

Enhanced Ferromagnetic States by Normal Metal Spacer

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Much attention has been directed to the study on the antiferromagnetic and ferromagnetic bilayers in the past decades. It is not only because of the promising application of the spin-valve structures in information storage devices, but also because of the interesting magnetic behaviors, such as exchange bias coupling in these systems. The previous study showed that the antiferromagnetic Mn can reveal ferromagnetic order by deposited in contact with the ferromagnetic Fe layers. This can be ascribed to the direct exchange interaction between Fe and Mn. However, it is still less known up to now about how this effect is influenced by indirect interaction, such as interlayer coupling. In this study we dedicated in the study of interlayer interaction between ferromagnetic and antiferromagnetic layers, including the domain evolution between them. Using photoemission electron microscopy (PEEM) with polarized X-ray light source, we conducted a comparative study of magnetic domains imaging between Mn/Fe(001) and Mn/Ag/Fe(001) to elucidate the influence of normal metal spacer on the effect of induced ferromagnetism, as shown in Fig. 1.



Figure 1. Schematic diagram for sample configuration.

In the PEEM endstation for the EPU beamline, the *in-situ* preparation Mn ultrathin films were performed in an ultrahigh vacuum chamber with base pressure 1×10^{-10} torr. The Fe(001) substrate was cleaning by cycling of Ar^+ ion sputtering and subsequent annealing procedures. The films were deposited by e-beam bombardment evaporators for good epitaxial growth. At room temperature, the magnetic circular dichroism was observed for Fe L-edge absorption peaks in both Fe(001) substrate and Mn/Fe(001) films. In addition, the Fe(001) substrate reveals the strap-like magnetic domains along its easy axis in the [100] direction, as shown in the PEEM image in Figs. 2(b)&(d). The Mn overlayer on top of Fe(001) was found to reveal ferromagnetic ordering, as shown in Fig. 2(a). It indicates that the antiferromagnetic Mn was induced as ferromagnetic ordering in contact with Fe. The similar domain contrast (darker upper half and bright lower half) for Mn to that for Fe(001) shows that Mn is ferromagnetically coupled with Fe, which is

compatible with the previous independent study by other group. This behavior remains unchanged after inserting a normal-metal Ag spacer layer between them. Rather than depressing, the Ag spacing layer increases this effect of induced ferromagnetism between Mn and Fe. The PEEM image of Mn/Ag/Fe(001) shows that the contrast between the upper half and lower half is in much evidence than the contrast for Mn/Fe(001), as shown in Fig. 2(c). The further study by *ab initio* calculation also shows the similar results with the experiments, revealing stronger interfacial magnetic moment for the Ag spacer case, as shown in Fig. 3. It may help to clarify the detailed mechanism for how the ferromagnetic state is induced in antiferromagnetic capping layer by the indirect coupling with ferromagnetic underlayer, which was usually neglected before. We believe that quantum well states of spacer might play an important role in this mechanism.

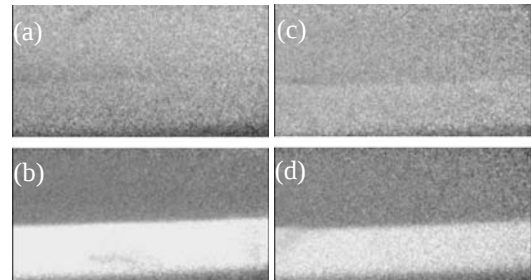


Figure 2. PEEM images for Mn and Fe in Mn/Fe(001) and Mn/Ag/Fe(001), respectively. (a) Mn in Mn/Fe(001), (b) Fe in Mn/Fe(001), (c) Mn in Mn/Ag/Fe(001), and (d) Fe in Mn/Ag/Fe(001).

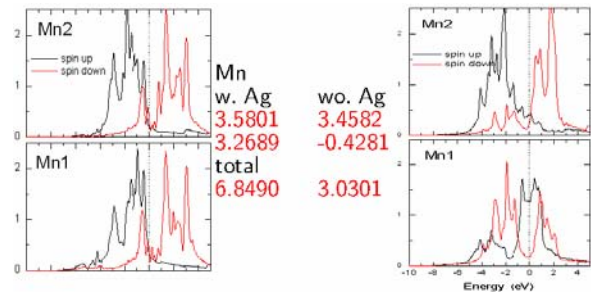


Figure 3. Calculated density of states of Mn on Ag/Fe(001) (left) and on Fe(001) (right), respectively.