

Background

Integrated circuits (ICs) are becoming more complex, requiring the supply of large amounts of power, and the dissipation of large amounts of heat. Traditionally, heat dissipation has been handled by convection technologies, such as fans, liquid cooling and heat pipes, or conduction methods that use high thermal conduction metals such as copper. These solutions increase the complexity of the system, and add to the size, weight and power of the electronic device. In addition, new materials such as gallium nitride (GaN) are capable of handling higher voltages and delivering higher output powers than conventional power amplifiers; however, the increase in power density imparts an even larger thermal load, requiring new methods of heat dissipation.

Significant research and development efforts have gone in to developing new thermal management for GaN and similar high power devices. While some efforts focus on applying conventional liquid or forced air cooling, the most promising methods involve the integration of diamond as a heat sink. This approach has proved successful, since diamond has the largest thermal conductivity of any material. However, limitations arise due to a number of material integration issues. Diamond has to be grown or deposited at temperatures above standard semiconducting processing steps, limiting when the diamond can be integrated with the GaN device. Similarly, the large thermal mismatch between diamond and GaN causes a significant amount of mechanical stress between the two materials. By using a process that integrates the diamond in to the GaN substrate early in the manufacturing process and places the heat sink in intimate contact with the active area of the power amplifier, dramatic performance improvements are possible.

Description

The primary problem with diamond integration with GaN devices is that the diamond heat sink is a significant distance from the highest thermal load. This reduces the effectiveness of the heat sink, since the heat generated by the high power device has to travel tens or hundreds of microns through the substrate before reaching the high thermal conductivity substrate.

The technology described herein aims to utilize unique semiconductor processing and growth methods to overcome the problem of distance between the device and heat sink. In this method, the diamond film is embedded in a trench in the starting substrate. Subsequently, GaN epitaxial layers are grown over the top of the diamond, using a method such as lateral epitaxial overgrowth (LEO). Post-growth fabrication techniques can then be used to planarize the sample, if needed. This unique processing method places the diamond only a few microns from the active device area, maximizing heat dissipation.

Advantages

There are three primary advantages of this technique compared to existing technologies and methods. First, the diamond thin film is in close proximity to the active area, allowing the dissipation of high heat loads. Second, the thin film deposition is completed prior to standard wafer fabrication. This allows for high temperature diamond thin film growth, without exceeding the thermal budget of later processing steps. Lastly, by embedding the diamond film in a narrow channel, there are no bulk mechanical stresses associated with the coefficient of thermal expansion (CTE) mismatch between diamond and GaN.

Applications

The primary market for this novel heat dissipation technology will be in the defense and aerospace industries. These are the primary users of high power RF electronics, commonly used in radar applications. However, many adjacent markets exist for thermal management, such as LEDs and high power laser diodes: devices that also utilize gallium nitride thin films.

- High power RF devices, such as radar and communications
- Optics applications, including high power laser diodes, and light emitting diodes (LEDs).

Intellectual Property Status

This technology is patent pending under US Patent application number 14/964,217 filed 12/09/2015.

Keyword List

Gallium nitride (GaN), thermal management, heat dissipation, diamond, high power RF

Contact

Andrew Myers
816-488-4432
amyers@kcp.com



The Department of Energy's Kansas City National Security Campus is a multi-mission engineering, manufacturing and sourcing enterprise delivering trusted national security products and government services. Managed by Honeywell Federal Manufacturing & Technologies, LLC., for the DOE under contract number DE-NA0002839.

