Reliability of IGBT devices via prognostic approach

EE765 : Course Project

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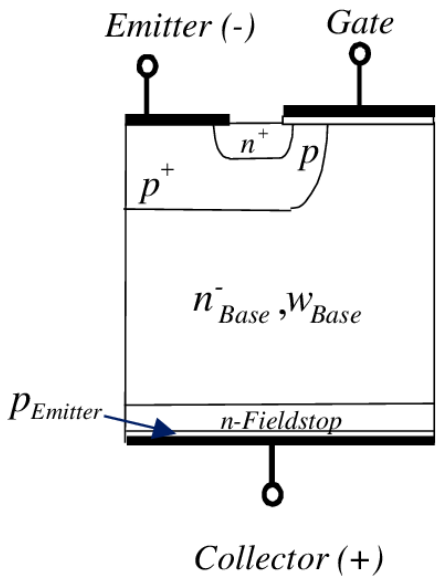
Outline

Introduction: IGBTs and thier applications

What are IGBT's?

Insulated Gate Bippolar transistor: three-terminal power semiconductor device primarily used as an electronic switch.



- Conducts when Gate Voltage $> V_{th}$
- High frequency switching
- Blocks large voltage, high current handling
- Low on state power loss

Source:https://en.wikipedia.org/wiki/Insulated-gate_bipolar_transistor

Applications:

- High power consuming electronic devices
- Switching of automobile and train traction motors
- Switched Mode Power Supply (SMPS)

Motivation : About prognostic approach

The failure of these switches can reduce the efficiency of the system, or lead to system failure.
There are two methods for reliability estimation:

1. Post failure diagnosis
2. Prognosis : Pre-failure analysis

Prognostic Approach

- Predict future health of the product
- By measuring the deviation or degradation from expected behaviour
- Extrapolating the damage with appropriate physics of failure models
- Cost benefits by avoidance of unscheduled maintenance.
- Taking measures to enhance reliability

Prognostic and Health Management method[3]

