The Effects of NO Passivation on the Radiation Response of SiO_2/4H-SiC MOS Capacitors

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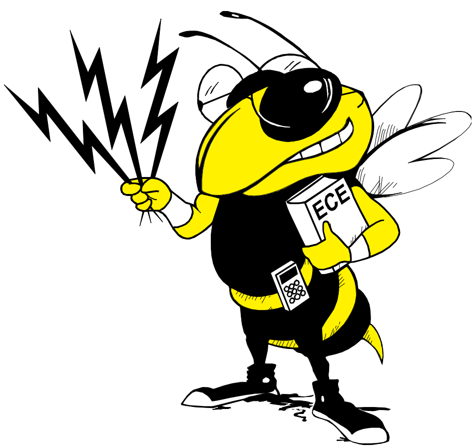

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Abstract

The radiation response of SiO_2 gate oxides grown on 4H-SiC to NO passivation is presented for the first time. The effects of gamma radiation on Q_{eff} are similar for n-4H-SiC MOS capacitors both with and without NO passivation, but are different in sign (negative) compared to SiO_2 on Si. The variation in D_{it} with total dose, however, is different for the passivated versus the unpassivated samples. Comparisons between Si SOI and 4H-SiC suggest that properly passivated SiC MOSFETs should have good radiation tolerance.

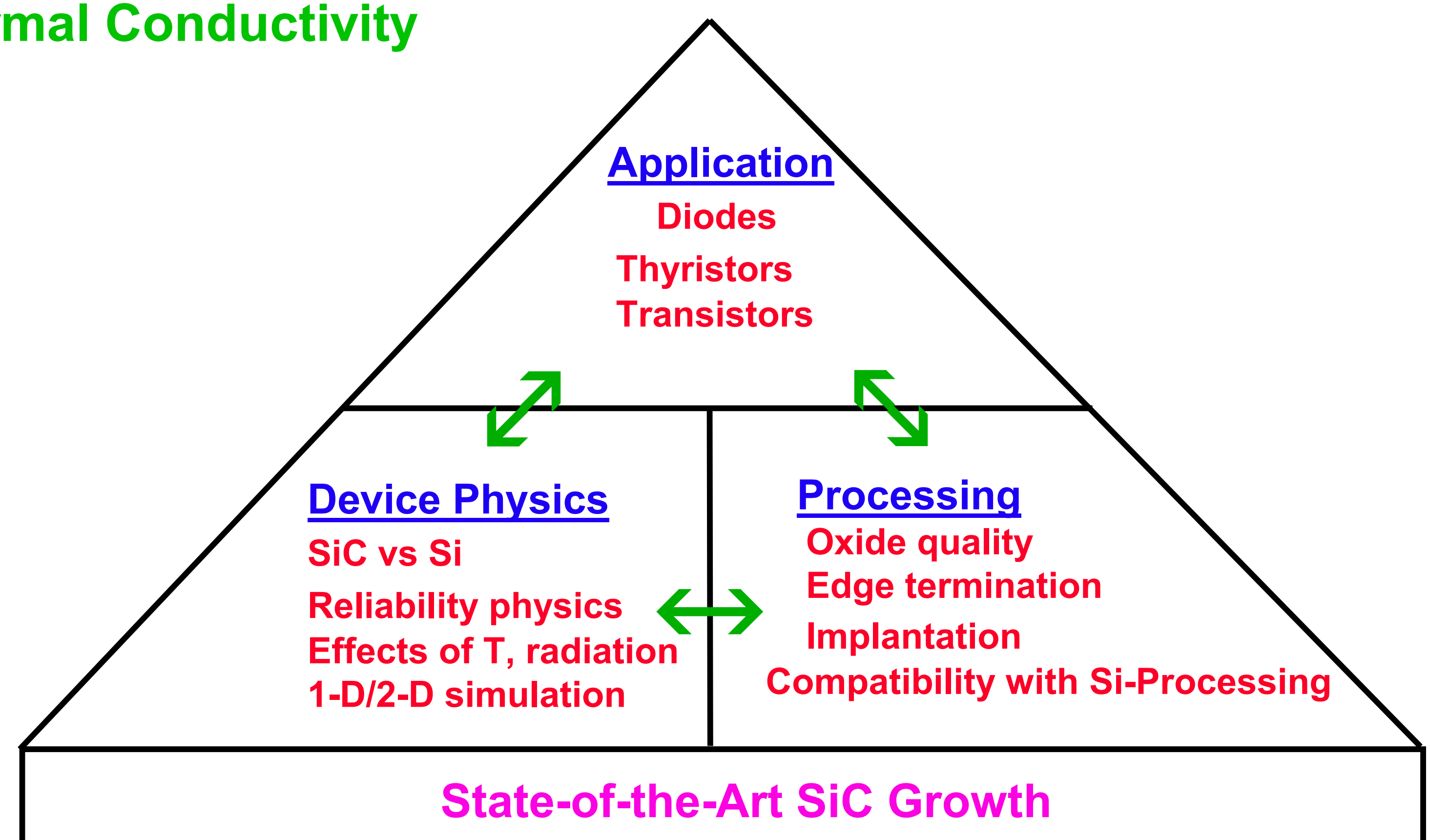
Keywords: Silicon carbide; MOS; Radiation; Passivation

