Supporting information

Colossal Magnetization and Giant Coercivity in Ion Implanted (Nb, Co) MoS_2 Crystals

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Table S1. Magnetization and coercivity of MoS_2 based diluted magnetic semiconductor

Sr No	Material	Saturation Magnetization (emu/cm^3)	Coercivity	Ref
1	Re doped MoS_2	0.0076	170 Oe	[1]
2	F adsorbed MoS_2	1.25	< 400 Oe	[2]
3	Cu doped MoS_2	0.115	~ 100 Oe	[3]
4	V doped MoS_2	0.335	1870 Oe	[4]
5	Co doped MoS_2	4	400 Oe	[5]
6	Ni doped MoS_2	3	175 Oe	[5]
7	Mn doped MoS_2	0.075	1076 Oe	[6]
8	Nb and/or Co doped MoS_2	1800	9000 Oe	This work

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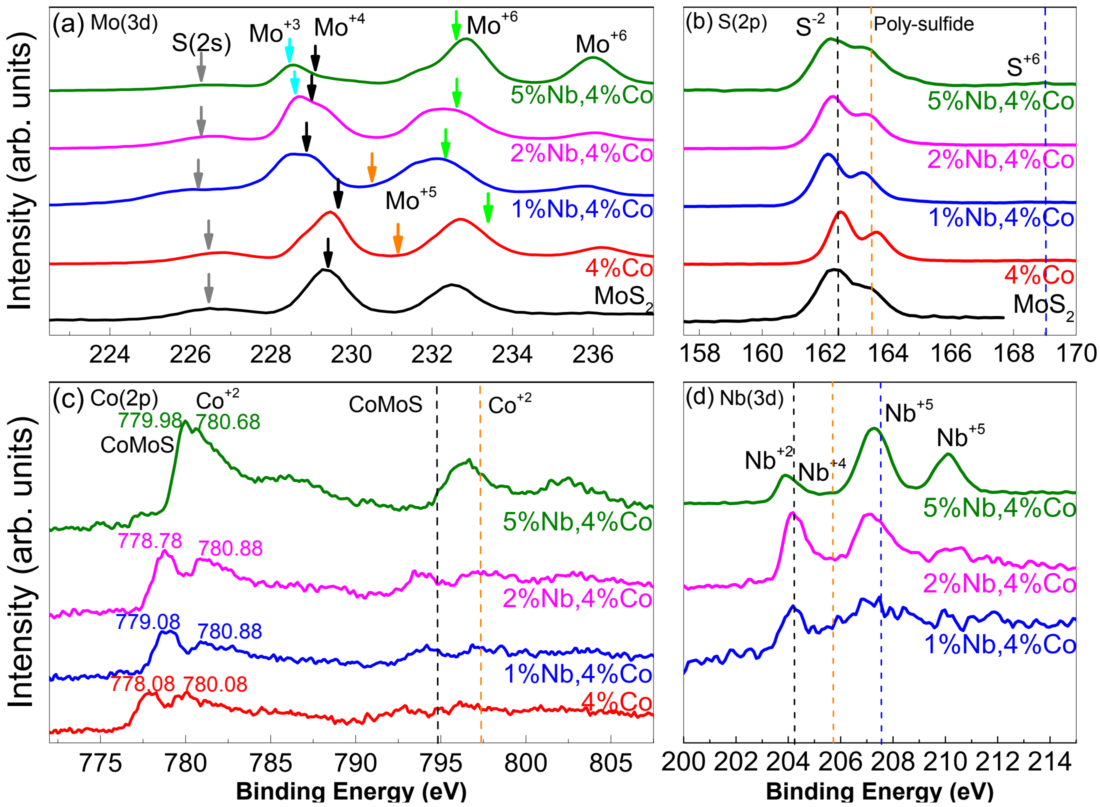

Figure S1. XPS spectra of Co & Nb co-doped MoS_2 with (a) Mo(3d), (b) S(2p), (c) Co(2p) and (d) Nb(3d) core levels.

