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Update on Elevated Temperature Reliability Testing of 1200 V SiC MOSFETs

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Overview

- SiC devices are theoretically superior to Si devices for power electronics applications
  - Wide bandgap and high thermal conductivity
  - Lower power loss and reduced cooling requirements lead to decreased system cost
  - Questions remain about reliability that limit implementation
- Sandia is evaluating the gate oxide reliability of several different 1200 V SiC MOSFETs under a variety of bias-temperature stress conditions

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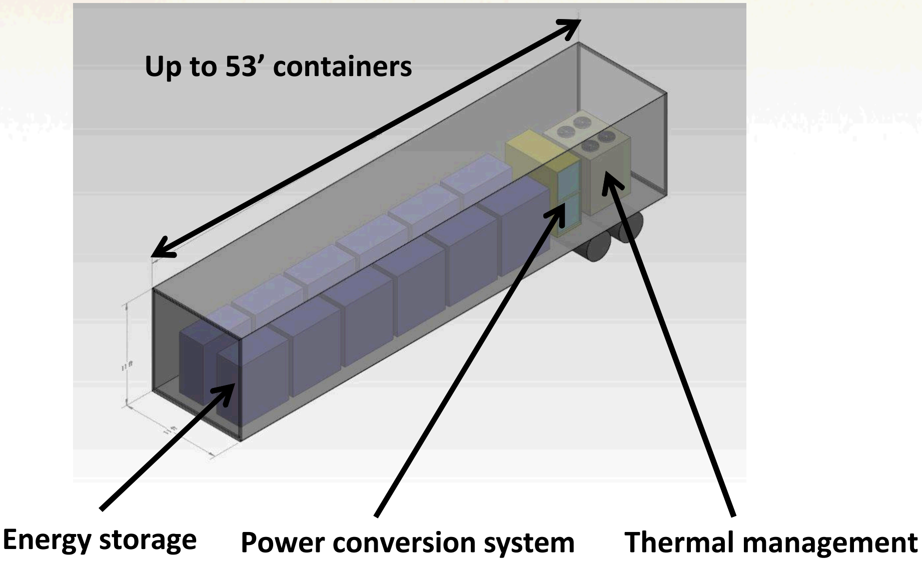
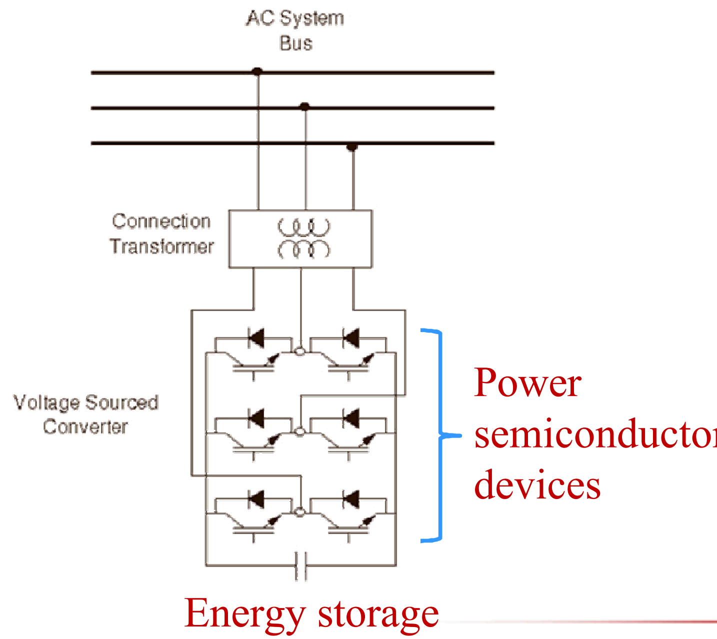
Example of Motivation for WBG Power Electronics: Portable Energy Storage



Typical Applications

- Grid stabilization
- Frequency regulation
- Renewable integration
- Peak shaving
- Voltage support