Outline

- Introduction to Silicon Carbide
- Motivation
- Fabrication of SiC MOS Capacitor
- Result and Discussion
- Open Issues
- Summary

What's SiC?

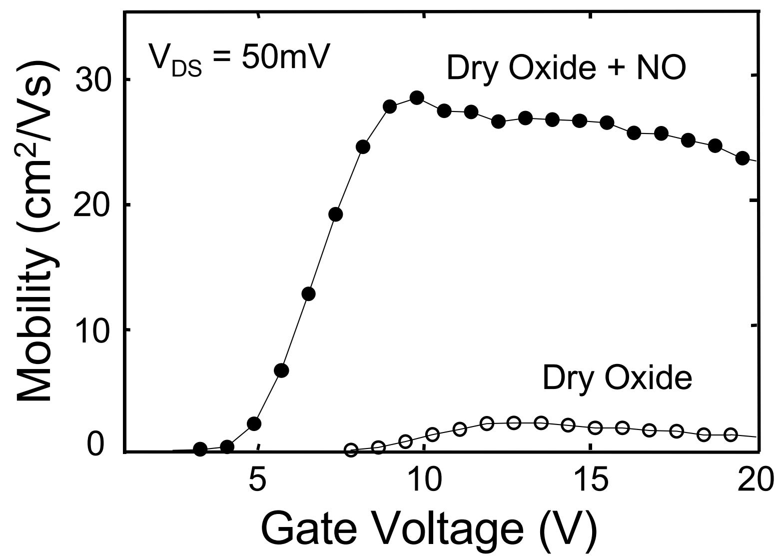
- A Compound Semiconductor with
  - ✈Wide Bandgap
  - ✈High Breakdown Field
  - ✈High Thermal Conductivity



Why NO Annealing?

- **Low effective channel mobility in SiC MOSFET due to interface defects and oxide trap density**
  - Carbon residue at growth interface
  - rough surface morphologies

