Measurement and Analysis of SiC-MOSFET threshold voltage shift

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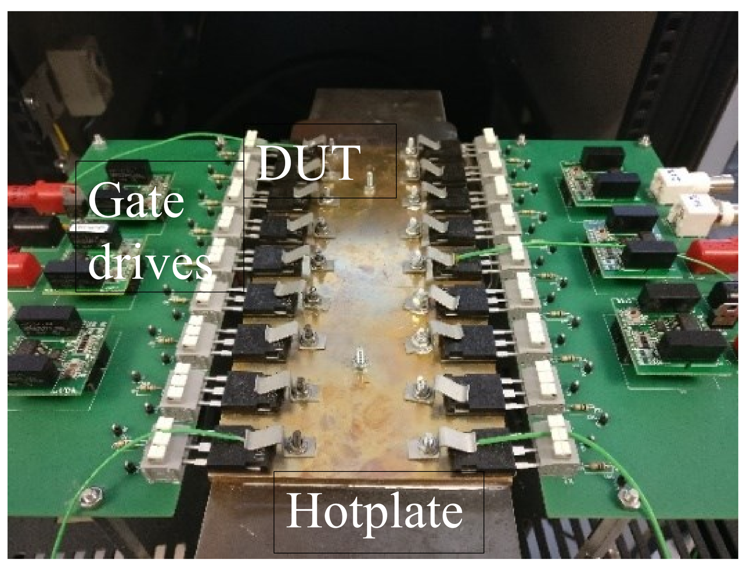
Abstract

Gate-oxide technology weakness is a main reliability issue of Silicon Carbide MOSFET transistors. The threshold voltage shift is a critical phenomenon that addresses the reliability of industrial power applications. It is important to have a better understanding of the phenomena implied in the gate threshold voltage shift. In this context, HTGB test is proposed and the resulting gate oxide stress is studied and discussed in this paper. Complementary testing was performed with HTGS test and gate oxide characterizations, such as the charge pumping technique. The results obtained are used to add insight to the current discussion of SiC MOSFET robustness. Measurement protocols implementation on 1.7 kV 45 mΩ are detailed, which will be useful for the next generation of SiC MOSFET.

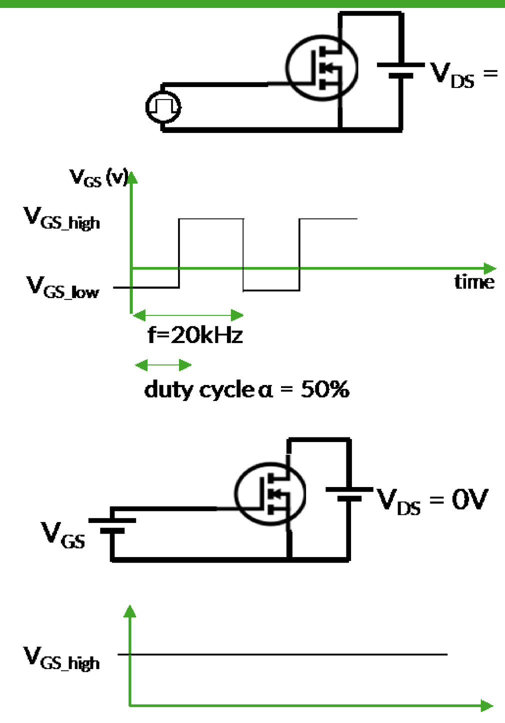
Experimental set-up

- 18 DUT (2 x9)
- Packaged devices
  - TO247
  - Ixys Isoplus i4
- Homogenous temperature on the hotplate



