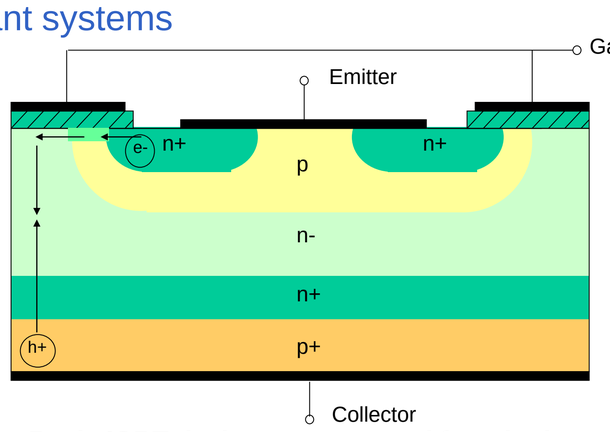
National Aeronautics and Space Administration

Prognostics for Electronics

Jose Celaya[1], Sankalita Saha[2], Phil Wysocki[3], Kai Goebel[4]
[1]Stinger Ghaffarian Technologies Inc., [2]Mission Critical Technologies, [3]ASRC Research and Technology Solutions,
[4]NASA Ames Research Center CA

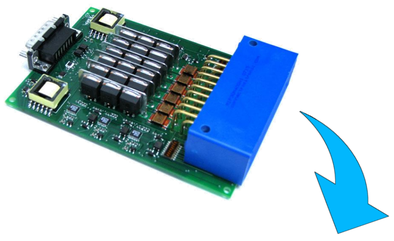
Motivation

- Electronic components have an increasingly critical role in on-board autonomous functions for vehicle controls, communications, navigation, and radar systems. Future aircraft systems will rely more heavily on electric and electronic components
- To obtain an understanding of the behavior of deteriorated components, as well as the capability to anticipate failures and predict the remaining life of embedded electronics
- Investment in prognostics technologies can enable risk mitigation and increase reliability, while lowering cost for redundant systems

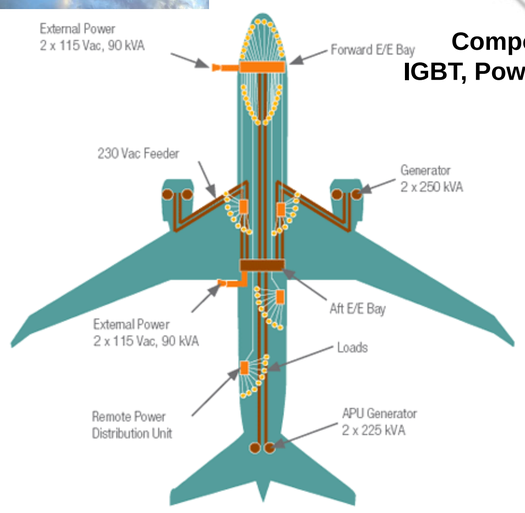


Basic IGBT device structure and functioning

LRU: Power Controller



Components: IGBT, Power MOSFET



System: Aircraft

Images courtesy of Boeing

Objectives

- Identify new and unexplored fault modes and failure mechanisms
- Identify precursors of failures in faulty components
- Discover physics-of-failure models of the degradation process
- Predict the remaining useful life of components and embedded electronics based on physics-of-failure models and identification of precursors of failures