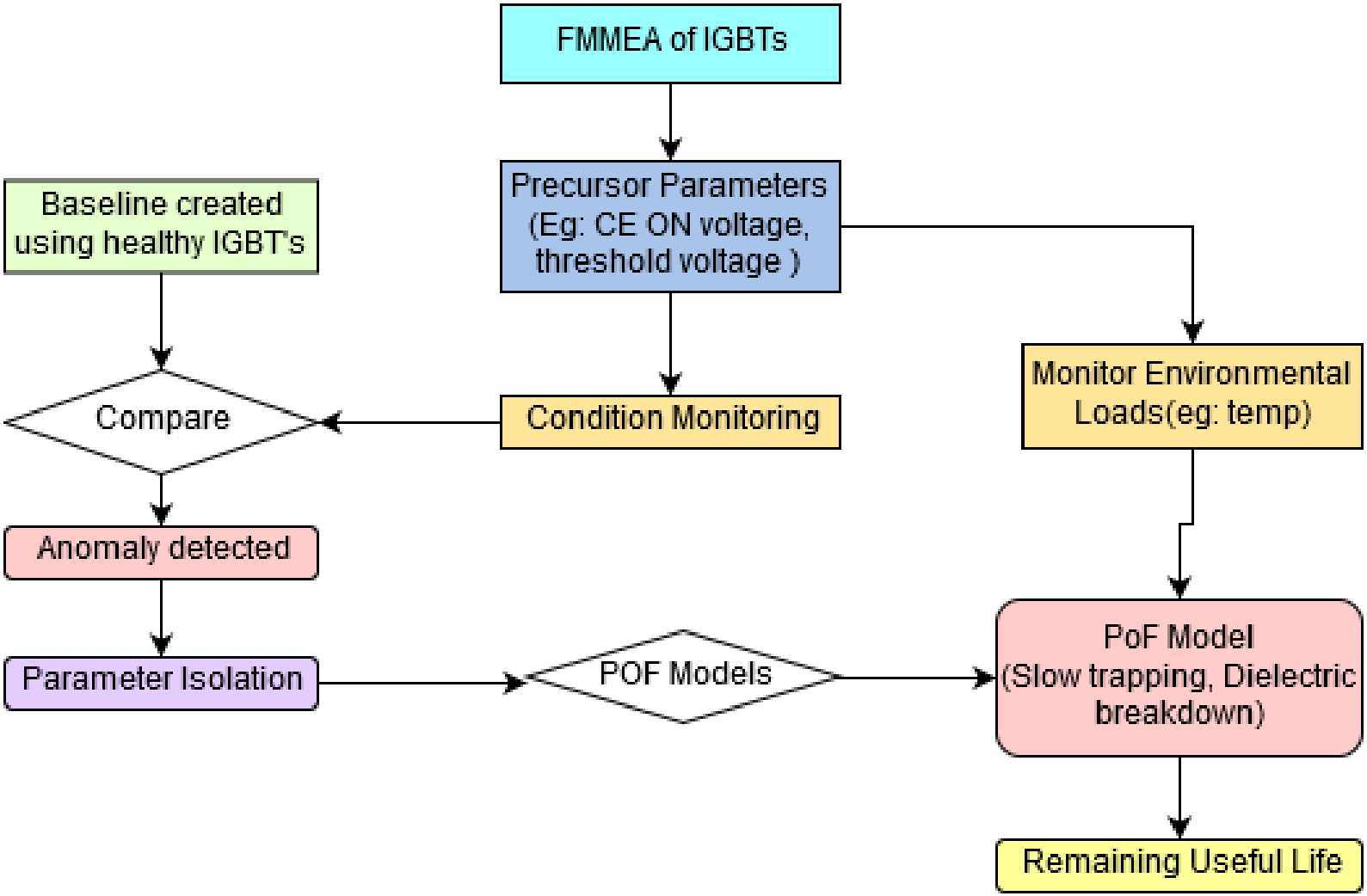


Figure: Flow chart of generic PHM method

First step : FMMEA

Failure Modes for IGBT: [1]

- Lost Gate control
- Short circuit
- Increased leakage current

Potential causes :

- High temperature
- High Electric Field
- Overvoltage

Failure mechanisms for IGBT:

- Dielectric breakdown
- Hot electron
- Latch up

Precursor parameters

- Failure precursor is an event or series of events indicative of an impending failure
- Precursor parameters are the device parameters to be monitored whose deviation from the baseline standard will be indicative of failure.

List of probable precursor parameters for IGBT failure:

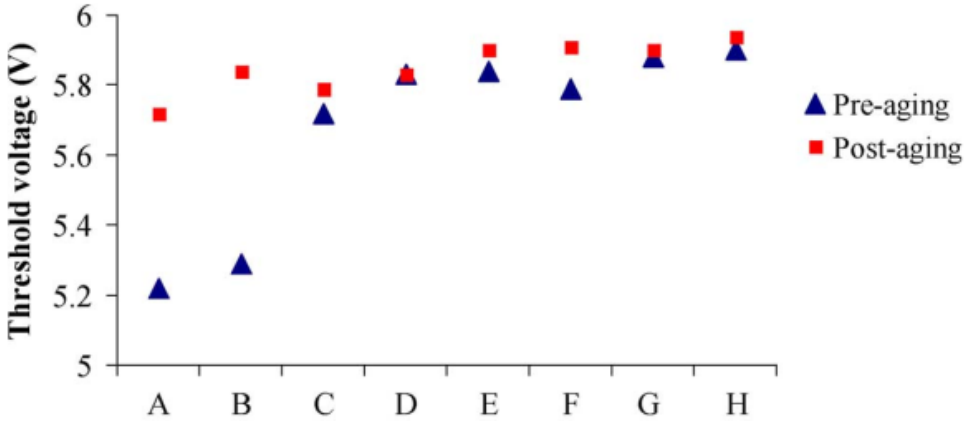
- Thermal voltage
- Emitter collector current
- Emitter-collector ON voltage drop
- Turn-off time of the transistor
- Transconductance

