Thermally oxidized SiO_2 formation on 4H-SiC substrate by considering the interface reaction kinetics

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Outline

1. Background and Objective

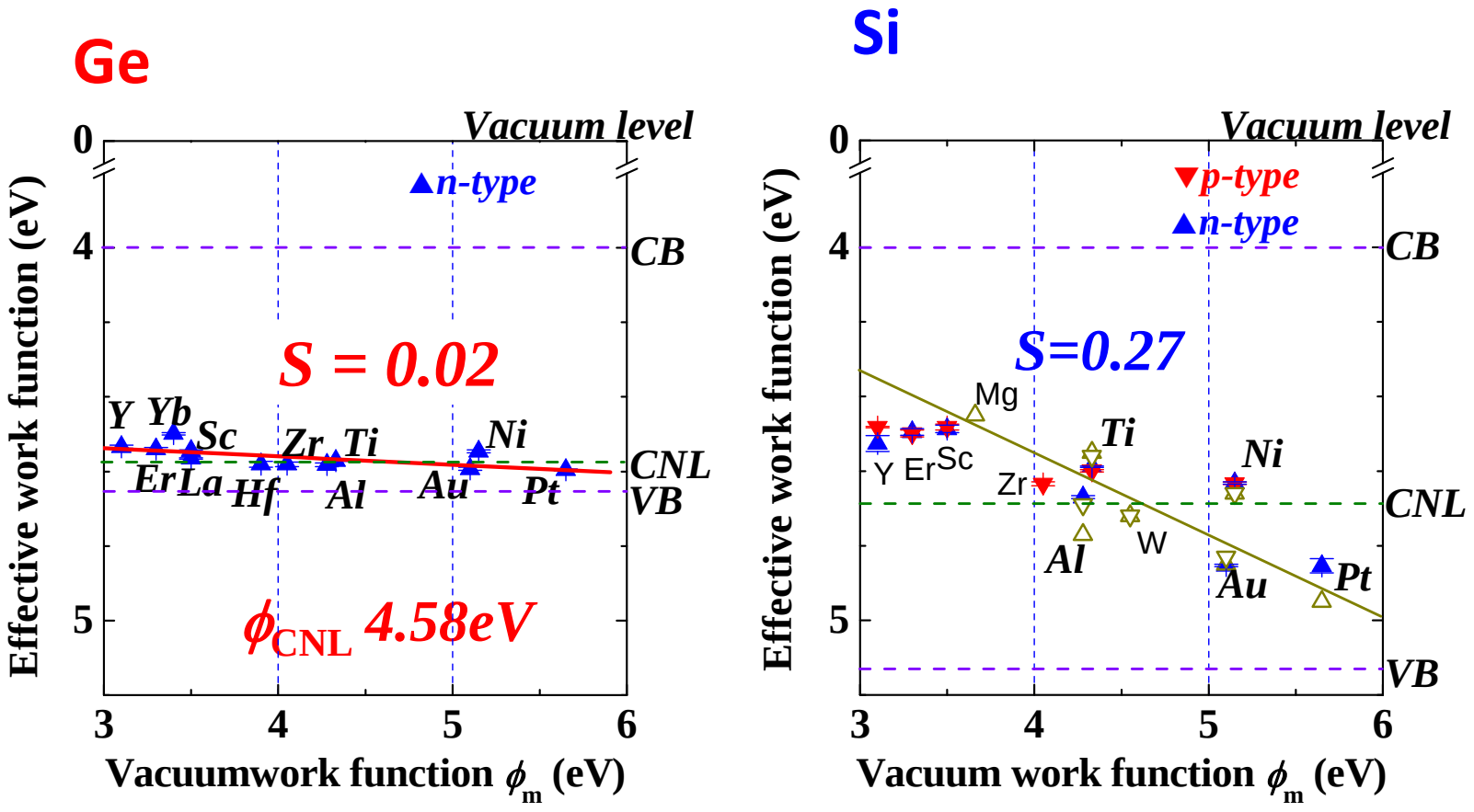
2. Sample Preparation

3. Experimental Results