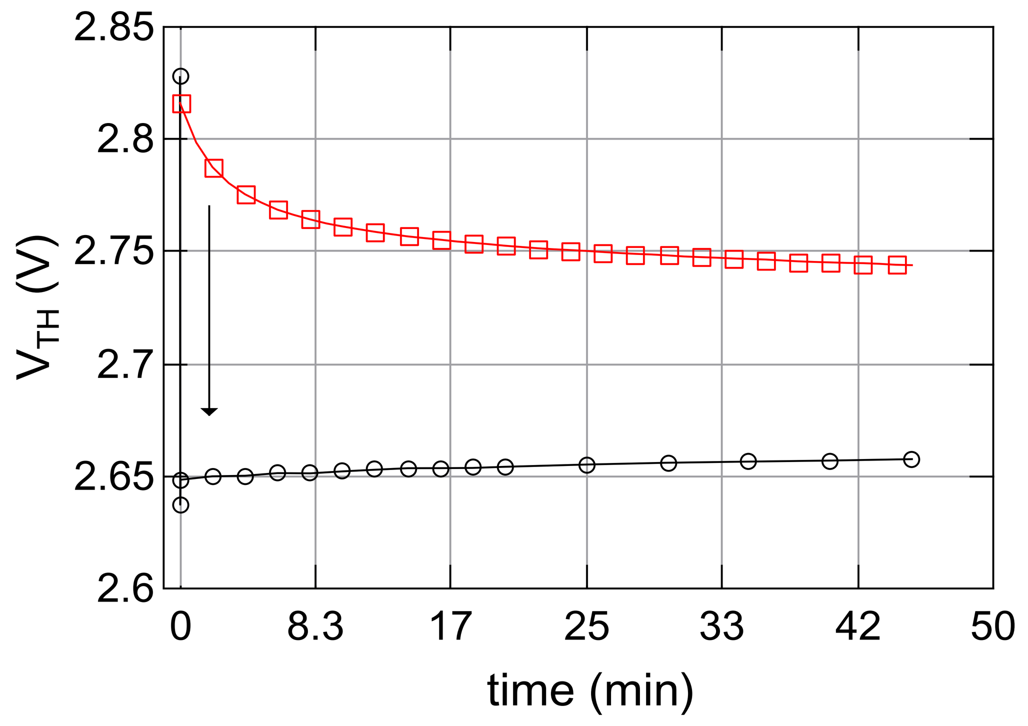
Gate oxyde reliability tests

- High Temperature Gate Bias
  - Static bias between gate and source
  - Maximum operating temperature
  - 1000 h
- High temperature Gate Switching
  - Gate switching conditions
  - Frequency and dutycycle
  - High operating temperature



