Supplementary information

Magnetic proximity effect and electrical field tunable valley degeneracy in MoS_2/EuS van der Waals heterojunctions

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Comparing with other TMDs/EuS heterojunctions

To verify our results that the MPE exists at the MoS_2/EuS interface, we have calculated other TMDs/EuS heterojunctions, such as WS_2/EuS and $MoSe_2$/EuS. Fig. S1 shows the charge density difference distribution and the spin density distribution at the interface for MoS_2/EuS, WS_2/EuS and $MoSe_2$/EuS in chemical and vdW adsorption states, respectively. It can be seen, both in chemical and vdW adsorption states, the charge density distribution at these three interfaces are similar, and spin polarizations are observed at Mo(W) atomic layer. Fig. S2 show the band structure for MoS_2/EuS, WS_2/EuS and $MoSe_2$/EuS in chemical and vdW adsorption states. The calculated adsorption distance "*d*", binding energy ΔE, induced magnetic moments and valley Zeeman splitting E_z are listed in the talble S1 below. We can see the TMDs/EuS have similar adsorption way and distance, and the magneitc proximity effect is generally existed in these systems in different degrees, which is due to due to the intrinsic SOC of these TMCDs, in addition, the different lattice mismatch and atoms configurations at the interface of these systems can also impact the MPE. The calculated valley Zeeman splitting of WS_2/EuS and $MoSe_2$/EuS are 33.2 and 15.6 meV in chemical adsorption states, while 4.7 and 2.5meV in vdW adsorption states.

Considering the measured valley Zeeman splitting rate of -233±10 μeV/T[1] and -220μeV/T[2] for single layer WS_2 and $MoSe_2$ in previous studies, the MPE introduces a MEF of 143 T and 20 T for WS_2/EuS in the chemical and vdW adsorption cases, while 71T and 11T for $MoSe_2$ in the chemical and vdW adsorption cases.

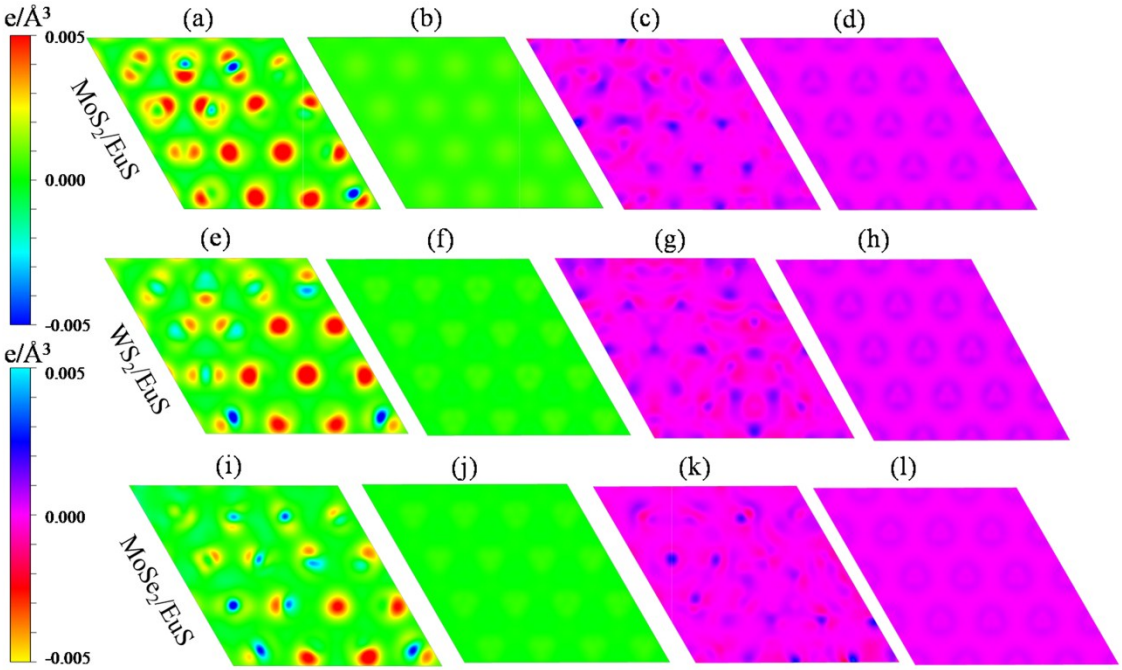

Figure S1. The charge density difference distribution at the interface of MoS_2/EuS (a, b), WS_2/EuS (e, f) and $MoSe_2$/EuS (i, j), in which the left column (a, e, i) indicate the chemical adsorption, and the right column (b, f, j) indicate the vdW adsorption. Also shown are the spin density distribution at the Mo (W) atomic layer of MoS_2/EuS (c, d), WS_2/EuS (g, h) and $MoSe_2$/EuS (k, l), in which the left column (c, g, k) indicate the chemical adsorption, and the right column (d, h, l) indicate the vdW adsorption.

