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Technology Offer

Milestone for Plasmonics: The Plasmon Generating Transistor

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The invention relates to a new method for a plasmon emitting transistor that operates in the single quantum regime. It is a major step towards future data processing technology that is no longer based on electric currents but on the transition of light.

Developments over past decades have gradually increased the performance of computer chips, but new technologies are needed to overcome the sizing limit of classical transistors. Replacing the role of electrical currents by the use of light is a promising approach but the necessary control of plasmons on the nanoscale was not yet demonstrated.

The newly developed transistor comprises a single molecule in a double tunnel barrier between two electrodes. It showed the behavior of a single-molecule plasmon generating field-effect transistor and is therefore a reliable way of converting electronic into plasmonic information.

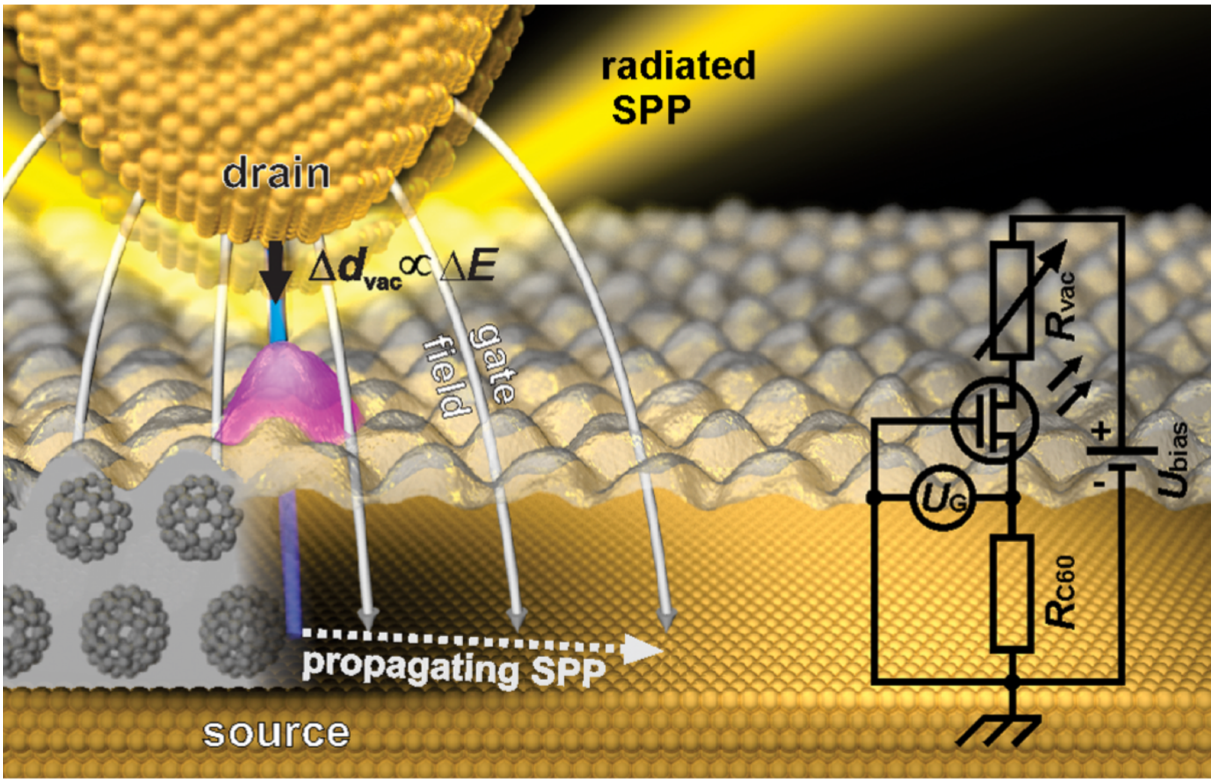

Fig. 1: The gating is achieved by a single molecule (magenta) in a double tunnel barrier of vacuum and C_{60} bilayer. The molecule is contacted via the gold substrate (source) and a gold tip (drain). The electric field is controlled via the spacing d_{vac} between the molecule and the drain contact. Above a certain field, surface plasmon polariton (SPP) modes are excited by electrons (blue) tunneling through the junction. These SPPs either propagate along the surfaces of the electrodes (dashed arrow) or are radiated as light (yellow).

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Advantages

- Simple design
- Direct conversion of electronic to plasmonic information
- Reliable
- Based on single quantum systems like molecules
- Central building block for implementation of plasmonics in modern computation

Applications

- Plasmonic circuits
- Junction between electronics and plasmonics

Background

The invention of the transistor sparked the outstanding development towards modern electronics. Nevertheless, the continuous miniaturization of transistors towards nanometer scales is prospected to stop within this decade as heat deposition becomes a major problem in smaller devices. Though, thermal heat can be significantly reduced by use of plasmonic circuits. These employ photon-like electromagnetic excitations localized on bulk solids – called plasmons, which can carry information in the same way as electric currents in classical electronics. However, implementation of plasmonic circuits requires fundamental building blocks for coupling of electronic and plasmonic circuits that have not yet been developed.

Technology

A novel transistor concept has been developed to overcome the aforementioned shortcoming that is capable of converting an electric current to plasmons and vice versa. The embodiment of this invention as shown in figure 1 consists of a single quantum system (i.e. a molecule) located in a double tunnel barrier between two electrodes. By varying the space between drain and the molecule d_{vac}, the gate voltage U_G and the electric field E can be changed and optimized independently from the tunnel voltage. Above a specific field strength, electrons tunneling through the junction excite surface plasmon polariton (SPP) that are either radiated as light or they propagate along the electrode surface. By varying the bias voltage applied to the electrodes, the Fermi level of one electrode shifts in resonance with the lowest unoccupied state of the quantum system raising both a significantly increased tunnel current and an increased emission of plasmons. Integrated as junctions between electronic and plasmonic circuits such transistors convert electronic information (voltage/current) into information carried by plasmons and vice versa. As a key technology, they are essential building blocks for embedding plasmonics into future electronics.

Patent Information

PCT *(WO2015082343A1)*, USPTO *(US10134498B2)*

Publications

C. Große *et al.* "*Dynamic Control of Plasmon Generation by an Individual Quantum System*", Nano Lett. (2014)

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