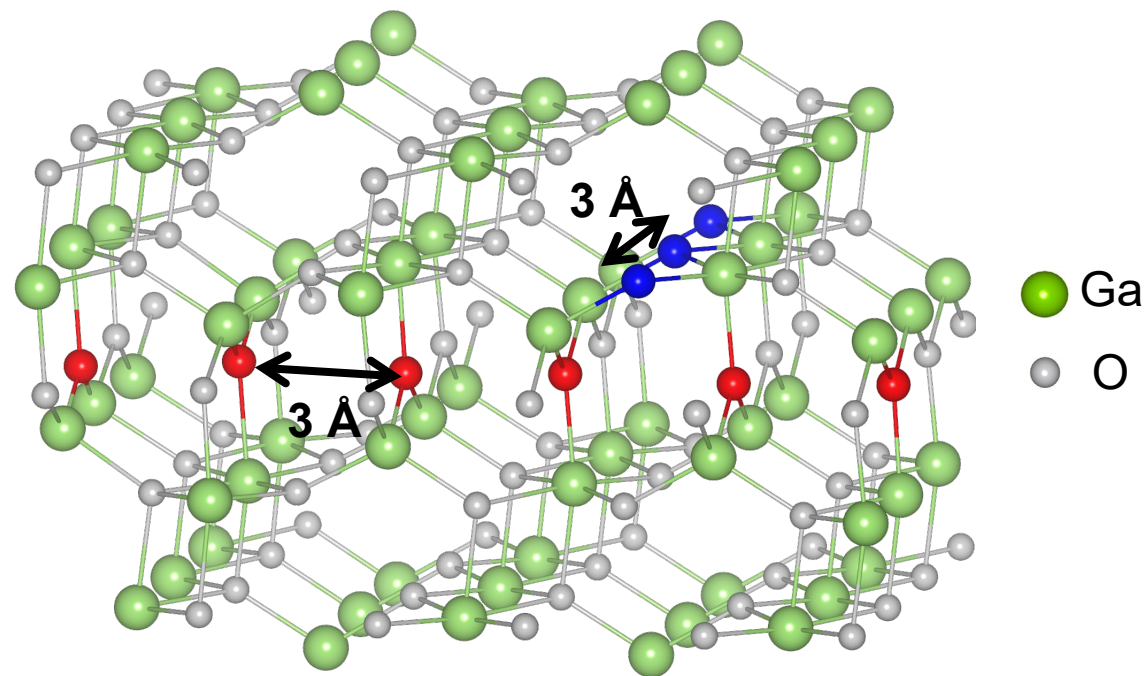
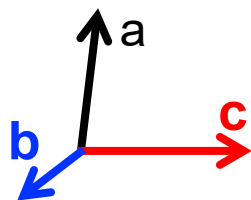
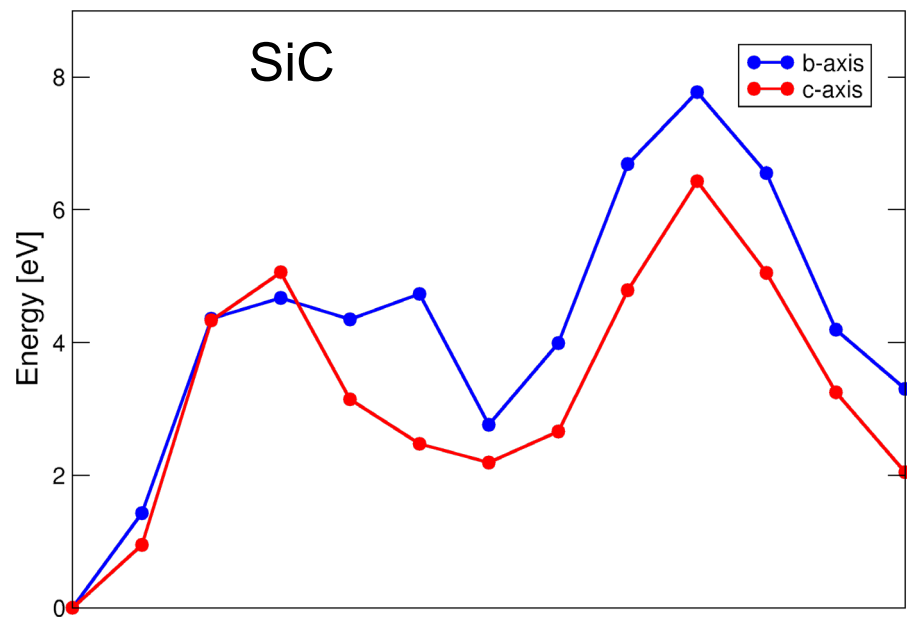
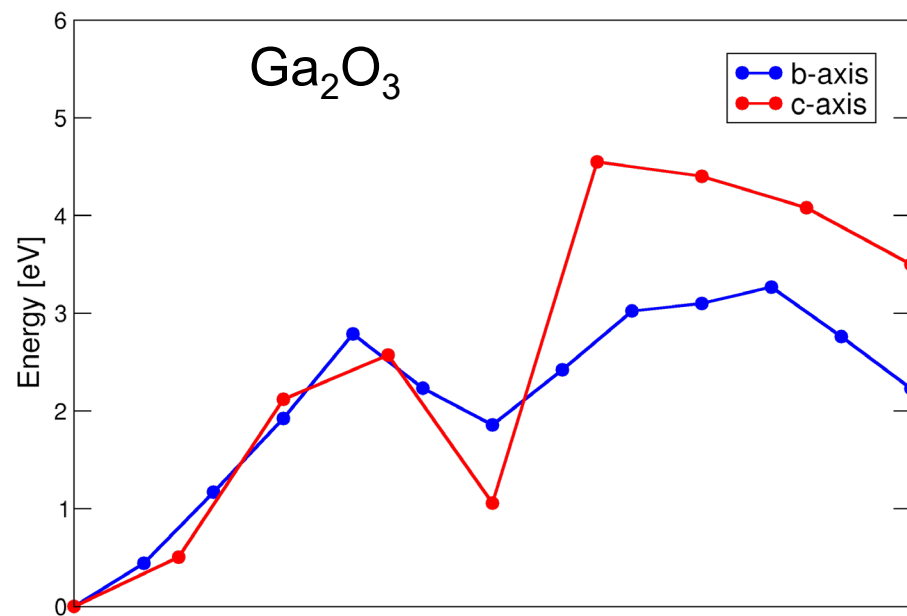
V_N

