This chapter describes how to deal with troubles that may occur while the automotive IGBT module is handled.

1. Troubleshooting

When the IGBT module is installed in an inverter circuit, etc. a failure of the IGBT module might be occurred due to improper wiring or mounting. Once a failure is occurred, it is important to identify the root cause of the failure. Table 4-1 illustrates how to determine a failure mode as well as the original causes of the failure by observing irregularities outside of the device. First of all, estimate a failure mode of the module by using the table when a failure is happened. If the root cause cannot be identified by using Table 4-1, see Fig. 4-1 as detailed analysis chart for helping your further investigation.

Table 4-1(a) Estimated causes and its device failure modes

<table>
<thead>
<tr>
<th>External abnormalities</th>
<th>Cause</th>
<th>Device failure mode</th>
<th>Further check point</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short-circuit</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arm short-circuit</td>
<td>After short-circuit detection, surge voltage excess SCSOA</td>
<td>Outside SCSOA</td>
<td>Integrity waveform of locus and device ruggedness</td>
</tr>
<tr>
<td></td>
<td>Insufficient dead time</td>
<td>Overheat</td>
<td>Integrity device (t_{\text{on}}) and dead time</td>
</tr>
<tr>
<td></td>
<td>dv/dt malfunction</td>
<td>SCSOA and/or overheat</td>
<td>confirm circuit malfunction</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>confirm failure phenomenon</td>
</tr>
<tr>
<td></td>
<td>Output short-circuit Faulty wiring, abnormal wire contact, load short-circuit</td>
<td>Integrity between device ruggedness and protection condition</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Ground short Faulty wiring, abnormal wire contact,</td>
<td>Wiring conditions</td>
<td></td>
</tr>
<tr>
<td>Overload</td>
<td>Overcurrent Logic circuit malfunction protection function setting fault</td>
<td>Overheat</td>
<td>Logic signal</td>
</tr>
<tr>
<td></td>
<td>Excessive DC voltage Overvoltage larger than device breakdown voltage apply between Corrector and Emitter</td>
<td>Excessive input voltage</td>
<td>Redesign of protection condition</td>
</tr>
<tr>
<td>Overvoltage</td>
<td>Excessive spike voltage Destruction due to excessive surge voltage larger than RBSOA at turn-off</td>
<td>RBSOA</td>
<td>Integrity confirmation RBSOA and operating locus at turn-off</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Redesign of snubber circuit</td>
</tr>
<tr>
<td></td>
<td>Excessive spike voltage Destruction due to excessive surge voltage larger than device breakdown voltage at reverse recovery</td>
<td>Overvoltage of (V_{\text{CES}})</td>
<td>Integrity spike voltage and device breakdown voltage</td>
</tr>
<tr>
<td></td>
<td>Reverse recovery phenomenon at operating with very narrow gate pulse (^*1) logic circuit or gate circuit malfunction due to noise Electromagnetic induction noise from main circuit to gate wiring</td>
<td>sunbber circuit</td>
<td>Logic circuit and/or gate circuit</td>
</tr>
<tr>
<td></td>
<td>Destruction by the main circuit wiring is too long, the surge voltage at the time of the turn-off to reach the dynamic avalanche voltage</td>
<td>Destruction due to dynamic avalanche</td>
<td>Mutual interference between gate circuit and main circuit</td>
</tr>
</tbody>
</table>

\(^*1\) Excessive reverse recovery voltage over device breakdown voltage is produced, if gate pulse width is less than few hundred nano second.
Table 4-1(b) causes of device failure modes

<table>
<thead>
<tr>
<th>External abnormalities</th>
<th>Cause</th>
<th>Device failure mode</th>
<th>Further checkpoints</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver supply voltage drop</td>
<td>$V_{GE}$ is increased by $V_{GE}$ lower than specified value. As a result, power consumption and Joule head are increased.</td>
<td>Overheat</td>
<td>Check circuit design</td>
</tr>
<tr>
<td>Excessive gate voltage</td>
<td>Electro static discharge on $V_{GE}$</td>
<td>Excessive $V_{GES}$</td>
<td>Assembly area environment against ESD</td>
</tr>
<tr>
<td>Operation under opened gate circuit</td>
<td>Voltage apply to Corrector and Emitter while gate is opened.</td>
<td>Overheat</td>
<td>Gate voltage</td>
</tr>
<tr>
<td>Overvoltege on temperature diode, sense IGBT</td>
<td>Temperature diode and/or sense IGBT destruction due to ESD</td>
<td>ESD</td>
<td>Assembly area environment against ESD</td>
</tr>
<tr>
<td>Overheat</td>
<td>Lack of heat dissipation capacity</td>
<td>Anomalous heating due to lack of heat dissipation capacity</td>
<td>Overheat</td>
</tr>
<tr>
<td></td>
<td>Thermal runaway</td>
<td>Total dissipation is increased by carrier frequency increased due to logic circuit malfunction</td>
<td></td>
</tr>
<tr>
<td>Stress</td>
<td>Stress</td>
<td>Soldered portion is broken by stress fatigue</td>
<td>Disconnection of circuit</td>
</tr>
<tr>
<td></td>
<td>Vibration</td>
<td>Stress from external wiring</td>
<td>Stress induced vibration</td>
</tr>
<tr>
<td>Reliability (Life time)</td>
<td>The application condition exceeds the reliability of the module</td>
<td>Destruction is different in each case.</td>
<td>Refer to Fig. 4-1(a-f)</td>
</tr>
</tbody>
</table>
Fig. 4-1(a) IGBT module failure analysis

