Novel advancements in radiation tolerance of HEMTs

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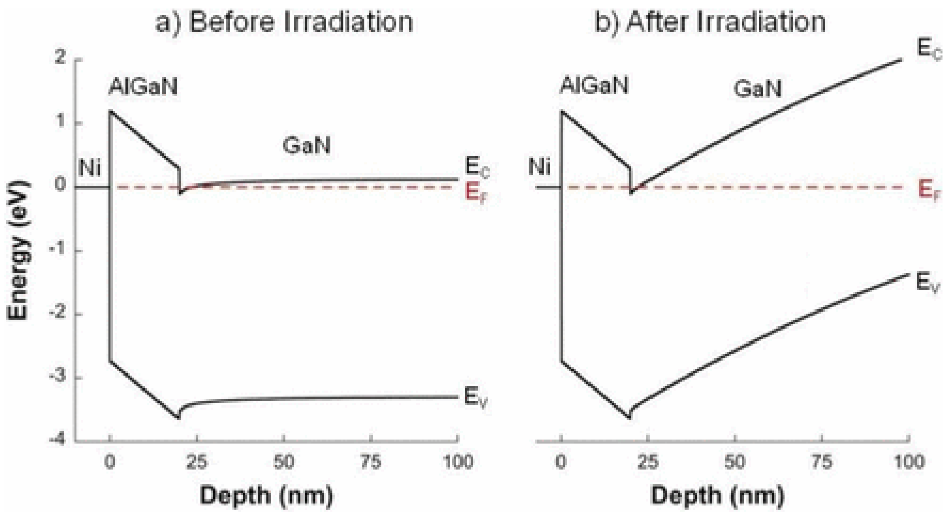

Credit: “On the Radiation Tolerance of AlGaN/GaN HEMTs“

When it comes to putting technology in space, size and mass are prime considerations. High-power gallium nitride-based high electron mobility transistors (HEMTs) are appealing in this regard because they have the potential to replace bulkier, less efficient transistors, and are also more tolerant of the harsh radiation environment of space. Compared to similar aluminum gallium arsenide/gallium arsenide HEMTs, the gallium nitride-based HEMTs are ten times more tolerant of radiation-induced displacement damage.

Until recently, scientists could only guess why this phenomena occurred:

Was the gallium nitride material system itself so inherently disordered that adding more defects had scant effect? Or did the strong binding of gallium and nitrogen atoms to their lattice sites render the atoms more difficult to displace?

The answer, according to scientists at the Naval Research Laboratory, is none of the above.

Examining radiation response

In a recent open access article published in the *ECS Journal of Solid State Science and Technology* entitled, "On the Radiation Tolerance of AlGaN/GaN HEMTs," the team of researchers from NRL state that by studying the effect of proton irradiation on gallium nitride-based HEMTs with a wide range of initial threading dislocation defectiveness, they found that the pre-irradiation material quality had no effect on radiation response.

Additionally, the team discovered that the order-of-magnitude difference in radiation tolerance between gallium arsenide- and gallium nitride-based HEMTs is much too large to be explained by differences in binding energy. Instead, they noticed that radiation-induced disorder causes the carrier mobility to decrease and the scattering rate to increase as expected, but the carrier concentration remains significantly less affected than it should be.

Applications in space exploration

Because of their relative radiation hardness, gallium arsenide- and gallium nitride-based HEMTs are desirable for space application. Take, for example, the Juno Spacecraft.

On July 4, the Juno Spacecraft successfully entered orbit around Jupiter - a planet scientists still know very little about, which generates extreme levels of radiation. Without the proper technology, the radiation levels of Jupiter could destroy the sensitive electronics in the satellite upon approaching the planet. Better understanding of why gallium arsenide- and gallium nitride-based HEMTs are more tolerant of radiation could ultimately accelerate innovative and bolster projects where radiation levels prove to be barriers.

Novel advancements in HEMTs

The paper was designated ECS Editors' Choice due to its significance and expected impact on the solid state science and technology community.

"Editors' Choice articles are elite publications because they are deemed by reviewers and journal editors to demonstrate a transformative advance, discovery, interpretation, or direction in a field," says Dennis Hess, Editor of the *ECS Journal of Solid State Science and Technology*. "They represent very high quality science and engineering and hold the promise of altering current technology practices."

Unexpected answers

The explanation for this novel discovery turns out to be rather elegant.

In gallium nitride-based HEMTs, a piezoelectric field forms at the aluminum gallium nitride/gallium nitride interface due to lattice strain. The field gives rise to two-dimensional electron gas by which carriers travel across the transistor from source to drain. It also provides an electrically attractive environment that causes carriers that are scattered out of the two-dimensional electron gas by radiation-induced defects to be reinjected. In this way, the scattering rate can increase and the mobility can decrease without greatly affecting the two-dimensional electron gas carrier density.

In other words, it is the internal structure itself that renders aluminum gallium nitride/gallium nitride HEMTs rad-hard.

"Gallium nitride is such a complicated system - not like gallium arsenide at all," says Bradley Weaver, co-author of the study. "We struggled for four years to figure out why it's so rad-hard, expecting a complicated solution. But the answer turned out to be really simple. Science does that sometimes."

More information: B. D. Weaver et al, Editors' Choice—On the Radiation Tolerance of AlGaN/GaN HEMTs, *ECS Journal of Solid State Science and Technology* (2016). DOI: 10.1149/2.0281607jss

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