Large-scale micromagnetic simulation for permanent magnets and soft-magnetic materials

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Micromagnetic simulations have revealed the magnetization process in various magnetic materials. Since the magnetization process governs the performance of magnetic materials, it is indispensable for developing high-performance magnetic materials. Micromagnetic simulation has been extensively applied to studying magnetic materials and devices. However, actual bulk magnetic materials pose a problem for micromagnetic simulation. For example, permanent magnets are composed of many crystal grains with a grain size of µm. On the other hand, the magnetic domain wall width is about a few nm due to crystalline magnetic anisotropy. Therefore, simulation models of actual bulk magnetic materials must be divided into many micro-regions, significantly increasing the computational cost.

Massively parallel computing uses many processes for numerical computation and data management. Because magnetic dipole fields generate long-range forces, calculations require all magnetization vectors in the simulation model. In addition, micromagnetic simulations require communication between all processes. Therefore, for highly efficient micromagnetic simulation in a massively parallel environment, we have developed algorithms that minimize the amount of inter-process communication.

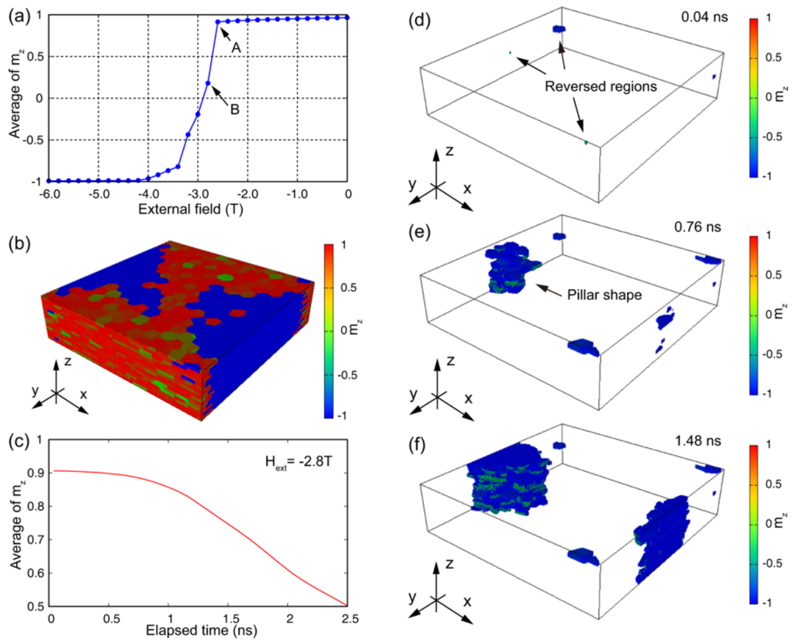

Figure 1: Magnetization dynamics during demagnetization process in hot-deformed permanent magnet. (© Originally published in NPG Asia Materials 12, 29 (2020). Published by Springer Nature. Licensed under CC BY 4.0. Modified from original.)

In this talk, we will present a massively parallel method for micro-magnetic simulation using the finite difference method and Message Passing Interface (MPI) and its application to bulk magnetic materials, namely permanent magnets and soft magnetic materials. The magnetization process inside permanent magnets and soft magnetic materials are simulated to reveal magnetization reversal nucleation and magnetic wall motion.

References

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