SD08

A Theoretical Study of an Amorphous Aluminium Oxide Layer Used as a Tunnel Barrier in a Magnetic Tunnel Junction

Eun Sun Noh[1]*, Sergio E. Ulloa[2], and Hyuck Mo Lee[1]
[1]Department of Materials Science and Engineering, Korea Advanced Institute of Science and Technology, 373-1 Guseong-Dong, Yuseong-Gu, Daejeon, 305-701, Korea
[2]Department of Physics and Astronomy, Clippinger Laboratory, OHIO University, Athens, OH 45701, USA
*Corresponding author: noheunsun@kaist.ac.kr, Phone: +82 42 869 3374, Fax: +82 42 869 3310

An amorphous aluminium oxide layer has been mostly used as a tunnel barrier in a magnetic tunnel junction due to its relative low barrier height and reliable formation. This study shows the relative low tunnel barrier height of an amorphous aluminium oxide layer by the density functional theory calculation. An amorphous aluminium oxide layer is assumed to be a condensed gas phase consisting of aluminium oxide molecules and, consequently, electron affinities of aluminium oxide molecules are calculated by using the Gaussian 98 computational package. The exchange-correlation functional is treated by employing the B3LYP and the basis set is set to be the Gaussian type basis set of 6-31G(d,p) level. Total energies and electron affinities of magnesium oxide molecules are also calculated for a comparison. As a result, the values of electron affinities are in the range of from 1.7 to 3.3 eV in the case of aluminium oxide molecules and from 0.8 to 1.7 eV in the case of magnesium oxide molecules. Work functions of magnetic transition metals as well as aluminium and magnesium have been reported to be around 4.5 and, thus, it is inferred that the barrier height of an amorphous aluminium oxide layer is lower than an amorphous magnesium oxide layer. Next, the tunneling magnetoresistance (TMR) has been observed to increase with the thickness of an amorphous aluminium oxide layer. This study shows the increase of the TMR as a function of the thickness of an amorphous aluminium oxide layer qualitatively by the spin-polarized one-band conduction model. The TMR and the resistance-area product are evaluated qualitatively by using the 3 spin-dependent conductancesbased on the Landauer-Buttiker formalism in the ballistic regime. The spin-dependent conductances arecalculated by summing up all the spin-dependent transmission probabilities with the transverse modes. The transmission probabilities are calculated by using a transfer-matrix method. The conduction band structure of ferromagnets is determined by using the free electron model and the stoner model. The band structure of a tunnel barrier is determined by defining the effective barrier width and the effective barrier height, where the effective barrier width means the average arbitrary size of aluminium oxide molecules and the effective barrier height decreases with the thickness of an amorphous aluminium oxide layer due to excess negative charges. As a result, the TMR and the resistance-area product increase with the thickness of an amorphous aluminium oxide layer, however, the increasing rate of the TMR is low if the thickness of amorphous aluminium oxide layer itself is used instead of the effective barrier width. This result shows once again that aluminium oxide molecules mainly determine the physical properties of an amorphous aluminium oxide layers.

REFERENCES

[1] E. Frisch, M. J. Frisch, and G. W. Trucks, Gaussian 98 (Gaussian Inc., Carnegie PA, 1998).
[2] N. R. Brinkmann, G. S. Tschumper, and H. F. Schaefer, J. Chem. Phys., 110, 6240 (1999).
[3] H. B. Michaelson, J. Appl. Phys., 48, 4729 (1977).
[4] J. H. Yu, M. Hayashi, M. Oogane, T. Daibou, H. Nakamura, H. Kubota, Y. Ando, T. Miyazaki, and H. M. Lee, J. Appl. Phys., 93, 8555 (2003).
[5] E. S. Noh, S. E. Ulloa, and H. M. Lee, J. Kor. Phys. Soc., 48, 451 (2006).
[6] K. Gloos, P. J. Koppinen, and J. P. Pekola, J. Phys.:Condens. Matter, 15, 1733 (2003).

