# Charge Trapping Properties of 3C- and 4H-SiC MOS Capacitors with Nitrided Gate Oxide

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# Overview

- Objective
- Motivation
- Introduction
- Experimental
- Results
- Discussion

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# Objective

- Effect of ionizing radiation on 4H- / 3C- SiC MOS capacitors.
- Charge trapping comparison of oxides with nitridation using two nitridation agents (NO, $N_2O$)
- Charge trapping for 3C and 4H substrates
- Electric field, Bias temperature, dose dependence



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# Motivation

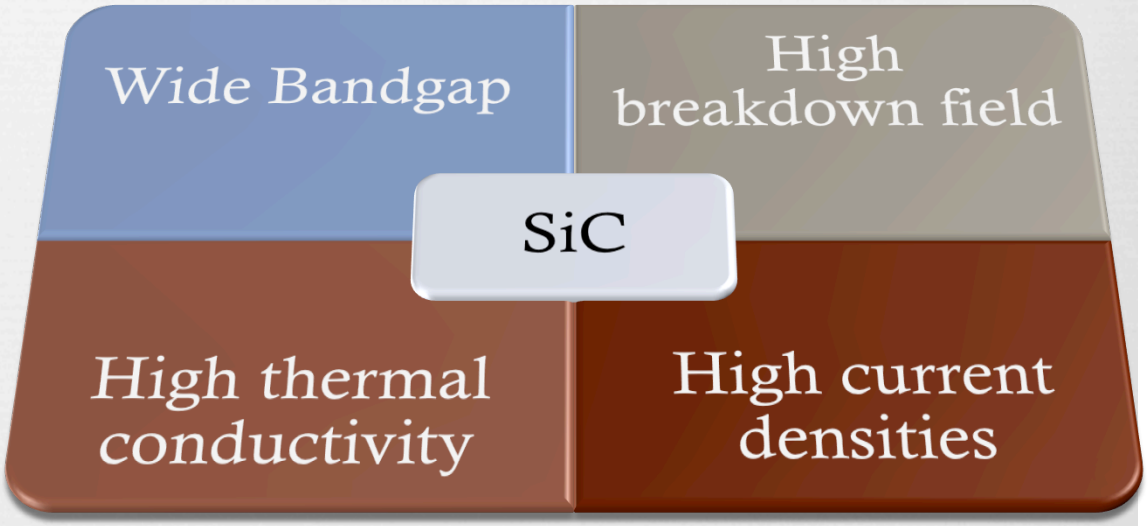
Space missions - Electronic switches and circuits

High power and high temperature systems

Concerns: Weight, efficiency and reliability

**~ 2.0 MV cm$^{-1}$**

**$E_g$ ~ 3.23 eV at RT**




**~ 4.5 Wcm$^{-1}$s$^{-1}$**

Only compound semiconductor whose native oxide is $SiO_2$



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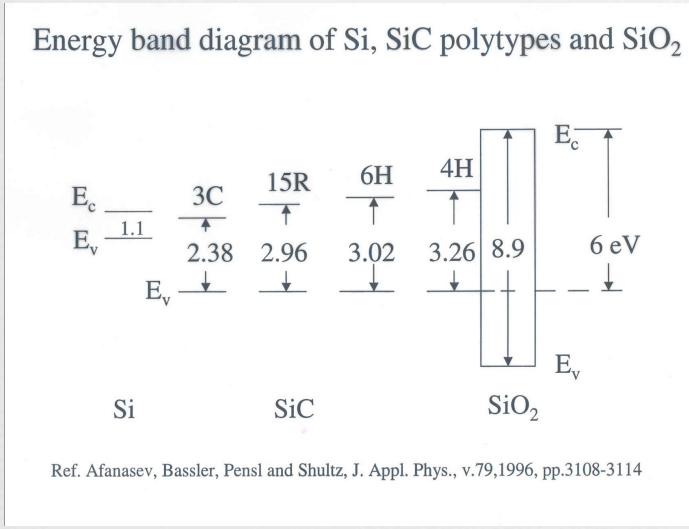
# Introduction

