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Magnetic Hysteresis in an Anisotropic Double Layer

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Abstract: *Magnetic hysteresis phenomen is studied in a two-layer Ising spin S=1 system. It is shown that magnetic hysteresis can be developed in two-layer system without domains and their wall motions or rotation unlike in bulk matter. Variation of hysteresis loop has been studied as a function of exchange constant J, biquadratic exchange interaction constant J', uniaxial single-ion anisotropy D and temperature T.*

Key Words: **Magnetic Hysteresis, Multilayers**

Anizotropik Bir Çift Katmanda Manyetik Histeresis

Özet:*Manyetik histersis olayı Ising Spin S=1 li bir çift katmanda incelenmiştir.Manyetik histersis olayının Ising Spin=1 li bir çift katmanlı sistemde yoğun madde deki gibi duvar, duvar hareketi ve rotasyonu olmadan da meydana gelebileceği gösterilmiştir. Histeresis eğrisinin davranışı değiş-tokuş sabiti J, bikuadratik değiş-tokuş sabiti J', tekeksensel tek-iyon anizotropisi D ve sıcaklık T nin fonksiyonu olarak değişimi incelenmiştir.*

Anahtar Kelimeler : **Manyetik Histersis, Katmanlar**

Introduction

Magnetic Hysteresis is very important and also very difficult phenomenon. Detailed study of magnetic hysteresis makes use of the ferromagnetic, antiferromagnetic, paramagnetic and other related magnetism theories at the same time since every single magnetic domain, which is principally responsible for the magnetic hysteresis, exhibites the one of the beheviors which can be well explained in the frame of above mentioned theories.

Ferromagnetism, antiferromagnetism and paramagnetism are just some well known examples of the single cooperative phenomena, one can interprete the magnetic hysteresis as a cooperative phenomenon composed of many different kind of single cooperative phenomenon.

The occurence of hysteresis can be explained on the basis of domains. Weiss put forward in 1907 that a ferromagnetic material contains a number of domains which are spontaneously magnetized. The magnitude of spontaneous magnetization is the vector sums of magnetic moments of each domain and that spontaneous magnetization in each domain is due to the existence of molecular field [1].

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By these reasons it is extremly important to study the spin configuration of single cooperative phenomenon (magnetic domain) in order to better understanding the magnetic hysteresis .

Theory

In my previous work I have proved that Hysteresis behaviour can be appear between parallel two layers decorated with Ising Spin-1 without single-ion anisotropy [2]. In this study I will include single-ion anisotropy term, I will prove that Hysteresis behaviour will apear again.

The system is composed by two two-dimensional layers.That is the tickness of each layer is just one- atom tick.The spins on the upper layer are initially oriented ferromagneticaly to an axis, say z-axis, which is perpendicular to the layers.The spins on the lower layer are are also oriented ferromagnetically but opposed to the spins on the upper layer. I assume that the interaction between upper and lower layers is negligible. Both layer has a simple square Bravais lattice (coordination number z = 4) on which Ising spins1 are decorated.

The spin-Hamiltonian with single-ion anisotropy for the double-layer above described can be written as follows:

$$\mathbf{H} = -J\sum_{\substack{\langle ij\rangle \\ i,j\in U.L}} S_{iz}S_{jz} - J'\sum_{\substack{\langle ij\rangle \\ i,j\in U.L}} S_{iz}^2 S_{jz}^2 - D\sum_{i} S_{iz}^2 - H\sum_{i} S_{iz} \qquad (1)$$

where J is exchange interaction constant

J' is biquadratic exchange interaction constant

D is uniaxial single-ion anisotropy

H is applied magnetic field

U and L denote the upper and lower layer respectively and finally <ij> means that the summation is taken over the nearest-neighbor spins only . The Hamiltonian can be approximated by making use of the pair approximation as

$$\begin{aligned}\mathbf{H} = &-J\,S_{iz}S_{jz} - J'S_{iz}^2 S_{jz}^2 - (z-1)\langle S_z\rangle(S_{iz}+S_{jz}) \\ &-\{D+(z-1)J'\langle S_z^2\rangle\}(S_{iz}^2+S_{jz}^2) - H(S_{iz}+S_{jz})\end{aligned} \qquad (2)$$

Magnetic induction **B** versus magnetic field **H** as function of the parameters α, β and γ which are the ratio of the coupling parameters J' and J , reduced temperature kT/J and ratio of the D and J respectively has been studied. In all cases, normalized inductance and magnetic field are used so that units in graphic are arbitrary. The definition **B=H+4πM** has been used instead of **B** =μ o(**H**+**M**) throughout all calculation. Since all the detailled information were given in the work [2] calculation procedure will not be given again here.