4. Discussion

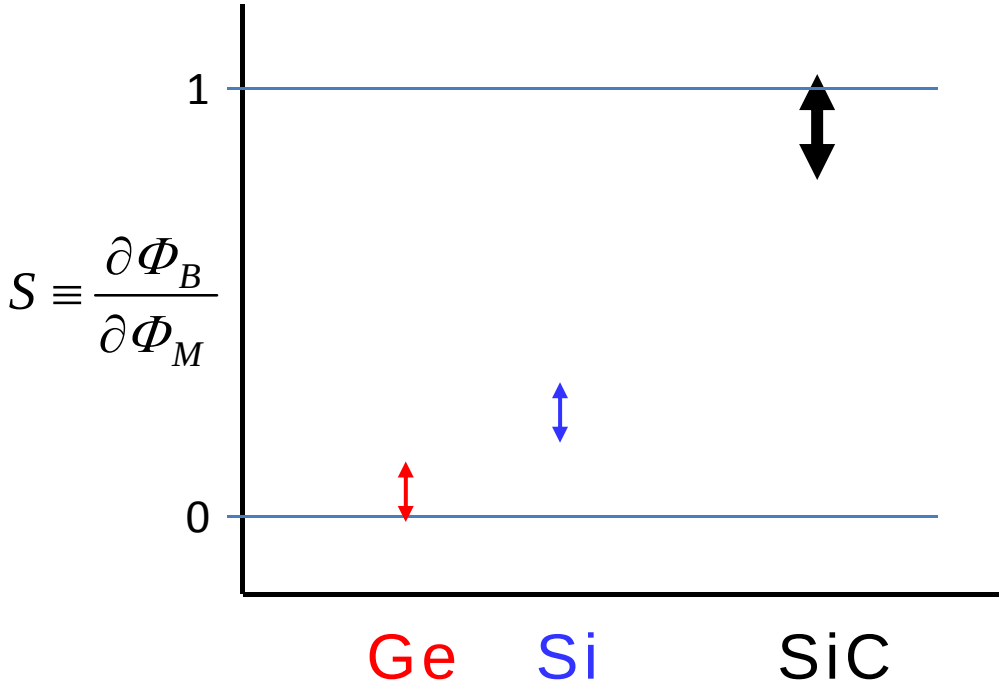
5. Conclusion

Effective WF vs. Vacuum WF



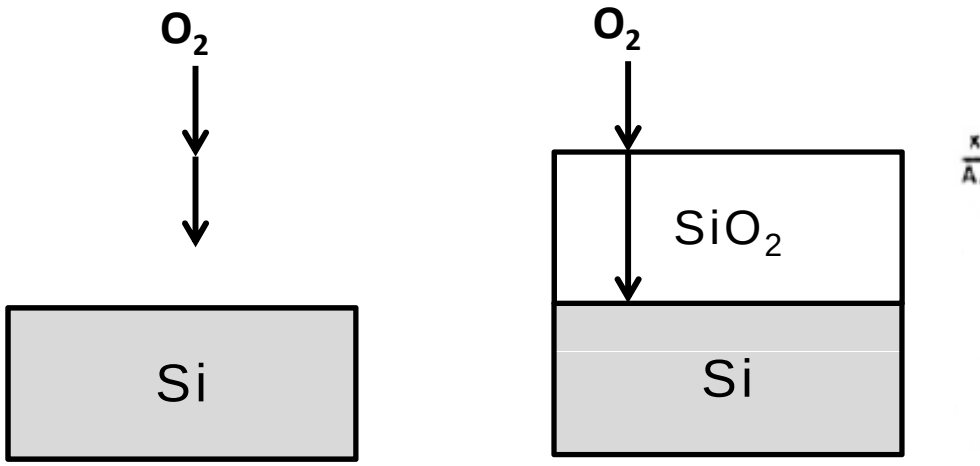
Interface Science of SiC

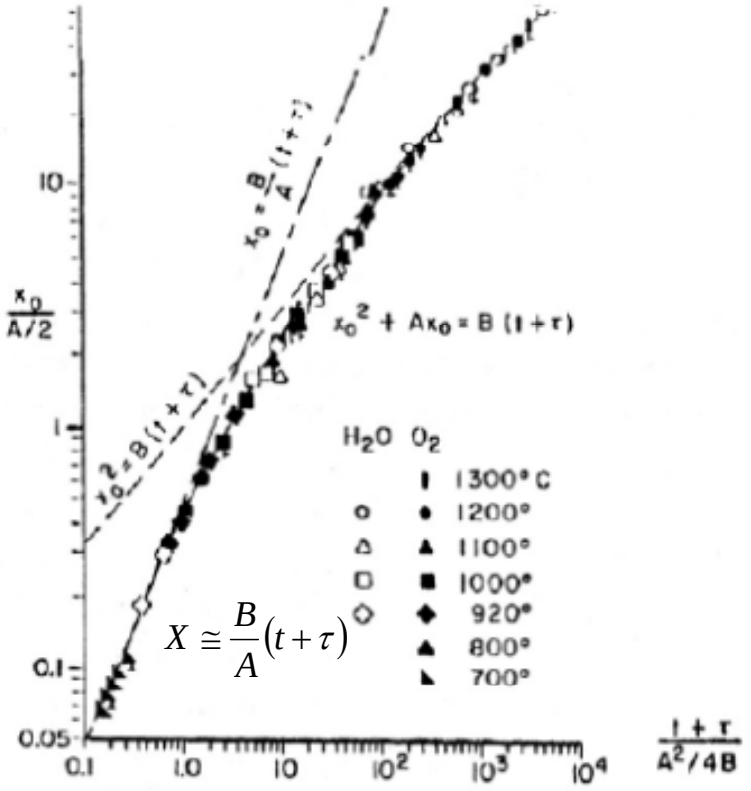
Schottky Barrier $\Phi_B = \Phi_M - \chi_S \quad (S = 1)$



