Huge Dzyaloshinskii-Moriya interactions in Re/Co[n]/Pt thin films

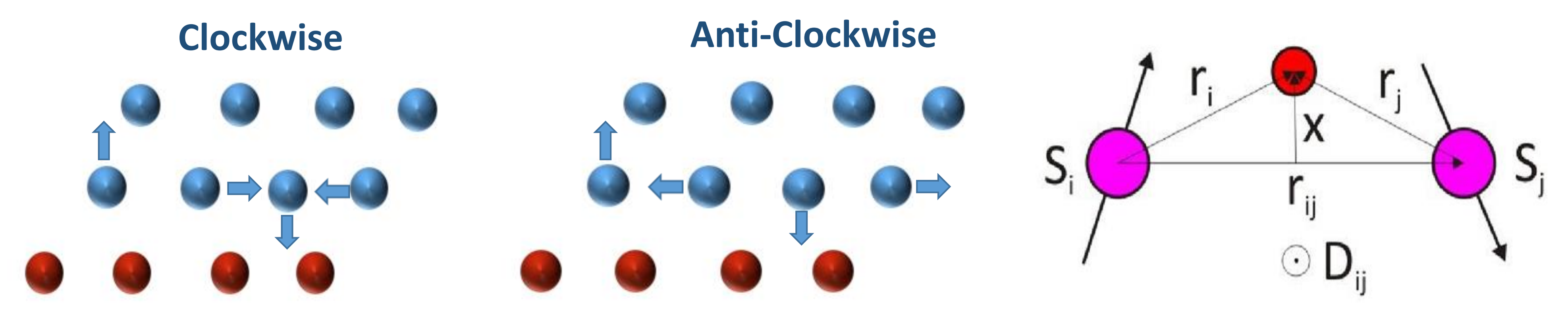
Amar Fakhredine[1], Carmine Autieri[2], Andrzej Wawro[1]

1. Institute of Physics, Polish Academy of Sciences, Aleja Lotników 32/46, PL-02668 Warsaw, Poland
2. International Research Centre MagTop, Institute of Physics, Polish Academy of Sciences, Aleja Lotników 32/46, PL-02668 Warsaw, Poland

Motivation

The Dzyaloshinskii Moriya interaction is an antisymmetric indirect exchange interaction occurring between two spins S_i and S_j. Initially, it explained the weak ferromagnetic interaction in antiferromagnets. This kind of interaction arises also in systems with broken inversion symmetry as in the case of interfaces [1], in addition to finite spin-orbit coupling. This interaction is fundamental for the appearance of complex magnetic structures, e.g. skyrmions which are promising for the industry of spintronic applications, offering ultra-small, ultrafast and low-power devices . As we are able to control the DMI in multilayered structures, we can also manipulate different sizes and stability of these magnetic objects [2].

