Electronic devices, Information and communication devices

Highly efficient and low-power consumption spin injection technology into next-generation high-performance semiconductors

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Abstract

Gallium nitride (GaN) has been widely studied in various fields, such as optoelectronics and power electronics. GaN is also an attractive material for semiconductor-based spintronic devices because of its relatively weak spin-orbit coupling. In this study, we develop a low-power consumption and high-efficiency spin injection technology using a high-performance spintronics material (Heusler-alloy magnet)/GaN Schottky tunnel contacts.

Background & Results

Gallium nitride (GaN) has been widely studied in various fields, such as optoelectronics and power electronics. Because of the intrinsically weak spin-orbit coupling in GaN, the possibility of semiconductor spintronic devices such as a spin LED and spin field-effect transistor has also emerged. However, almost all of the previous related studies have used an insulating tunnel barrier for electrical spin injection into GaN to solve the spin resistance mismatch problem, resulting in high-resistance contacts. In addition, magnetic materials used in the previous related studies have low performance, resulting in low efficiency in generating spin-polarized states in semiconductors.

To overcome these issues, we develop a low-power and high-efficiency spin injection technology using a high-performance spintronics material (Heusler-alloy magnet)/GaN low-resistance contacts. In general, it has been difficult to epitaxially grow high-quality Heusler-alloy magnets on GaN because the crystal structures of Heusler-alloy magnets with a body-centered cubic structure and GaN with a wurtzite-type crystal structure are completely different and there is no matching between the lattice length and symmetry (left figure of Figure 1). In this study, we succeeded in epitaxially growing a high-quality Heusler-alloy magnet film on GaN by inserting a few atomic layers (about 0.4 nm) of cobalt (Co) with a hexagonal close-packed crystal structure at the heterointerface between the Heusler-alloy magnets and GaN (right figure of Figure 1). Using lateral spin-valve devices with Heusler-alloy magnet /n^+-GaN Schottky tunnel contacts (Figure 2 and left figure of Figure 3), we succeeded in electrical spin injection at room temperature with a high spin polarization and a low bias voltage (right figure of Figure 3).

Significance of the research and Future perspective

GaN is a promising material for high-performance optical semiconductor spintronic devices such as spin lasers. We succeeded in electrical spin injection at room temperature with a high spin polarization and a low bias voltage. The research is expected to open a path to the development of a GaN-based spin laser for on-chip battery-operated devices.

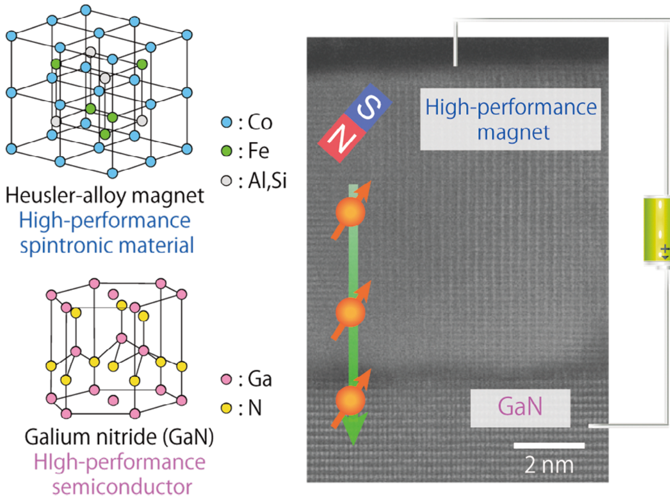

Figure 1

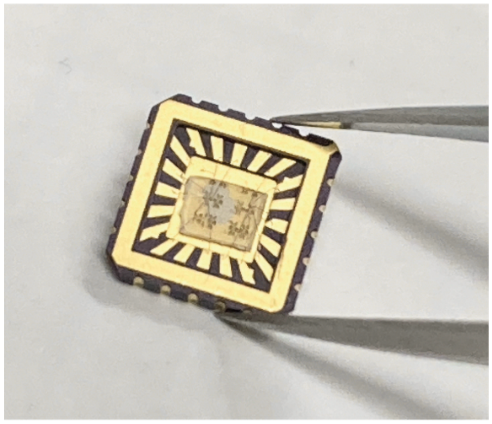

Figure 2

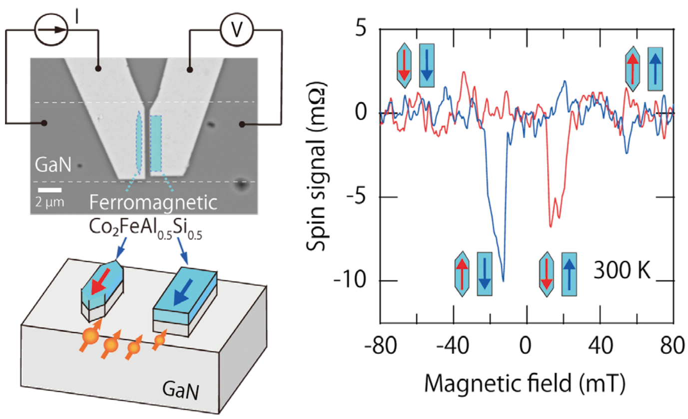

Figure 3

Patent	
Treatise	Yamada, Shinya; Ichikawa, Shuhei; Hamaya, Kohei et al. Half-metallic Heusler alloy/GaN heterostructure for semiconductor spintronics devices. Advanced Electronic Materials. 2023, 9(7), 2300045. doi: 10.1002/aelm.202300045
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