Si Oxidation

$$X^2 \cong \left(\frac{A}{2}\right)^2 \frac{t}{\frac{A^2}{4B}} = Bt$$

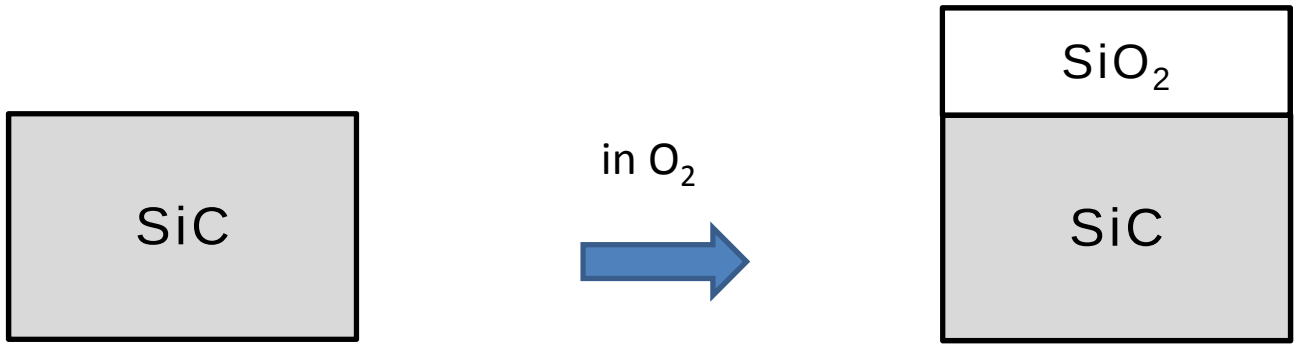




Deal-Grove Model

Objective

To demonstrate high quality SiO_2/SiC interface in thermal oxidation process of SiC