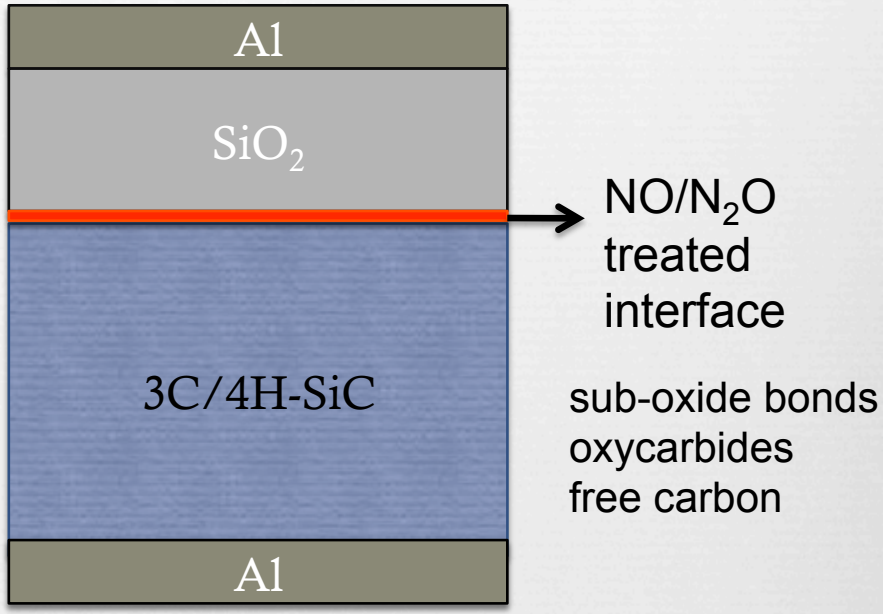
- Thermal oxidation of SiC
- $SiO_2$/SiC interface is different from $SiO_2$/Si
- Hydrogen treatment not effective, nitridation effective

Close to CB edge:

$D_{it} \sim 10^{13}\ cm^{-2}\ eV^{-1}$ ---> as-oxidized

$D_{it} \sim 10^{12}\ cm^{-2}\ eV^{-1}$ ---> nitrided




- NO is toxic, $N_2O$ is not
- 3C-SiC is grown on Si substrates



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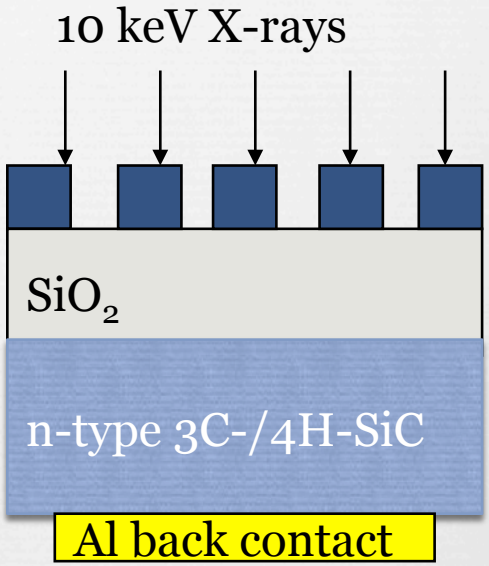
# Experimental

Irradiation:

10 keV X-rays, RT radiation

31.5 krad($SiO_2$)/min dose rate

- Function of dose
- Function of positive bias [~0.8 MV/cm, ~1.5 MV/cm]




Characterization:

- Stress-characterize-stress routine
- *C-V*, *I-V*, $D_{it}$-*E*



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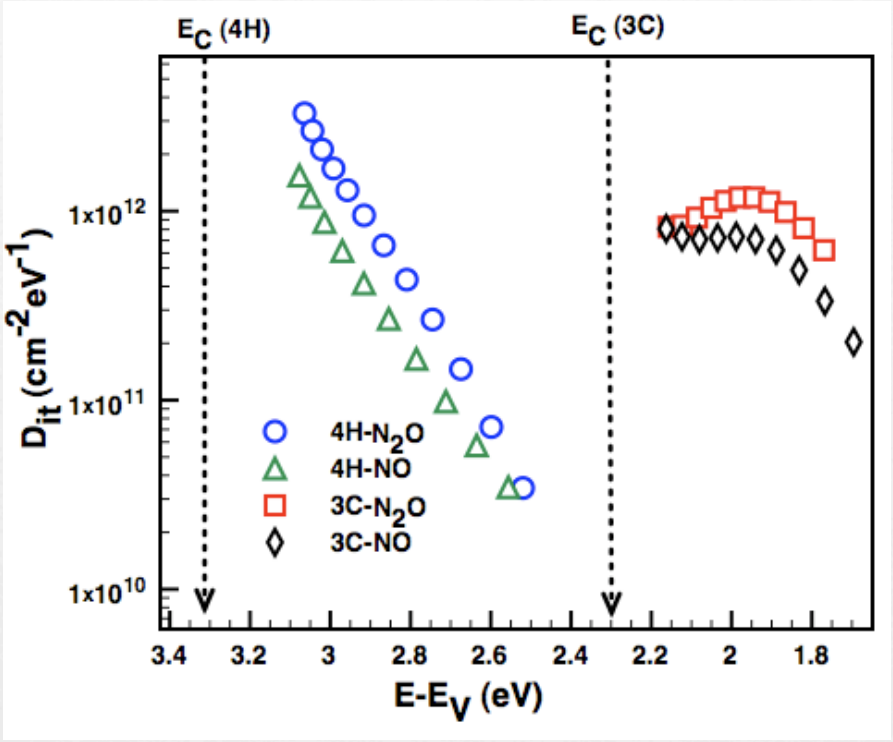
# Interface trap density




$N_2O$ treated oxides have greater interface trap density than NO treated on both 3C- and 4H-SiC

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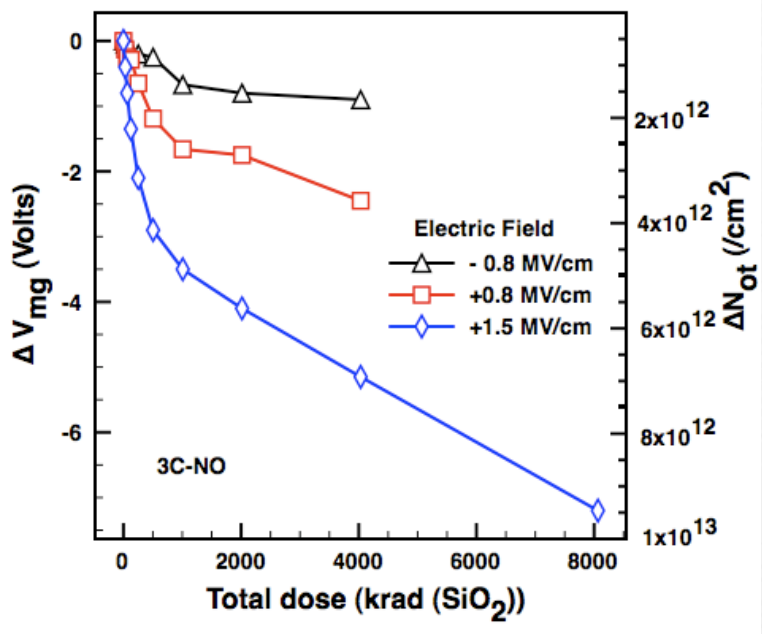
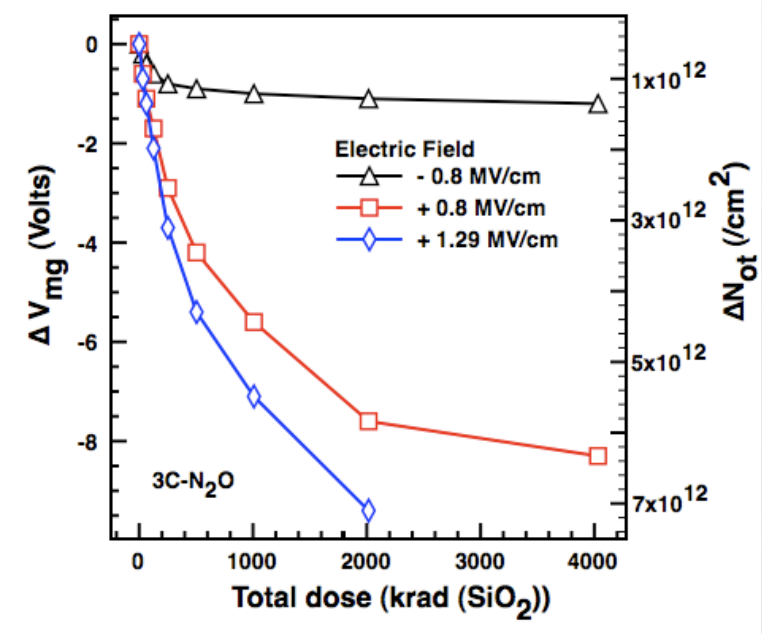
# Midgap voltage shifts – 3C-SiC