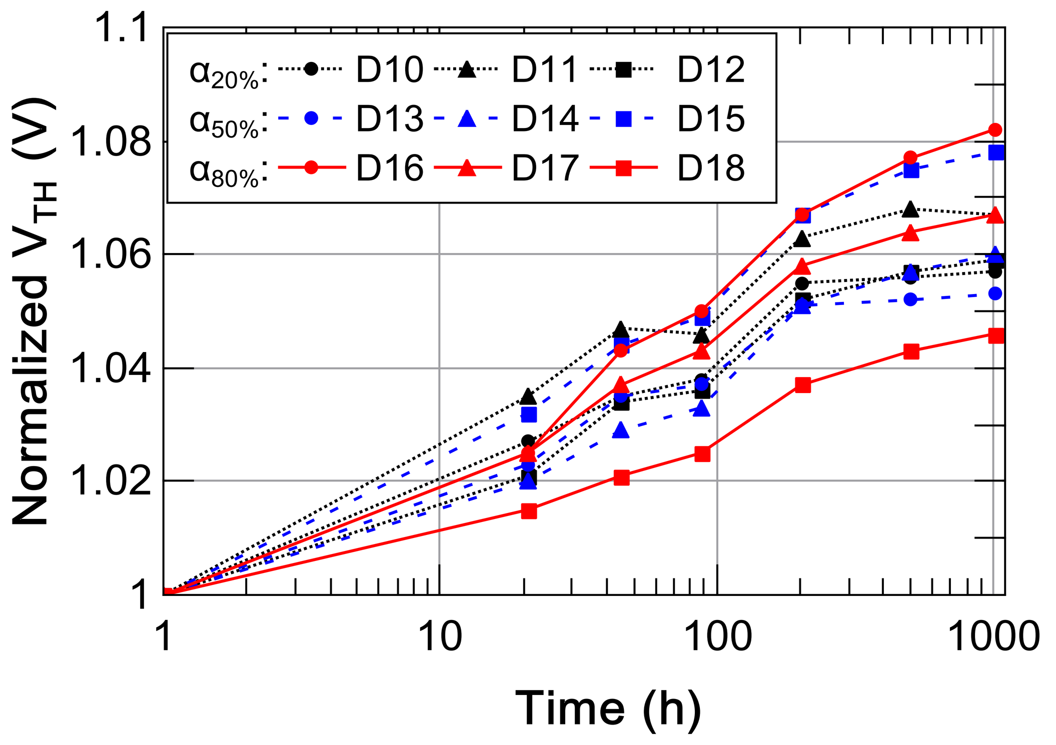
V_{TH} relaxation

- Threshold voltage shift after positive bias
- Measurement protocols : negative bias to get rid of positive shift