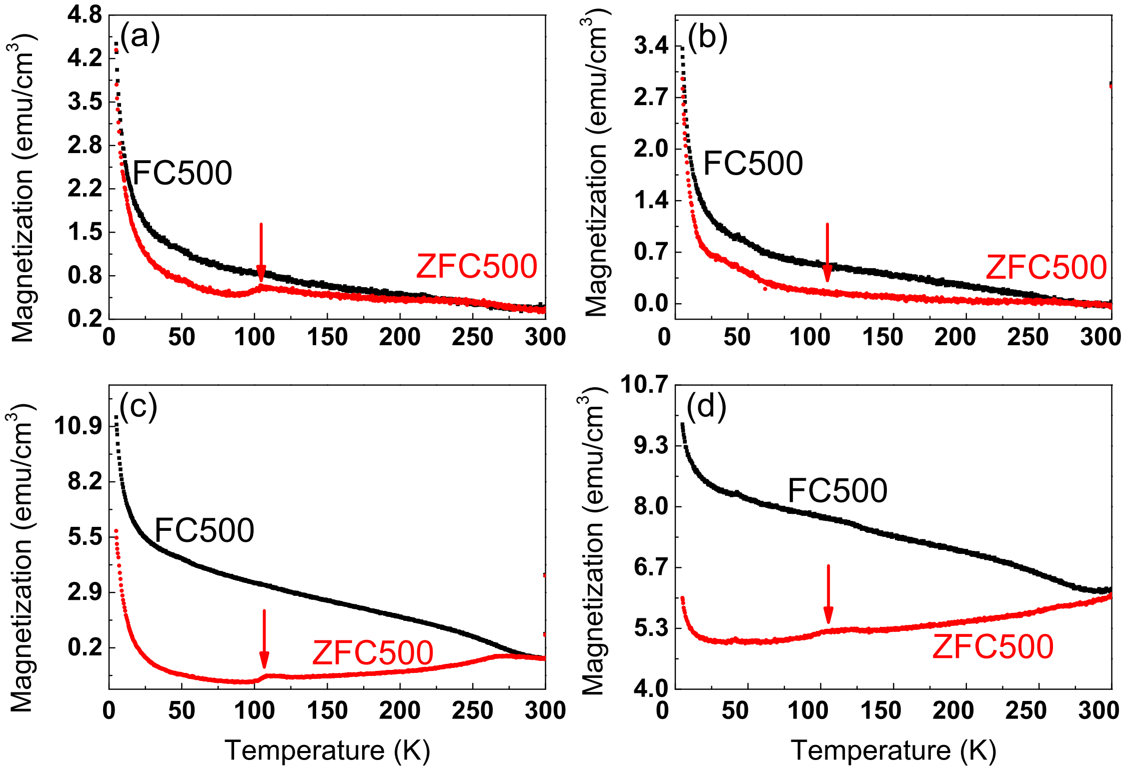

Figure S2. Zero field cooling (ZFC) and field cooling (FC) of (a) 4 at% Co doped MoS_2; (b) 1 at% Nb + 4 at% Co co-doped MoS_2; (c) 2 at% Nb + 4 at% Co co-doped MoS_2 and (d) 5 at% Nb + 4 at% Co co-doped MoS_2.