3C-NO




3C-$N_2O$

Consistent trend (a linear increase followed by saturation)



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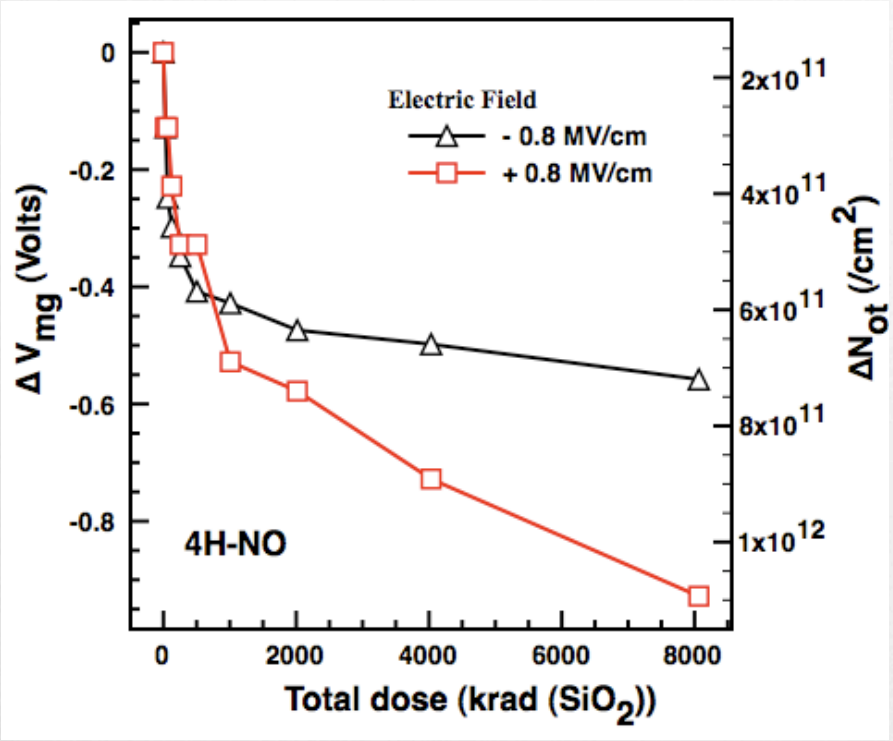
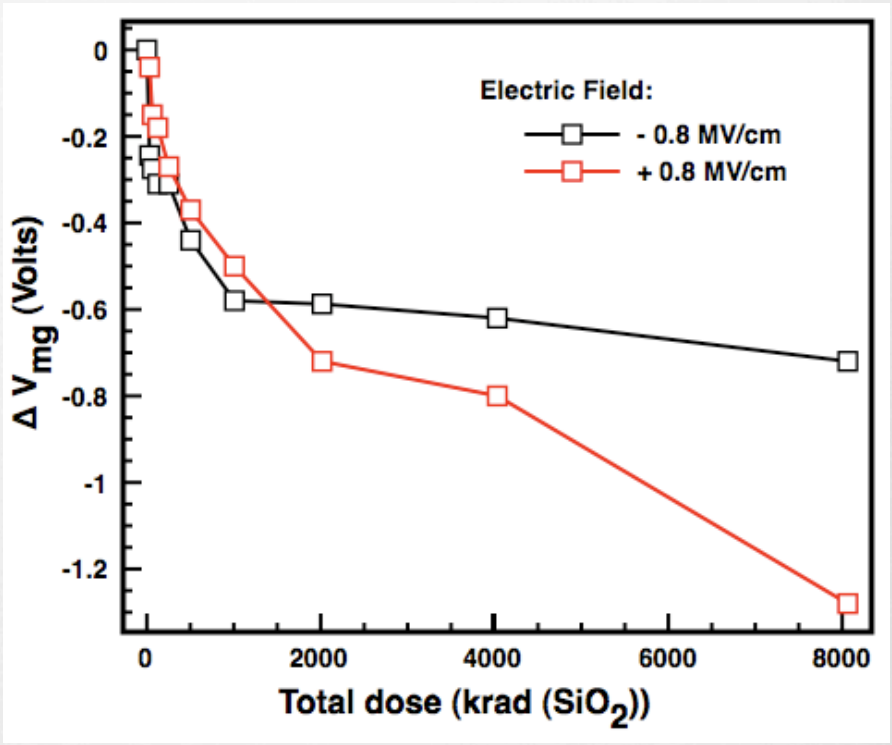
# Midgap voltage shifts – 4H-SiC