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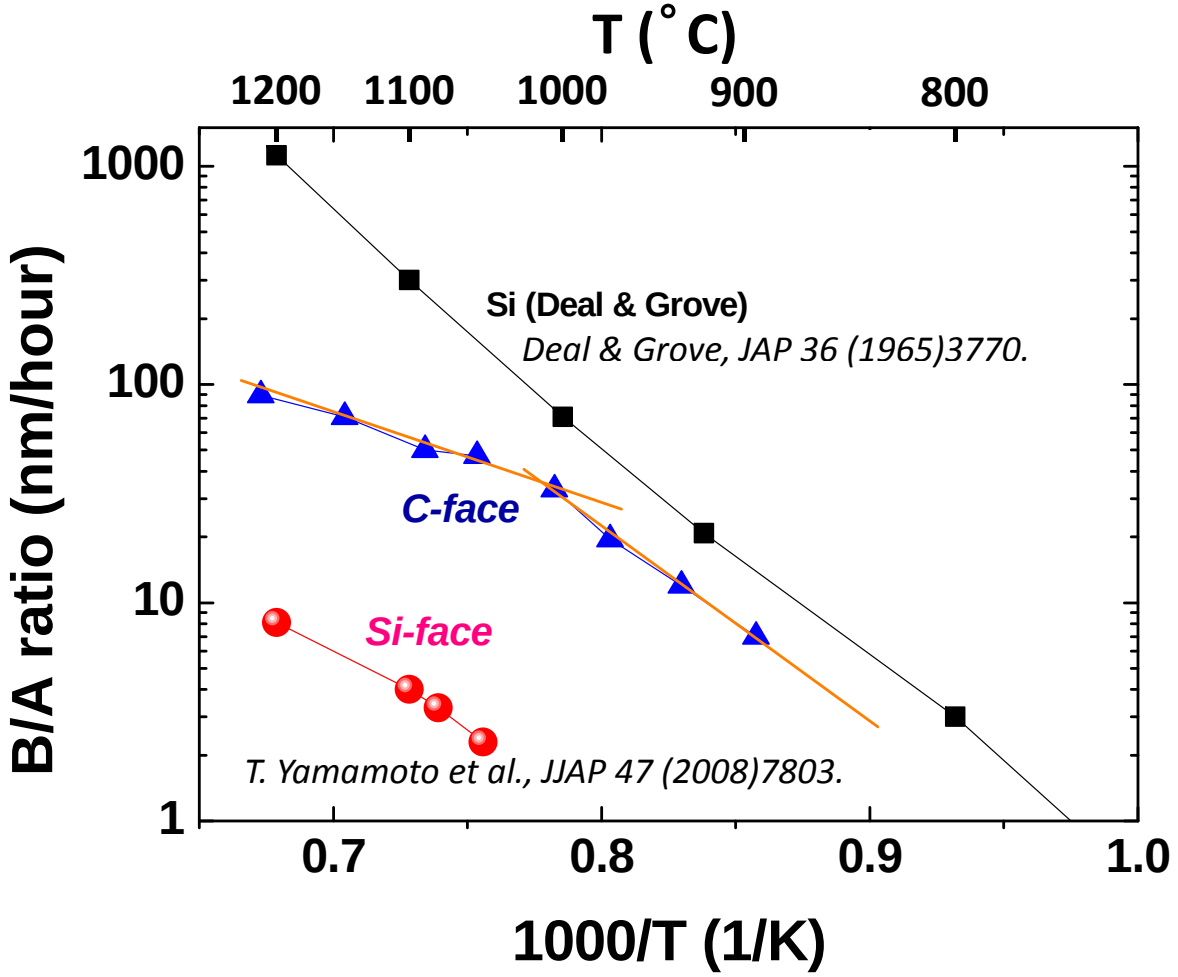
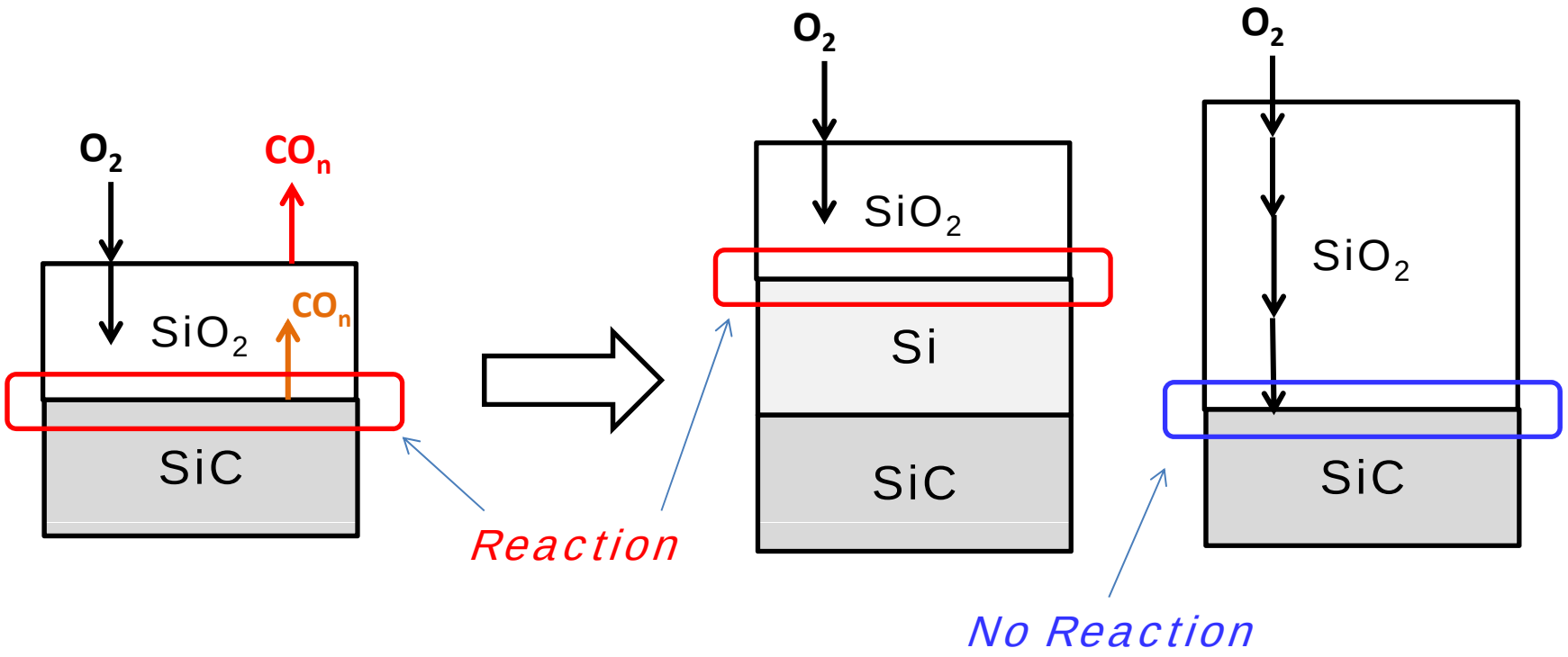
Kinetic Consideration of SiC Oxidation



Because oxidation process is reaction-limited,
its rate is Si > C-face SiC >> Si-face SiC.

Kinetic Consideration of SiC Oxidation

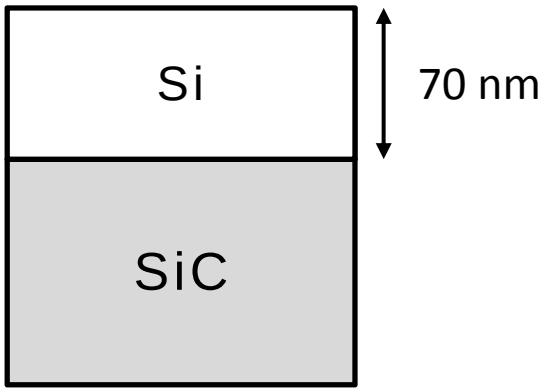


Metal–oxide–semiconductor capacitors formed by oxidation of polycrystalline silicon on SiC