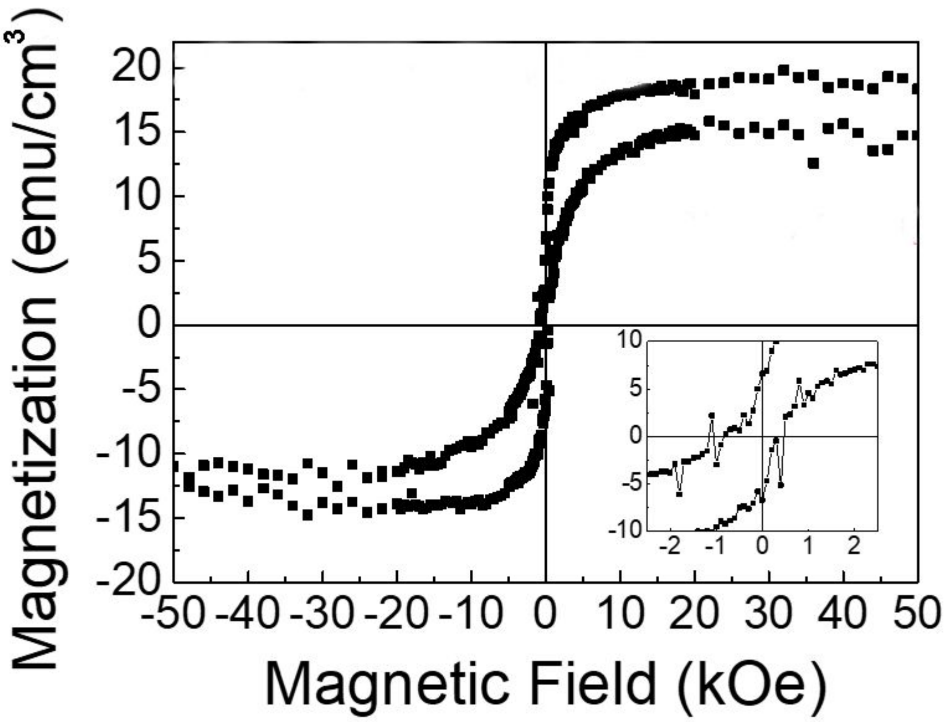

Figure S3. The hysteresis loop of Annealed 2 at% Nb + 4 at% Co co-doped MoS_2 at 100 K shows ferromagnetic signal. The magnetization at the applied magnetic field of 50 kOe at 100 K is enhanced a little (18.351 emu/cm^3) compared to that of un-annealed 2 at% Nb + 4 at% Co co-doped MoS_2 (16.14 emu/cm^3). Moreover, a reduction in coercivity (822.9 Oe) is observed in the sample of annealed 2 at% Nb + 4 at% Co co-doped MoS_2 (inset). The reduction in coercivity may be attributed to the removal of defects and lattice strain induced during ion implantation process.

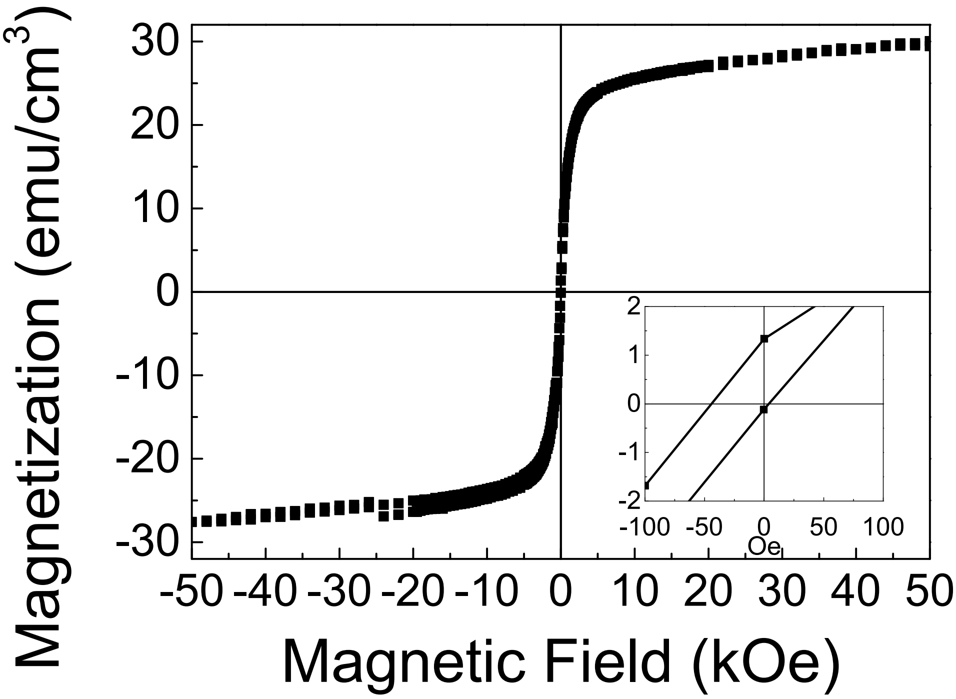

Figure S4. The hysteresis loop of 2 at.% Nb doped MoS_2 at 100 K shows ferromagnetic signal. The magnetization at the applied magnetic field of 50 kOe at 100 K is 30.03 emu/cm^3. Moreover, a reduction in coercivity (44.2 Oe) is observed in the sample of 2 at.% Nb doped MoS_2 (inset).