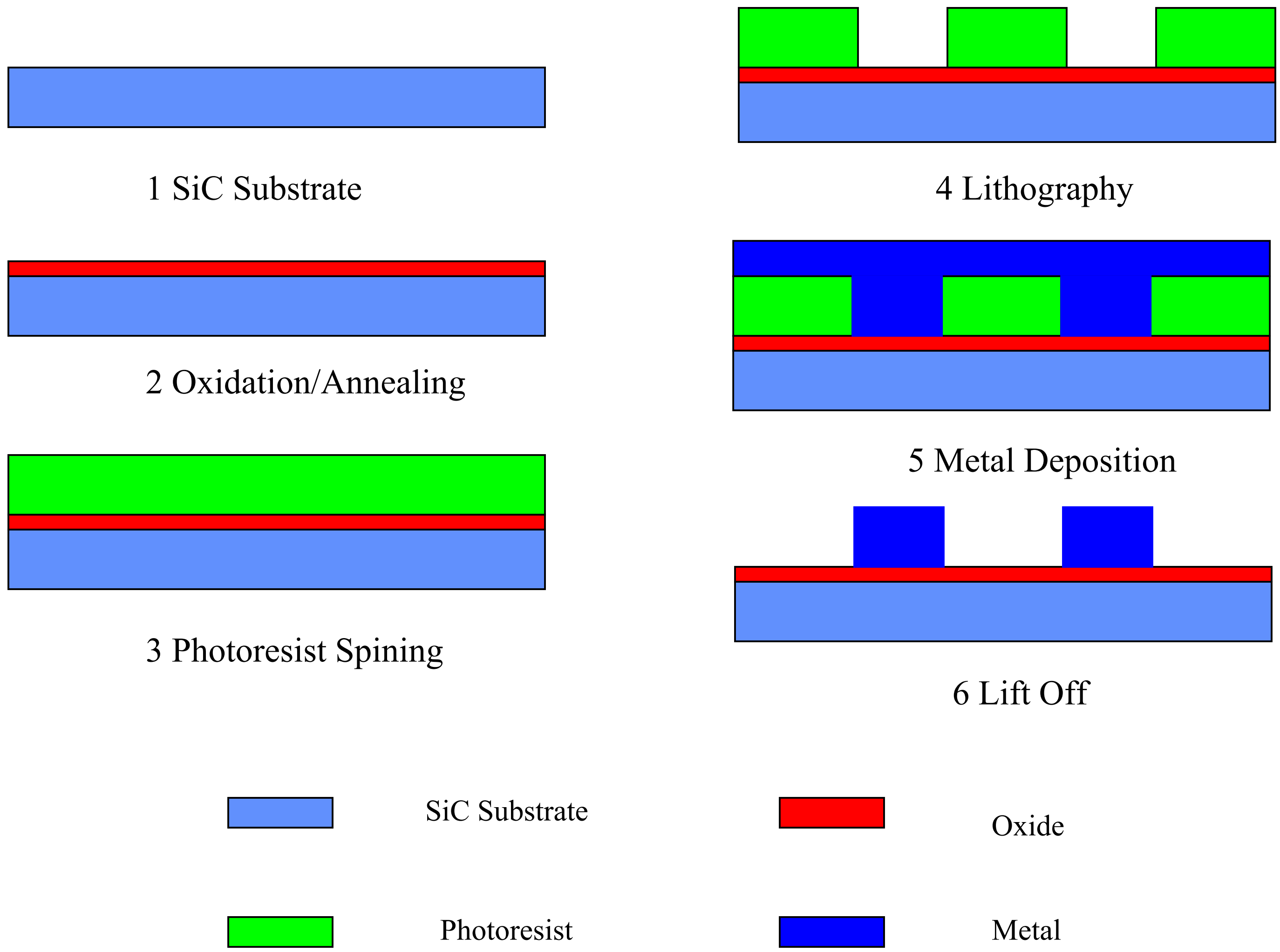
- **Effective channel mobility of 4H-SiC MOSFET increases significantly after NO annealing**



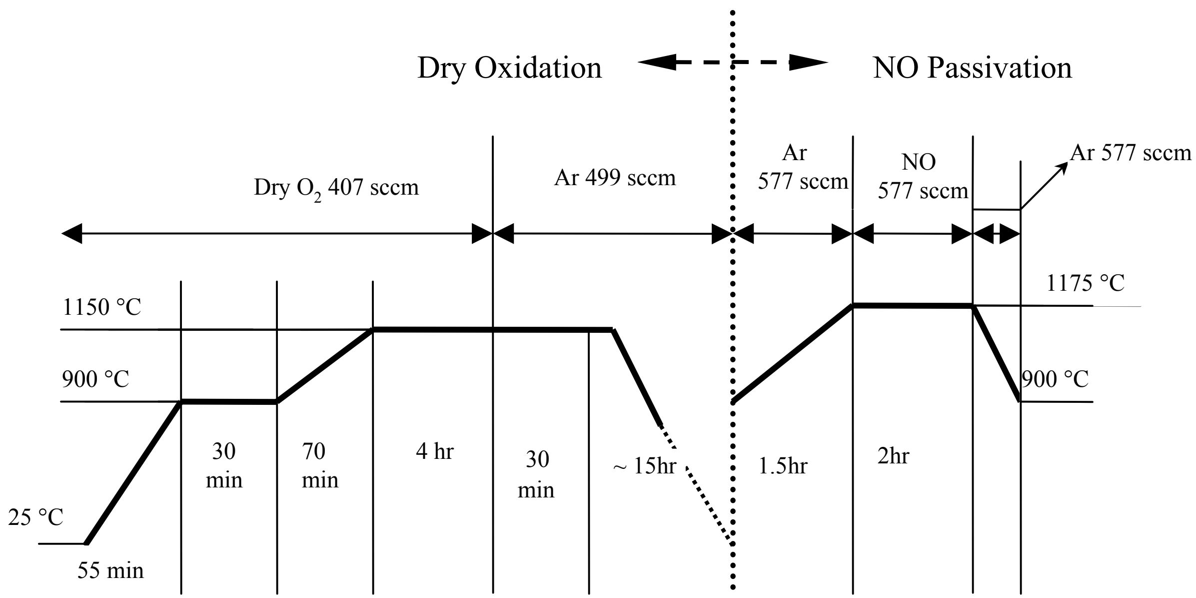
Field effect mobility for dry oxide 4H-SiC MOSFETs fabricated with and without an NO passivation.

