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US Air Force team makes GaN-on-diamond advance

2 August 2006

Using epitaxial material from Emcore attached to a diamond substrate by Group4 Labs, engineers at the US Air Force Research Laboratory say that they have made the world's first GaN-on-diamond transistor.

Engineers at the US Air Force Research Laboratory (AFRL) claim to have fabricated the first operational GaN-on-diamond high electron mobility transistor.

Although details from the AFRL team are sketchy, with no mention of output power or frequency of operation, the team did reveal the following: "Initial transistor results show that the AlGaIn/GaN material survived all the process steps, including high-temperature ohmic contact anneal."

Because of its very high thermal conductivity, diamond has long been regarded as the ideal material on which to base high-power transistors. However, the lattice mismatch between it and GaN alloys has proved to be a major stumbling block.

To get around that issue, the transistor epilayers were first grown on a sacrificial "non-SiC" substrate using MOCVD by Ivan Eliashevich and colleagues at Emcore's electronic materials division (EMD).

Next, GaN-on-diamond specialists at California-based Group4 Labs took the epitaxial structure and carefully attached it to a chemically vapor deposited (CVD) diamond substrate.

A thin, thermally-conductive attachment layer is sandwiched between the CVD diamond and the epitaxial structure, ensuring that the transistor channel is in close proximity to the diamond.

Critically, this enables almost-instantaneous heat extraction from the device. In theory, this should mean that transistors with an extremely high power density could be processed using the novel combination of materials.

"We are excited by the promise of this technology," said Eliashevich, the director of research and development at EMD.

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"It combines the most robust semiconductor material with the best heat spreader."

"Epitaxial wafers based on a GaN-on-diamond platform should enable device manufacturers to push the limits of high-power performance and reliability across a wide range of applications."

Eliashevich expects that transistors based on the novel material combination will first find applications in high-performance military applications.

However, he adds that because the CVD diamond and epitaxy approaches are inherently scalable to 4-inch or even larger wafers, the technology could eventually penetrate lower-cost, higher-volume commercial markets.

Despite the hardness of diamond, wafer dicing is not expected to be a problem. Eliashevich says that the laser -dicing approach now used widely in GaN LED production is also applicable.

Apart from RF and power switch applications, the approach may also turn out to be useful for improving heat dissipation in optoelectronic devices, which could enable brighter LEDs and more powerful laser diodes.

The GaN-on-diamond transistor development was supported in part by a DARPA-funded co-operative agreement between Emcore and AFRL.

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