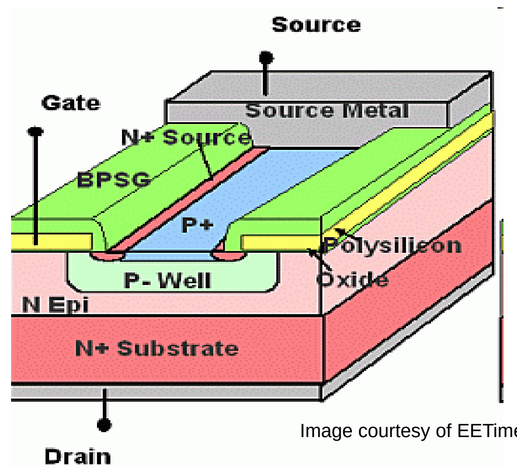


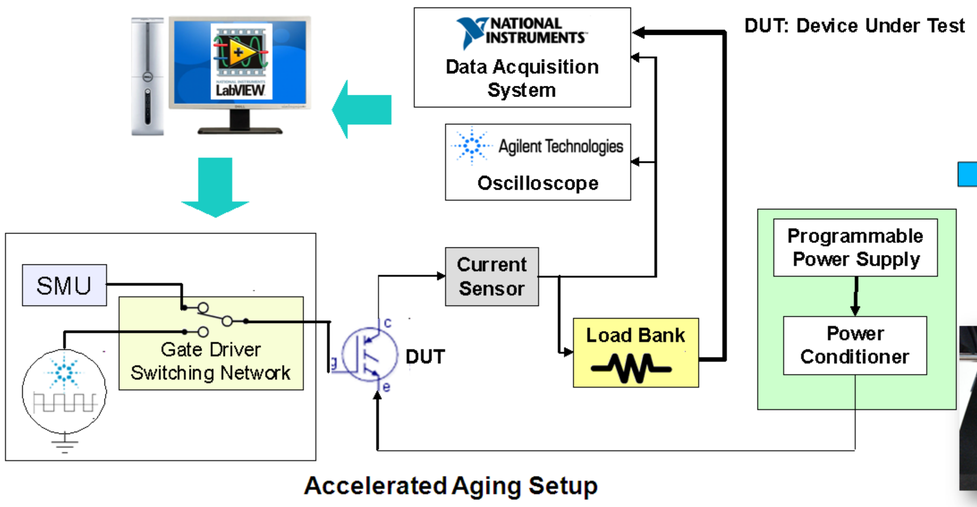
Image courtesy of EETimesAsia

3D power MOSFET device structure

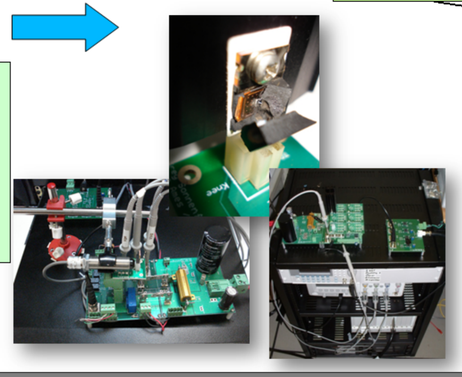
Methodology

Aging and Characterization System

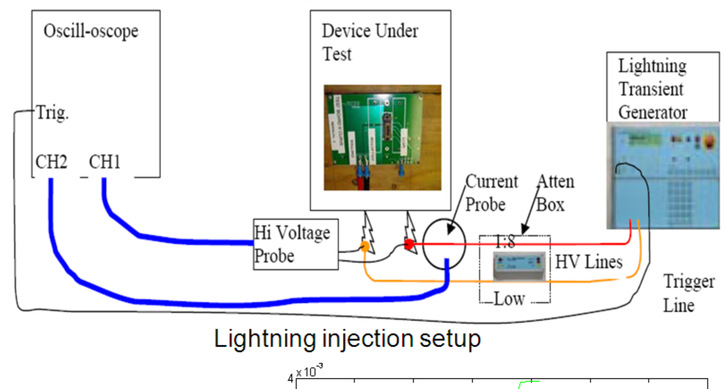
- Enables aging and characterization of gate-controlled power transistors
- Supports thermal cycling, dielectric over-voltage, acute/chronic thermal stress, and current overstress
- Allows in-situ state monitoring, including measurements of the steady-state and transient voltages and currents, and thermal transients at varying gate and drain voltage levels