Table S1. The adsorption distance "*d*", binding energy ΔE, averaged induced magnetic moments in Mo (W) and valley Zeeman splitting E_z calculated for MoS_2/EuS, WS_2/EuS and $MoSe_2$/EuS heterojunctions in chemical and vdW adsorption states.

System	**$MoSe_2$/EuS**		**WS_2/EuS**		**MoS_2/EuS**	
Adsorption type	**Chemical**	**vdW**	**Chemical**	**vdW**	**Chemical**	**vdW**
***d* (Å)**	2.624	6.820	2.586	6.511	2.554	6.456
ΔE (meV)	166	32	185	47	192	44
Mo\W (μ_B/atom)	0.076	0.013	0.118	0.023	0.124	0.024
***E_z* (meV)**	15.6	2.5	33.2	4.7	37.3	5.1

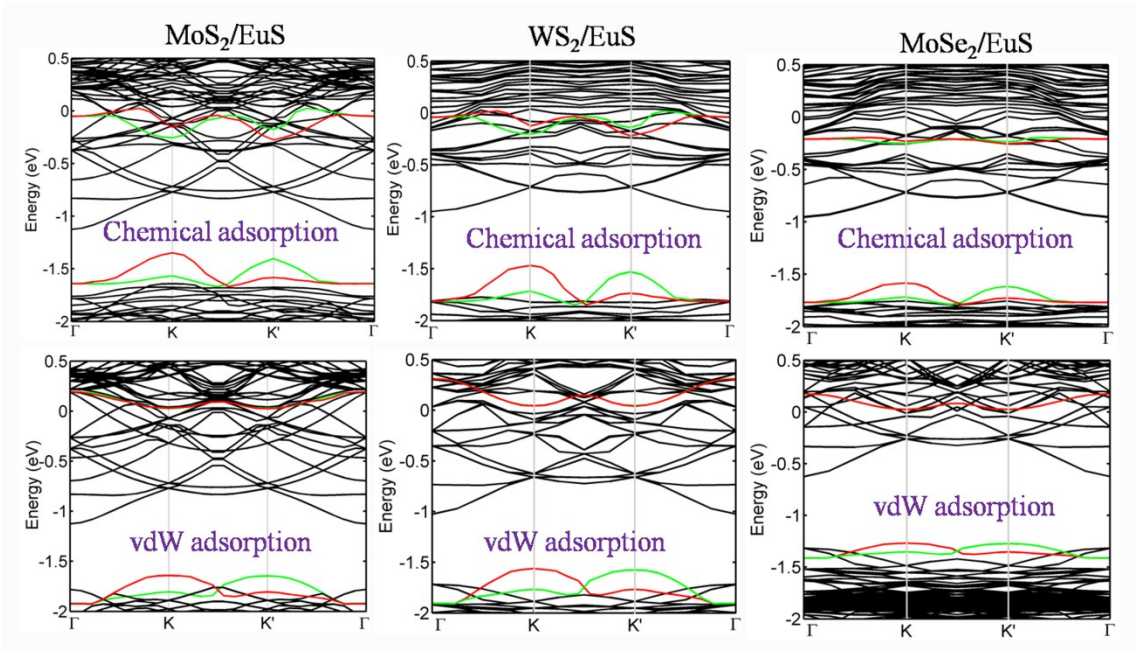

Figure S2. The band structure calculated for MoS_2/EuS, WS_2/EuS and $MoSe_2$/EuS heterojunctions in chemical and vdW adsorption states.

Comparing several vdW correction methods

To check the vdW correction method used in our study, we also using other vdW correction method to check our results on MoS_2/EuS system, such as optB88-vdW[3] and optB86b-vdW[4], which are also appropriate for layered systems[5]. Table S2 shows the adsorption distance "*d*", binding energy ΔE, averaged induced magnetic moments calculated for MoS_2/EuS using different vdW correction methods. We can see these three methods give out similar adsorption distance and binding energy, in particular, the magnetic moments induced in Mo atoms are agree well with each other, which indicated the degrees of our estimated MPE at this interface is reasonable. Fig. S3 shows the projected density of states (PDOS) of Mo, S, Eu atoms at the MoS_2/EuS interface using different vdW correction mesthods. From the calculated PDOS, we can see the three different vdW correction has little effect on the electron structure, in particular, the band gap of MoS_2.

