TO-110 • PT 1.2725
Peter Grünberg Institute
Quantum Theory of Materials (PGI-1)

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Novel Magnetic Tunnel Diode and Transistor for High-Speed Electronics: Non-volatile, Reconfigurable and High-Frequency Operation

Technology Description

The invention relates to a magnetic tunnel diode and a magnetic tunnel transistor, along with methods for their use. These devices are considered promising candidates for high-speed electronic devices. Operating frequencies of up to 30 THz have been achieved in metal-insulator-metal tunnel diodes and graphene-based vertical quantum tunnel transistors. The invention addresses current problems by using a magnetic tunnel diode with two terminals and a tunnel contact consisting of a semi-metallic magnet, a tunnel barrier, and a semiconductor layer without spin excitation gap. The magnetic tunnel transistor has three terminals and a similar structure. These devices offer non-volatility and reconfigurability, making them suitable for applications in storage media and computer processors.

Problem

Quantum tunnel diodes and quantum tunnel transistors, such as hot-carrier diodes and hot-carrier transistors, are considered promising candidates for high-speed electronic devices. However, there are several challenges to overcome, including low rectification ratio, high threshold voltages, limited currents, and low magnetoresistance. These limitations make magnetic tunnel diodes unsuitable for low-power applications. Similarly, existing magnetic tunnel transistors suffer from high base-collector leakage currents and inadequate transfer rates. The lack of combinability of non-volatility and reconfigurability in tunnel diodes and tunnel transistors hinders their technological advancement.

Solution

The magnetic tunnel diode and magnetic tunnel transistor achieve non-volatility and reconfigurability by using a semi-metallic magnet and a semiconductor without spin excitation gap. This combination allows for improved asymmetric current-voltage characteristics, enabling easy adjustment of the threshold voltage. These devices offer advantages such as high operating speeds (THz range), low power consumption, and simple circuit structures. By using only two magnetic tunnel diodes, all

IP: PCT/EP2016/076041, DE102015221521.0, WO 2017/076763, EP3371836, US10644227, JP6780871, CN108352446
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Keywords: Tunnel diodes and transistors, Hot-carrier diodes and transistors, Non-volatile memory, ICs

More Information
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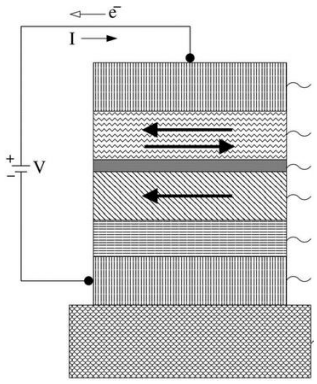
As of 10/2023



logical functions can be implemented, reducing the manufacturing cost and wafer usage compared to conventional metal-oxide-semiconductor field-effect transistors (MOSFETs). The non-volatility and reconfigurability of these devices allow for the combination of logic and memory on a single chip, eliminating the need for external memory.

Potential Use

Devices based on the magnetic tunnel diode and tunnel transistor offer high operating frequencies, low power consumption, and simple circuit structures. They can be controlled by sending commands to reconfigure gates during operation, allowing for application-specific reconfigurations. The non-volatility and reconfigurability enable the combination of logic and memory on the same chip, eliminating the need for external memory. The magnetic tunnel transistor exhibits symmetrical transistor functions similar to conventional MOSFETs but with the added advantages of non-volatility, reconfigurability, and high-frequency operation up to the THz range. These devices have potential applications in high-speed electronics, storage media, and computer processors.

Development Status and Next Steps

Devices based on the magnetic tunnel diode and tunnel transistor offer high operating frequencies, low power consumption, and simple circuit structures. They can be controlled by sending commands to reconfigure gates during operation, allowing for application-specific reconfigurations. The non-volatility and reconfigurability enable the combination of logic and memory on the same chip, eliminating the need for external memory. The magnetic tunnel transistor exhibits symmetrical transistor functions similar to conventional MOSFETs but with the added advantages of non-volatility, reconfigurability, and high-frequency operation up to the THz range.

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