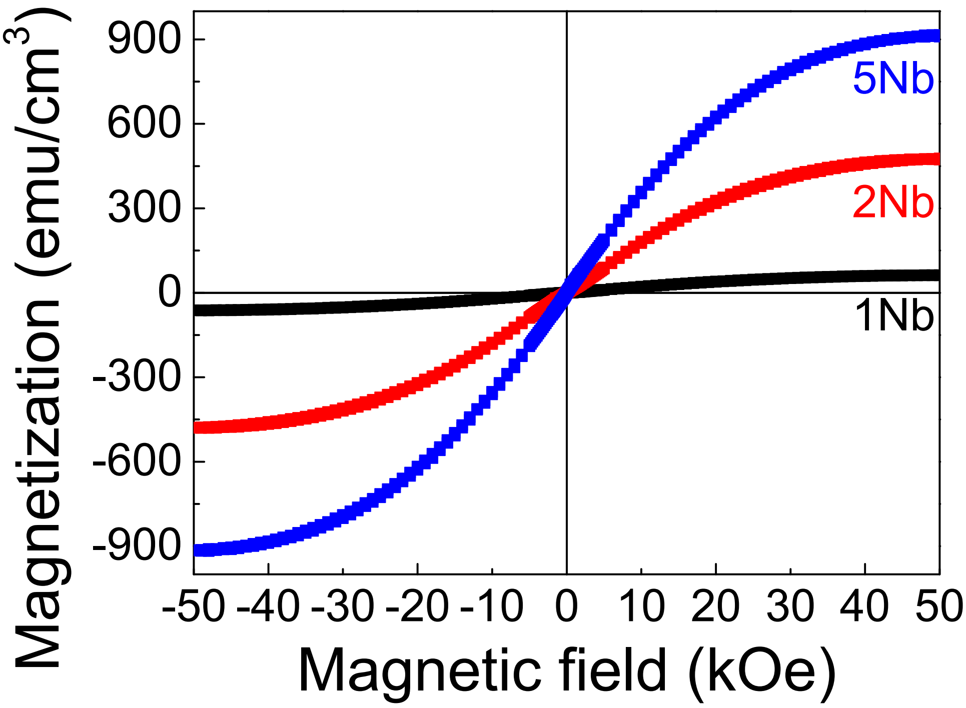

Figure S5. The hysteresis loop of MoS_2 doped with different concentrations annealed at 500 K in Ar environment. At the applied magnetic field of 50 kOe at 5 K, the magnetization of 915 emu/cm^3, 473 emu/cm^3 and 62.43 emu/cm^3 were observed attributed to the 5 at.% Nb, 2 at.% Nb and 1 at.% Nb doped MoS_2.

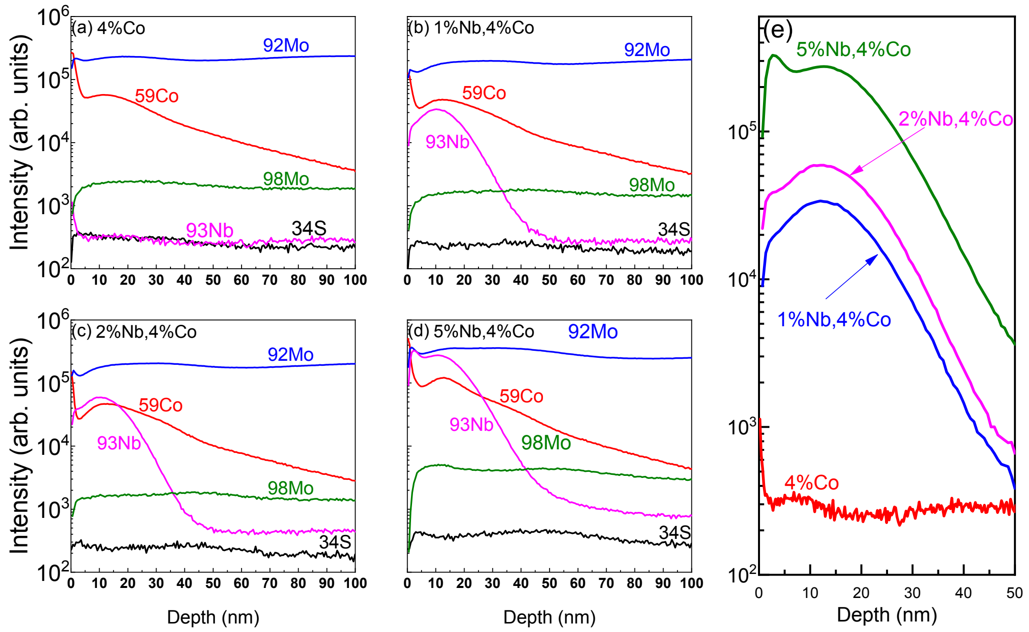

Figure S6. Depth profile of Mo, Co, Nb, and S element in ion implanted single crystals of (a) 4 at.% Co doped MoS_2; (b) 1 at.% Nb + 4 at.% Co co-doped MoS_2; (c) 2 at% Nb + 4 at.% Co co-doped MoS_2 and (d) 5 at% Nb and 4 at.% Co co-doped MoS_2. (e) Depth profile of Nb with different doping concentrations in MoS_2.