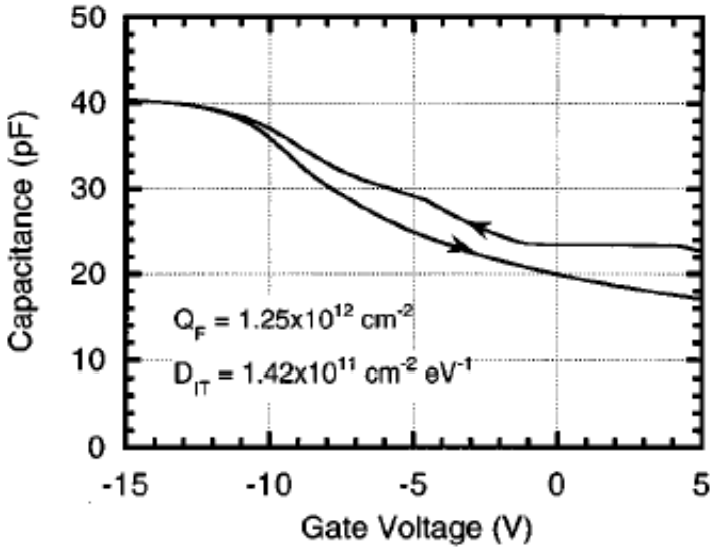
J. Tan, M. K. Das, J. A. Cooper, Jr. and M. R. Melloch[a)]
School of Electrical and Computer Engineering, Purdue University, West Lafayette, Indiana 47907-1285

(Received 27 January 1997; accepted for publication 28 February 1997) APL 70 (1997) 2280.

A uniform oxidation on nonplanar SiC by depositing Si prior to SiC oxidation



Si Oxidation at 1050°C in Wet O_2



Oxidation of deposited thick Si on SiC in high temperature also causes oxidation of SiC.

