GA01

Can undoped semiconducting oxides be ferromagnetic?

Nguyen Hoa Hong*[1], Alessandro Barla[2], Joe Sakai[3], and Nguyen Que Huong[4]

[1]Laboratoire LEMA, UMR 6157 CNRS, Université François Rabelais, Parc de Grandmont, 37200 Tours, France
[2]Experiments Division, CELLS-ALBA, Edifici Cn.- Mòdul C/3 Campus UAB, E-08193 Bellaterra, Barcelona, Spain
[3]School of Materials Science, JAIST, Asahidai 1-1, Nomi, Ishikawa 923-1292, Japan
[4]Physics Department, Marshall University, Science Building Room 256, One John Marshall Drive, Huntington, WV 25755-2570, U.S.A.

*Corresponding author: nguyen.hoahong@univ-tours.fr , Phone: +33 2 47 36 73 36, Fax: +33 2 47 36 71 21

In 2000, Dielt theoretically predicted that the ferromagnetism (FM) at high temperature can be obtained in many semiconductors such as ZnO, GaAs, GaN, etc if we dope Mn plus a certain concentration of holes into those systems, basically as *p*-type. And the magnetic ordering should be originated from the Ruderman - Kittel - Katsuya - Yoshida interaction via the dopants. Experimentalists have tried to dope transition-metals (TM) into many oxides such as ZnO, TiO_2, SnO_2, In_2O_3. And actually room temperature FM was obtained in those oxides under the thin film form. However, the phenomenon is not as what Dietl supposed, because in most of the cases, the compounds are found to be *n*-type.

The finding of FM in HfO_2 thin films of Coey's group in 2004 has urged researchers in the field to re-judge the real role that a doping may play in tailoring the magnetism of semiconducting and insulating oxides. A theoretical work attributed the cause of FM in HfO_2 to defects on Hf sites. However, this model seems not to work, since later, it is found that there must be a strong link between ferromagnetic ordering in HfO_2 and defects on the oxygen sites, but not on the Hf sites.

Our observation of FM in various undoped oxides such as TiO_2, HfO_2, In_2O_3, and ZnO confirmed that magnetism is certainly possible in undoped oxide thin films. As for the TiO_2, In_2O_3, and HfO_2 films, the data show that FM is most probably due to oxygen vacancies. The assumption is strongly supported with a recent report of Yoon *et al.* on TiO_2 films, and another of C. N. R. Rao's group on room temperature FM in nanoparticles of CeO_2, Al_2O_3, ZnO, In_2O_3, and SnO_2. The assumption for FM due to oxygen vacancies/defects in TiO_2 thin films is strongly confirmed by our X-ray magnetic circular dichroism measurements (XMCD): There is a presence of XMCD signals at both O *K* and Ti $L_{2,3}$ edges. While the Ti $L_{2,3}$ edges signals reveal a paramagnetic feature, the O *K*-edge XMCD shows clearly a ferromagnetic origin. As for ZnO, our data have revealed that the FM in this compound does not originate from oxygen vacancies as in the case of TiO_2 and HfO_2 films, but more likely from defects on Zn sites.

It appears that as for semiconducting and insulating oxide thin films, the theory of Dietl does not work well, and the originof magnetism is in fact not due to the doping but oxygen vacancies and/or defects. A really big issue in the field of magnetism at the moment is that how to find a more appropriate model to explain better the mechanism in Diluted Magnetic Semiconducting Oxides (DMSO) systems. We propose a model that is based on an electronic structure calculation using the tight binding method in the confinement configuration. According to this model, vacancy site in TiO_2, HfO_2, In_2O_3 films could create spin splitting andhigh spin state, so that the exchange interaction between the electrons surrounding the oxygen vacancy with the local field of symmetry could lead to a FM ground state of the systems. The theoretical calculations give the results of 3.18 μB per vacancy for TiO_2, 3.05 μB /vac for HfO_2 and 0.16 μB /vac for In_2O_3. It also confirms that the mechanism for ZnO system is different, that FM cannot stem from oxygen vacancies but from other sources. The model suggests strongly that confinement effects should play a key role in shaping up magnetic properties of low dimension systems.

GA02

Multilayered Multifunctional Multiferroics for Spintronics

N.H. Duc[1], D.T. Huong Giang[1], P.D. Thang[1], T.M. Danh[1], C.G. Kim[2], N.T. Thanh[1,2] and L.T. Tu[2]

[1]Laboratory for Nano Magnetic Materials and Devices, Faculty of Engineering Physics and Nanotechnology, College of Technology, Vietnam National University, Hanoi, E3 Building, 144 Xuan Thuy Road, Cau Giay, Hanoi, Vietnam
[2]Department of Materials Science and Engineering,Chungnam National University, 220 Gung-dong, Yuseong-gu, Daejeon 305-764, South Korea

*Corresponding author: ducnh@vnu.edu.vn, Phone: +84-4-7547203, Fax: +84-4-7547460

Spintronics is a new branch of physics and nanotechnology, which aims to simultaneously exploit both the charge and the spin of electrons in the same device and describes the new physics. Spintronics is mainly related to the spin switching phenomena, among which field-induced magnetization switching, thermally assisted switching and spin transfer switching are well described. Presently, the current induced magnetization switching, *i.e.* spin-transfer-driven, is already known as a useful mechanism for writing information within non-volatile magnetic random access memories. In addition, it is considered to be more efficient than the alternative of using current-generated magnetic fields to control magnetic bits.

Multiferroics are materials which possess simultaneous ferromagnetic and ferroelectric properties as well as interesting magnetoelastic phenomena. Due to the magnetoelectric coupling between these properties, the magnetization or electric polarization can be turned by applying an external electrical field or magnetic field, respectively. This magnetoelectric (ME) effect proposed another magnetization switching mode, called ME-induced spin reorientation. It can give new advances in nanostructures, in particular, in giant magnetoresistive (GMR) and tunneling magnetoresistive (TMR) architectures. In general, the ME effect has been attracting a significant interest for multifunctional applications such as transducers, actuators and other microsensors. This paper, however, focuses to the following aspects:

(i) Microtesla magnetic-field sensors based on magnetostrictive/piezoelectric Terfecohan/PZT and $(Fe_{80}Co_{20})_{78}Si_{12}B_{10}$/PZT multiferroics.

(ii) Combination of the ME and Hall effect of Terfecohan films.

(iii) ME-induced spin reorientation in GMR and TMR systems with one magnetostrictive layer: $Ni_{80}Fe_{20}$/Cu/$Co_{50}Fe_{50}$/$Ni_{80}Fe_{20}$ and Co/Al_2O_3/$Co_{50}Fe_{50}$/$Ni_{80}Fe_{20}$.

These aspects are rather promising for high density and easy data processing.