Structural and Electronic Properties of Mn Implanted MoS_2

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2-dimensional molybdenum disulfide (MoS_2) is an intrinsically non-magnetic semiconductor. Introducing and controlling magnetism is critical in order to explore MoS_2 in spintronic and quantum technologies [1]. Various transition metal dopants have been predicted to induce robust ferromagnetic coupling [2] in MoS_2, with Mn and V identified as the most promising candidates [1,2]. Various approaches to magnetically dope MoS_2 have arguably been limited in terms of reproducibility, scalability and control over the doping process (dopant concentration and incorporation configuration).
Here, we present an in-depth study of the effects of Mn doping using ultra-low energy (ULE) ion implantation [3] on the structural and electronic properties of single-layer MoS_2 (supported on Au(111)[4]). Our ULE implantation approach allows precise tuning of the kinetic energy of Mn ions, providing control over the form of incorporation and concentration while preserving the structural and electronic properties. Samples spanning different implantation parameters (fluence, energy and temperature) were studied via synchrotron-based X-ray photoelectron spectroscopy (XPS), angle-resolved photoelectron spectroscopy, X-ray absorption near edge spectroscopy and Raman spectroscopy. Mn implantation results in an increase in surface defects, however, the electronic structure of MoS_2 is preserved. A significant fraction of the implanted Mn atoms pass through (rather than being incorporated in the MoS_2 layer) and get trapped at the MoS_2-Au interface thus modifying the charge transfer from Au to MoS_2 and resulting in Fermi-level unpinning. This work forms the basis for further studies on the magnetic and spintronic properties of magnetically doped MoS_2.

References

[1] X.-L. Fan et al., Nanoscale Research Letters, 11(1) (2016) 12
[2] A. Ramasubramaniam and D. Naveh, Physical Review B, 87 (2013) 195201
[3] P.-C. Lin, R. Villarreal, **H. Bana** et al., ACS Nano, 15 (2021) 5449
[4] F. Tumino et al., Nanoscale Advances, 1 (2019) 643

Figures

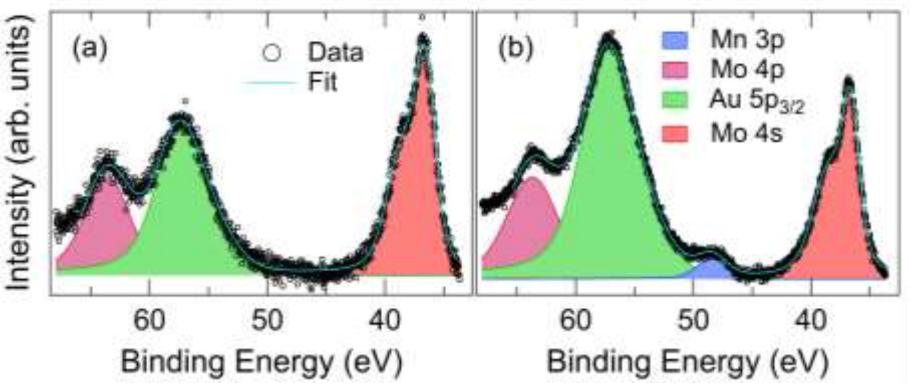

Figure 1: High-resolution XPS measurement performed at 400 eV photon energy along with the resulting fit (line) and the deconvoluted components (solid areas) for (a) pristine MoS2 and (b) ULE Mn implanted MoS_2 showing the Mn 3p core level.