Scientists invent a hot-emitter transistor for future high-performance, low-power, multifunctional devices

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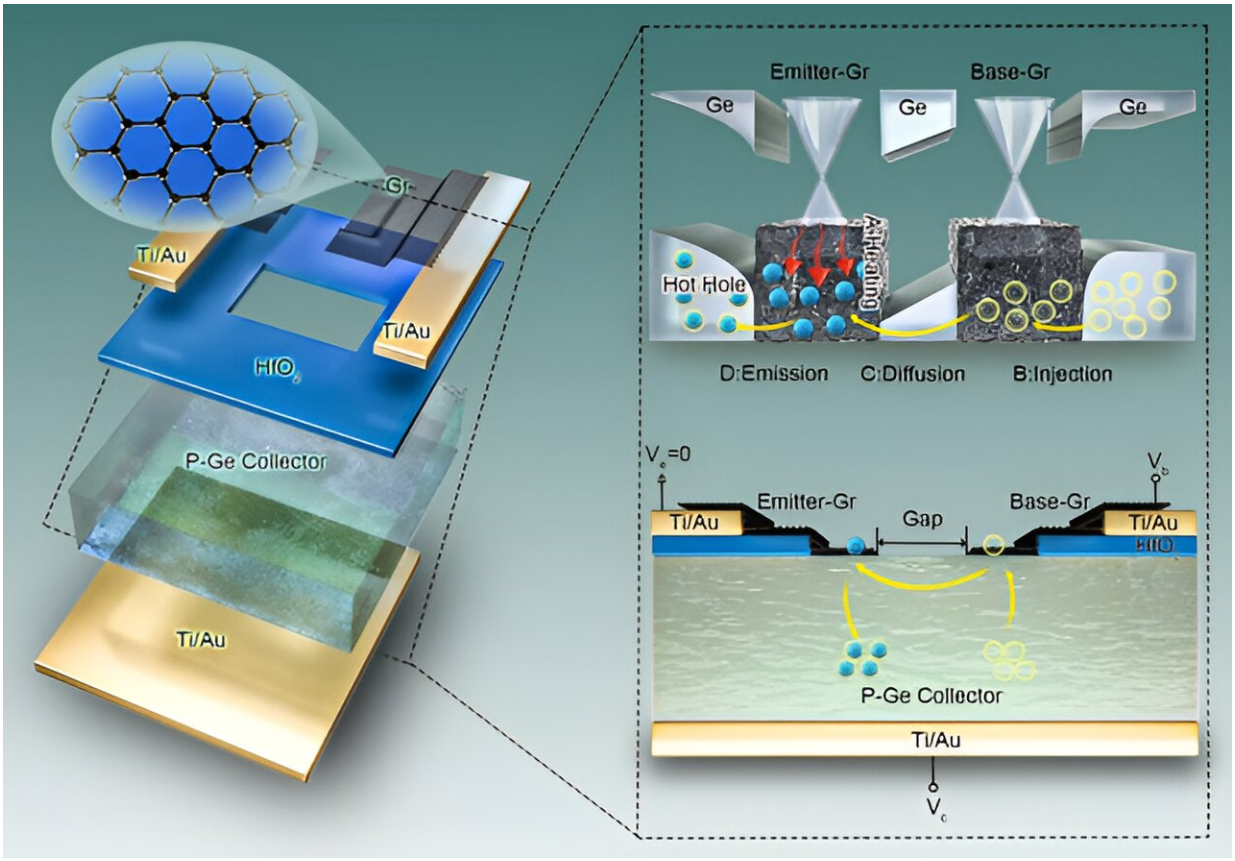

A hot-emitter transistor based on stimulated emission of heated carriers. Credit: IMR

Transistors, the building blocks of integrated circuits, face growing challenges as their size decreases. Developing transistors that use novel operating principles has become crucial to enhancing circuit performance.

Hot carrier transistors, which utilize the excess kinetic energy of carriers, have the potential to improve the speed and functionality of transistors. However, their performance has been limited by how hot carriers have traditionally been generated.

A team of researchers led by Prof. Liu Chi, Prof. Sun Dongming, and Prof. CHeng Huiming from the Institute of Metal Research (IMR) of the Chinese Academy of Sciences has proposed a novel hot carrier generation mechanism called stimulated emission of heated carriers (SEHC).

The team has also developed an innovative hot-emitter transistor (HOET), achieving an ultralow sub-threshold swing of less than 1 mV/dec and a peak-to-valley current ratio exceeding 100. The study provides a prototype of a low power, multifunctional device for the post-Moore era.

This work was published in *Nature*.

Low-dimensional materials like graphene, due to their atomic thickness, excellent electrical and optical properties, and perfect surface without defects, can easily form hetero-structures with other materials. This creates a variety of energy band combinations, offering new possibilities for developing novel hot carrier transistors.

Researchers at IMR developed a hot-emitter transistor using a combination of graphene and germanium, leading to an innovative mechanism for hot carrier generation. This new transistor is composed

of two coupled graphene/germanium Schottky junctions.

Carrier stimulated emission in hot-emitter transistor. Credit: IMR

During operation, germanium injects high-energy carriers into the graphene base, which then diffuse to the emitter, triggering a substantial current increase due to the preheated carriers there. This designs sub-threshold swing of less than 1 mV/dec surpasses the conventional Boltzmann limit of 60 mV/dec.

Meanwhile, this transistor also shows a peak-to-valley current ratio exceeding 100 at room temperature. The potential for multi-valued logic computing has further been demonstrated based on these characteristics.

"This work opens a new realm in transistor research, adding a valuable member to the family of hot carrier transistors and showing broad prospects for their application in future high-performance, low-power, multifunctional devices," said Liu.

More information: Chi Liu et al, A hot-emitter transistor based on stimulated emission of heated carriers, *Nature* (2024). DOI: 10.1038/s41586-024-07785-3

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