Chung GY et. al, IEEE Elec. Dev. Lett, vol. 22, pp. 176-178, 2001

Fabrication of SiC MOS



Oxidation/Annealing

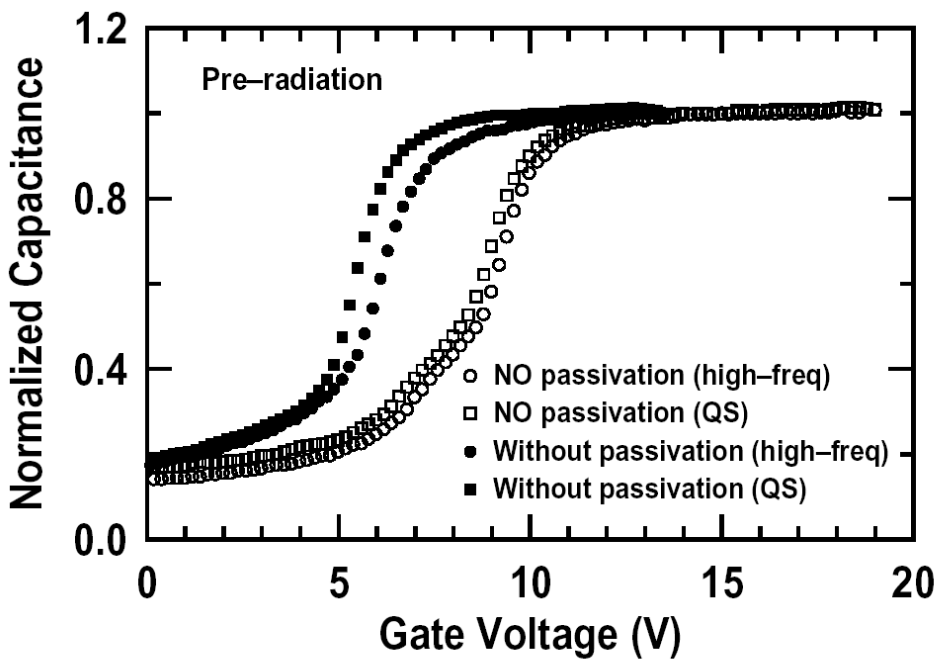


CV Result

CV Theory

$$Q_{OX} = C_{OX}\left(W_{MS} - V_{FB}\right)$$

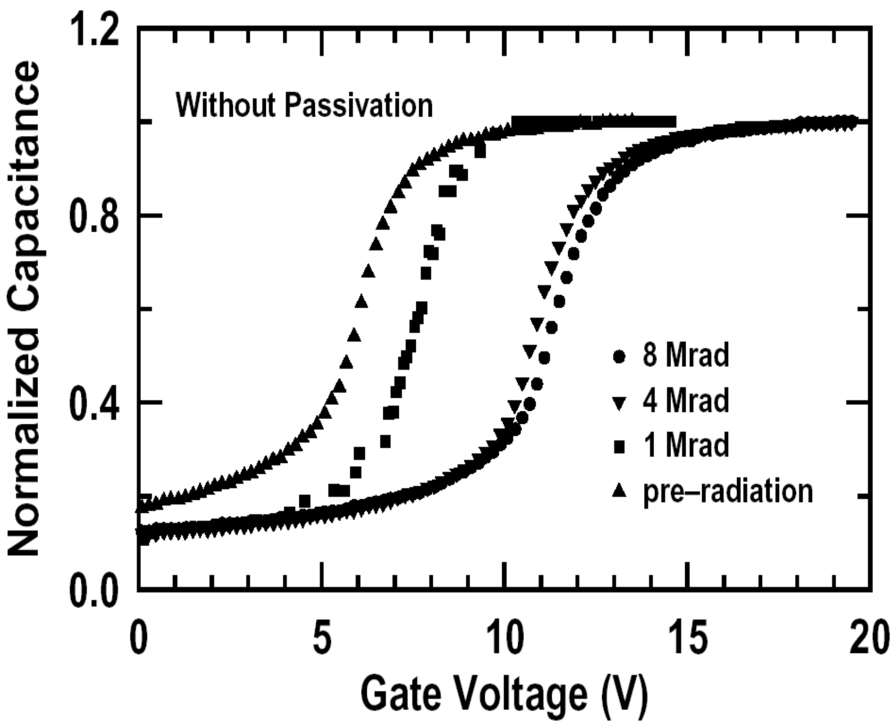
$$D_{it} = \frac{1}{q}\left[\left(\frac{1}{C_{QS}} - \frac{1}{C_{OX}}\right)^{-1} - \left(\frac{1}{C_{HF}} - \frac{1}{C_{OX}}\right)^{-1}\right]$$