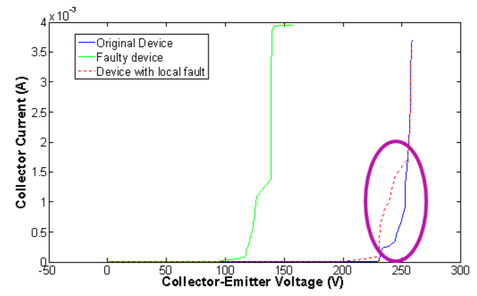
Accelerated Aging Setup

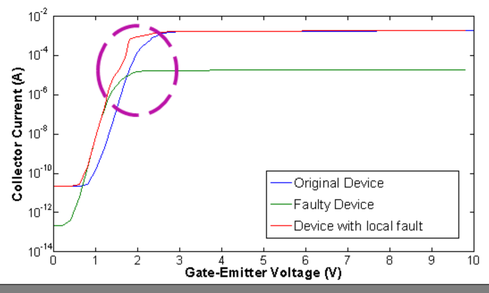


Aging with pre-seeded faults



Lightning injection setup





ESD stress test results

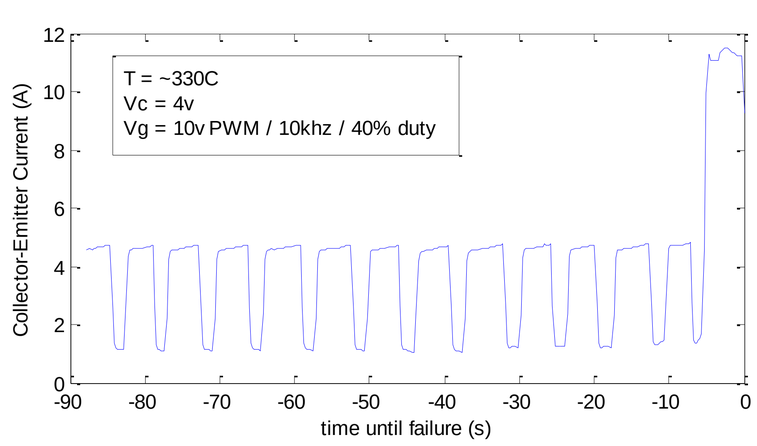
Results

Experiments

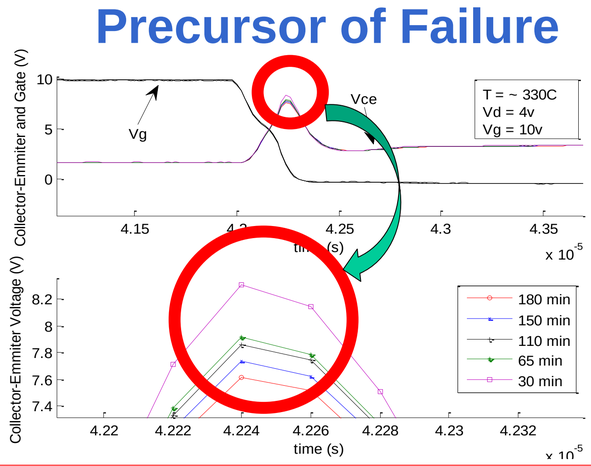
- A preliminary thermal overstress aging test was conducted on IGBTs and power MOSFETs
  - International Rectifier IRG4BC30KD with 600V/15A rating in a T0220 package
  - International Rectifier IRF520N with 100V/9A rating in a T0220 package
- The temperature was measured from the package without external heatsink
- The experiment was stopped after thermal runaway or latch-up failure
- A hysteresis temperature controller was used to control the aging process through switching of the gate voltage
- Aging experiment settings for IGBT:
  - Gate driven by a PWM signal at 10V, 10KHz and 30-40% duty cycle
  - Temperature thresholds: Low=329°C, High=330°C, and Runaway= 340°C

Failures observed in IGBTs

- The average collector-emitter current was monitored during the experiment in order to detect latch-up condition
- Latch-up failure occurred at ~90 minutes of aging. As a result, gate control was lost. In addition, the device was found to be functional after returning to room temperature



Precursor of Failure



The collector-emitter voltage turn-OFF transient showed a significant decrease in its peak value with increase in temperature and aging time