Influence of the interfacial exchange coupling on the hysteresis curves of ferrimagnetic thin films FeTb / Ta / FeGd.

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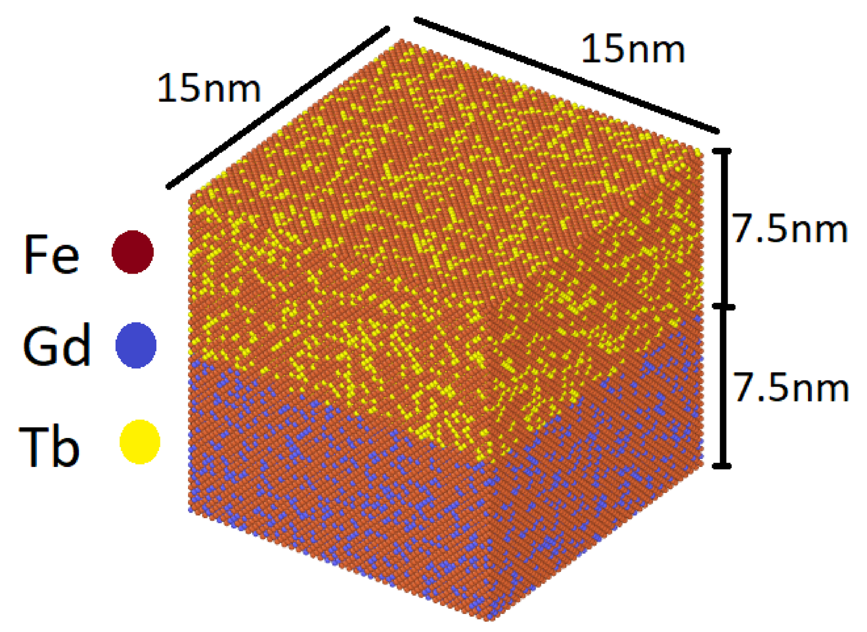
1. Abstract

Thin films have a large number of applications [1], in particular ferrimagnetic films are of great interest for the development of information processing and recording technologies [2]. Additionally, this type of system paves the way for understanding the phenomenon known as exchange bias [3]. In this study, the FeTb / Ta / FeGd multilayer was modeled using the Heisenberg atomic spin model and the extended Heisenberg Hamiltonian. The Ta (non-magnetic) layer was indirectly simulated through a parameter, its thickness modulates the intensity of the interfacial exchange coupling between the ferrimagnetic layers. The simulations were executed using the Landau-Liftshitz-Gilbert stochastic equation implemented in the VAMPIRE program [4]. The results show that by varying the thickness of the Ta layer we can control the hysteresis of the ferrimagnetic layers as well as the intensity of the exchange bias field.

2.Atomic simulation model

We generate each film (amorphous alloy) from an fcc crystalline structure, in which we place the Fe, Gd and Tb atoms randomly at the net sites. So the compositions $Fe_{76}Gd_{24}$ y $Fe_{76}Tb_{24}$ were obtained.



3. Theory

The simulations are performed using VAMPIRE package.The code is based on an atomistic level spin simulation model.The Hamiltonian of the system includes the Heisenberg exchange interaction, uniaxial anisotropy, and Zeeman (applied field) energy:

$$H = -\sum_{i\neq j}^{N} J_{ij}\mathbf{S}_i\cdot\mathbf{S}_j - k_u\sum_{i=1}^{N}(\mathbf{S}_i\cdot\mathbf{e})^2 - \sum_{i=1}^{N}\mu_s\mathbf{S}_i\cdot\mathbf{H}_{ap} \quad (1)$$

Time-dependent spin dynamics is governed by the Landau-Lifshitz-Gilbert (LLG) equation for localized atomistic spins.