Vacancy chains can form in different directions

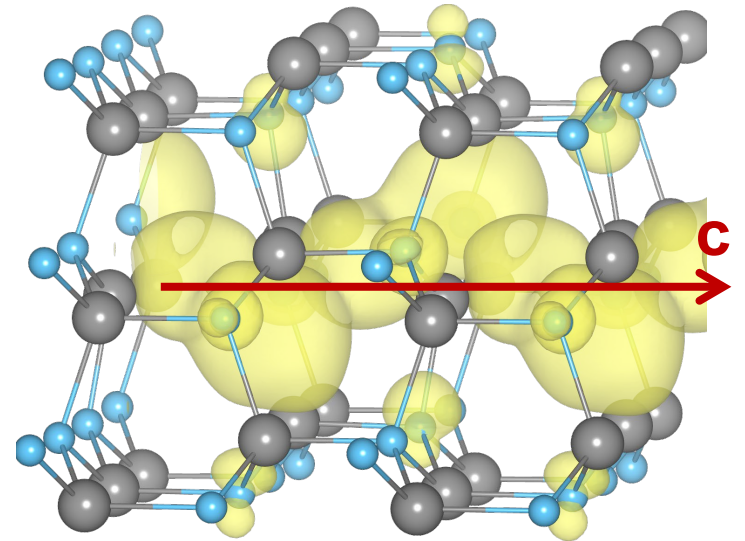
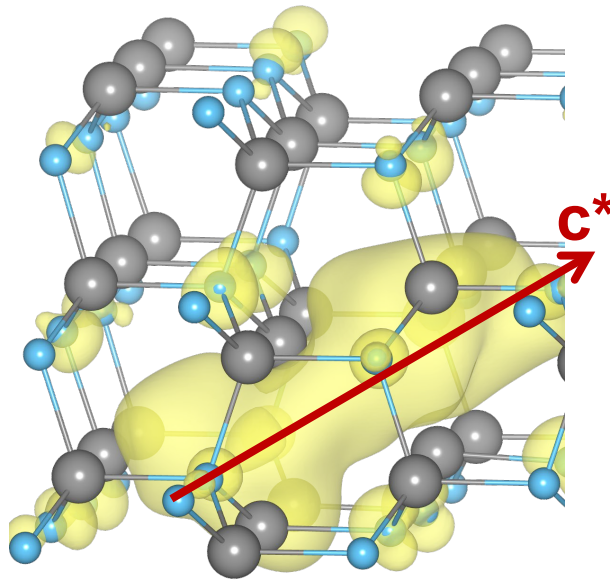
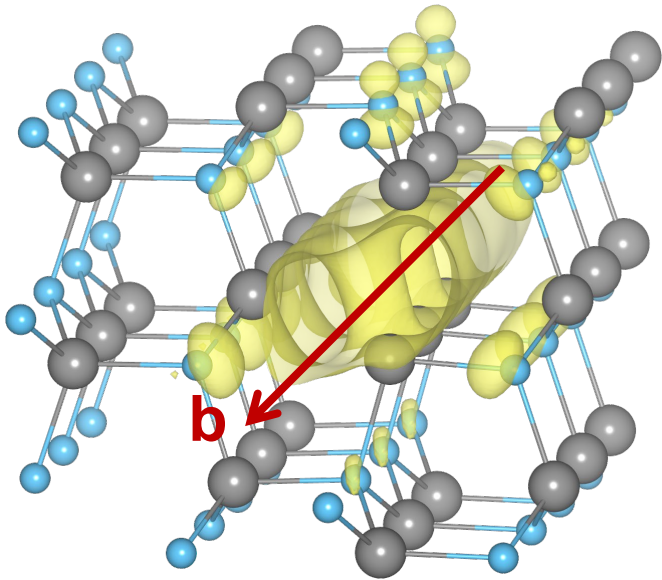
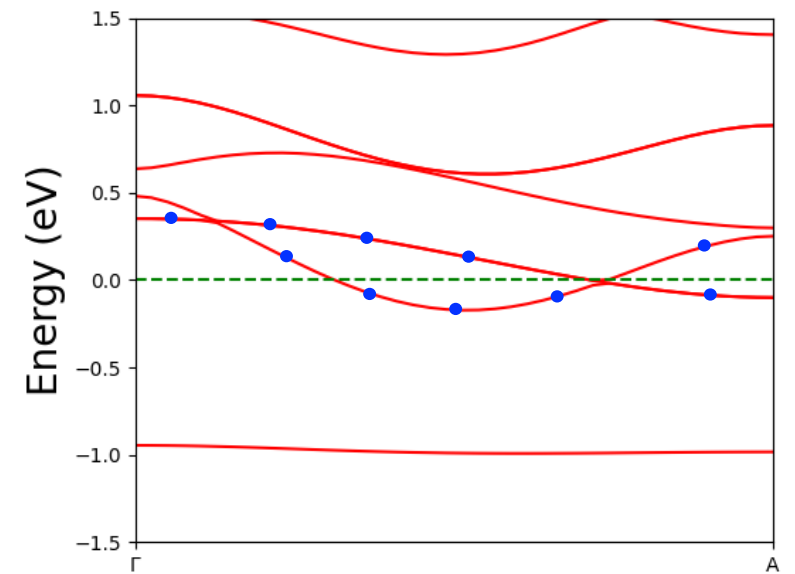
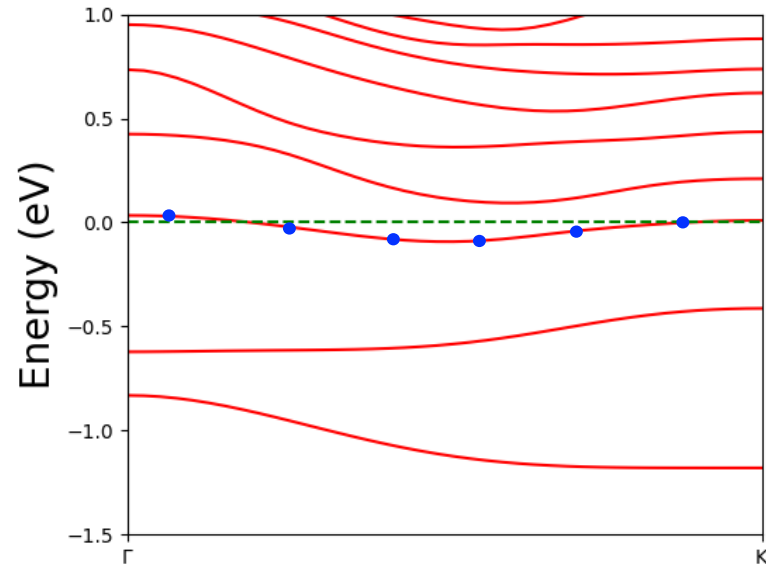
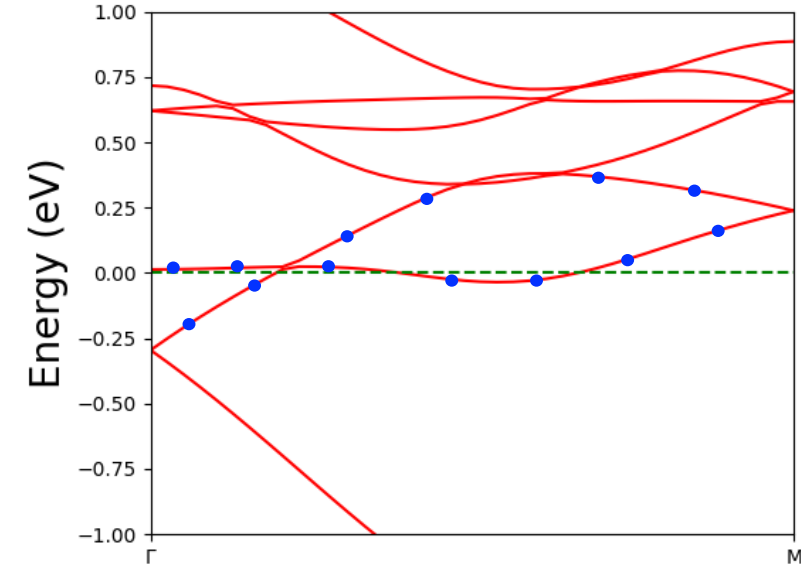


