Asymmetric magnetic proximity interactions in van der Waals heterostructures

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Magnetic proximity interactions (MPIs) between atomically thin semiconductors and two-dimensional magnets provide a means to manipulate spin and valley degrees of freedom in non-magnetic monolayers, without using applied magnetic fields. In such van der Waals heterostructures, MPIs originate in the nanometre-scale coupling between spin-dependent electronic wavefunctions in the two materials, and typically their overall effect is regarded as an effective magnetic field acting on the semiconductor monolayer. Here we demonstrate that MPIs in $MoSe_2/CrBr_3$ van der Waals heterostructures can in fact be markedly asymmetric [1]. Valley-resolved reflection spectroscopy reveals strikingly different energy shifts in the K and K´ valleys of the $MoSe_2$ due to ferromagnetism in the $CrBr_3$ layer. Density functional calculations indicate that valley-asymmetric MPIs depend sensitively on the spin-dependent hybridization of overlapping bands and as such are likely a general feature of hybrid van der Waals structures.

References

[1] J. Choi, C. Lane, J.-X. Zhu, S. A. Crooker, Nature Materials, 22 (2023), 305-310

Figures

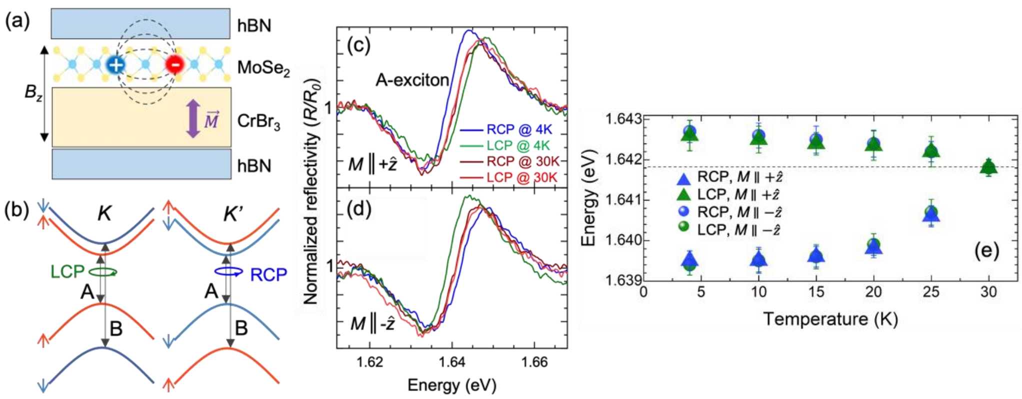

Figure 1: (a) Layer schematic of $hBN/MoSe_2/CrBr_3/hBN$ heterostructure. The red and blue spheres depict and electron and hole pair in the $MoSe_2$, forming an exciton. (b) Band diagram depicting the relevant optical transitions of A and B excitons in $MoSe_2$. (c, d) Comparison of the MPI-induced shift of the $MoSe_2$ A exciton in the K and K´ valleys at T=4 K, as measured by the normalized reflection spectra, R/R_0, of left circularly polarized (LCP) and right circularly polarized (RCP) light (green and blue traces, respectively). The $CrBr_3$ magnetization M is oriented along $+\hat{z}$ or $-\hat{z}$. Red and orange traces show reference spectra acquired at 30 K (above T_C), where the $CrBr_3$ is unmagnetized. (e) Temperature dependence of the MPI-induced valley shifts of the A exciton, for both circular polarizations and for both $\pm\hat{z}$ $CrBr_3$ magnetizations. The horizontal line indicates the exciton resonance energy at 30 K when the $CrBr_3$ is not magnetic.