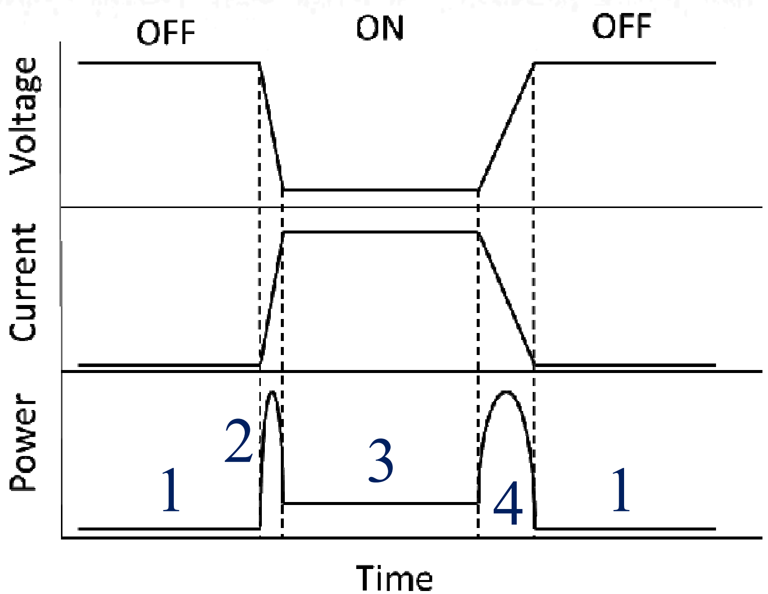
Benefits of portable storage

- Low installation cost
- Short time from installation to operation
- System is optimized for use at multiple sites

Typical portable power conversion system

- PWM voltage sourced converter
- Silicon-based power electronics
- Water cooled (*complex, bulky, and expensive*)

Potentially Lower Power Loss for SiC Compared to Si



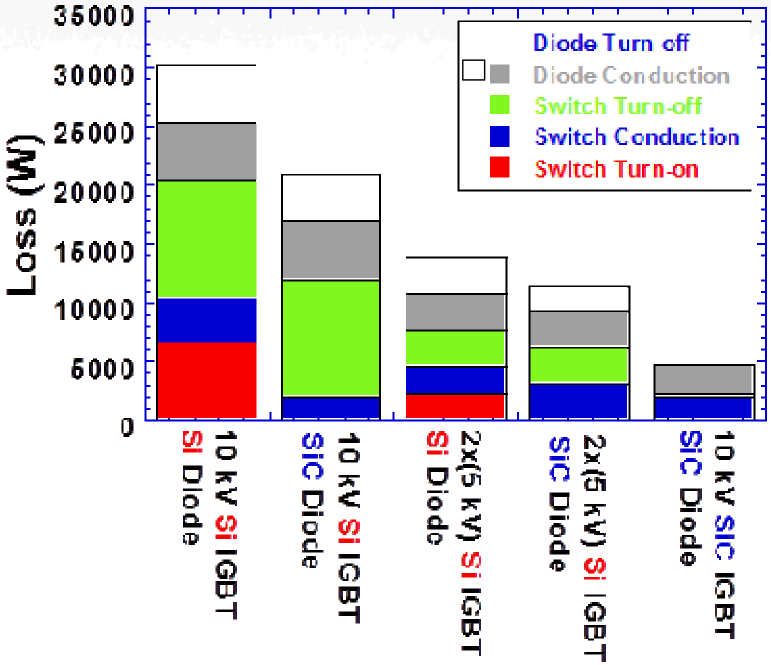


Figure courtesy of Prof. D. K. Schroder, ASU

Power loss mechanisms:

1. Leakage
2. Turn-on
3. Conduction (R_{ON})
4. Turn-off

We have characterized the reliability of several commercially available 1200 V SiC power MOSFETs

Reliability Testing at Sandia

- Bias-temperature stress on commercially available SiC MOSFETs
  - Comparison of plastic and metal packages
  - Junction leakage also evaluated

- Currently testing the 2nd generation of the same devices
  - Negative V_T shifts have reduced
  - Switching gate bias tests performed