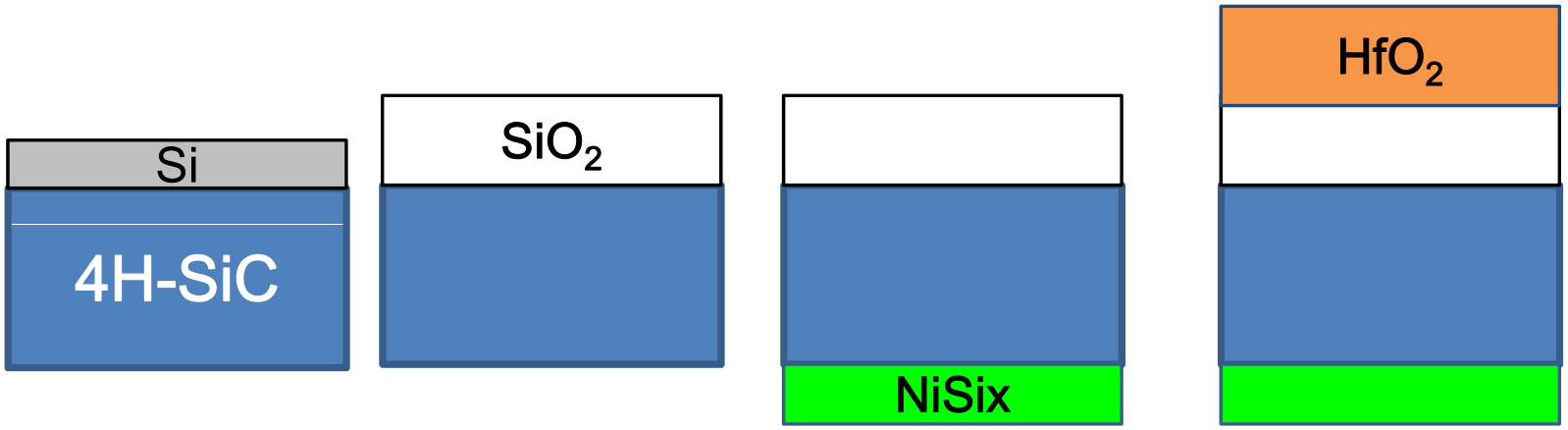
Sample Preparation

Wafers

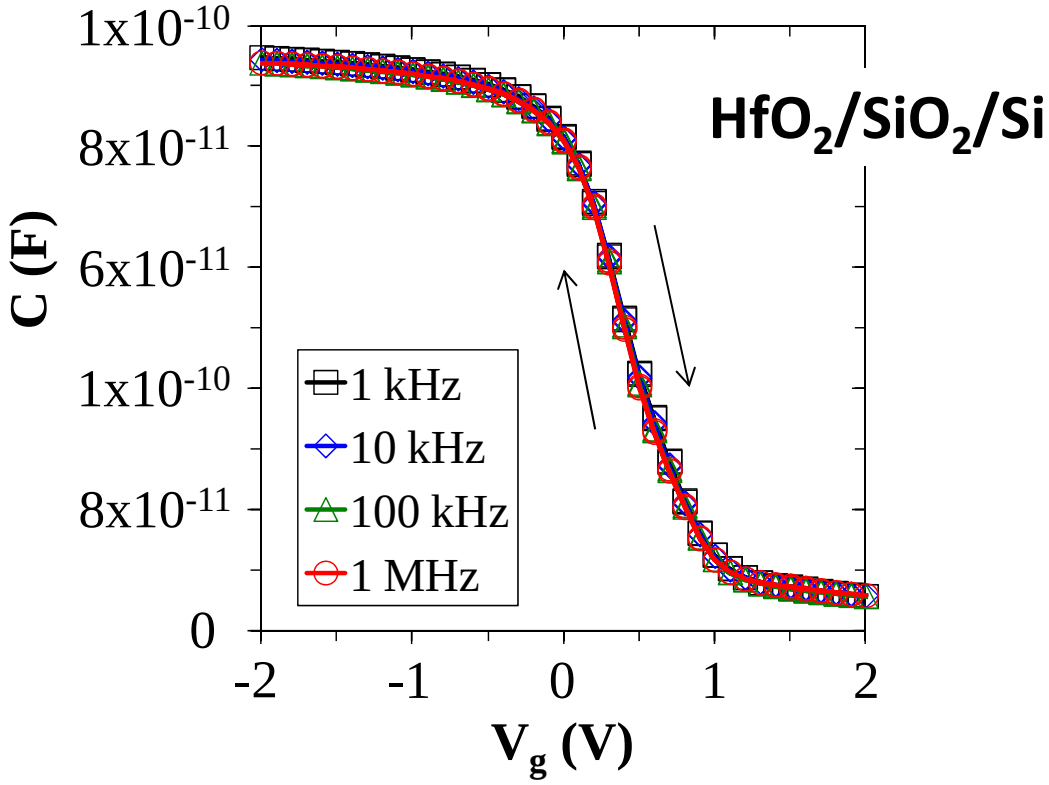
Si- and C-face 4H-SiC
5~6μm epi layer
N-dope ~1E16cm-3

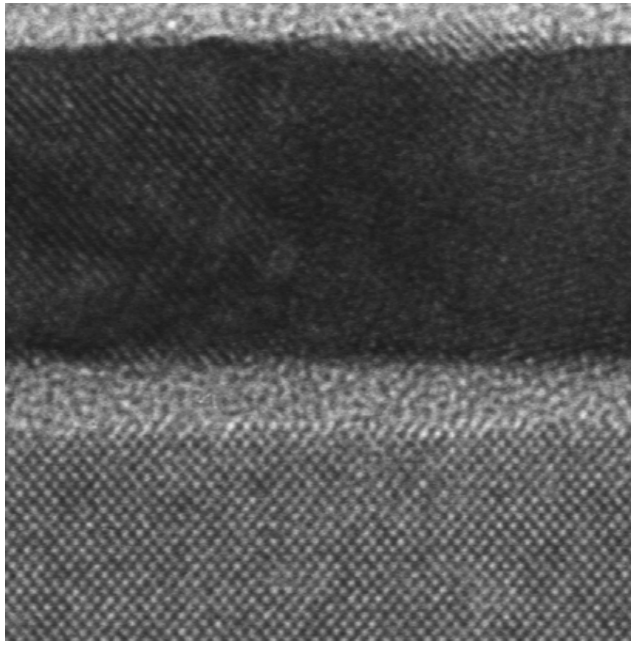
Main process flow

Si deposition(~3 nm)
Thermal oxidation / 800°C, dry O_2
5, 15, 50 min
Back metallization (Ni)
PMA / 940°C, N_2, 5 min
HfO_2 deposition(~10 nm)
PDA / 500°C, 0.1% O_2, 30 sec
Au electrode



Why HfO_2 ?





