Contribution ID: **24** Type: **Poster**

Proximity effects across oxide interfaces of superconductor-insulator-ferromagnet hybrid heterostructure

Tuesday, 18 September 2018 17:15 (15 minutes)

A case study of electron tunneling or charge-transfer-driven orbital ordering in superconductor (SC)-ferromagnet (FM) interfaces has been conducted in heteroepitaxial $YBa_2Cu_3O_7$ (YBCO) / $La_{0.67}Sr_{0.33}MnO_3$ (LSMO) multilayers interleaved with and without an insulating $SrTiO_3$(STO) layer between YBCO and LSMO. X-ray magnetic circular dichroism (XMCD) experiments at BESSY in Germany revealed anti-parallel alignment of Mn magnetic moments and induced Cu magnetic moments in an YBCO/LSMO multilayer. As compared to an isolated LSMO layer, the YBCO/LSMO multilayer displayed a (50%) weaker Mn magnetic signal, which is related to the usual proximity effect. It was a surprise that a similar proximity effect was also observed in a YBCO/STO/LSMO multilayer, however, the Mn signal was reduced by 20%. This reduced magnetic moment of Mn was further verified by depth sensitive polarized neutron reflectivity at the neutron reflectometer MARIA at FRM II in Germany. Electron energy loss spectroscopy experiment showed the evidence of Ti magnetic polarization at the interfaces of the YBCO/STO/LSMO multilayer. This crossover magnetization is due to a transfer of interface electrons that migrate from $Ti^{(4+)-}$ to Mn at the STO/LSMO interface and to Cu^{2+} at the STO/YBCO interface, with hybridization via O $2p$ orbital. So charge-transfer driven orbital ordering is identified as the mechanism responsible for the observed proximity effect and Mn-Cu anti-parallel coupling in YBCO/STO/LSMO. This work provides an effective pathway in understanding the aspect of long range proximity effect and consequent orbital degeneracy parameter in magnetic coupling.

Publication:

PROXIMITY EFFECTS ACROSS OXIDE-INTERFACES OF HYBRID SUPERCONDUCTOR-INSULATOR-FERROMAGNET HETEROSTRUCTURE:
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Sci. Rep. 8, 3732 (2018).

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Presenter: PAUL, Amitesh

Session Classification: Poster session 2

Track Classification: P5 Thin films, 2D materials and surfaces