Figure S6 shows the concentration of Co and Nb elements as a function of depth for all four Co and Nb-doped MoS_2 samples. In all four samples (Figure S6a-d), Co shows Gaussian profile with the peak at around 12.5 nm from a surface and then a linear reduction in concentration for further depth. Standard deviation (also called straggling) for this set of sample is 7 nm. Therefore, the thickness of the doping is considered around 20 nm.

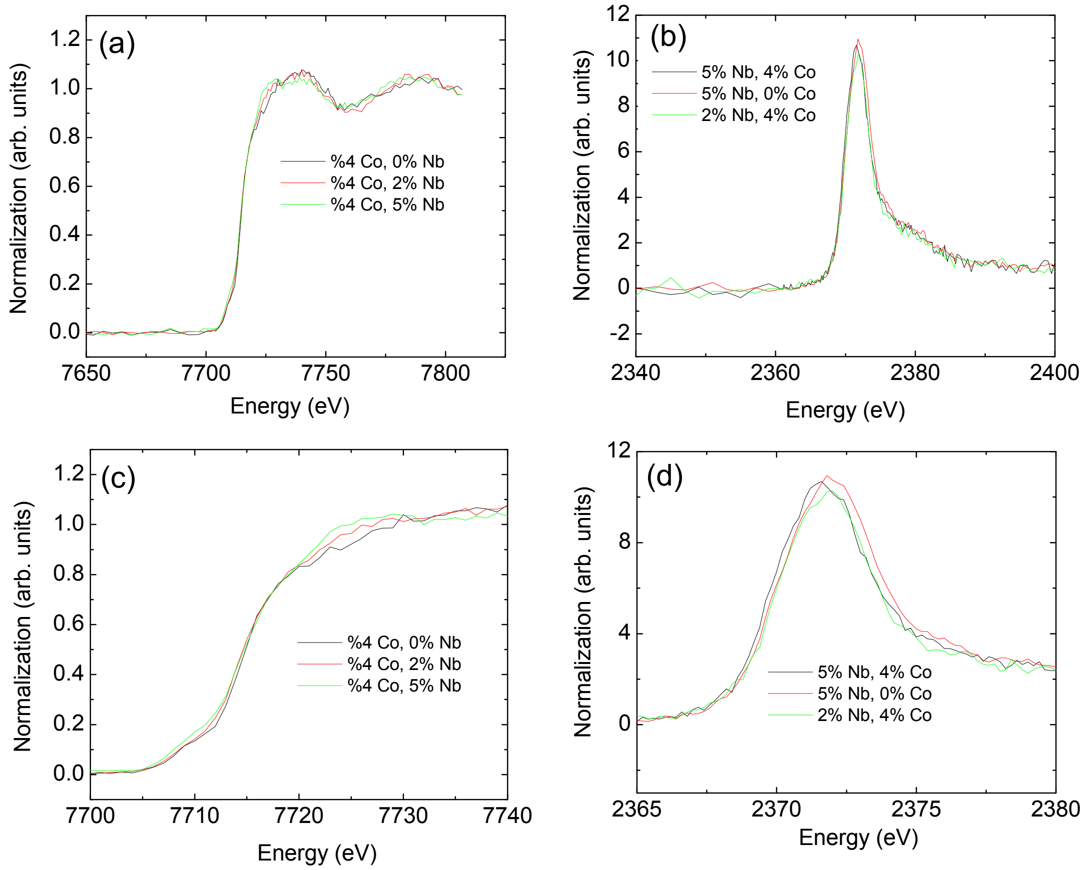

Figure S7: (a) X-ray Absorption Near Edge Structure (XANES) of Co K edge; (b) XANES of Nb L_3 edge; (c) Small scale of (a); (d) Small scale of (b). Due to the bulk signal from XANES, there is no significant difference for different concentration of doping.