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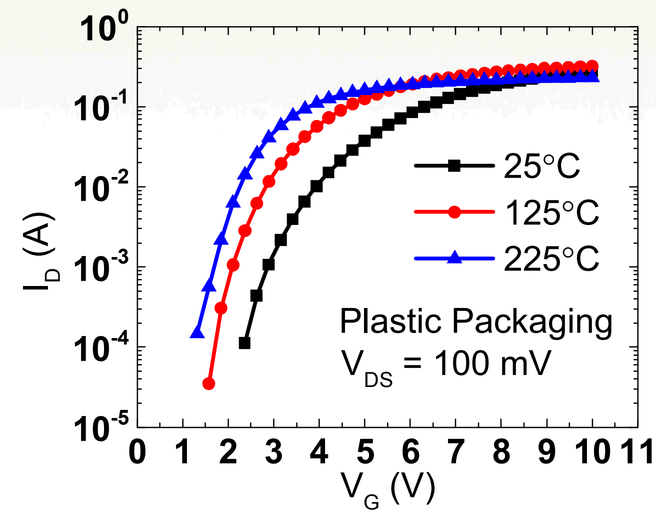
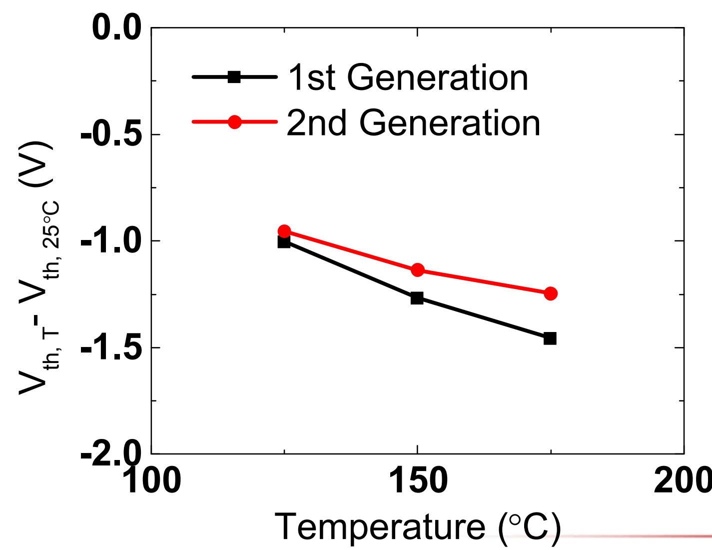
V_T at Elevated Temperatures

- Shifts with temperature more significant than silicon
- At 125°C, V_T decreased by roughly 1 V
  - Potential issues if OFF voltage is 0 V
- 2nd gen parts show small reductions in V_T shifts with temperature
  - May indicate fewer traps