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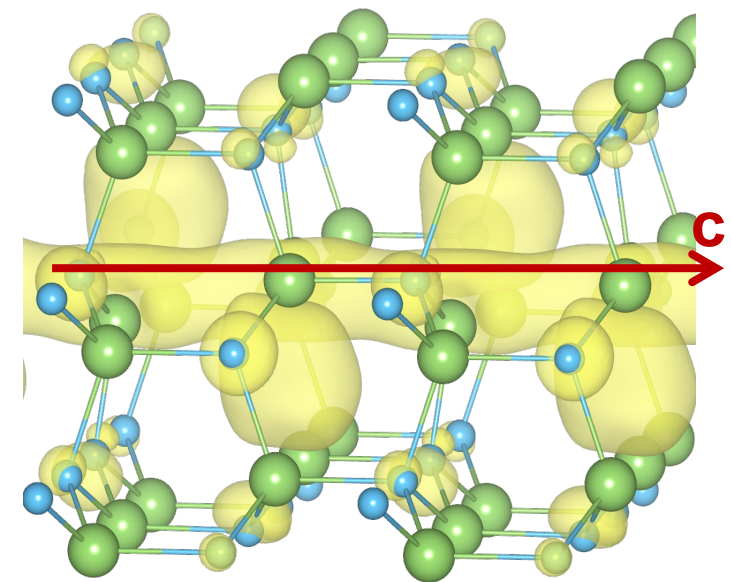
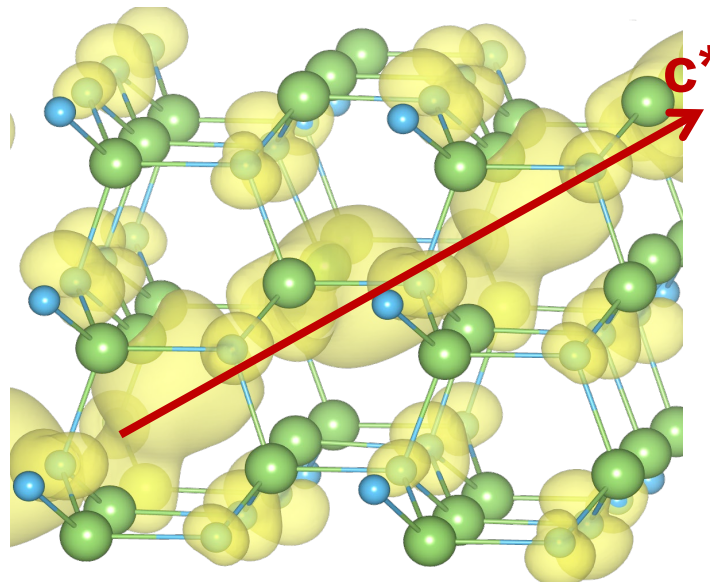
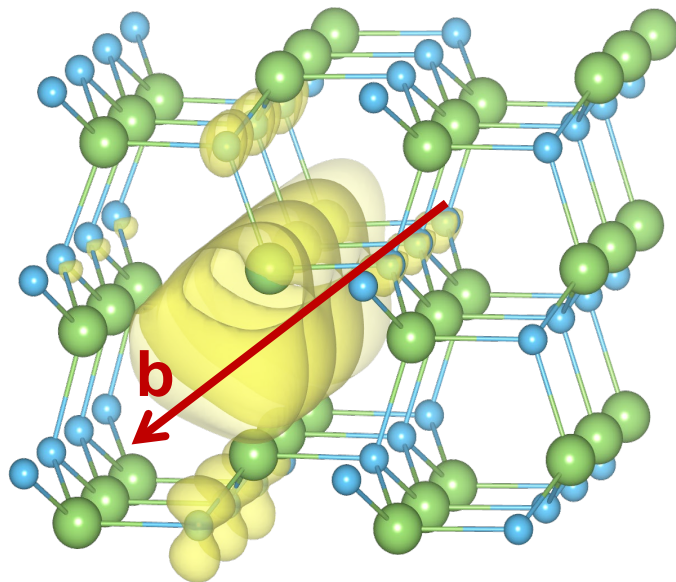
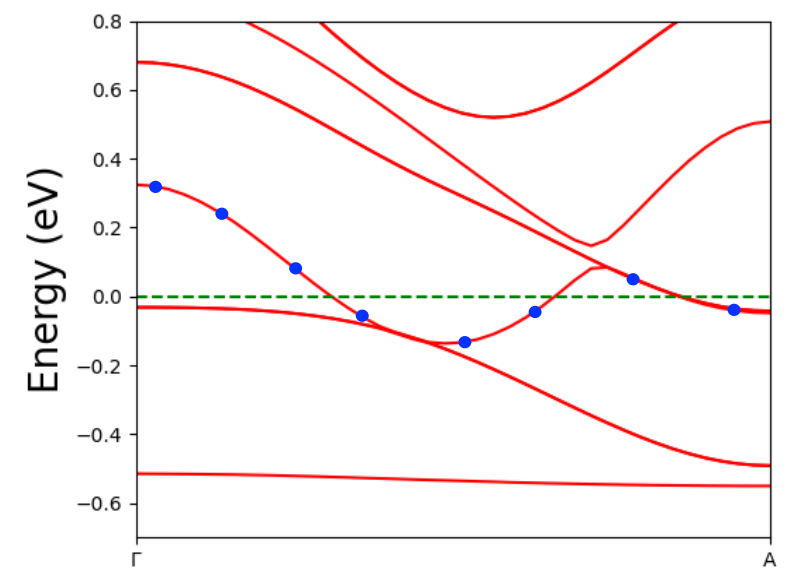
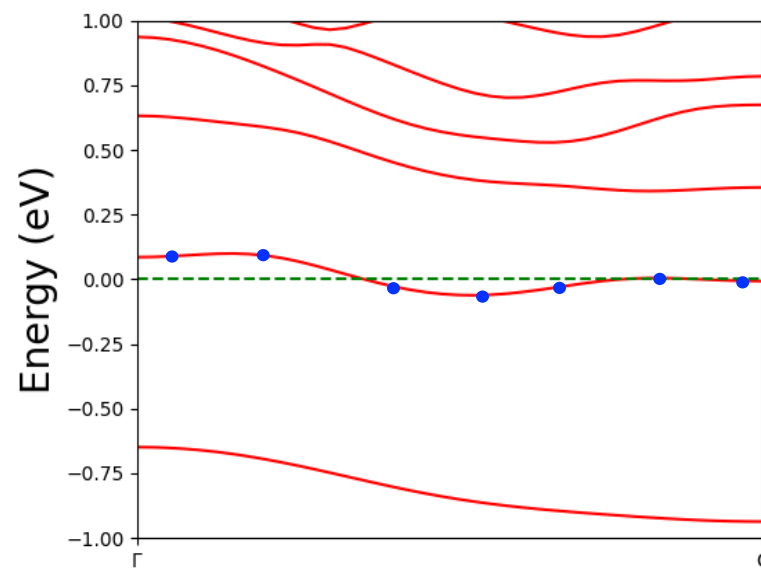
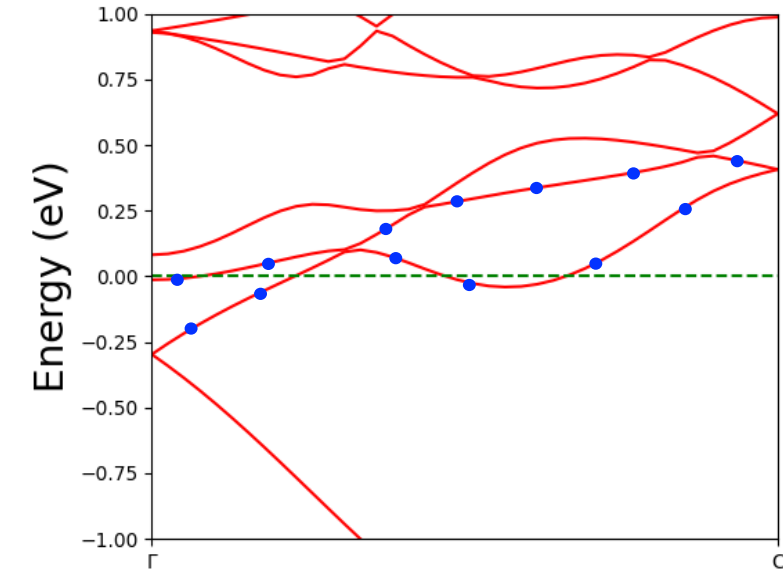
Primary vacancy nucleates vacancy chains