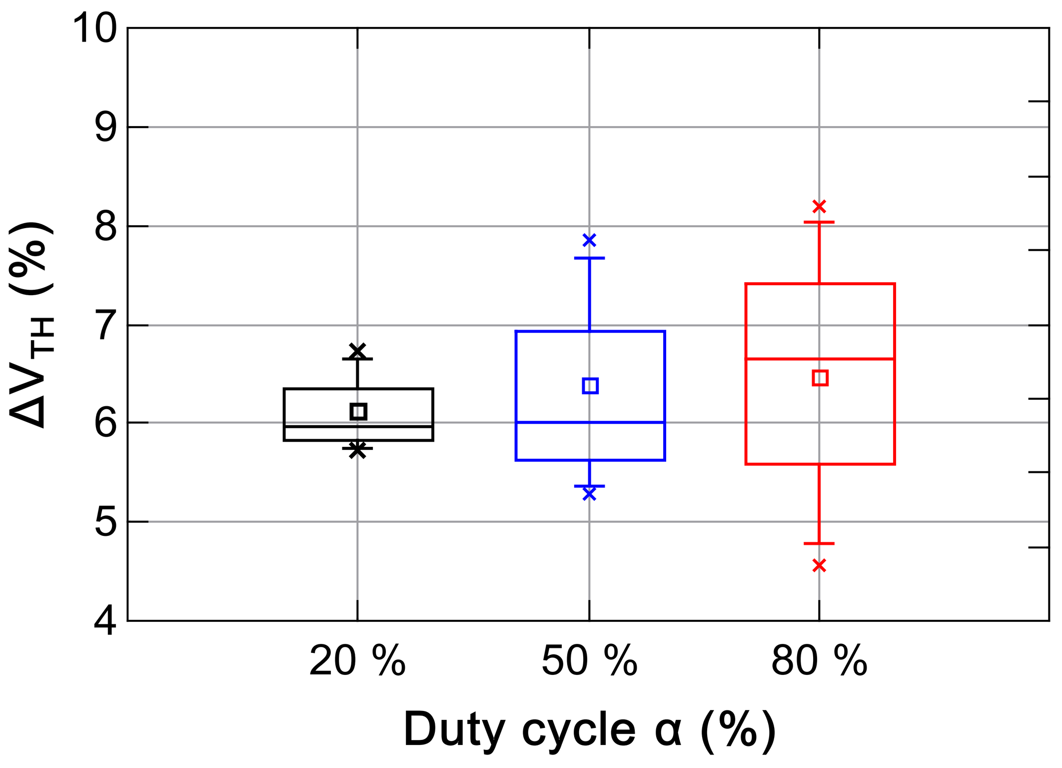
HTGS results 1

- V_{TH} drift during ageing ~170 mV



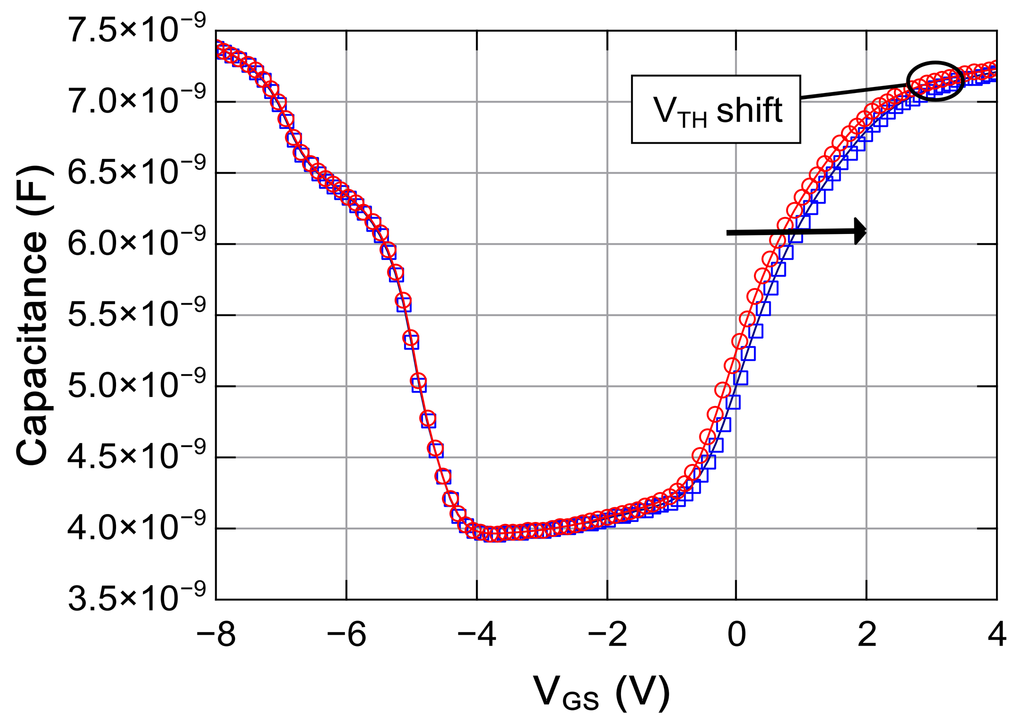
HTGS results 2

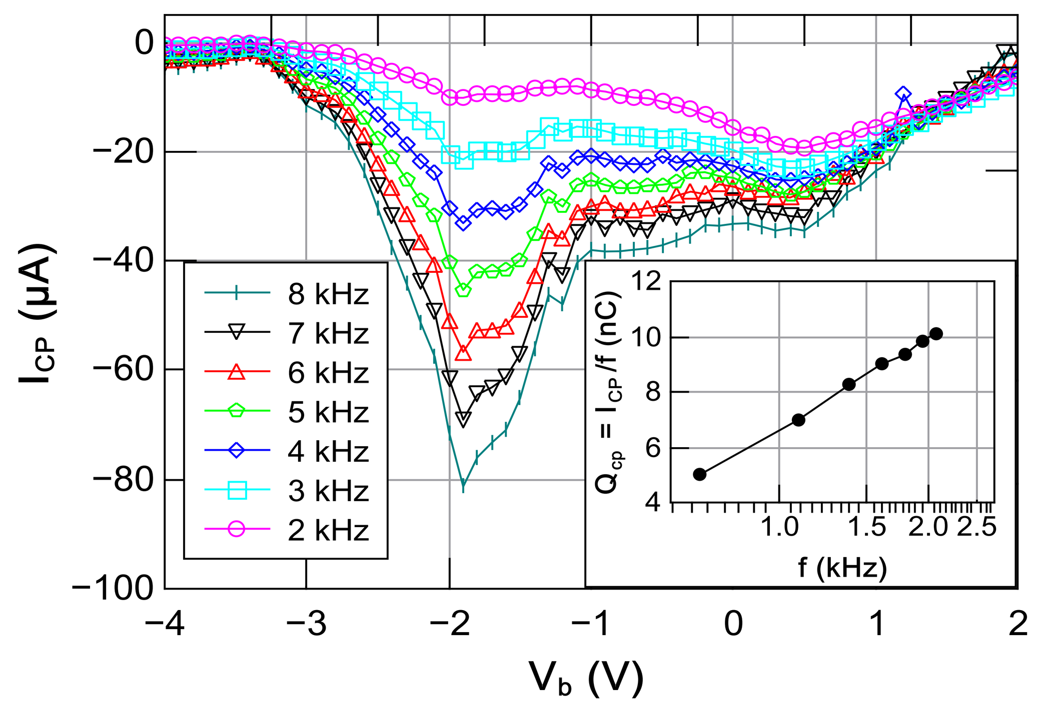
- Duty cycle impact on V_{TH} shift and dispersion
  - 6.1 % for α = 0.2, 6.4 % for α = 0.5, and 7.2% for α = 0.8

