Q&A: Toward the next generation of computing devices

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Anjan Soumyanarayanan and his team at A*STAR's Institute of Materials Research and Engineering (IMRE) are paving the way for next generation computing based on magnetic skyrmions. Credit: Anjan Soumyanarayanan

Ever noticed how our smartphones and computing devices become faster within short spans? You can thank Moore's law for that. Back in 1965, Intel co-founder Gordon Moore predicted that the processing power of computers would double about every two years, and incredibly this empirical rule-of-thumb has held on for over five decades.

However, modern computing technology is now reaching its scaling limits, potentially bringing Moore's law to a screeching halt. Meanwhile, the demand for computing power continues to grow rapidly—in part due to the advent of artificial intelligence.

Circumventing these restrictions on memory and computing power is the need of the hour, and it requires one to look beyond conventional devices and computing architectures. Behold one of the candidates: tiny magnetic quasi-particles called skyrmions that may offer a way to surpass conventional processing limits.

Because the information storage memory and decision-making functions of computers are typically kept separate, performing even the simplest of tasks consumes energy. Skyrmions, one of the candidates that may combine the two functions, are opening the doors to faster processing and real-time decision making with reduced power.

Discovered over a decade ago, magnetic skyrmions have proven tricky to control. But not anymore, thanks to a breakthrough technique pioneered by Anjan Soumyanarayanan and his colleagues from A*STAR's Institute of Materials Research and Engineering (IMRE). Through their method, the team managed to finetune the size, density and stability of the skyrmions, drawing them closer to realizing energy-efficient computing.

For literally putting a fresh spin on skyrmions and harnessing quantum phenomena for nanoelectronics, Soumyanarayanan received the Young Scientist Award at the 2018 President's Science and Technology Awards. Soumyanarayanan, who is also an assistant professor at the National University of Singapore and the 2018 recipient of the IEEE Magnetics Society Early Career Award, gives us a closer look at skyrmions and the role they could play in next-generation computing.

Tell us about the key problem you are trying to solve with your research.

Moore's law, or the exponential growth of computing power with time, is reaching its limits after a five-decade reign as the cornerstone of modern electronics. One promising alternative is to use the electron "spin" instead of charge to store, process, and transfer information. Spin electronics, or spintronics, may offer devices with faster processing speeds while drastically reducing power consumption.

Of late, my research efforts have focused on magnetic skyrmions. Recently discovered in industry-compatible materials, skyrmions are nanoscale arrangements of electron spins that behave like individual magnetic particles. They have promising attributes as base elements for next-generation computing. We are developing thin-film materials hosting such skyrmions and investigating their behavior in nanoscale devices.

What are some seminal findings in your field that you intend to build upon?

First, spintronic devices require the ability to electrically detect (read) and manipulate (write) spins to form 0 and 1 states—to represent the binary system used in conventional computer code. Discovered three decades ago, these capabilities were recognized with the 2007 Nobel Prize and are commercially used in modern hard disk drives and magnetic random access memory (MRAM).

More recently, the coupling between electron spin and momentum—known as spin-orbit coupling (SOC)—has emerged as an attractive ingredient in industry-compatible thin films. On one hand, SOC enables the creation of magnetic skyrmions and other novel phenomena. On the other hand, it provides a fast and energy-efficient means for electrical writing.

Finally, we hope that such devices may find use in mimicking the biology of neurons, thereby realizing brain-inspired or "neuromorphic computing. This burgeoning topic is seeing numerous device proposals to achieve recognition, pattern-matching and decision-making capabilities mimicking the human brain.

How did you become interested in studying magnetic skyrmions?

The formation of magnetic skyrmions relies on three key ingredients: spin-orbit coupling, magnetism as well as the unique topology at certain material surfaces and interfaces. These concepts are central to several emergent phenomena discovered over the last 10 to 15 years. In 2010, these concepts were the backbone of a successful grant proposal that I co-wrote with my Ph.D. advisor to support my thesis work on topological materials. Upon returning to Singapore, A*STAR's deep capabilities in magnetic thin films provided a natural pivot towards skyrmions. I am glad that it came with challenges in materials science and device engineering—both of these have proven to be valuable learning opportunities.

Could you please describe one of the most exciting projects you are working on right now?

Though magnetic skyrmions show great promise as nanoscale data processing elements, they're not the easiest to work with. In fact, till recently magnetic skyrmions were previously observed only at low temperatures. Therefore, our initial efforts on this topic focused mostly on establishing and tailoring their room temperature properties in thin films. Recently we have been exploring their electrical behavior within device configurations compatible with large-scale fabrication. Eventually, we hope to realize electrical detection, or reading, and electrical manipulation, or writing of skyrmions in such devices. The seamless integration of diverse capabilities—such as materials development, device fabrication and electrical characterization—required for them to work is challenging and yet exciting.

What are some of the industrial/social implications of your research? Who will benefit from the findings?

Our research aligns with broader efforts in the field of spintronics. Spintronic technologies are commercially used in hard disk drives and magnetic memory. Future discoveries from spintronic research could enable new computing architectures, in addition to low power device operation at extremely fast speeds. Such devices could help us achieve energy-efficient computing platforms.

This could potentially manifest in data centers with reduced power consumption. Alternatively, they could be used to develop personal or edge computing devices with AI capabilities. Eventually, such research may be applied in diverse domains ranging from manufacturing to healthcare and surveillance, as it can aid in monitoring as well as recognizing faults for intervention.

How do you see your research area evolving in the next 5-10 years?

Use-inspired research areas, including ours, are evolving rapidly in how problems are defined and tackled. For example, defining problems requires increased and sustained engagement with stakeholders across the entire value chain. Likewise, solving complex, large-scale problems requires forming interdisciplinary teams comprising materials scientists, physicists, electrical engineers and computer scientists. Notably, machine learning techniques are now playing an increasingly vital role in the prediction, design and analysis of materials and device parameters. These and other emerging factors will help shape our research area in the near future.

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