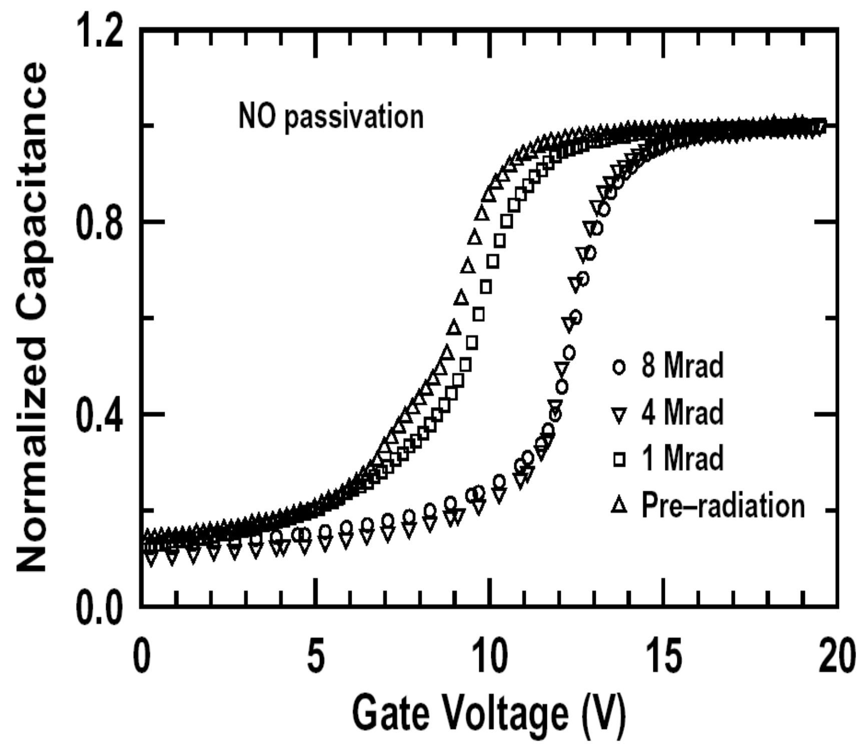


Pre-radiation C-V characteristics of SiO_2/SiC MOS capacitors both with and without NO passivation.

CV Results (cont.)

CV versus irradiation dose





Oxide Charge

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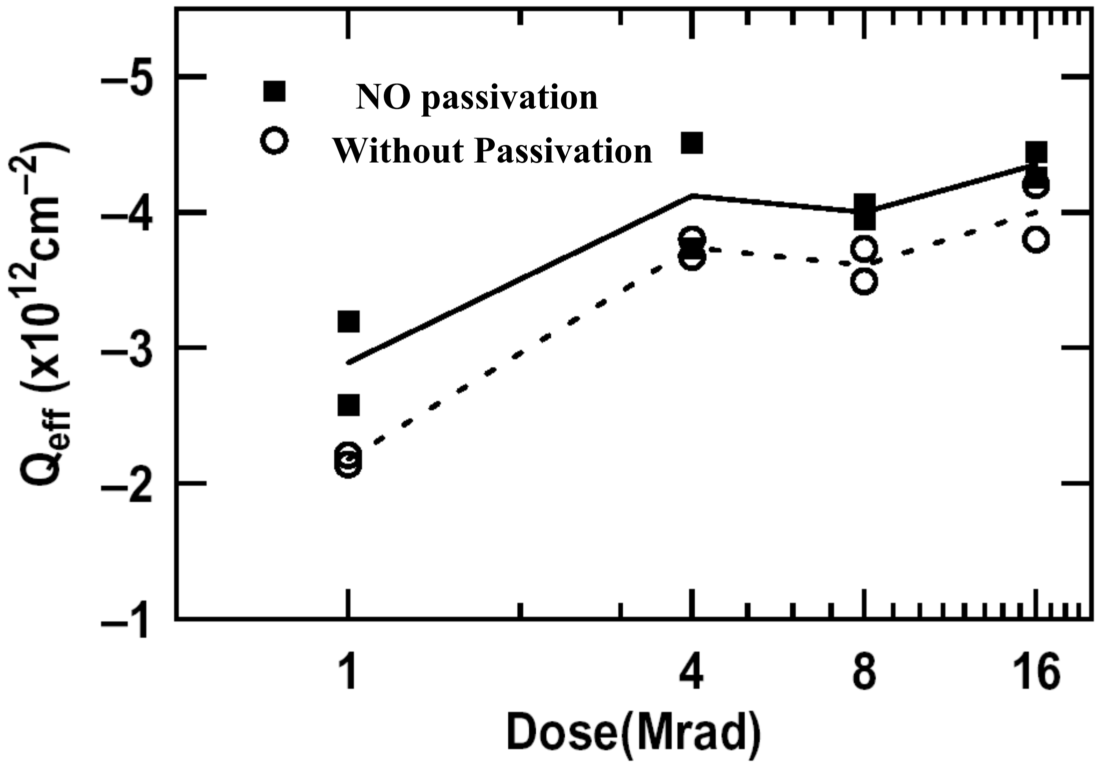
- Q_{eff} increases with irradiation dose
- Q_{eff} increases after NO passivation



