Altermagnetism A New Class of Magnetism

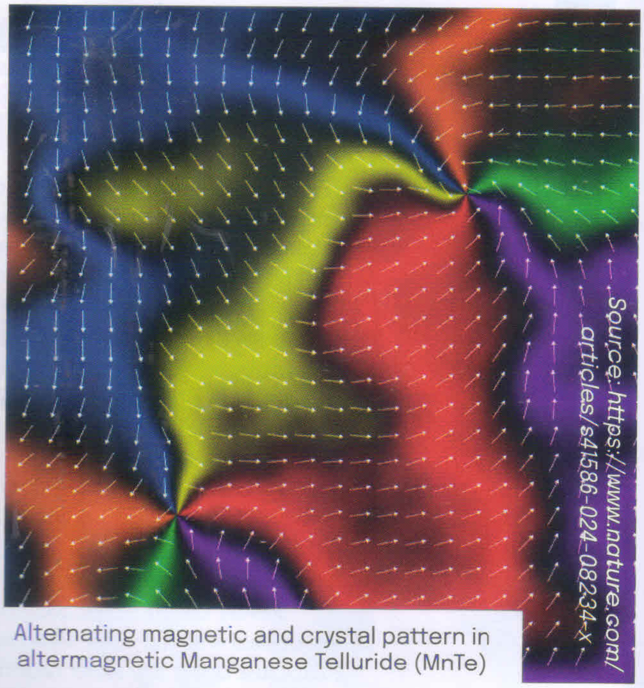
MAGNETISM, a fundamental and expansive area within condensed matter physics, plays a crucial role in advancing technology. Traditionally, this field has primarily focused on two magnetic phases: ferromagnetism and antiferromagnetism. For instance, iron is attracted by magnets due to the magnetic spin moment. On the other hand, in Manganese Oxide (MnO), the spin moment cancels, resulting in no net magnetization. Recent developments have introduced a groundbreaking form of collinear magnetism known as "Altermagnetism", which is the exciting marriage between ferromagnetism and antiferromagnetism. This is now called the third phase of magnetism, which has opened up new frontiers in physics, chemistry, and material science. This exclusive new class of magnetism research is being reported in the journal *Nature* by Peter Wadley, Professor at the School of Physics and Astronomy, University of Nottingham, and his colleagues.

The novel third phase is characterised by a compensated magnetic order in real space, where opposite-spin sublattices are related by crystal-rotation symmetries. In reciprocal momentum space, this is mirrored by an unconventional spin-polarization order that adheres to the same rotational symmetries. This can be visualised in the crystal of Manganese Telluride (MnTe) in the adjacent figure. The direct-to-reciprocal-space correspondence results in electronic band structures with broken symmetry and alternating momentum-dependent signs of spin splitting in the same way chameleon changes its colour in response to the change in environment.

Also, the emerging magnetic phase is characterised by robust time-reversal symmetry breaking, antiparallel magnetic order (like Antiferromagnetic substances (AFMs) having net zero magnetic moments), and alternating spin-splitting band structures. Yet, it exhibits vanishing net magnetisation constrained by symmetry in contrast to Ferromagnets (FMs), known for their spin polarisation that mirrors the macroscopic magnetisation, facilitating a myriad of time-reversal symmetry-breaking responses.

Further, altermagnets are a newly identified class of collinear, spin-compensated magnetic materials characterised by net-zero magnetisation. Despite this, they exhibit electronic properties commonly associated with non-compensated magnetic materials, such as ferromagnets. These unique behaviours stem from spin-split bands that emerge under particular symmetry conditions in the absence of spin-orbit coupling.

Altermagnetism represents a unique fusion of characteristics traditionally regarded as exclusive to collinear ferromagnetism and antiferromagnetism, enabling phenomena and functionalities that were previously unattainable within these conventional magnetic categories. Experimental studies have validated the existence of the altermagnetic phase, highlighting its distinctive properties and potential applications. Research on altermagnets is expanding rapidly, focusing on uncovering novel physical phenomena, methods for inducing altermagnetic states, and identifying promising altermagnetic materials.



Alternating magnetic and crystal pattern in altermagnetic Manganese Telluride (MnTe)

Interestingly, altermagnets exhibit an unusual combination of ferromagnetic and antiferromagnetic properties, which remarkably more closely resemble those of ferromagnets. Hallmarks of altermagnetic materials, such as the anomalous Hall effect, have been observed before (but this effect occurs also in other magnetically compensated systems, such as non-collinear antiferromagnets). Altermagnets also exhibit unique properties, such as anomalous and spin currents, that can change signs as the crystal rotates.

It has been presumed that altermagnetism may have applications in the field of nanotechnology, spintronics, practical superconductors, topological materials, etc., may shape the future of electronics (like computer hard drives and mobile chips), and quantum computing, and storage devices with greater accessibility to data. As tuning of altermagentic materials allows us to control the magnetic properties of substances, precisely controlling the altermagentism is possible, and we can improve the efficiency of future devices. The research will inspire further innovative studies on altermagnetic materials, which can potentially revolutionise applications in technology and materials science.

Dr Bibhuti Narayan Biswal, Academic Lead, Reliance Foundation Schools Academic Council (RFSAC), Reliance Corporate Park, Navi Mumbai.
E-mail: bibhuti.nb@gmail.com