Table S2. The adsorption distance "*d*", binding energy ΔE, averaged induced magnetic moments calculated for MoS_2/EuS using different vdW correction methods.

vdW correction	**optB86b-vdW**		**optB88-vdW**		**revB86b-vdW-DF2**	
Adsorption type	**Chemical**	**vdW**	**Chemical**	**vdW**	**Chemical**	**vdW**
***d* (Å)**	2.538	6.423	2.634	6.611	2.554	6.456
ΔE (meV)	198	50	185	48	192	44
Mo (μ_B/atom)	0.121	0.026	0.112	0.019	0.124	0.024
S (μ_B/atom)	0.003	0.000	0.000	0.000	-0.005	0.000
Eu (μ_B/atom)	6.932	6.947	6.910	6.922	6.951	6.982

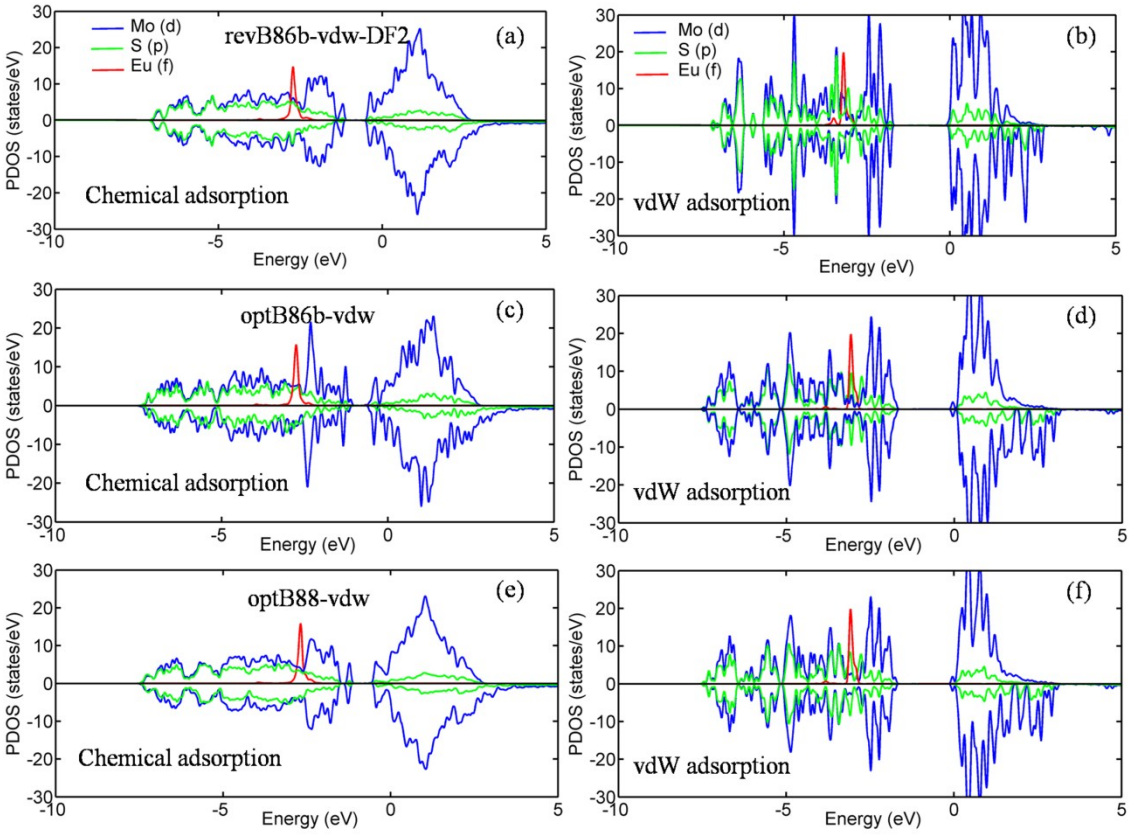

Figure S3. The calculated projected density of states (PDOS) of Mo, S, Eu atoms at the MoS_2/EuS interface using different vdW correction methods.

Reference

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