Spin configurations used to calculate the DMI at the Co interfaces



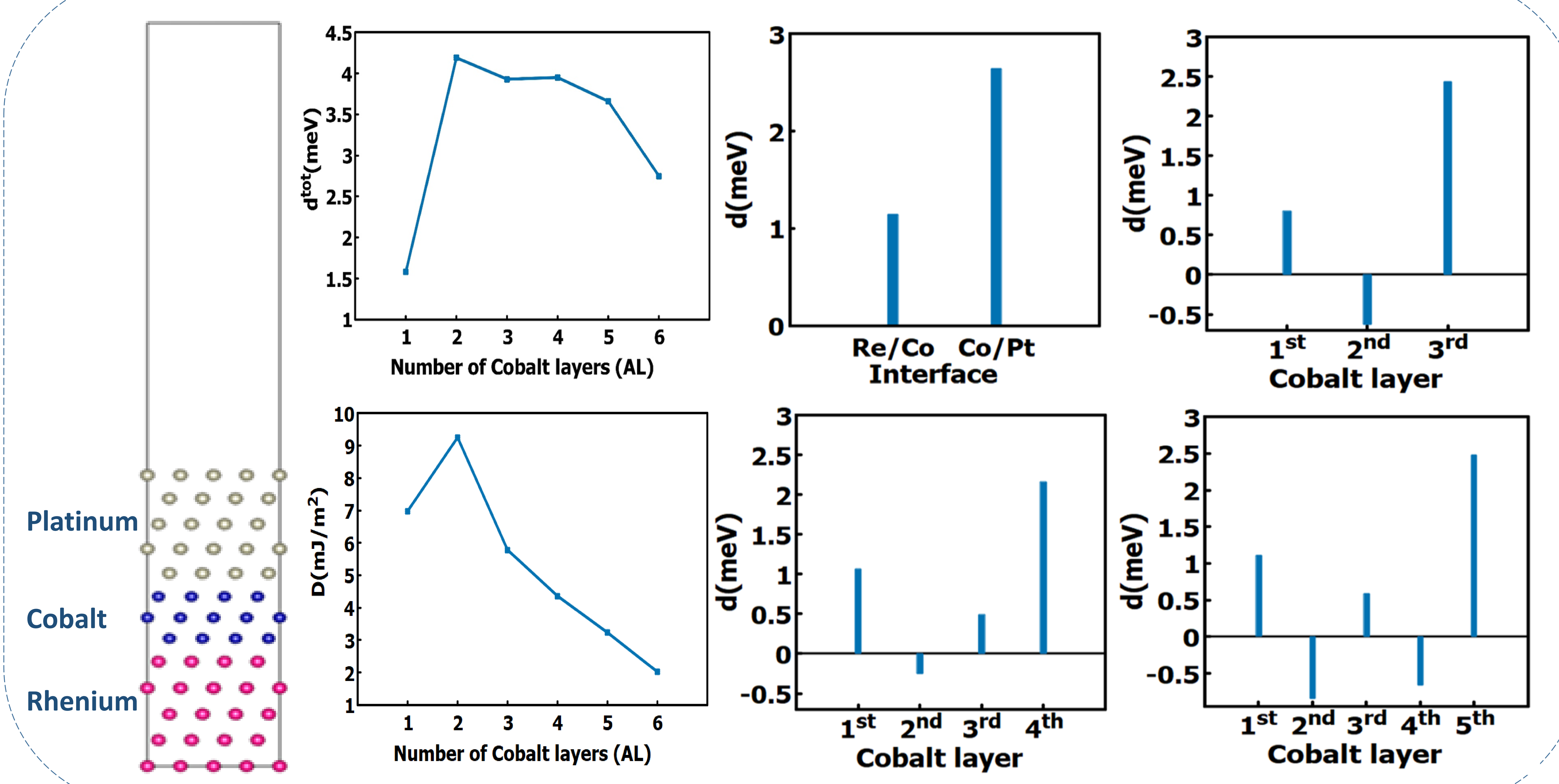
Computational details

The technique of constraining the magnetic moments in a supercell was used to calculate the DMI of Re/Co[n]/Pt multilayers through the density functional theory (DFT) framework. The Vienna ab-initio simulation method (VASP) was used in all calculations. For modeling the geometries of the interfaces, the experimental in-plane (IP) lattice constant of the Pt (111) surface which is equal to 3.92 Å was used, hcp layer growth was assumed for Co and Re layers, while for Pt, fcc growth was considered.

Evaluation of the results

The DMI strength (d [meV]) parameter was calculated from the energy differences between clockwise and anti-clockwise energy configurations of the magnetic spirals in the Co atomic layers (AL) which were further used to calculate the micromagnetic DMI (D [mJ/m²]). This method has been used for DMI calculations in bulk frustrated systems and insulating chiral-lattice magnets [3]. We modeled the Re/Co/Pt thin films with 5 AL of Pt and 5 AL of Re tuning the number of Cobalt layers from 1 to 6 layers. The system with one Co layer gave a value of d^{tot} equal to 1.58 meV, considering one common interface between Re and Pt. For the systems with n= 2-5, the DMI is around 4 meV. Eventually, the micromagnetic DMI was calculated from the d^{tot} values by the equation given by Yang et al [4]. The value D decreases as the number of Co layers increases from 2 to 6 layers.

Results of the total, micromagnetic, and layer resolved DMI at the Cobalt layers



Discussions

A strong DMI appears at the Pt/Co and Co/Re interface. The DMI vectors at the Pt and Re interface show opposite chiralities. This is in agreement with experiments where the values at Co/Pt and Re/Co add up in the Re/Co/Pt systems producing a huge total DMI. It is also worth to mention that the micromagnetic DMI depends on the magnetic layers' thickness because DMI appears mainly at the interface as an effect of the hybridization between magnetic moment in the 3d Cobalt layers and the strong SOC in 5d states of Pt and Re.

References

[1] H. Soumyajyoti, S. Meyer, A. Kubetzka, and S. Heinze. "Distorted 3Q state driven by topological-chiral magnetic interactions." *Physical Review B* 104, no. 18 (2021): L180404.
[2] Morshed, Md Golam, Khoong Hong Khoo, Yassine Quessab, Jun-Wen Xu, Robert Laskowski, Prasanna V. Balachandran, Andrew D. Kent, and Avik W. Ghosh. "Tuning Dzyaloshinskii-Moriya interaction in ferrimagnetic GdCo: A first-principles approach." *Physical Review B* 103, no. 17 (2021): 174414.
[3] Mazurenko, V. V., Yaroslav O. Kvashnin, A. I. Lichtenstein, and M. I. Katsnelson. "A DMI guide to magnets micro-world." *Journal of Experimental and Theoretical Physics* 132, no. 4 (2021): 506-516.
[4] Yang H., Thiaville A., Rohart S., Fert A. & Chshiev M. Anatomy of Dzyaloshinskii-Moriya Interaction at Co/Pt Interfaces. Physical Review Letters 115, 267210 (2015).
[5] S. K. Jena, R. Islam, E. Milińska, M. M. Jakubowski, R. Minikayev, S. Lewińska, A. Lynnyk, A. Pietruczik, P. Aleszkiewicz, C. Autieri and A.Wawro "Interfacial Dzyaloshinskii–Moriya interaction in the epitaxial W/Co/Pt multilayers." Nanoscale 13, no. 16 (2021): 7685-7693.

Acknowledgement

This project was supported by the Polish National Science Centre under the project no. 2020/37/B/ST5/02299. This work is supported by the Foundation for Polish Science through the international research agendas program co-financed by the European Union within the smart growth operational program.