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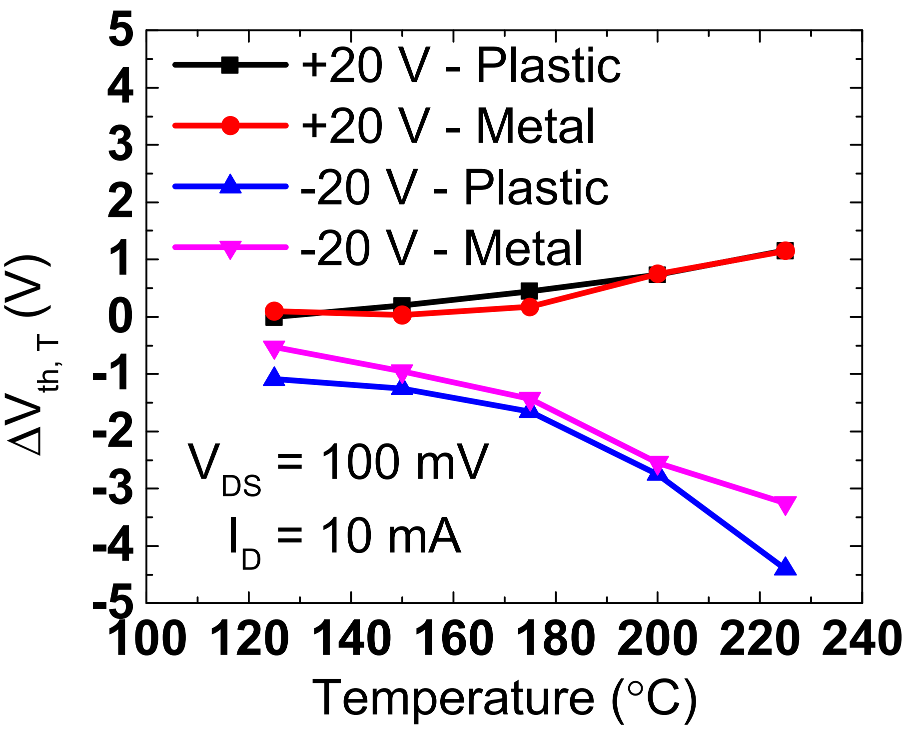
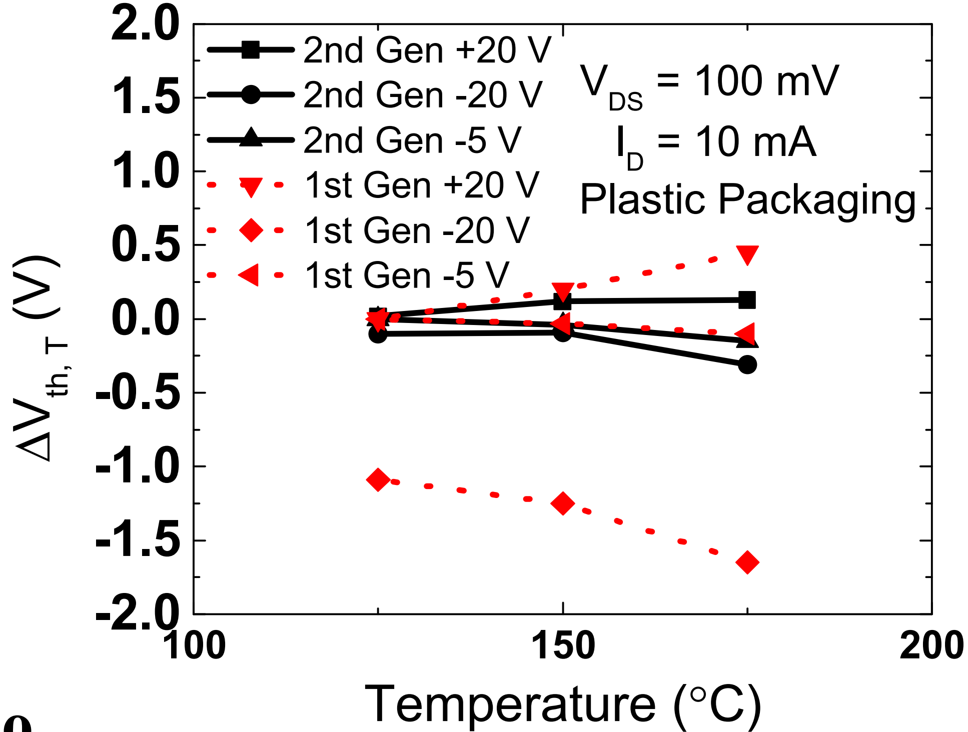
Constant Bias-Temperature Stress – 1st Gen

- 30 minute constant bias stress
  - +20 V, -20 V, and -5 V V_G
  - Plastic packaging rated at 125°C, metal at 225°C
- Packaging appears to have little effect
  - Significantly above 125°C
- V_G of -5 V shows little effect