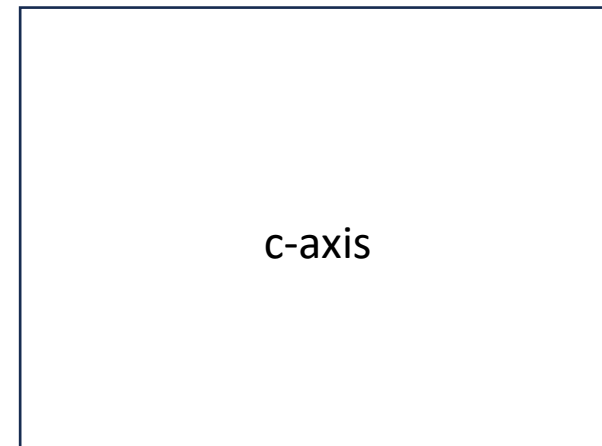
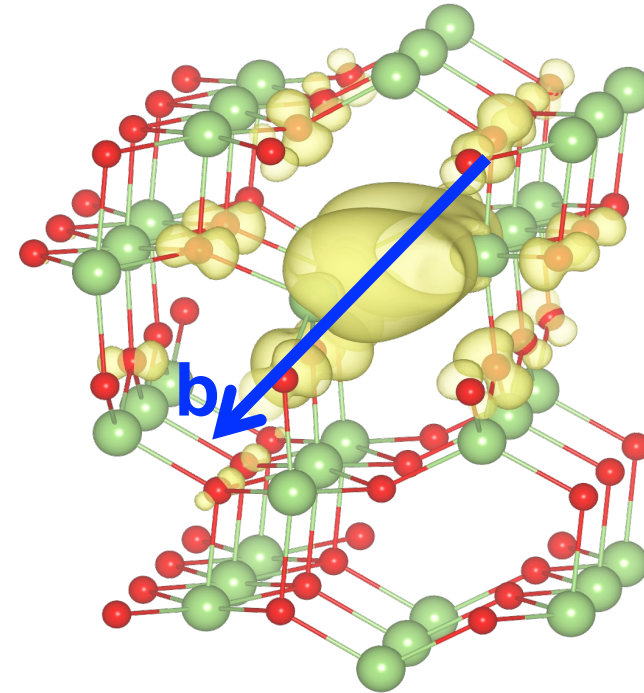
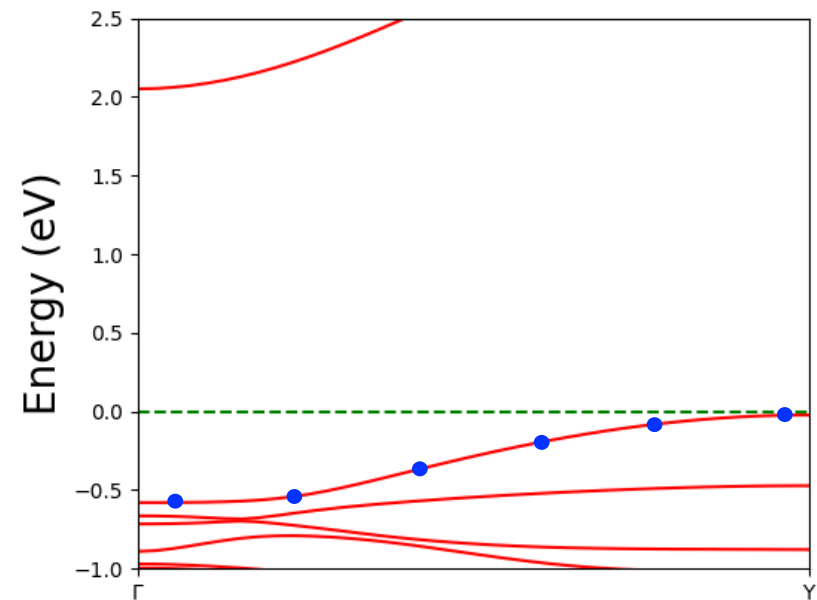
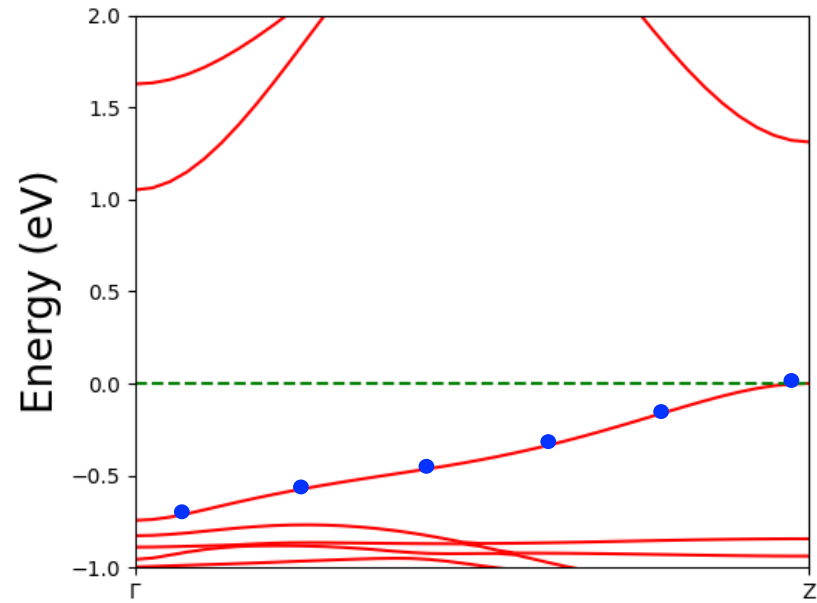
Conductive vacancy chains - AlN