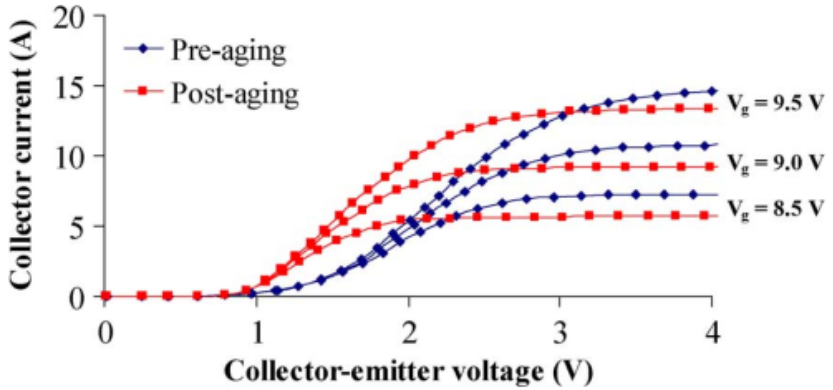
Aging Process

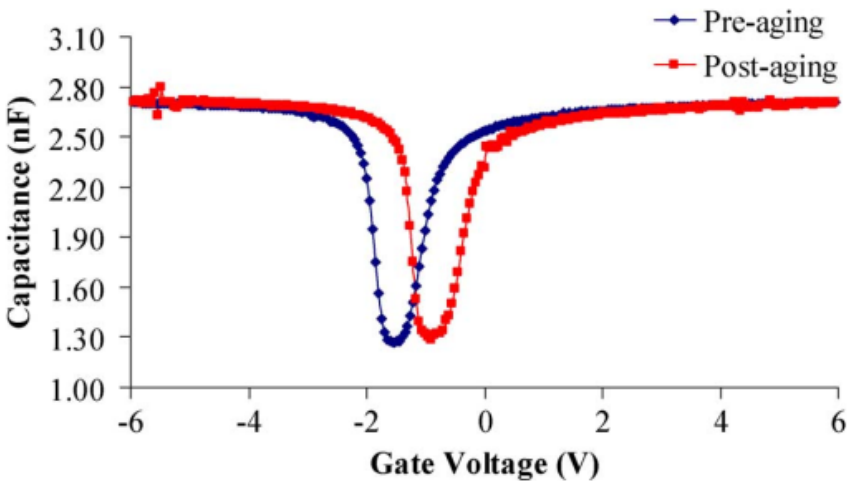
- Accelerated aging is done while montitoring of selected parameters
- Electrical and physical degradation analysis to correlate changes in monitored parameters to degradation in the devices under test
- Accelerated aging conditions were based on failure modes, mechanisms, and effects analysis (FMMEA) of IGBT described.
- The damage was realized by removing the heat sink, then switching the component such that it would heat itself
- For aging the IGBT, the gate voltage was chosen to be a square signal with amplitude of 8 V, a frequency of 1 kHz, and a duty cycle of 40%.
- Thermal cycling was done through switching ($T_{min} to T_{max}$) until latch up was seen
- On latch-up, the collector current is no longer controlled by the gate

Observations

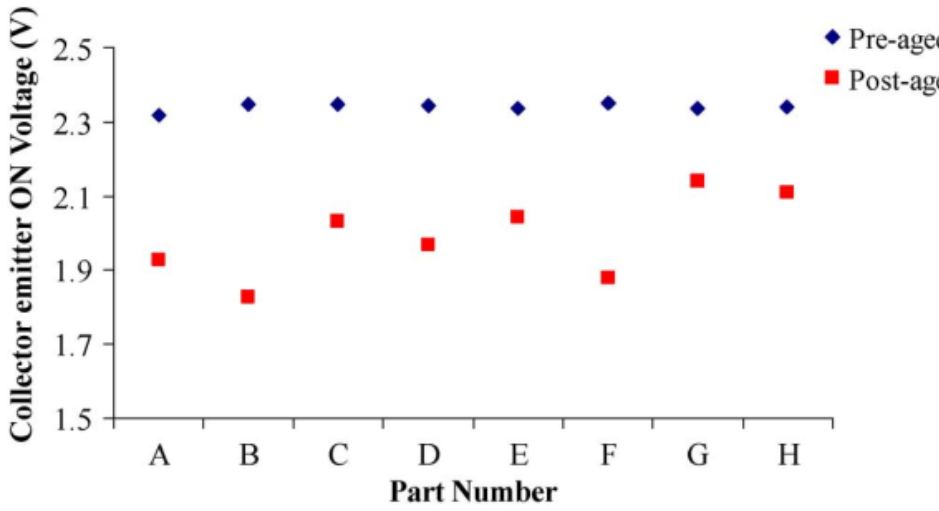
Following electrical observations were made:







[2]

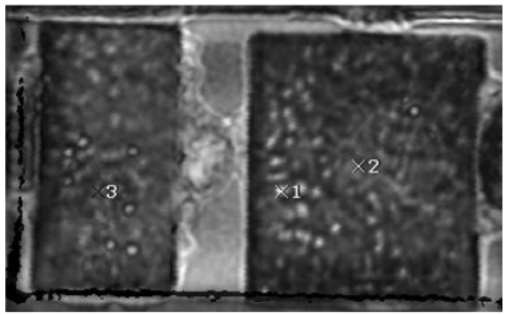


Observations

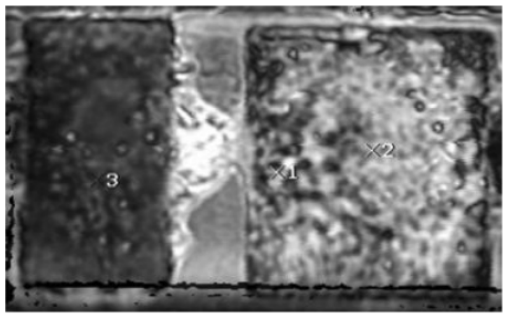
Physical degradation measurement via Scanning acoustic microscopy.

SAM(Scanning acoustic microscopy)[2]

- Used to detect delaminations and voids in microelectronic packages.