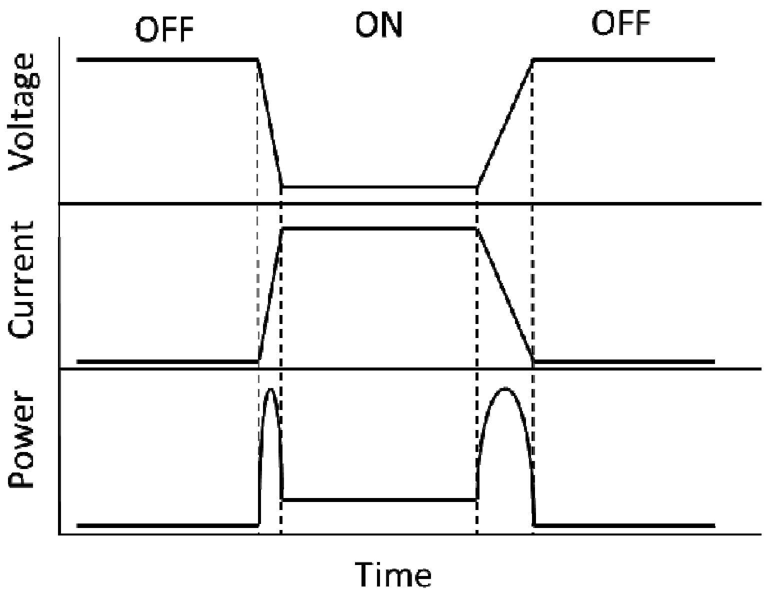
Constant Bias-Temperature Stress – 2nd Gen

- Plastic packaging rated at 150°C
  - Tested up to 175°C
- Significant reductions in negative V_T shift when the gate bias is – 20 V
  - Even above rated temperature
  - Reductions for +20 V also



Switching Gate Bias

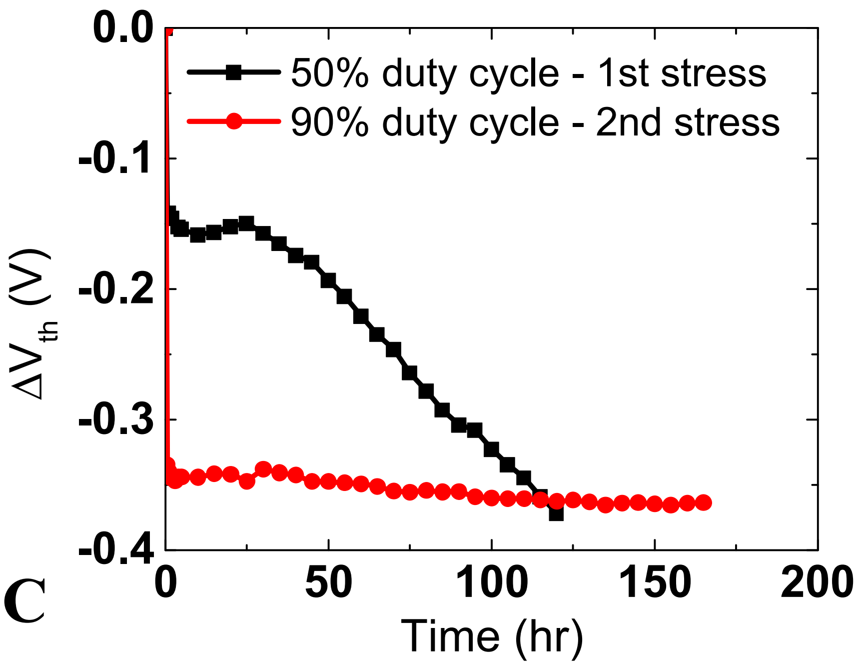
- **A switching gate bias is more representative of real world conditions**
  - **Higher power dissipation due to switching**



- **Previous data has shown different response compared to constant bias stress**

Switching Gate Bias

- +20 V/-5 V, 100 Hz, 150°C
- 50% and 90% duty cycles
- Gradual degradation after ~25 hours
  - -2.5 mV/hr for 50% DC
  - -0.26 mV/hr for 90% DC
  - Negative shift even at 90% DC
- Abrupt shifts after 1st measurement
  - Possible cumulative damage



Conclusions

- Commercially available 2nd generation plastic-packaged SiC MOSFETs show significant reductions in V_T shifts compared to 1st generation devices
  - V_T shifts by only -300 mV using -20 V gate stress at 25°C above the rated temperature
- Switching bias stress shows a rapid V_T shift followed by a gradual V_T shift
  - Gradual shift depends on duty cycle
  - Parts appear to be more sensitive to hole injection when using -5 V to turn the device off
  - Potential cumulative damage

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Questions

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- Programmatic Contact
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