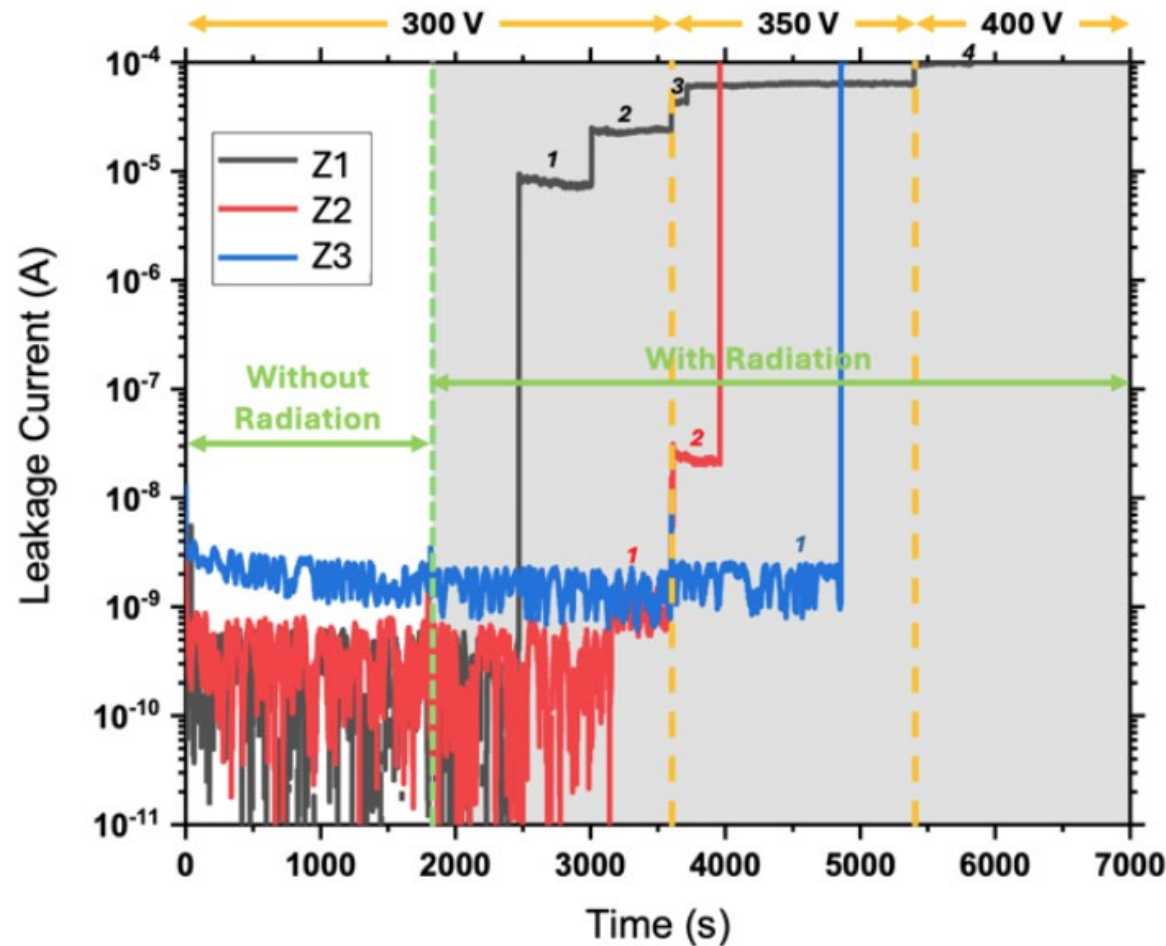
Conductive vacancy chains - GaN



Conductive vacancy chains - Ga_2O_3



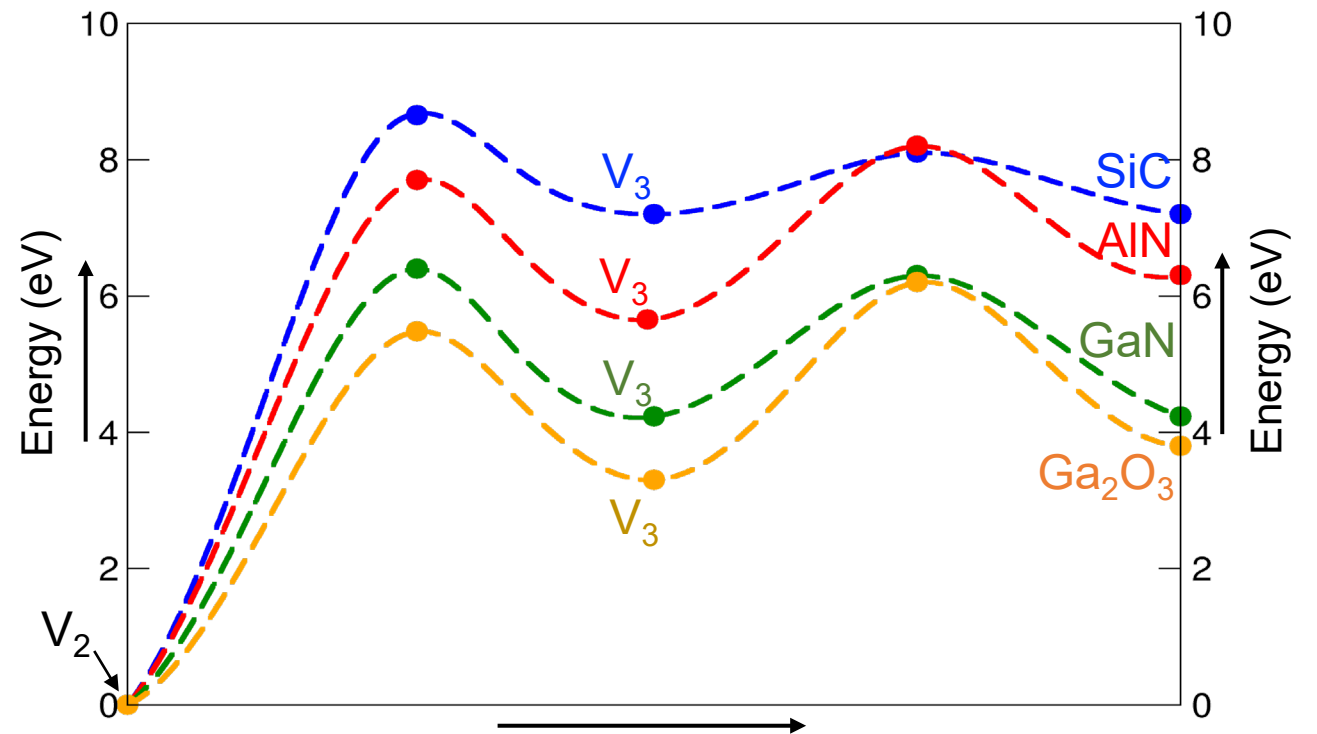
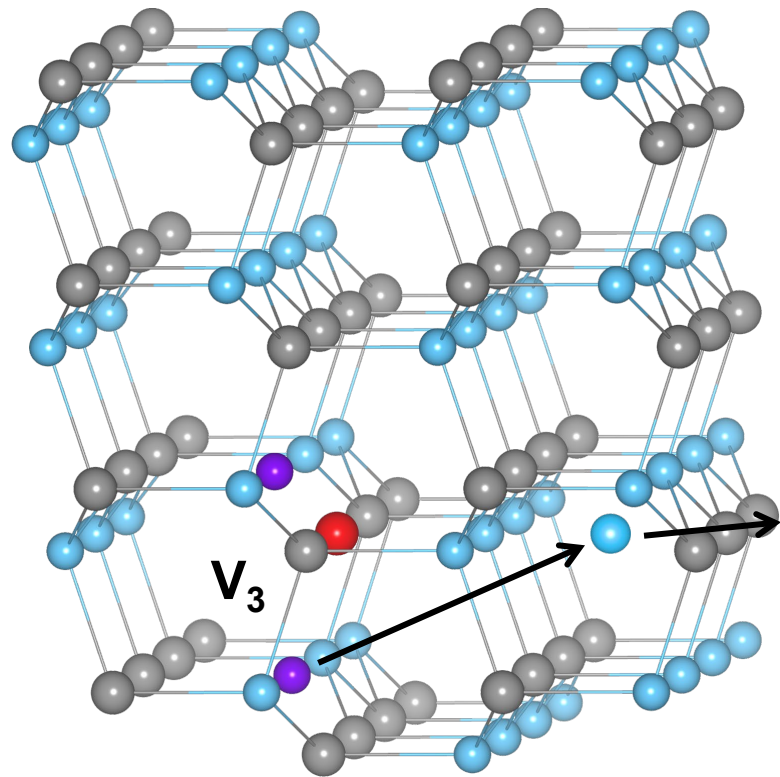