Interface defect Density

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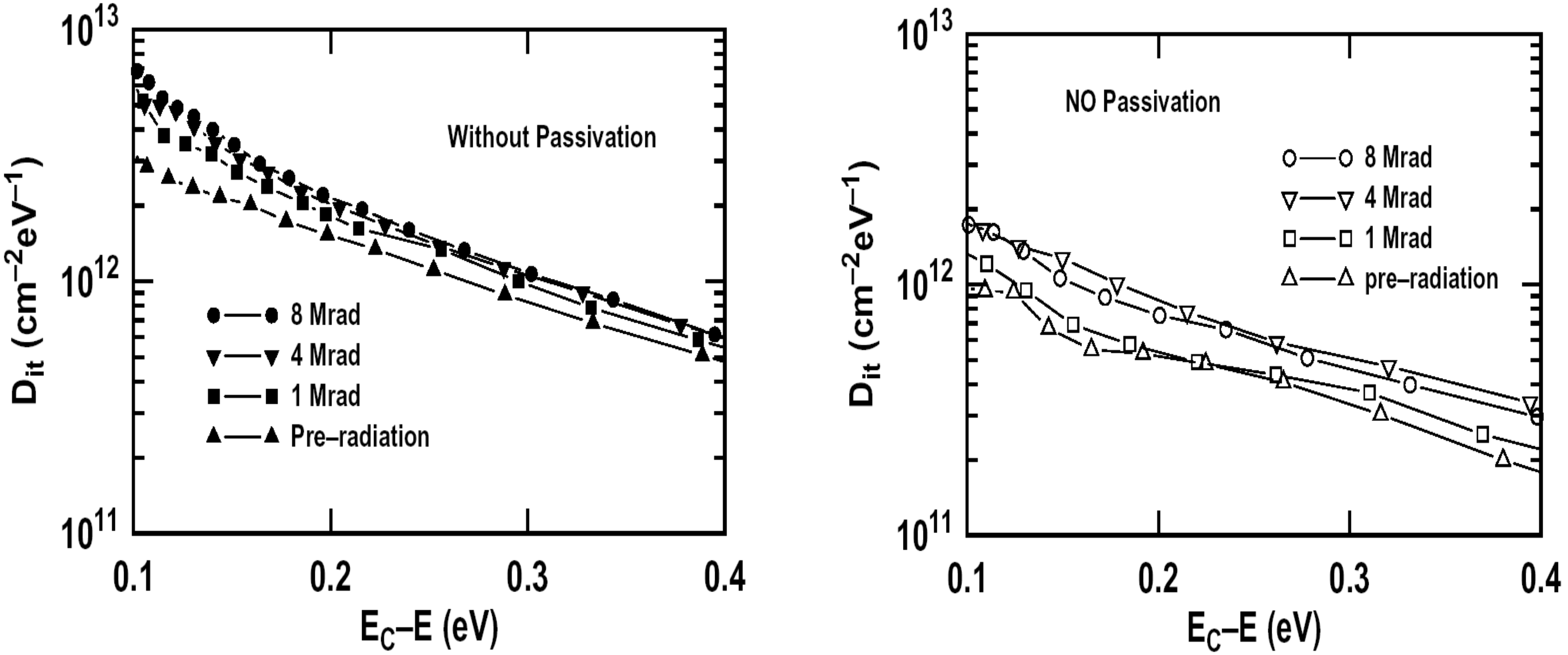
- D_{it} increases slightly with irradiation dose
- D_{it} decreases dramatically after NO passivation



D_{it} Results (cont.)