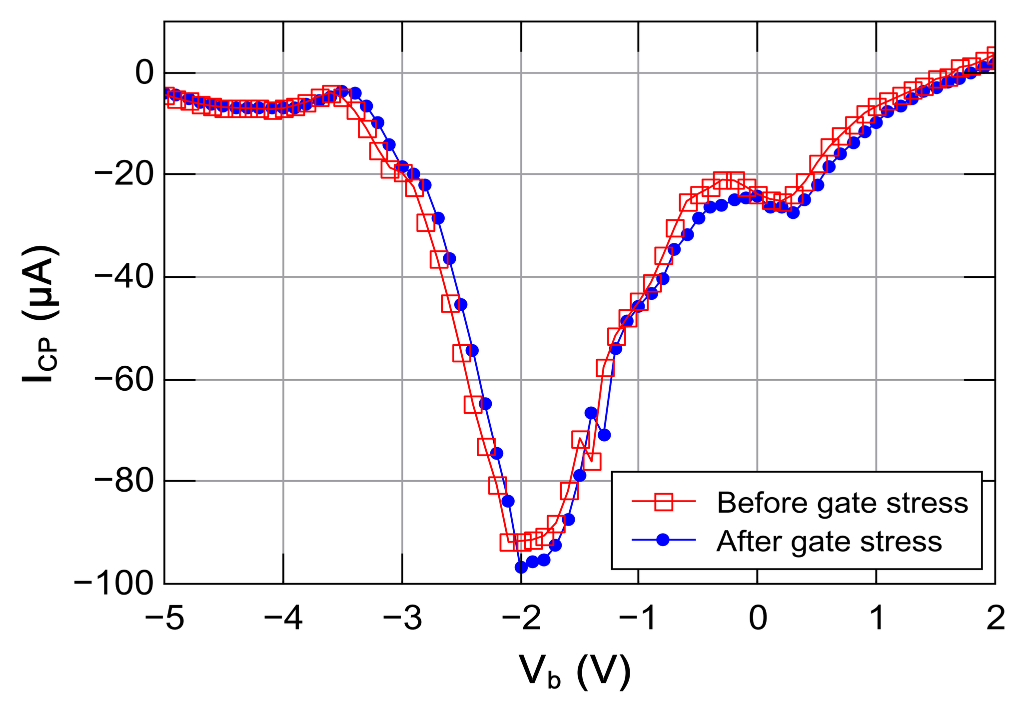


Gate oxyde analysis

- C-V measurement
  - Positive shift: e- injection from the n region under the gate
  - Consistent with V_{TH} positive shift during ageing
- Charge pumping measurement
  - Three terminal configuration
  - Pumped current is not increasing but shifting towards positive value
  - Trapping of negative charge confirmed







Conclusions

- HTGB and HTGS scenarii both show positive shift
  - Investigation completed with C-V and three terminal charge pumping measurements.
  - Injection of e- from n source region into the oxide
- Enhanced measurement protocols
  - Getting rid of the V_{TH} relaxation phenomena
  - Remaining shift is definitive
- Perspectives
  - TCAD modelisation of the trapping effect

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