国立大学法人 豊橋技術科学大学

TOYOHASHI UNIVERSITY OF TECHNOLOGY

PRESS RELEASE

Source: Toyohashi University of Technology, Japan, Committee for Public Relations

Release Title: Establishing an elemental structure that facilitates high-intensity broadband spin waves

Release Subtitle: Contributing to the realization of ultra-low energy consuming spin-wave circuits

Overview

A research team including Assistant Professor Taichi Goto of Toyohashi University of Technology has conducted simulations to demonstrate that using a substrate that combines the semiconductor silicon (Si) and the magnetic insulator yttrium iron garnet (YIG) can realize an element that facilitates excitation and detection of high-intensity broadband spin waves, even when miniaturized like chips. It is hoped that spin waves can be used in next-generation ultra-low energy consumption devices because they transmit through magnetic insulators that do not let electric currents through. At the same time, it is thought that it can be combined with generally and widely used semiconductor devices, and this research may serve as an indicator for substrate technology and material development that have that aim.

This research was jointly conducted by PhD candidate Kanta Mori, Takumi Toguchi, Assistant Professor Taichi Goto, Associate Professor Yuichi Nakamura, Professor Lim Pang Boey, and Visiting Professor Mitsuteru Inoue of Toyohashi University of Technology as well as Chief Researcher Toshiaki Watanabe of Shin-Etsu Chemical and Professor Alexander Ustinov of Saint Petersburg Electrotechnical University.

Details

It is hoped that spin waves can be used in next-generation ultra-low energy consumption devices because they transmit through the magnetic insulator yttrium iron garnet (YIG) that does not let electric currents through. Demonstrations of logical operation elements using spin waves are being conducted in Russia, Germany, the United States, Japan, and other countries across the world. At Toyohashi University of Technology, research is being done on making spin-wave devices smaller and miniaturize them to chip size. When miniaturizing spin-wave devices, it is necessary to make the elemental structure that excites spin wave small.

However, as research progressed, it became clear that simply making existing structures small causes the spin waves excited to have narrow bandwidth and low intensity. This has to do with the electrode structure of the element exciting spin waves. The element exciting spin wave consists of two electrodes and YIG. It was found that these two electrodes need to form on the front and back of the YIG film in order to excite high-intensity broadband spin waves.

However, the thickness of YIG films in recent spin-wave device research has ranged from a few micrometers to nanometers, making them so thin that it is not possible to simply make electrodes on both sides since the film will break.

As such, this paper suggests a YIG-on-metal (YOM) structure where a 1-micrometer thick YIG film is attached on silicon (Si) via metal. Since an electrode already exists on the back of the YIG when using a YOM substrate, it is possible to make an element exciting spin waves simply by creating another electrode on the front. Simulating this structure has shown that it is possible to create an element exciting spin waves with a functional index more than twice that of conventional electrode structures, achieving broader frequency bandwidth and higher intensity.

Future Outlook

The proposed YOM structure is formed on top of a Si substrate, so it is thought that it will accelerate research on combining spin-wave devices using magnetic bodies and electronic devices using semiconductors. Based on the results of these simulations, Toyohashi University of Technology plan to collaborate with Shin-Etsu Chemical, who specialize in Si and YIG material development, and Saint Petersburg Electrotechnical University, who specialize in spin-wave element development, to develop actual YOM substrates and spin-wave elements. Finally, the aim is to develop comprehensively excellent device systems by having the strong functions of spin-wave elements complement the weak functions of electronic circuits using semiconductors.

Reference

This research was reported in the following paper. It can be downloaded for free.

Kanta Mori, Taichi Goto, Toshiaki Watanabe, Takumi Koguchi, Yuichi Nakamura, Pang Boey Lim, Alexey B. Ustinov, Mitsuteru Inoue, “Broadband excitation of spin wave using microstrip line antennas for integrated magnonic devices”, *Journal of Physics D: Applied Physics*, https://doi.org/10.1088/1361-6463/ac3f10

This research received the following support.

- Grants-in-Aid for Scientific Research, Japan Society for the Promotion of Science (JSPS): No. 20H02593, No. 19H00765, and No. 20K20535
- Bilateral Exchange Project, JSPS and RFBR: No. JPJSBP120214807
- New Energy and Industrial Technology Development Organization (NEDO) No.20002157-0
- Foundation for Technology Promotion of Electronic Circuit Board
- Research Foundation for the Electrotechnology of Chubu

Further information

Toyohashi University of Technology

1-1 Hibarigaoka, Tempaku, Toyohashi, Aichi Prefecture, 441-8580, JAPAN

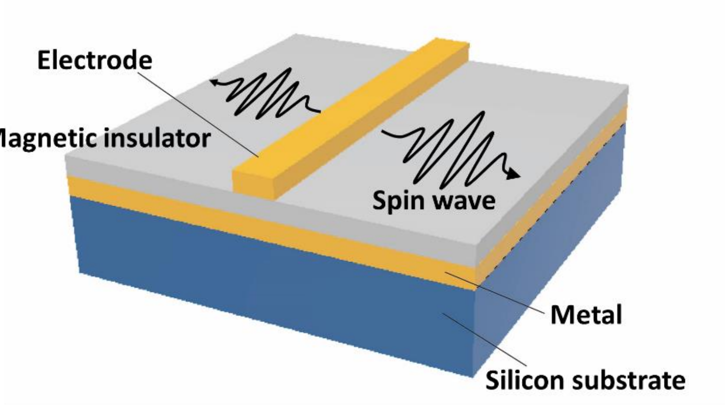
Inquiries: Committee for Public Relations

E-mail: press@office.tut.ac.jp

Toyohashi University of Technology founded in 1976 as a National University of Japan is a research institute in the fields of mechanical engineering, advanced electronics, information sciences, life sciences, and architecture.

Website: https://www.tut.ac.jp/english/

Figure:



Title: Outline of proposed structure for exciting and detecting spin waves.

Caption: There is a magnetic insulator between the top electrode and the metal, all of it lying on top of a silicon substrate.

Keywords: Magnetic semiconductors, Electrodes, Silicon, Yttrium, Iron, Electronic devices, Integrated circuits