4H-NO




4H-$N_2O$



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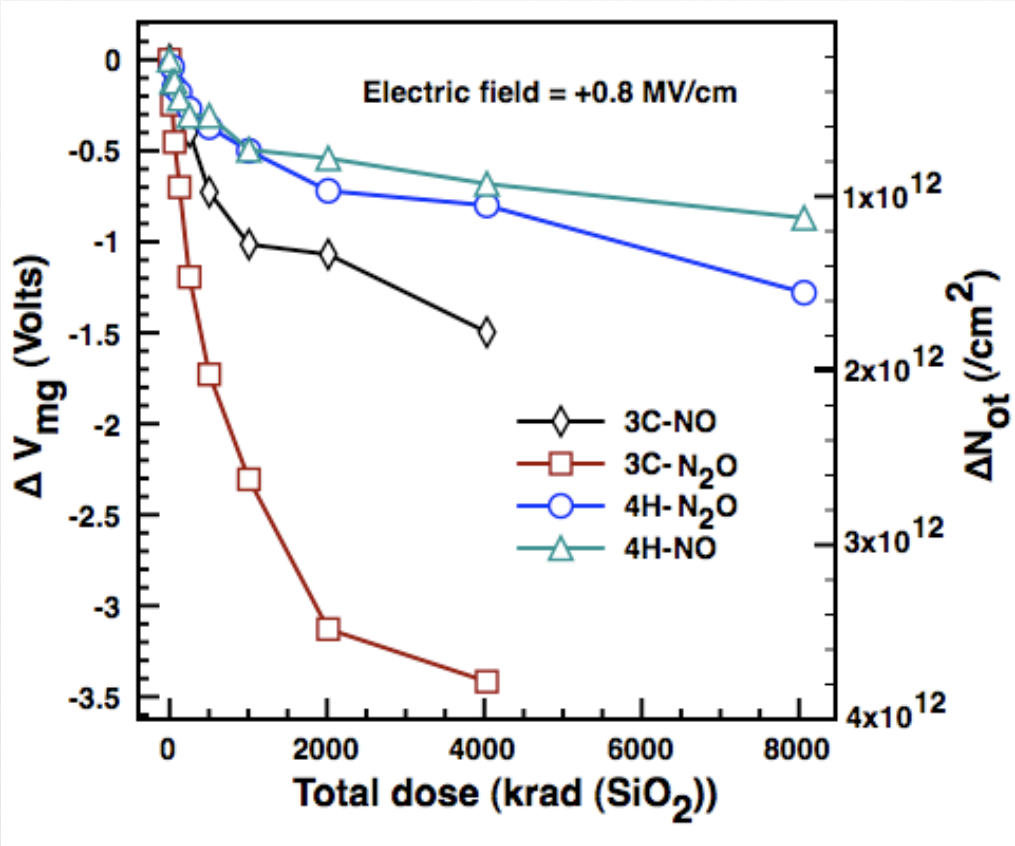
# Comparison




✧ Greater charge trapping for $N_2O$ treated oxide than for NO treatment.

