Wirebondless Technology for Power Electronic Building Blocks

ENERGY EFFICIENCY AND RENEWABLE ENERGY

OFFICE OF FREEDOMCAR AND VEHICLE TECHNOLOGIES

Transportation

FOR THE 21ST CENTURY

Background

A key element toward making hybrid electric vehicles (HEVs) practical is the development of low-cost integrated power electronic modules capable of handling up to 100 kilowatts of power for vehicle operation within necessary size and weight parameters. HEVs also require a compact, lightweight, high-efficiency inverter to power and control the vehicle's AC traction motor. To meet these requirements, the U.S. Department of Energy (DOE) and the Office of Naval Research (ONR) initiated a joint program in 1995 to develop advanced power electronics technologies for use in automotive, defense, and other industrial applications. The Automotive Integrated Power Module (AIPM) that was developed is one of a new class of Power Electronic Building Block (PEBB) technologies that integrate a complex power electronics system into a single modular package. Integral to the AIPM's function is the use of advanced power semiconductors to control the flow of electric power by shaping the supplied voltages. These devices include Insulated Gate Bipolar Transistors (IGBTs), diodes, and thyristors. Such solid-state power controllers are analogous to integrated circuits in the computer industry, but are designed for use in power circuits. They are helping to replace complex power electronics with a single device; reduce development and design costs for complex power circuits; and simplify the development and design of large electric power systems. Advances in packaging have eliminated the need for wirebonding, or the use of fine wires to connect the power semiconductor device to the leads on its package. The elimination of wirebonding on these devices has dramatically improved thermal cycling capability while minimizing package inductance and resistance.

The Technology

Power semiconductors are solid-state switches capable of handling large electrical currents at high voltages. They handle more power, operate more efficiently, and provide the ability to control power with vastly increased precision, and at increased reliability. Power semiconductors find application in everything from computer power supplies to industrial welders, and are crucial to the development of advanced aircraft, ships, and tanks. The semiconductors are used ubiquitously to control the flow of electricity in motor drives, heavy industrial equipment, electric vehicles, medical equipment, and utility electrical transmission and distribution systems.

The wirebondless package (ThinPak) is a soldered assembly of a semiconductor power device, such as an IGBT, and a thin ceramic lid. The lid is metalized on the bottom side and designed to mate to large and small device electrodes, which are connected by metalized vias to a more rugged and convenient pattern of top-side metal. If the lid material is a good conductor and/or if the lid vias are very dense, the ThinPak lidded device can be cooled from both sides or treated as a flip chip device, but without the usual limitations in achievable breakdown voltage.

The low impedance and small size and weight of the device, as well as the rather large mechanical tolerances of the lid, make it convenient for module applications. A device which has been ThinPak packaged is 100% power testable and can be handled like any surface mount part. This simplifies module manufacturing so that it can be automated greatly reducing manufacturing costs. In addition, the ability to pretest ThinPak packaged devices before module assembly leads to larger yields and better device paralleling, especially with other bipolar devices.

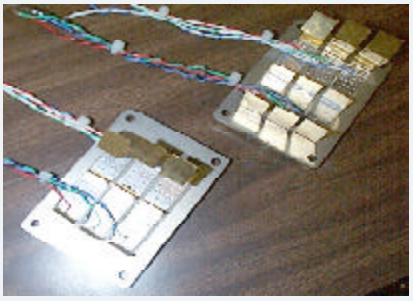
Innovative ThinPak packaging technology accounts for at least a factor of two reduction in power module size, and thereby reduced material cost. The elimination of the wirebond reduces parasitic power losses by an order of magnitude, and modules where ThinPak lids have replaced the wirebonds have a 40% reduced mechanical stress leading to an order of magnitude improved temperature cycling life.

Commercialization

In 1998, Silicon Power Corporation (Exton, Pennsylvania), a manufacturer of power electronic systems and semiconductor devices acquired Harris Semiconductor's PEBB technology development and testing facilities in Latham, New York. SPCO also licensed Harris's PEBB-related intellectual property, including the wirebondless technology. SPCO is commercializing the novel PEBB technologies and ThinPak-packaged devices, such as IGBTs and SPCO's proprietary MOS-controlled thyristor (MCT), and had device sales of approximately half a million dollars in 2001. The worldwide market for power semiconductors and modules is expected to grow at an average rate of 19% per year (from $1.2 billion in 1998 to $2.8 billion in 2003), and SPCO expects to contribute heavily to the expanding market for hybrid electric vehicles. Rockwell Automation, a world leader in industrial electric drives, is a subcontractor to SPCO on the AIPM program, and has been responsible for the AIPM team's low cost software and hardware for AIPM control. Rockwell is poised to be one of the first major industrial users of the ThinPak technology.

Benefits

- **Minimum package volume, size and weight, therefore reduced cost**
- **Minimum stray inductance and resistance (no wirebonds)**
- **Flexible power module component simplifies assembly**
- **Easily cooled for better performance and longer life**
- **Lid provides convenient substrate for control circuit, and increases die mechanical and electrical reliability**



The ThinPak uses a double-sided patterned ceramic lid, instead of wires, to contact 90% of the power device active area for very low impedance and high current capability.

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