SD09

On the Modeling of an Electromagnetic Conveyance System

Cheng-Tsung Liu[1]*, Sheng-Yang Lin[1], and Yang-Yi Yang[2]
[1]Dept. of Electrical Engineering, National Sun Yat-Sen Univ., No. 70, Lien-Hai Rd., Kaohsiung, 80424, Taiwan
[2]Steel & Al. Research & Develop. Dept., China Steel Corp., No. 1, Chung-Kang Rd., Kaohsiung, 81233, Taiwan
*Corresponding author: ctliu@ieee.org, Phone: +886 7 5254152, Fax: +886 7 5254199

To enhance production steadiness and reduce operational noise in steel mills, electromagnetic conveyance systems based on linear induction machine have been extensively proposed. The double-column laboratory prototype is shown in Fig. 1 with its primary windings being arranged to supply adequate electromagnetic forces and the steel plate being operated as the movable secondary. This paper is aimed to provide a concise model for analyzing the quasi-static magnetic characteristics of the proposed system. Such effective approach, which can be directly applied for preliminary system operational characteristic evaluations, will be essential for designers and on-site engineers.

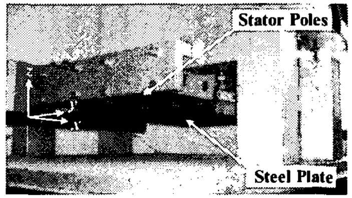

Fig. 1. Laboratory prototype.

By referring to Fig. 2, where a homogeneous space is assumed to generalize the derivations, the Helmholtz's governing equation is given as

$$\nabla^2 \mathbf{A} = -\mu \mathbf{J}_s + \mu\sigma \frac{\partial}{\partial t} \mathbf{A} \quad . \qquad (1)$$

With its periodical pole arrangements, a general solution for the vector potential can be expressed as

$$\mathbf{A} = \sum_{n=1}^{\infty} \left(C_1 e^{\alpha_1 z} + C_2 e^{-\alpha_1 z} \right)\left(D_1 \sin \alpha x + D_2 \cos \alpha x \right) \qquad (2)$$

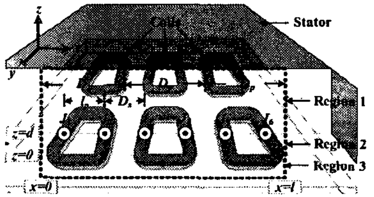

Fig. 2. Definition of analytical model.

By incorporating specific boundary conditions, the magnetic flux density B can be derived, and the y-directional eddy current density in region 3 (steel plate) can also be devised as

$$\mathbf{J}_e = \sum_{k=1}^{m} \sum_{n=1}^{\infty} j\omega\mu\sigma J_0 \frac{e^{-\alpha d + \alpha_1 z}}{\alpha + \alpha_1} \cos \alpha\left(x - x_k\right) e^{i(\omega t + \phi_k)} \hat{y} \qquad (3)$$

Consequently, the force density distribution can be obtained by $\mathbf{F} = \mathbf{J}_e \times \mathbf{B}$ and the system operational magnetic force can then be calculated by proper integrations over the entire steel plate (region 3).

To verify the model adequacy, a detail 3-D finite element analysis (FEA) has been performed. Fig. 3 shows the comparison results of eddy current densities obtained from analytical model and 3-D FEA at certain operational conditions. As the major differences can be attributed to flux leakage among windings and assumption of no end effects, the feasibility and rationality of the proposed scheme for predicting and evaluating the system performance, without going through detailed 3-D FEA for on-site engineers, can be confirmed.

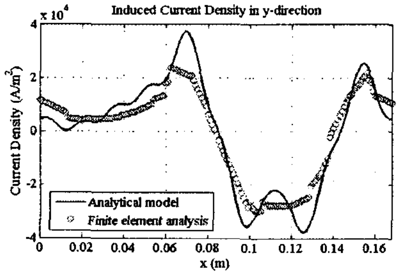

Fig. 3. Eddy current densities comparsion.