Energy saving AI using (artificial) topological materials

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Remarkable success in the deep learning triggered the 3rd boom in demand for the artificial intelligence (AI). Exploding demands requires R&D of energy saving AI system. One of the effective way is the usage of TPUs (tensor processing unit) that already reduced the energy consumption of the alpha-GO by a factor of 1/40. Another attempt is to make neuromorphic hard ware using certain physical phenomena. In this talk, two attempts to realize energy saving AI chips from topological magnetic system will be introduced.

The first attempt is to make neuromorphic system using MRAM technology. The neuromorphic system needs to have memory capability and non-linear calculation capability. Needless to say, MRAM is a memory. In addition, if magnetic cells in MRAM interact each other through dipole-dipole interaction, MRAM may get non-linear calculation capability. Such method was tested in our group using simulations. As a result, the device with 12 magnetic cells could be trained to calculated AND, OR and XOR of two bits among successive 3 bits inputs [1]. However, the training was possible only at low temperature, because of small energy of the dipole coupling. To overcome this difficulty, we started to use topological state to carry information. One of the example is an artificial spin-ice in a honeycomb lattice with 72 magnetic cells. The system is capable to learn XOR with 2-bit delay [2].

The second attempt is to make zero-power consumption calculator using magnetic skyrmions in a film. Magnetic skyrmion is known as a topological object appeared in ferro(antiferro)-magnetic materials without point symmetry. Interesting point of this object is its Brownian motion. Skyrmion shows Brownian motion in all solid state device without any motion of real mass. Therefore, it can be an ideal system to investigate a diffusion and information thermodynamics. By now, we have successfully controlled diffusion of skyrmions by an application of voltage [3] (Fig. 1), through a voltage induced change in the magnetic anisotropy [4], or DMI [5]. By using such techniques, we are now trying to design reconfigurable Boltzmann machine with zero energy consumption. It does not consume energy for the calculation in principle but small energy for the observation, just like the Maxwell's daemon does.

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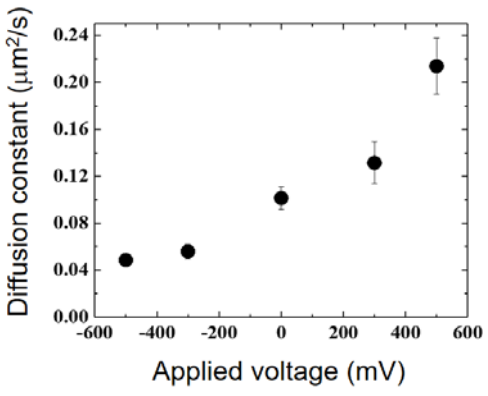

Fig. 1 Diffusion constant of skyrmions as a function of applied voltage [3].

Reference

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