Fig. 4-1(b) Mode A: Outside RBSOA
**Fig. 4-1(c) Mode B: Gate overvoltage**

- **Gate overvoltage**
  - Static electricity
  - Spike voltage

**[Origin of failure]**
- Manufacturing fault
- Gate wire too long

**Fig. 4-1(d) Mode C: Junction overheating**

- **Junction overheating**
  - Saturation voltage increase $V_{CE(sat)}$
  - Collector current increase

**[Origin of failure]**
- Faulty gate drive circuit
- Faulty power supply control circuit
- Faulty control PCB
- Faulty gate drive circuit
- Faulty control PCB
- Abnormal load
- Faulty control PCB
- Abnormal load
- Faulty control PCB
- Abnormal load
- Faulty control PCB
- Faulty snubber circuit
- Faulty gate drive circuit
- Faulty control PCB
- Faulty gate drive circuit
- Faulty control PCB
- Faulty snubber circuit
- Faulty control PCB
- Faulty gate drive circuit
- Faulty control PCB
- Faulty control PCB
- Pump failure
- Clogging of pipe
- Cooling system failure (Water leakage)
- Degradation of water quality
- Cooling system failure (foreign matter)
- Module installation direction
- Lower flow rate
- Cooling system failure (radiator)
Fig. 4-1(e) Mode D: FWD destruction of the RC-IGBT

- Excessive junction temperature rise
- Static loss increase
- Overload
- Switching loss increase
- Switching increase
- $dv/dt$ malfunction
- Gate drive signal malfunction
- Increase in carrier frequency
- Thermal resistance increase
- Insufficient water flow rate
- Clogging of fin
- Retention of air bubbles
- Water temperature increase
- Excessive surge voltage at reverse recovery
- $di/dt$ increase at turn-on
- Forward bias gate voltage increase
- Decreasing of gate resistor
- Short off pulse reverse recovery
- Gate signal interruption by due to noise

[Origine of failure]
- Power factor drop
- Abnormal load
- Faulty control PCB
- Faulty snubber circuit
- Faulty gate drive circuit
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Faulty control PCB
- Pump failure
- Clogging of pipe
- Cooling system failure (water leakage)
- Water quality degradation
- Cooling system failure (foreign matter)
- Module installation direction
- Lower flow rate
- Cooling system failure (radiator)
- Faulty of snubber circuit
- Faulty of gate derive circuit
- Faulty of gate derive circuit
- Faulty of gate derive circuit
- Faulty of control PCB
<table>
<thead>
<tr>
<th>Destruction due to handling</th>
<th>Loading during product storage</th>
<th>Loading conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>External force or load</td>
<td>Stress produced in the terminals when mounted</td>
<td>Stress in the terminal section</td>
</tr>
<tr>
<td></td>
<td>Excessively long screws used in the main and control terminal</td>
<td>Screw length</td>
</tr>
</tbody>
</table>

- **Excessive tightening torque**
  - Insufficient tightening torque for main terminal screws
- **Vibration**
- **Impact**
- **Soldered terminal heat resistance**
- **Storage in abnormal conditions**
- **Electric static discharge**
- **Cooling water leakage**

**Analysis of Failure**

- **Reliability induced destruction**
  - Soaking in high temperature
  - Soaking in low temperature
  - Soaking in high temperature and high humidity
  - Thermal stress fatigue in temperature cycle
  - Thermal impact by sharp rise or fall in product temperature

**Long term bias on G-E or C-E under high temperature conditions**
**Long term usage on high temperature**
**Voltage applied for long term under hot and humid conditions**
**Long term usage on high temperature and humidity**

**Fig. 4-(f) Mode E: FWD destruction**