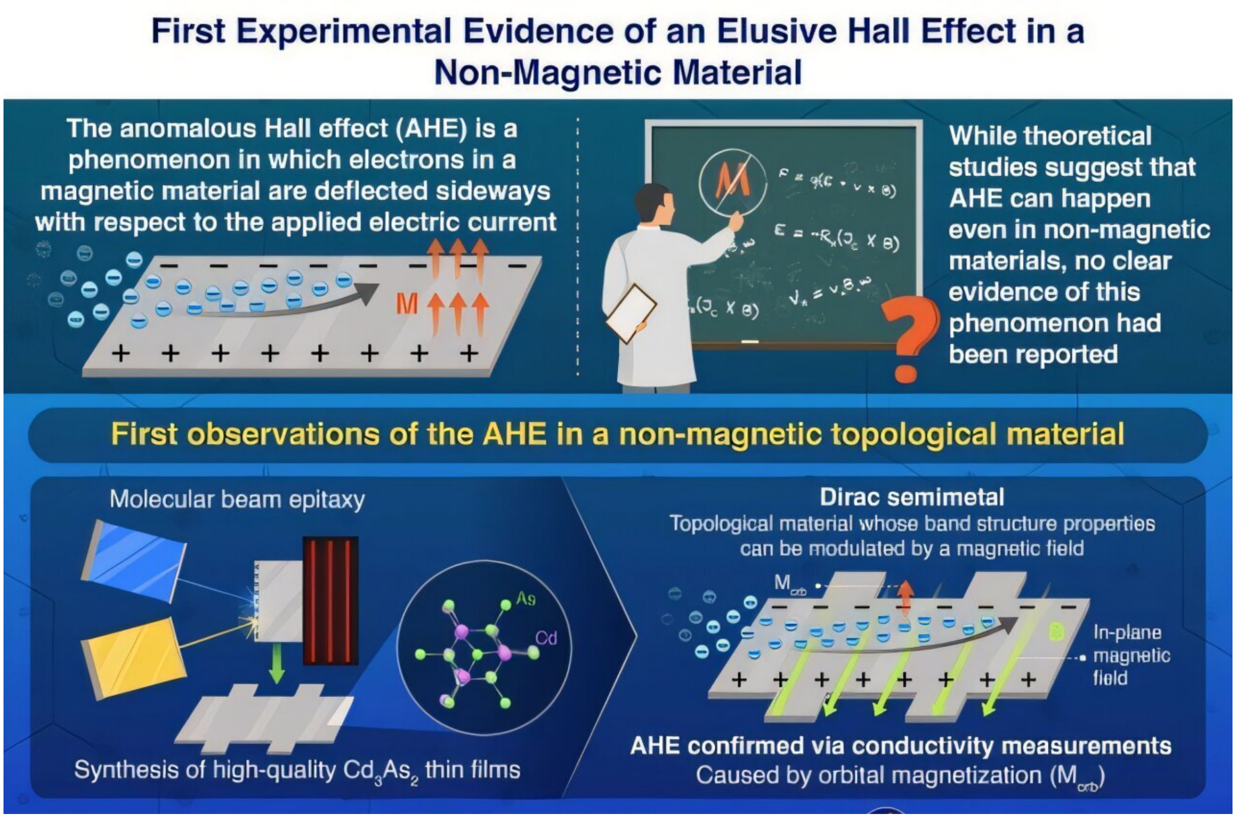
Physicists observe an elusive form of the Hall effect for the first time

August 28 2025



This infographic depicts the technique used by the research team to observe the anomalous Hall effect in a nonmagnetic material for the first time. The team utilized a Dirac semimetal and applied an in-plane magnetic field to observe the anomalous Hall effect. Credit: Institute of Science Tokyo

A giant anomalous Hall effect (AHE) has been observed in a nonmagnetic material for the first time, as reported by researchers from Japan. This surprising result was achieved using high-quality Cd_3As_2 thin films, a Dirac semimetal, under an in-plane magnetic field. By modulating the material's band structure, the team isolated the AHE and traced its origin to orbital magnetization rather than spin, challenging long-held assumptions in condensed matter physics.

In 1879, American physicist Edwin Hall discovered that a voltage develops across a conductor when it carries an electric current in a magnetic field, caused by the sideways deflection of moving charges. This phenomenon, which later became known as the Hall effect, quickly became a hot topic in the field and led to notable advances in the theoretical, experimental, and practical realms alike. Soon after the initial discovery of the Hall effect, scientists noticed that magnetic materials exhibited a similar phenomenon—this was coined the anomalous Hall effect (AHE).

Much more puzzling than the ordinary Hall effect, the AHE has stirred up debate among physicists for decades regarding the true nature of its origin. Some theoretical predictions have even hinted that AHE may be possible even in nonmagnetic materials. However, experimental confirmation of these predictions had never been achieved—until now.

In a recent study, a research team led by Associate Professor Masaki Uchida from the Institute of Science Tokyo, Japan, reported the first observation of the AHE in a nonmagnetic material. This breakthrough is published in the journal *Physical Review Letters*.

To achieve this feat, the team turned to Dirac semimetals. These materials have unique features in their electronic band structure called Dirac points, in which electrons behave like massless particles. Under an external magnetic field, these Dirac points turn into Weyl points as a result of symmetry breaking, giving rise to more complex, directional electron behavior.

By modulating the band structure properties of the material in this way, the researchers devised a strategy to drown out the contributions of the ordinary Hall effect and focus on the AHE exclusively.

"Our study is the first to experimentally confirm that AHE can be quantitatively detected in nonmagnetic materials using in-plane magnetic fields," notes Uchida.

Using molecular beam epitaxy, the team produced high-quality Cd_3As_2 thin films, a Dirac semimetal with the necessary symmetries. They applied an in-plane magnetic field to these films and measured the Hall conductivity of the material. Based on the changes in this conductivity in response to variations in the applied magnetic field, the researchers could infer the magnitude of the induced AHE.

Surprisingly, the team managed to induce a giant AHE with this setup. Detailed analysis of the experimental results suggested that this effect originated from orbital magnetization—that is, magnetization due to the orbital motion of electrons rather than their spin.

Taken together, these findings provide valuable insights into a well-studied yet not fully understood physical phenomenon. "The approach used in our study is widely applicable beyond Dirac semimetals, challenging long-standing assumptions about Hall effects. Future research could lead to the development of next-generation devices," notes Uchida.

Notably, understanding the AHE in more detail opens up pathways to explore electron properties based on orbital magnetization. "We expect these results to catalyze both basic research into the underlying physics and applied research into devices that leverage the AHE," says Uchida.

"Hall sensors and other devices that exploit AHE in nonmagnetic materials could become more efficient and operate under broader conditions than current technologies."

More information: Shinichi Nishihaya et al, Anomalous Hall effect in the Dirac semimetal Cd_3As_2 probed by in-plane magnetic field, *Physical Review Letters* (2025). DOI: 10.1103/5d7l-mr7k. On *arXiv*: DOI: 10.48550/arxiv.2503.04195

Provided by Institute of Science Tokyo