Results and Discussion

Throughout the all calculation, for the sake of computation facilities, I have assumed the value of Boltzmann constant as unity. It is evident that this assumtion does not make changes quantitavely. So units in all of graphs are arbitrary units. I also used the expression **B** = H + 4πM instead of **B** =μo (H + M). Variations and changes in shape of the hysteresis loop as a function of exchange constant J, biquadratic exchange interaction constant J', uniaxial anisotropy constant D and reduced temperature k.T / J has been investigated and the results are summarized as graphs below.

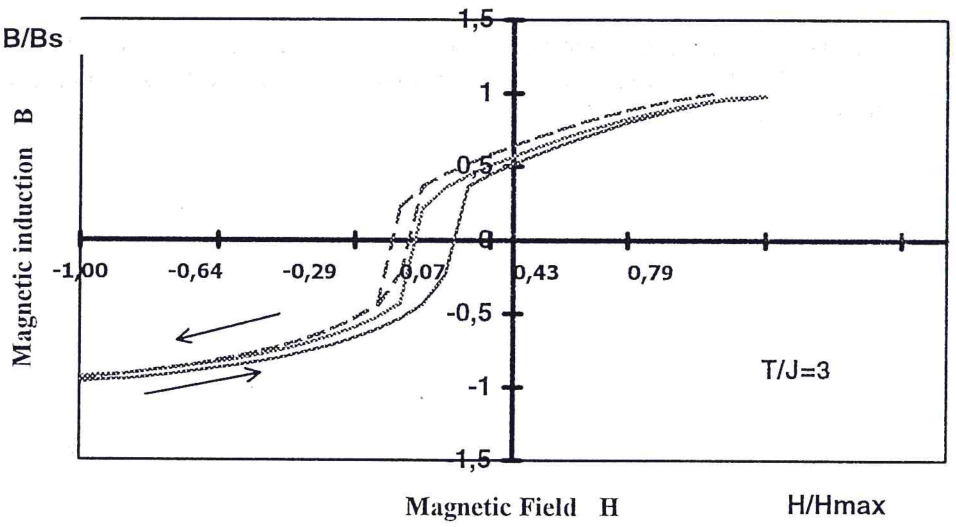

Figure 1.Hysteresis Loops of the Bilayer for J' / J = 0.2, kT / J =0.5, D = 0.5, D = 1

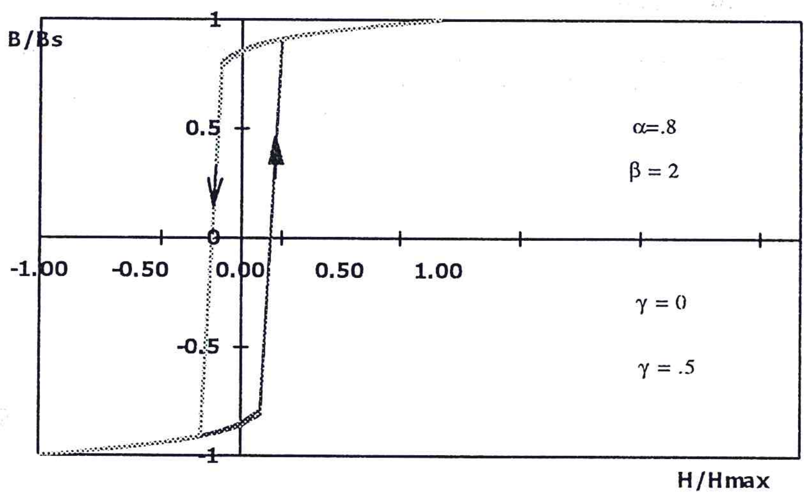

Figure 2 .Hysteresis Loops of the Bilayer for J' / J = 0.2, kT / J =0.5

In Fig1. the anisotropy has been introduced for the values 0.2 and 0.5 of parameters of α and β respectively and for value of $\gamma = 0.5$ and 1.The upper loop corresponds to the case $\gamma = 0.5$.

In Fig.2, hysteresis loops have been drawn as a function of magnetic field H for the values same values of parameters of α and β but for value of $\gamma = 0$.(without sinle-ion term). In this case, remanance field has been modified very slightly but coercivity field has not been modified

In conclusion, magnetic hysteresis phenomenon has been studied in a double layer Ising system. It is shown that magnetic hysteresis can develope in a double layer, which is a micromagnetic system, without domains and their wall motions or rotation unlike in bulk matter. It is also shown that the biquadratic exchange interactions in micromagnetic bilayer studied play the role of domains in bulk matter.

Finally, in this work it has been shown that magnetic hysteresis can also develope without domains.

The other interesting magnetic properties of the system such as variations of remanance and coercivity fields as a function of temperature T and anisotropy D would be very intresting. This will be subject of future studies.

References

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