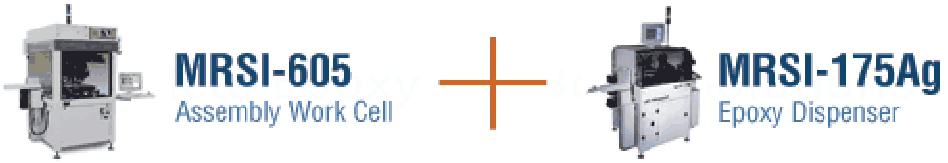

Advanced Packaging Online Article

Packaging Needs for High Temperatures and Harsh Environments

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High-temperature electronics are poised to become the strategic technology of this century. Increases in worldwide demand for oil, evolving electronic needs in the automotive industry, and a resurgence of high-reliability in the military and aerospace industry are driving interest in applications such as deep-well logging tools, automotive under-the-hood electronics, and fly-by-wire aircraft. Because these harsh-environment applications require electronic systems that can survive well beyond the traditional MIL-STD operating temperature range of -55°C to +125°C, the need for robust electronic systems that can operate well beyond 125°C in high shock and vibration environments will become even greater.

Oil and Gas Exploration
A record number of energy exploration activities currently underway to handle the surging demand for oil and gas require high-temperature electronics. While the majority of current downhole electronic applications do not exceed an operating temperature of 150°C, to explore deeper downhole well formations applying advanced sensing and logging technologies, electronics must be able to withstand temperatures of 200°C and beyond. In addition, to handle permanent downhole logging applications, the lifecycle of electronic devices must be increased. Next-generation tools are currently being designed to operate in the 200°C to 250°C temperature range, some of them with high-level electronic circuit functionality for signal conditioning and processing capability.

Automotive
Over the last two decades, automobile electronics have increased rapidly. A growing number of "smart transducer" devices have been designed to improve performance in engine, transmission, steering, and traction control. Because the majority of these sensing electronics and control devices are placed in under-hood and -body environments, they can rapidly cycle from 180°C to -40°C operating temperature, depending on driving location and

climate.

High-reliability Military/Aerospace
Fly-by-wire and fly-by-light will become the next-generation technologies in the commercial and military aircraft industries. The end goal is to replace hydraulic control for the benefits of weight reduction, ease of maintenance, and improved reliability. As a result, the hydraulic actuator will be replaced by electronic control actuators throughout the aircraft, presenting a major challenge of having electronic devices operating in a high-temperature environment without auxiliary cooling supports.

Reasons for Electronic Failure in High Temperatures and Harsh Environments
Standard silicon (Si) semiconductor devices will fail in these advanced, high-temperature applications due to increasing intrinsic carrier density and leakage current as temperature rises. Traditional, organic PCB material, such as FR-4, will also degrade and cause board-level failure. Another main concern of board-level packaging is the reliability of interconnections, as interconnection failure can be triggered by intermetallic formation at the connection junction or metal migration across conductor trace at high operating temperatures. In addition, coefficient of thermal expansion (CTE) mismatches on packaging material can cause stress- and fatigue-related failure, while degradation of dielectric material can cause a major shift in capacitor values.

How to Make It Work
For applications in 250°C+ environments, new semiconductor wafer material and processing technology is required. Silicon-on-insulator (SOI) technology is a promising solution that isolates devices on the IC dielectrically instead of relying on reverse biased junctions in a standard Si process. As a result, leakage and latch-up problems are prevented. For applications above 300°C, a wide band-gap semiconductor from the III-V compound group, such as silicon carbide (SiC), is needed for reliability and performance improvement. At the board level, organic PCB material must be replaced by inorganic substrate material such as ceramic. For example, many down-hole instrumentation tools manufactured today still use organic-material packaging technology to produce electronic modules. However, with organic PCBs, standard packaged discrete semiconductor and SMT-type passive components are limited to operating temperatures in a range well below 175°C. By using hybrid microelectronics technology, engineers can increase the maximum operating temperature limit to up to 250°C in a production environment. In addition to performance improvements at the upper operating temperature limits, this alternative packaging approach can also prolong the lifecycle of electronic devices under harsh operating environments.

Conclusion
Although the present market for high-temperature electronics is relatively small and has been dominated by the petroleum well-logging industry, the increasing demand for under-the-hood electronics from the automotive industry and the resurgence of the high-reliability military and aerospace market sector is expected to increase demand in the near future. Besides higher operating temperature ranges and device lifecycle increases, the benefits of deploying high-temperature electronics also include the elimination of auxiliary cooling support, as well as a reduction in component weight and size. Moreover, high-temperature electronics will be easily integrated with robust sensor devices to offer smart transducer feature sets for a number of next-generation harsh-environment applications. For example, combining a sensing device and smart sensor electronics improves noise immunity, simplifies communication requirements, and reduces the large number of interconnections. High-temperature electronics have demonstrated a high level of performance and reliability in oil and gas down-hole tool applications; it is just a matter of time before the technology gains wider acceptance in all other harsh-environment application areas.

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