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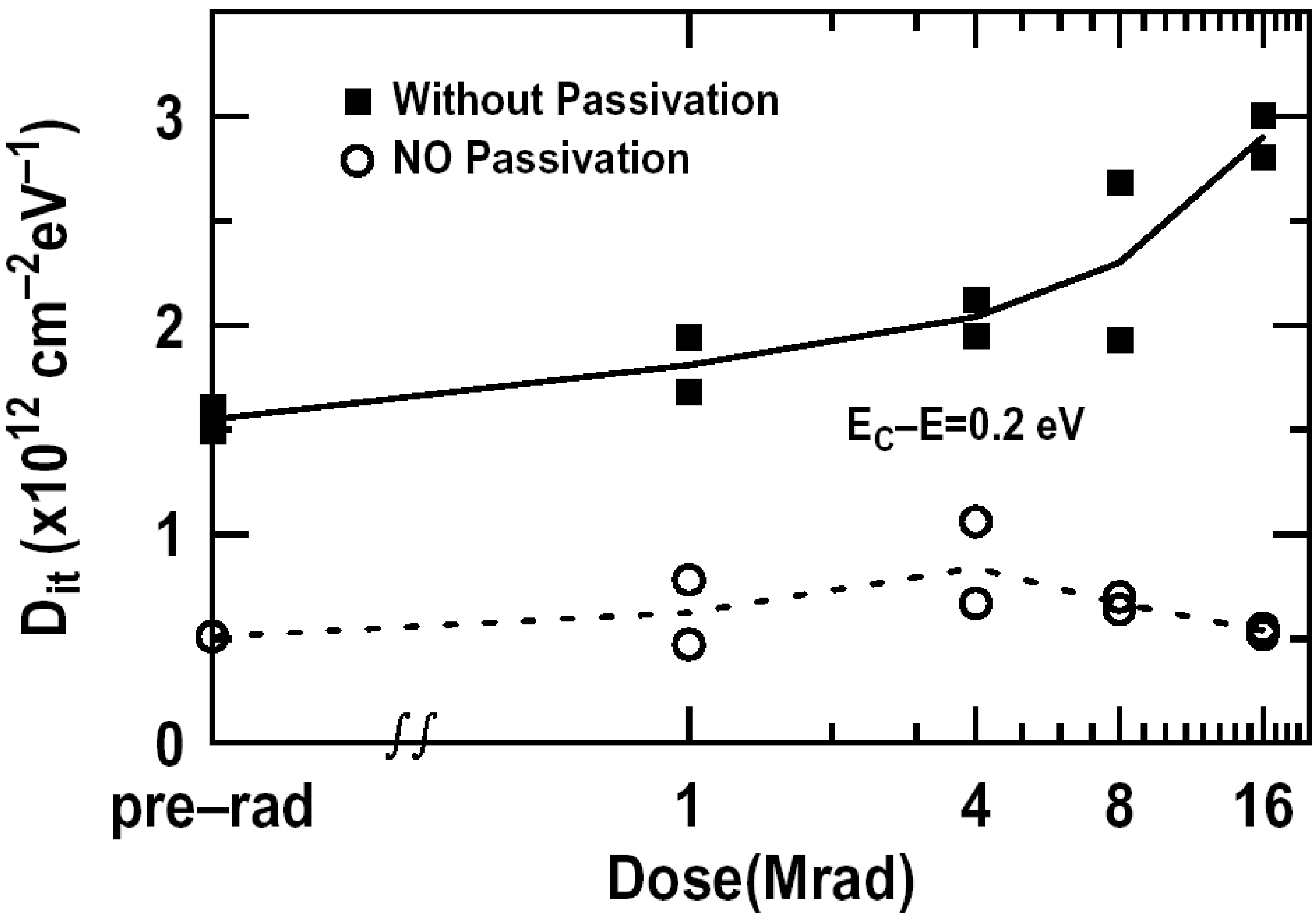
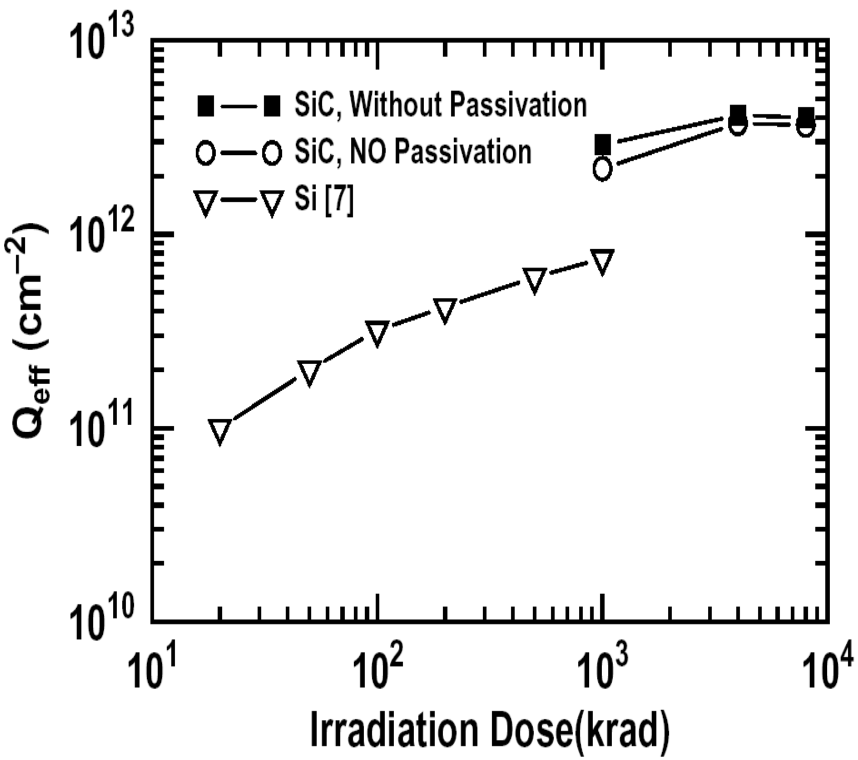
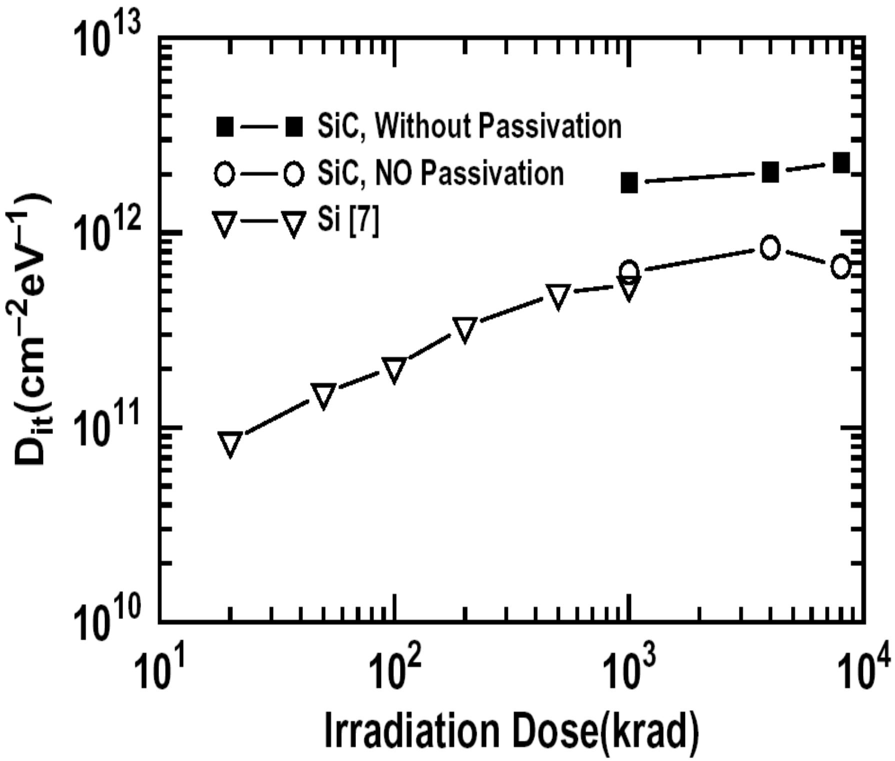
- D_{it} decreases by 3~4x after NO passivation



Compare with Si Tech

- Q_{eff} much higher than Si MOS capacitor
- Comparable D_{it} after proper NO passivation





Open Issues

- CV data only offer information about net charge!

  -----TSC (thermally stimulated current)

- How to decrease those interface defects?

  -----EBIC (electron beam introduced current)

  -----DLTS (deep level transient spectroscopy)

Summary

- NO passivation increase Q_{eff} slightly while decrease D_{it} by 3~4x
- Q_{eff} increases with irradiation dose and saturate after 4 Mrad, independent of the passivation
- D_{it} increases with irradiation dose and saturates only for NO passivated SiC MOS capacitor