OVERALL INFERENCE FOR WIDE-GAP SEMICONDUCTORS



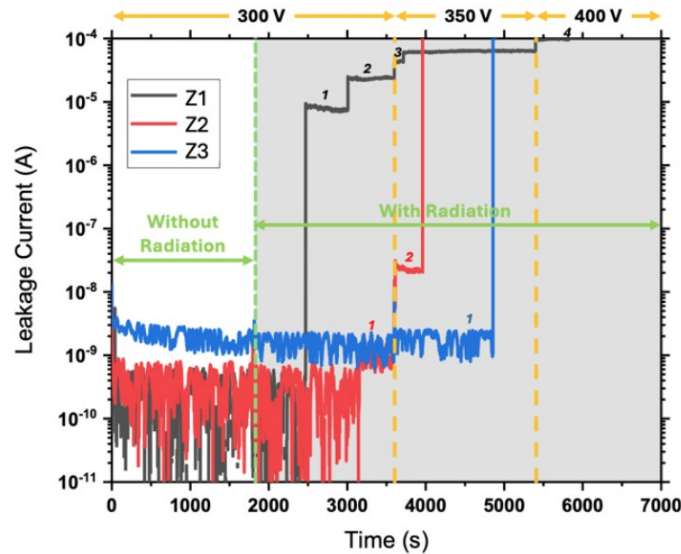
**SELC MEDIATED BY
VACANCY NANOWIRES**

RELATIVE ROBUSTNESS OF MATERIALS: $\text{AlN}, \text{SiC} > \text{GaN} > \text{Ga}_2\text{O}_3$

