World's First Observation of the Transverse Thomson Effect

— A New Principle 170 Years After the Discovery of the Thomson Effect: Pioneering Next-Generation Thermal Management Technologies —

For the first time in the world, a joint research team from NIMS, Nagoya University and The University of Tokyo has successfully observed the transverse Thomson effect—a phenomenon in which metals or semiconductors release or absorb heat when a heat current, charge current and magnetic field are applied orthogonally to each other. This achievement may contribute to advances in physics and materials science related to the conversion between heat, electricity and magnetism, as well as to the development of new thermal management technologies. The research was published in *Nature Physics* on June 26, 2025.

Research Overview

■ Current Issues

The Thomson effect—discovered by William Thomson, a pioneer in thermodynamics and electromagnetism—is a fundamental thermoelectric effect, along with the Seebeck and Peltier effects. It is a phenomenon in which metals or semiconductors release or absorb heat when a heat current and charge current are applied in the same direction. These three effects depicted in Figure 1a–c are referred to as "longitudinal" thermoelectric effects, which the interconversion between the heat current (or temperature gradient) and charge current in a parallel direction. By contrast, the Nernst and Ettingshausen effects are classified as "transverse" thermoelectric effects, which interconvert heat and charge currents in perpendicular directions. Transverse thermoelectric devices have attracted increasing attention in recent years due to their simpler structures and potential applicability in thermal management (Figure 1d–e). All these longitudinal and transverse thermoelectric effects were discovered as early as the 1800s (Figure 1a–e). Although materials and devices exhibiting these effects have been actively researched and developed worldwide, the transverse Thomson effect had not been experimentally observed—despite longstanding theoretical expectations of its existence.

■ Research Highlights

The research team applied a heat current, charge current and magnetic field to bismuth–antimony alloys orthogonally to each other. As a result, the team observed heat release and absorption signals with patterns that could not be explained by conventional thermoelectric effects. When the direction of the magnetic field was reversed, heat release switched to heat absorption. This resulting temperature behavior was found to be consistent with predictions of the transverse Thomson effect (Figure 1f). This effect—fundamentally distinct from the conventional Thomson effect—can occur only through the simultaneous action of the Nernst and Ettingshausen effects.

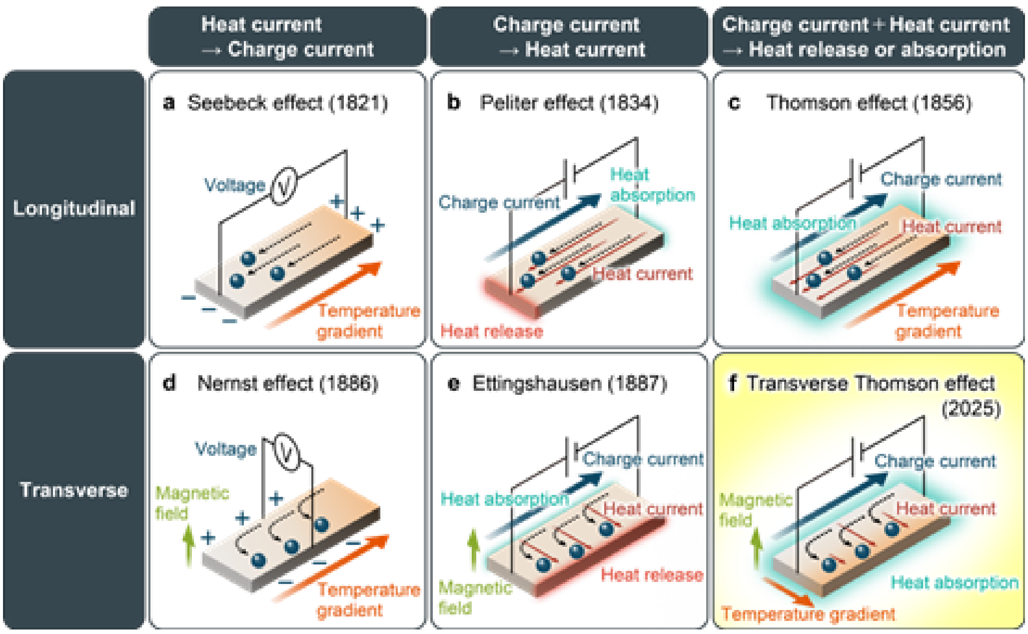

Figure 1. Conceptual diagrams of longitudinal and transverse thermoelectric effects

Note: Please use "NIMS" consistently as the abbreviation for the National Institute for Materials Science.

■ Future Outlook

The first experimental observation of the transverse Thomson effect represents a major milestone in thermoelectric research. Discovering materials with stronger transverse Thomson effects in future studies could enable the development of technologies capable of actively controlling heat release and absorption in materials and devices by simply reversing the direction of an applied magnetic field.

■ Other Information

- This project was carried out by Atsushi Takahagi (Graduate Student, Department of Mechanical Systems Engineering, Nagoya University; also a trainee at NIMS) as part of his doctoral program, in collaboration with the following researchers: Ken-ichi Uchida (Distinguished Group Leader, Research Center for Magnetic and Spintronic Materials (CMSM), NIMS; and Professor, Department of Advanced Materials Science, Graduate School of Frontier Sciences, The University of Tokyo), Takamasa Hirai (Senior Researcher, CMSM, NIMS), Sang Jun Park (Postdoctoral Researcher, CMSM, NIMS), Hosei Nagano (Professor, Department of Mechanical Systems Engineering (DMSE), Nagoya University (NU)), and Abdulkareem Alasli (Designated Lecturer, DMSE, NU).
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