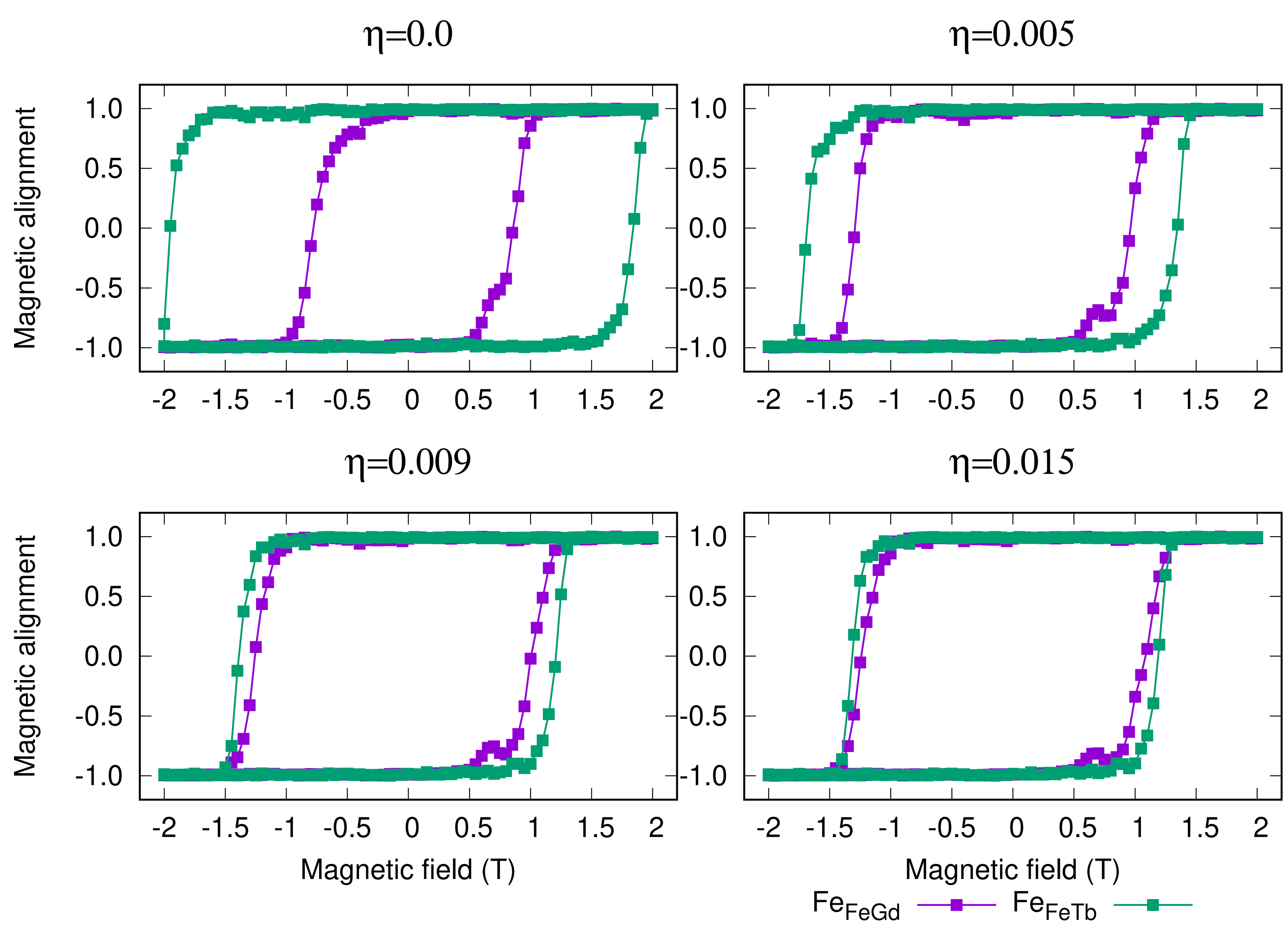
$$\frac{\partial\mathbf{S}_i}{\partial t} = -\frac{\gamma}{(1+\lambda^2)}[\mathbf{S}_i\times\mathbf{H}^i_{eff} + \lambda\mathbf{S}_i\times(\mathbf{S}_i\times\mathbf{H}^i_{eff})] \quad (2)$$

All the simulations are performed at 300K.

4. Results I

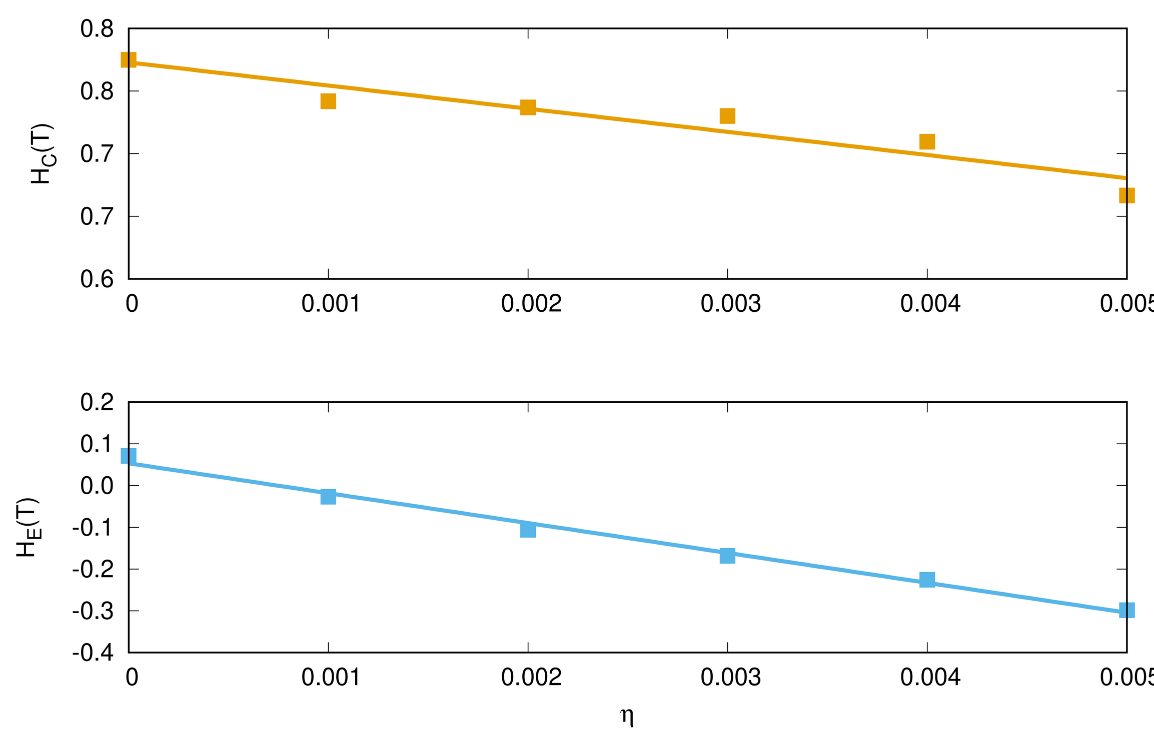
In our simulations the periodic boundary condition is used in the thin film plane (i.e. xy plane) while the open boundary condition in z-axis direction. Inside the FeGd or FeTb layer, for the same kind of rare earth(RE) or transition metal(TM) atoms, the standard ferromagnetic exchange coupling are used for the neighbor spins. In contrast, the exchange coupling between TM and RE atoms is antiferromagnetical coupling.At the interface, the interlayer exchange coupling strength between the FeGd and FeTb layers is relative weaker, compared with the intralyer coupling within FeGd layer or FeTb layer. For that, we define a fraction factor of to describe this reduction.