No frequency dispersion, nor hysteresis

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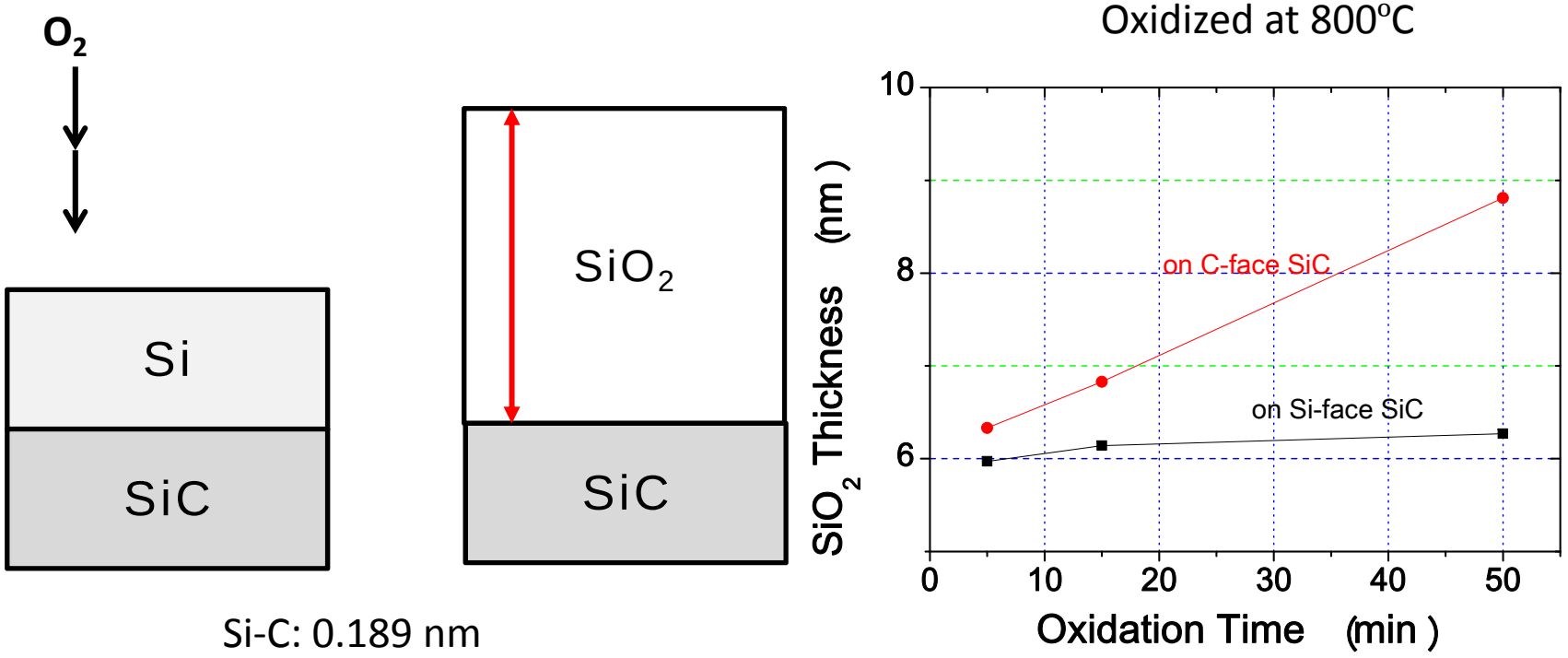
Comparison between Si-face and C-face SiC - Oxidation Rate -



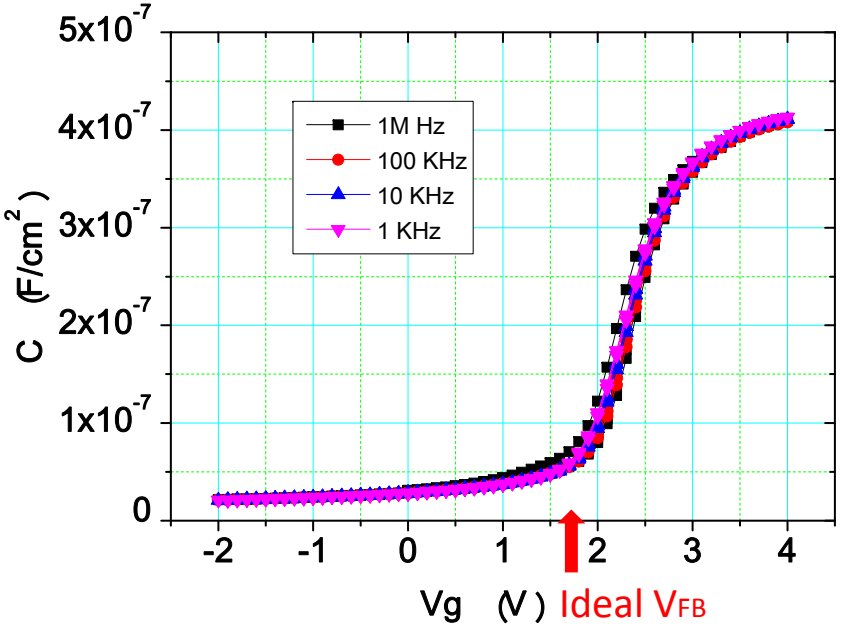
Si-C: 0.189 nm
Si-O: 0.162 nm

Just a monolayer SiO2 if any.

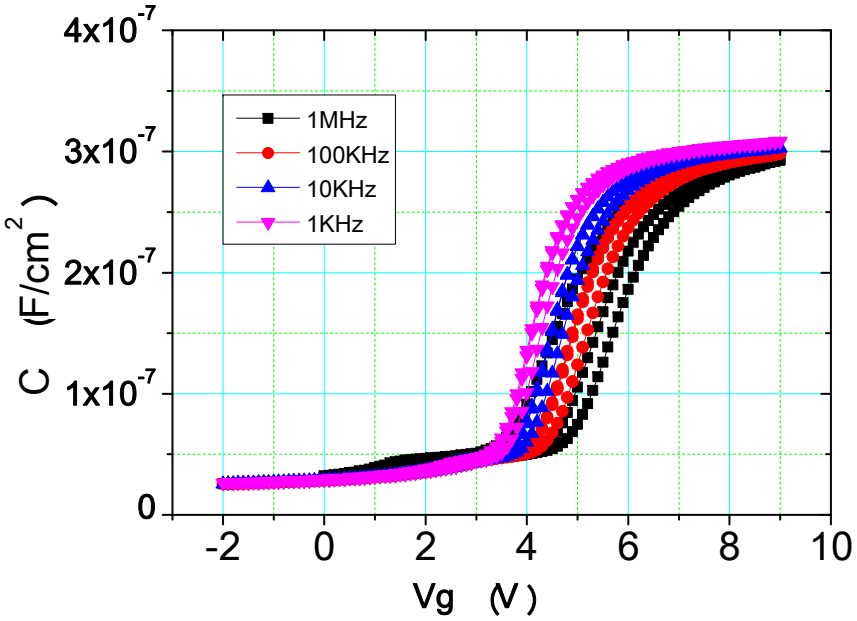
Fig. 3

Comparison between Si-face and C-face SiC - Bi-directional C-V Characteristics -

Si-face



C-face



Dry oxidation at 800ºC for 50 min

On Si-face, there are little frequency dependence and hysteresis, and V_{FB} is close to the ideal value.

