Physics of Failure and Reliability of Power Electronics Devices

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Background of the Course:

Small signal commercial electronics have traditionally been designed to operate at temperatures from 0°C to 70°C. Increased temperature often compromises performance and when combined with the higher voltages, current densities, and heat dissipations associated with power electronics can result in an increased susceptibility to oxide breakdown, electromigration, and other catastrophic on-chip failure mechanisms. Furthermore, the large temperature swings of extreme environments and the rapid temperature cycles resulting from turning on and off large amounts of power can cause fatigue of the die, wires, die attach, and substrate in the package. This course focuses on understanding the device technologies, and developing packaging and thermal management strategies that mitigate risks related to the operating temperatures and large temperature cycles common in extreme temperature and power electronics.

Included will be issues related to the effect of high and low operating temperatures on device and packaging reliability, power device (IGBT, MOSFET, BJT) and material (Si, SiC, GaN) selection, passive component and packaging materials selection, thermal management, and assembly of reliable high power and extreme temperature electronic systems. Finally, failure mechanism models for high temperature and power electronics will be presented together with a discussion of design options to mitigate failure.

This course teaches the basic degradation mechanisms of materials, through the understanding of the physics, chemistry, mechanics of such mechanisms. Mechanical failure mechanisms concentrate on fatigue, and creep. Chemical failure mechanisms emphasize corrosion and oxidation. Physical mechanisms such as diffusion, electromigration, defects and defect migration, surface trapping mechanisms, charge creation and migration are also taught.

Topics covered in this course:

Reliability and Failure Mechanisms of Power Electronics
Reliable design and manufacture of power semiconductor components
Reliable design of power inverters and converters
Effects of temperature on device performance and reliability
Reliable packaging of power module and assemblies