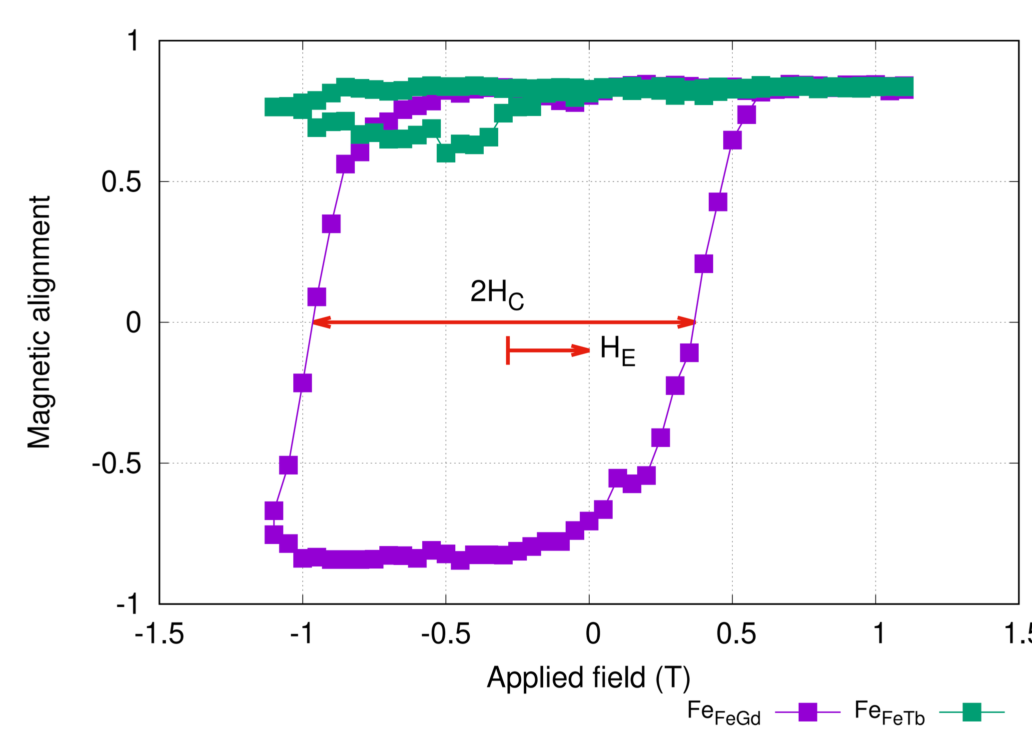
$$J^{interface}_{\alpha,\beta} = \eta J_{\alpha,\beta} \quad (3)$$



5. Results II

The simulations are performed with n=0,005. The system is first saturated, both the FeGd and FeTb is set to +z direction. Then, the field is swept from 1.1 to -1.1 T and then backwards. In this case, a left shifted hysteresis loop is observed for the FeGd layer while the magnetic moment of the hard layer remains at the +z direction. It is also observed that the intensity of the coercive field and the exchange bias field changes with n in an almost linear way.





6. Conclusions

*The coercivity of the layers can be gradually tuned varying the intensity of the interfacial coupling.
*The smallest hysteresis cycle shows an exchange bias effect when n varies from 0 to 0.005.

7. References

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