✧ Greater charge trapping for 3C- than 4H-SiC substrate

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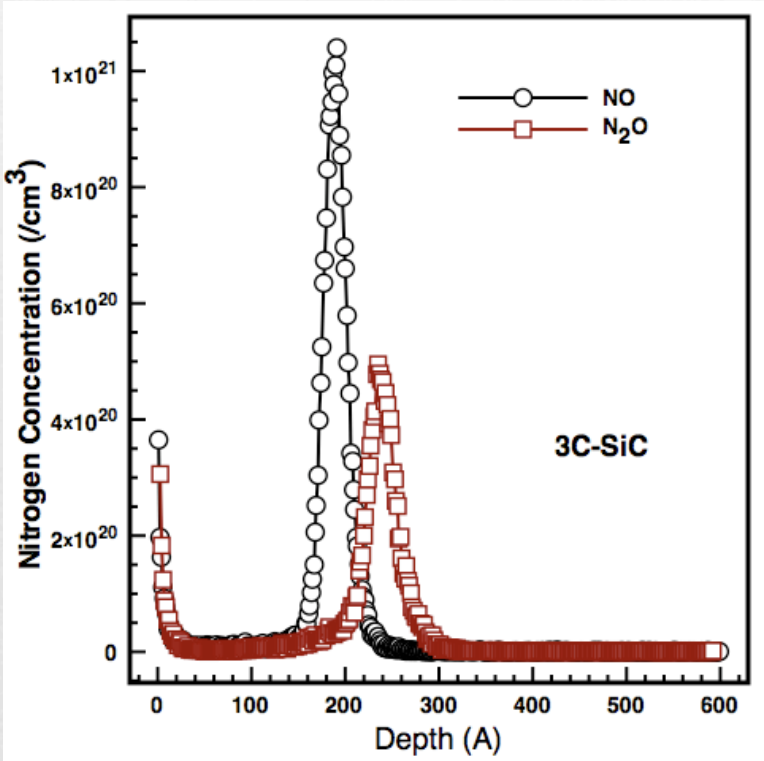
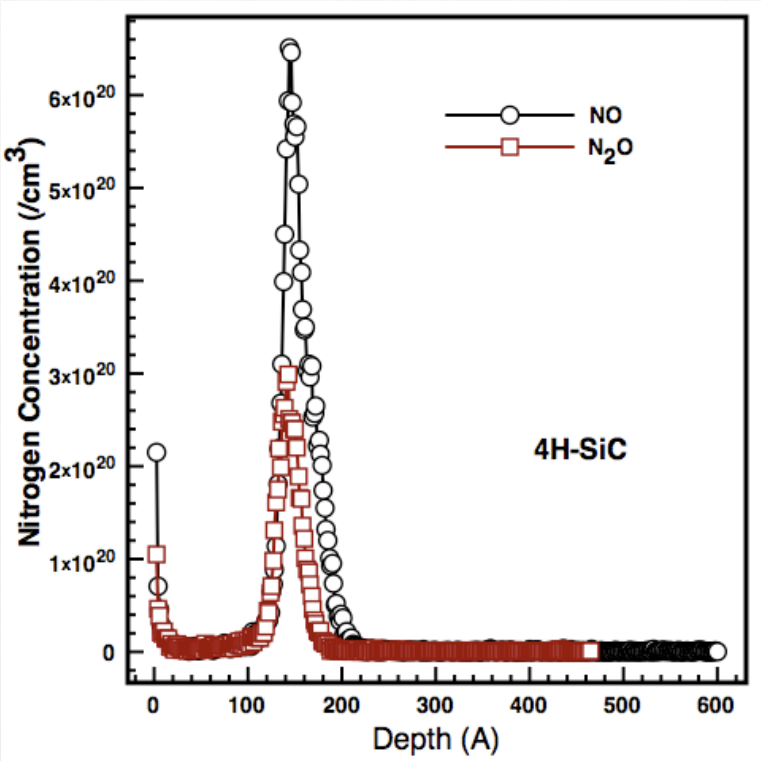
# Nitrogen SIMS profiles




NO treated oxides deposit greater nitrogen content at the $SiO_2$-SiC interface for both 3C- and 4H-SiC MOS capacitors.

Objective Motivation Introduction Experimental Results Discussion

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# Mechanisms

✧Why nitridation helps in decreasing interface/ oxide trap densities:

- creates strong Si≡N bond that passivates interface traps due to dangling and strained bonds
- passivates carbon related interface traps, removes interstitial carbon and complex silicon-oxycarbon bonds

✧ Mechanism behind greater charge trapping for $N_2O$ treated oxides:

- more efficient removal of interfacial carbon clusters for NO as compared to $N_2O$
- $N_2O$ upon dissociation creates $O_2$ which generates additional carbon.



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# Conclusions

- Oxides grown on 3C-SiC trap more charge than those grown on 4H-SiC.
- $N_2O$-annealed oxides trap more charge for both 3C- and 4H-SiC substrates than do the NO-annealed oxides.
- NO treatments deposits greater nitrogen content at $SiO_2$-SiC interface then the $N_2O$ treatment.
- $N_2O$ treatment results in greater interface trap densities.

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