Pre-Aging



Post-Aging

[2]

- The C-scan image of the die attach of IGBT before, and after aging
- The brighter parts shows the degradation in the die attach of IGBT.
- It was found that the degradation was proportional to reduction in collector-emitter ON voltage after aging

Discussion

- The right shift in C-V plot indicates the degradation of gate oxide due to the electron trapped.
- The die attach is an integral part of the heat dissipation path, and its degradation is hypothesized to be the cause for drop in collector-emitter ON voltage.
- The degraded die attach leads to an increased temperature at the p-n junction above the collector which increases the number of intrinsic carrier concentration which eventually leads to the decrease in the voltage.[4]
- Increase in minority carriers also leads to the reduction in turnoff time.

Real Life Realization of prognostic approach

The idea is to apply PHM on students performances and derive the probable outcomes in future.

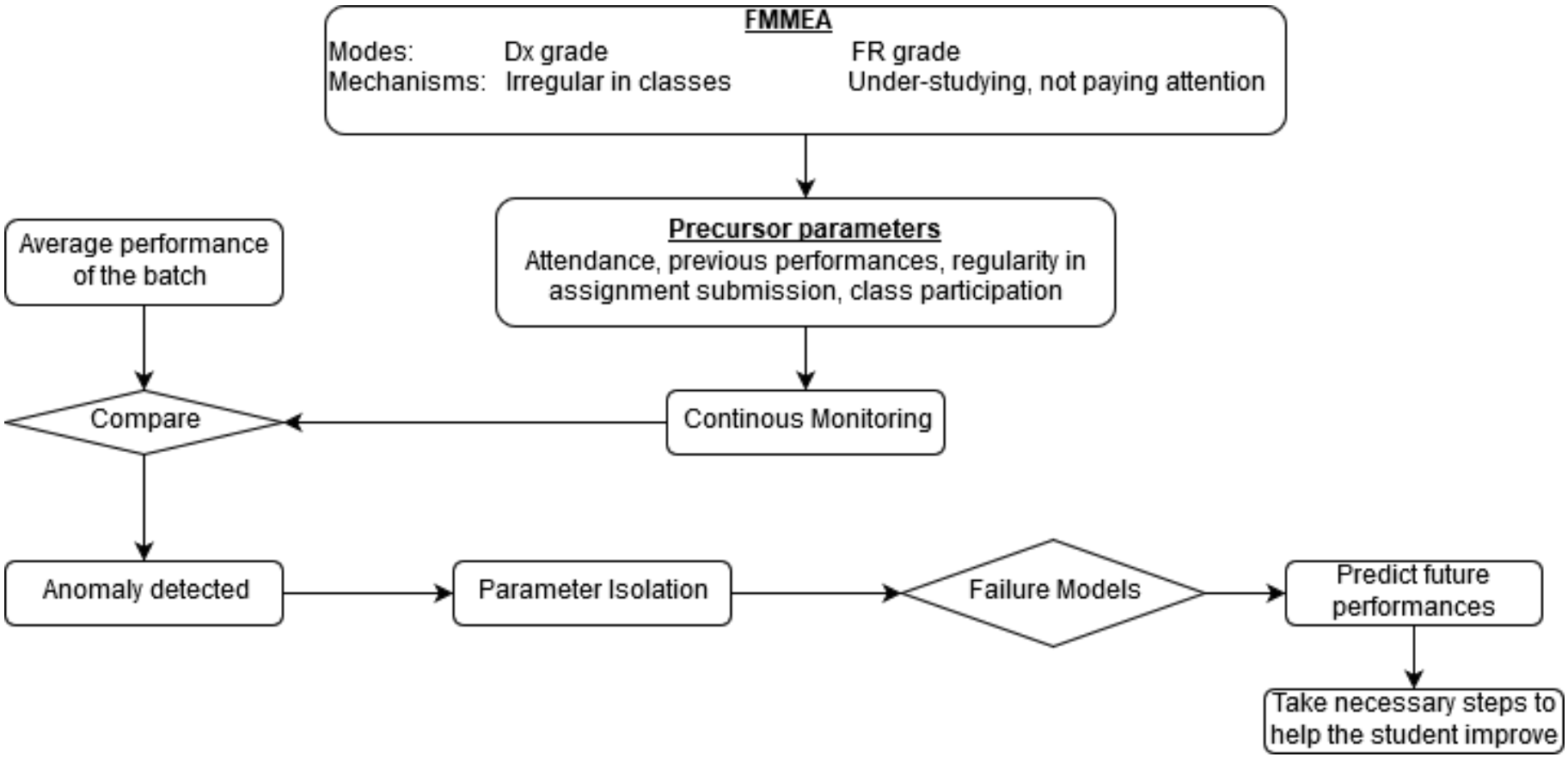


Figure: FMMEA

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