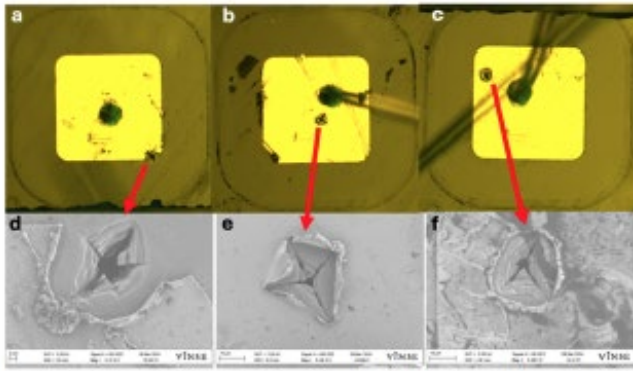
Void growth -- Trivacancy formation



OVERALL INFERENCES FOR WIDE-GAP SEMICONDUCTORS



- SELC MEDIATED BY VACANCY NANOWIRES

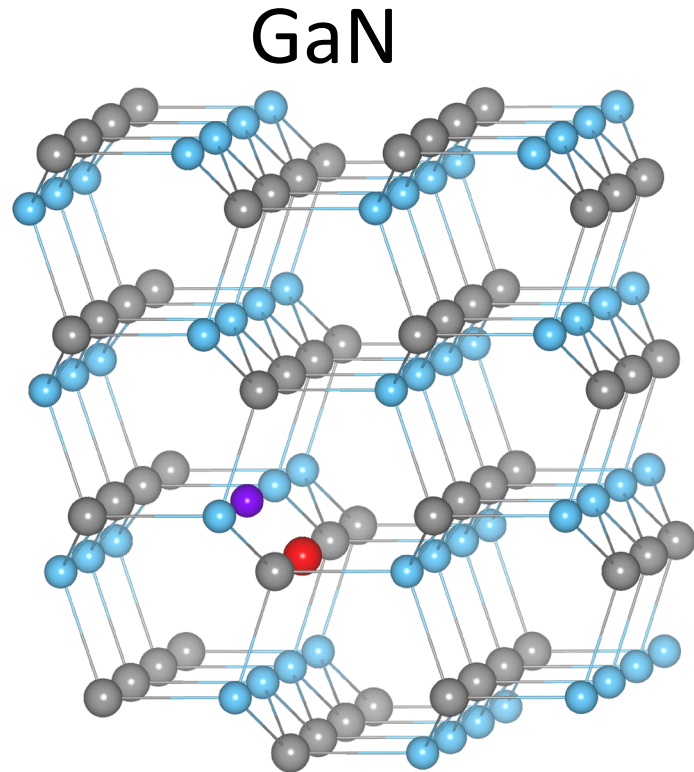


- S.E. BURNOUT **ACCOMPANIED** BY NANOVOID MINI EXPLOSION

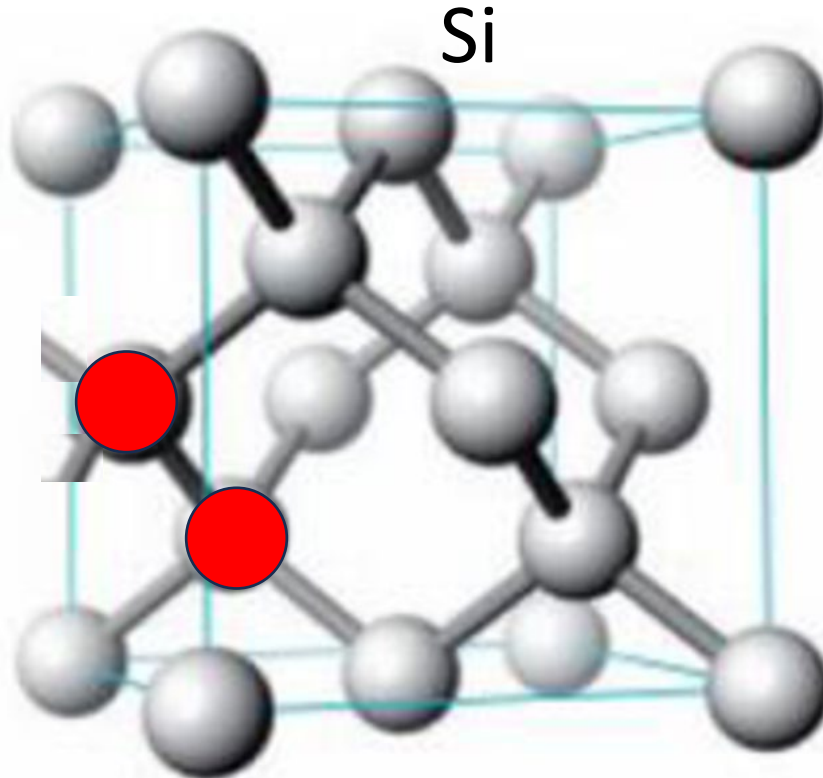
A. S. Senarath et al. 2024

RELATIVE ROBUSTNESS OF MATERIALS: AlN , SiC > GaN > Ga_2O_3

WHAT ABOUT SILICON?



N-vacancy nanowires
SELC, SEB



- Energy to create neighboring vacancy ~5 eV
- Just primary and secondary knock-out atoms
- Vacancies and Interstitials are highly mobile
- ➡ Random V-I clusters
- Single Event Displacement Damage (SEDD)

