Determination of the Dzyaloshinskii-Moriya interaction from a single magnetic domain image using image recognition

The University of Tokyo [1], Toyota Technological Institute [2], Gifu University[3], University of Electro-Communications[4]

○Masashi Kawaguchi[1], Kenji Tanabe[2], Keisuke Yamada[3], Takuya Sawa[2], Shun Hasegawa[1], Masamitsu Hayashi[1], and Yoshinobu Nakatani[4]

E-mail: masashi.kawaguchi@phys.s.u-tokyo.ac.jp

The Dzyaloshinskii-Moriya interaction (DMI), generating chiral magnetic orders in symmetry broken ferromagnetic multilayers, plays important roles in magnetization dynamics in spintronics devices like a racetrack memory. For evaluation of DMI, several methods have been proposed, however, they are complicated and difficult to obtain accurate values due to complex behavior of the many-body system of magnetization with DMI. Recently, rapidly developing machine learning provides powerful methods to analyze such complex systems, e.g. image recognition. In this study, we demonstrate a determination of DMI employing machine learning with convolution neural network (CNN), often referred to as AI, from a single magnetic domain image.

In order to train CNN, we prepared a training data set of magnetic domain images using micromagnetic simulations with DMI parameter D varied from 0 to 1.0 mJ/m^2 (Fig.1(a)). The accuracy of the trained CNN was evaluated by a testing data set generated from the simulations. The testing results shown in Fig.1(b) display that CNN estimate D with an accuracy of ~0.05 mJ/m^2. Finally, we tested the trained CNN with experimental data set, combinations of magnetic domain images and D values, obtained from ferromagnetic multilayers, Si sub./Ta (d)/Pt (2.6 nm)/Co (0.9 nm)/MgO (2 nm)/Ta (1 nm). The determined D by CNN reproduce experimental values roughly (Fig.1(c)), which implies that CNN can extract DMI influence on magnetic domain patterns.

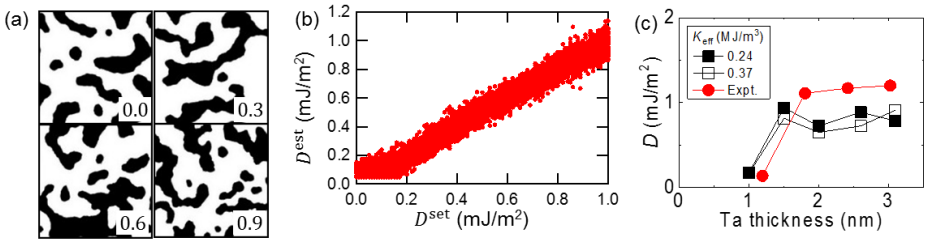

Figure 1 (a) Magnetic domain patterns generated by micromagnetic simulations with each D value for supervised learning. (b) D estimated by CNN vs D set for testing data. (c) Experimental D values (red circles) and estimated D values (black and white squares). Data taken from Ref. [1].

[1] M. Kawaguchi, K. Tanabe, K. Yamada et al., npj Computational Materials, *in press.*