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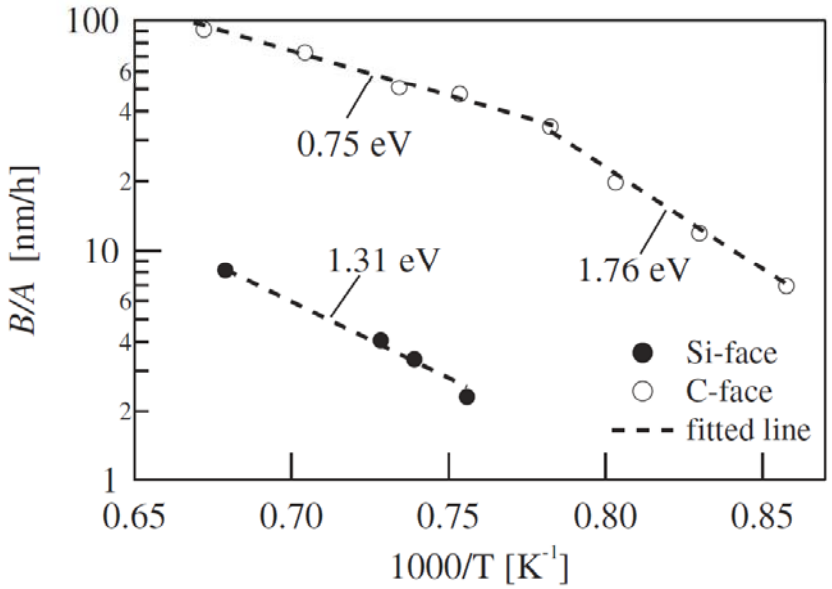
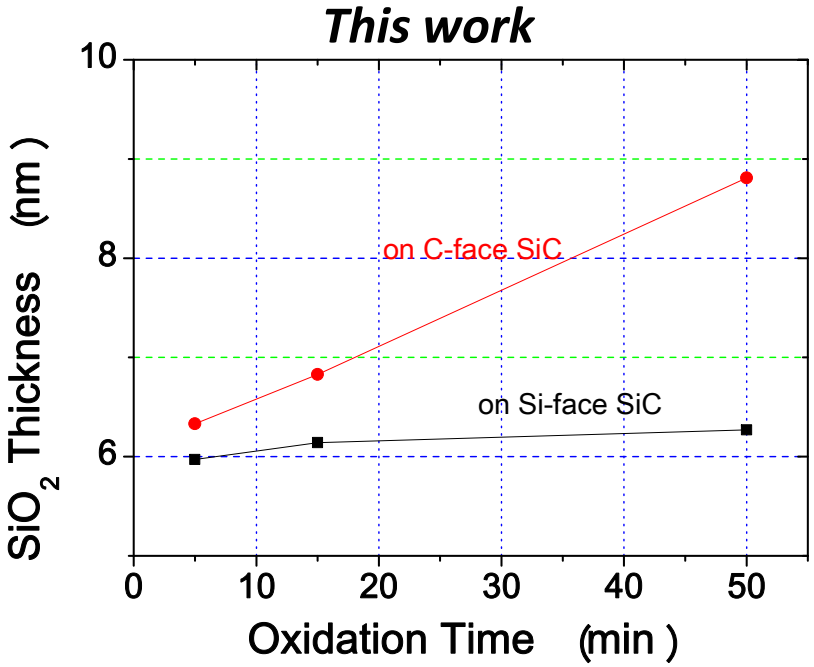
A big difference between Si-face and C-face SiC



T. Yamamoto et al., JJAP 47 (2008)7803.



Although oxidation rate is significantly different, a same amount of C should be introduced into a given thickness of SiO_2.

On Si-face, no carbon will be introduced Into SiO_2, because of negligible oxidation of Si-face SiC.

We can make a carbon-free SiO_2 on Si-face SiC by low temperature oxidation of Si/SiC.

Conclusion and Future Outlook

- **Good C-V characteristics in SiC MOS capacitors have been demonstrated simply by oxidation in dry O_2 at 800^{o}C, on the basis of thermodynamic and kinetic consideration.**
- **High-k dielectric films will be applicable for SiC gate stacks by using stable interfacial SiO_2 layer.**
- ***SiC interface research is old but will be a hot topic.***
- **Si-face is much better than C-face due to a considerably lower oxidation rate in the present method.**
- **MOSFET fabrication and characterization will be the next challenge.**