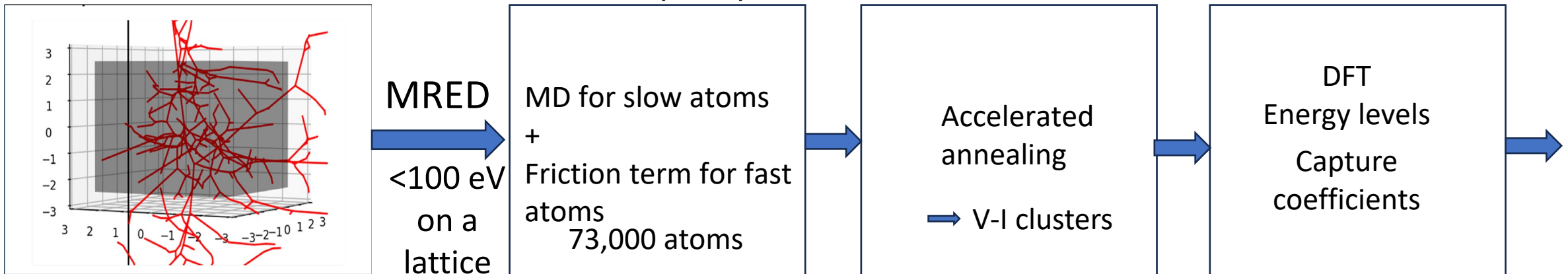
Poster # 23

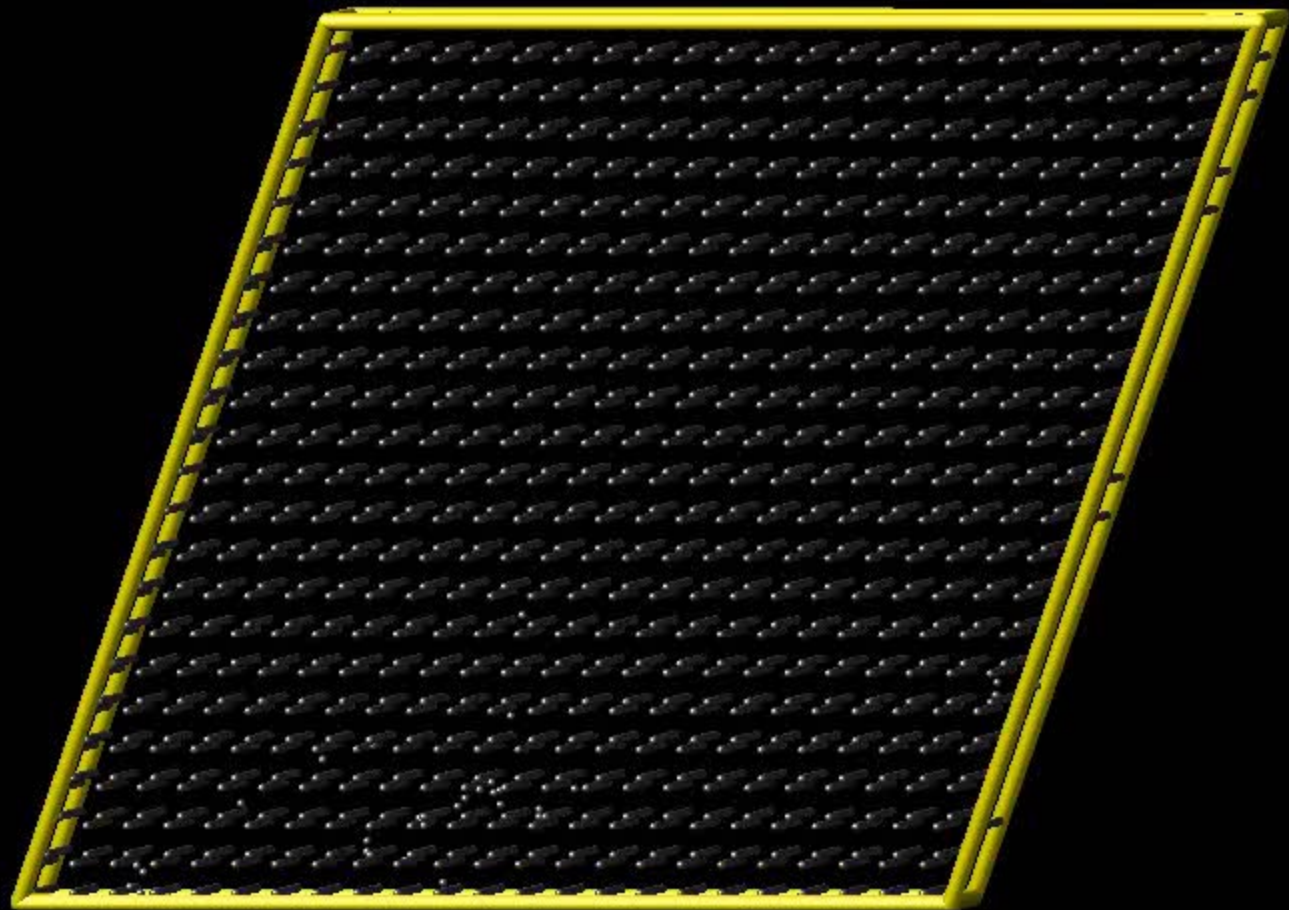


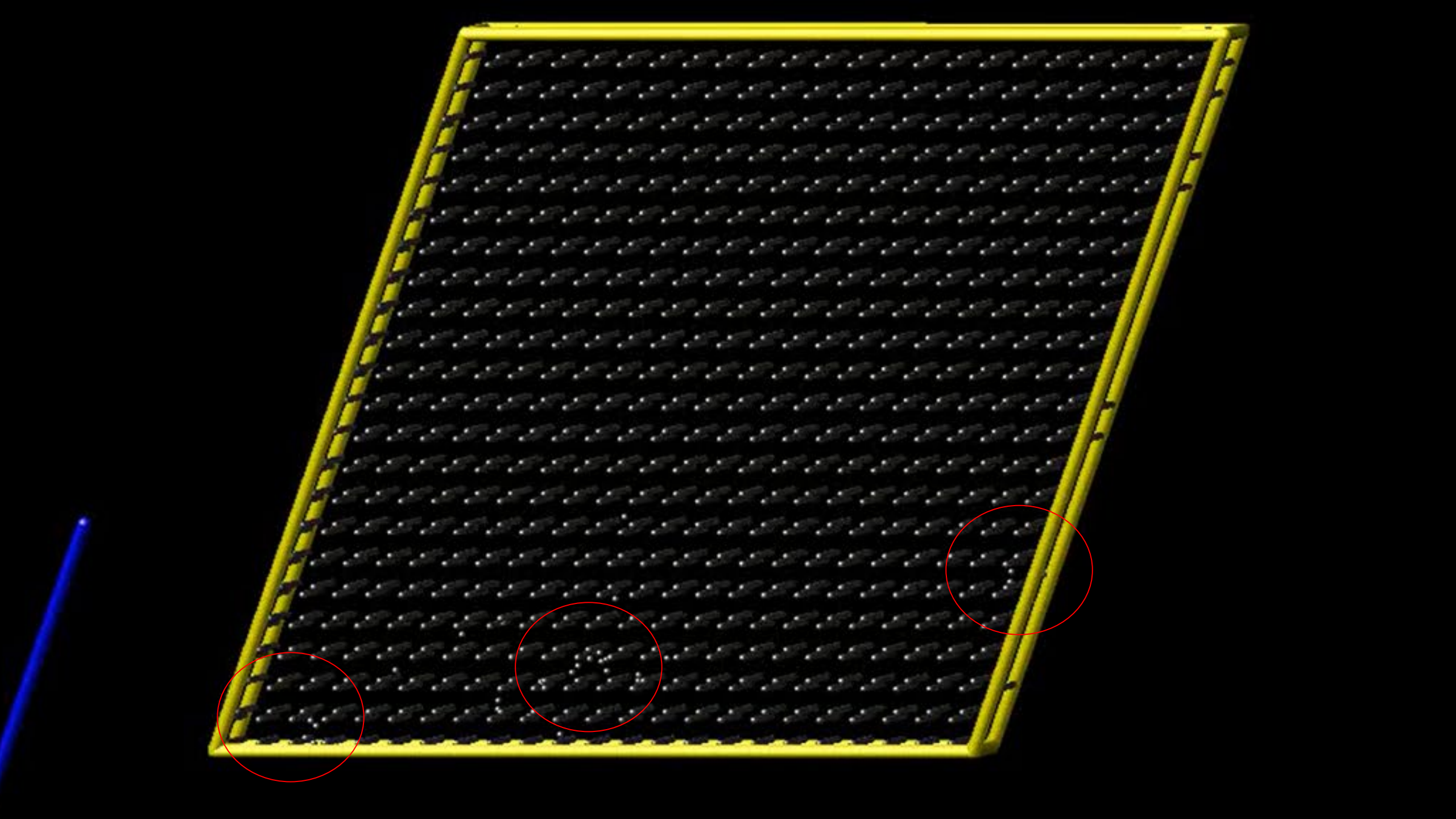
James Trippe



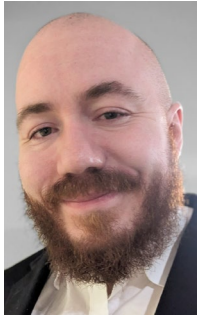
Grant Mayberry







Poster # 23



James Trippe



Grant Mayberry

