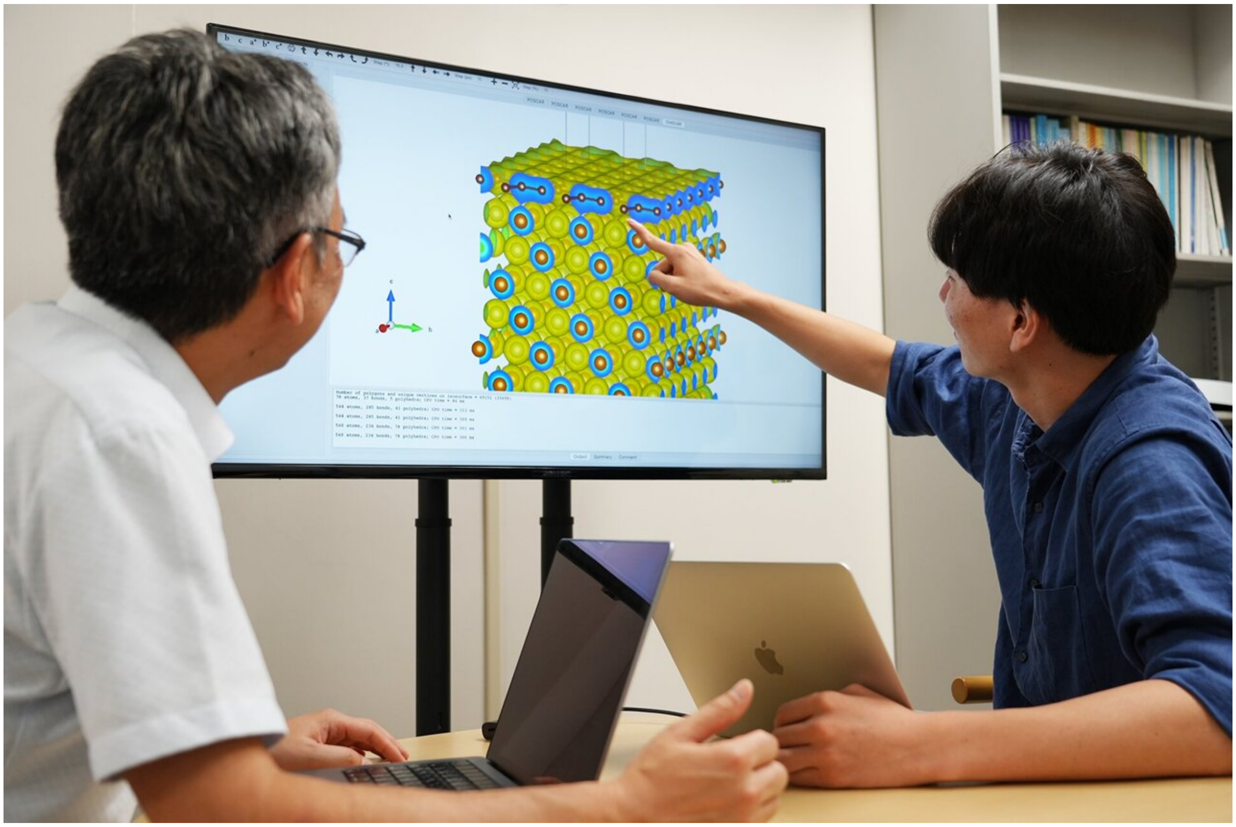
How you make it matters: Spintronics device performance tied to atomic interface changes

September 18 2025



Kobe University ONO Tomoya (left) is an expert in calculating the properties of materials based on the behavior of their electrons. His team now showed that the interface between a ferromagnet and an insulator as used in certain spintronics devices is different depending on the production technique. Credit: Kobe University

Spintronics devices will be key to realizing faster and more energy-efficient computers. To give us a better understanding of how to make them, a Kobe University team now showed how different manufacturing techniques influence the material properties of a key component.

Electronic devices could be made more efficient and faster if electrons could carry more information at once. This is the basic idea behind spintronics, where researchers try to use the electrons' spin in addition to charge in data storage, processing and sensor devices to significantly improve our computers.

One component for such devices is the "magnetic tunnel junction," which may be used, for example, for neuron-like behavior in information processing or in a new type of fast and non-volatile memory. They consist of two ferromagnets, usually a nickel-iron alloy, sandwiching a thin insulating layer such as graphene.

Kobe University electronic engineer ONO Tomoya says, "The issue is that we know very little about how the interface between the materials behaves, so there are many unknowns in how to produce these devices."

Ono and his team realized that the way these materials are produced probably changes the electronic structure of the interface.

Being experts in first-principle calculations, that is, calculating the properties of materials based on the behavior of its electrons, they investigated, first, how metal and insulator would align on an atomic scale depending on the production technique; and second, how this would influence the magnetic properties at the interface that are relevant for spintronics applications.

For a part of their calculations, they used the Kobe-based RIKEN supercomputer Fugaku, which was the world's fastest supercomputer until 2022.

In the *Journal of Applied Physics*, the Kobe University team have published their results. They show that the surface of the ferromagnet is different when the insulator is transferred to it compared to when the ferromagnetic crystal is grown on a flake of the insulator.

More specifically, a bulk nickel-iron magnet, onto which graphene can be transferred, usually has more nickel on its surface, whereas a magnet grown on a flake of graphene will feature a layer of iron. This makes a difference for a magnetic tunnel junction's behavior, whether they are for sensors or for storage devices.

The reason these two situations differ lies in how the electrons of the insulator's carbon atoms interact with the metal atoms' electrons.

"At the interface between nickel-iron and graphene we studied, the electrons of the iron atoms and the carbon atoms mix, or 'hybridize,' as we say. Electrons of carbon and nickel don't do that. This influences how the junction as a whole behaves," explains Ono.

The results don't only pave the way for better control over the manufacture of this specific component. Since the researchers found a basic mechanism governing the interface structure between ferromagnetic metals and two-dimensional materials, they extend to other material systems, too.

Ono says, "Our goal is to develop high-performance magnetic tunneling junctions made from other materials, too. We believe we have achieved fundamental and valuable results that will advance studies throughout the field."

More information: Naohiro Matsumoto et al, Theoretical

investigation of interface atomic structure of graphene on NiFe alloy substrate, *Journal of Applied Physics* (2025). DOI: 10.1063/5.0283881

Provided by Kobe University

Citation: How you make it matters: Spintronics device performance tied to atomic interface changes (2025, September 18) retrieved 1 October 2025 from https://phys.org/news/2025-09-spintronics-device-atomic-interface.html

This document is subject to copyright. Apart from any fair dealing for the purpose of private study or research, no part may be reproduced without the written permission. The content is provided for information purposes only.