Triplet superconductivity in van der Waals hybrid devices

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Van der Waals materials have a layered structure and can reveal a broad palette of electronic properties ranging from superconducting via metallic, insulating, semimetallic to ferromagnetic behavior, and can be exfoliated down to the 2D limit. Hybridizing thin flakes of different vdW systems allows to tailor electronic properties on demand. Of particular interest are hybrid systems of superconductors and magnetically ordered systems with the goal for application in superconducting spintronic applications.

Magnetotransport measurements performed on flakes down to the 2D limit show that the helimagnetic metal $Cr_{1/3}NbS_2$ hosts magnetic soliton excitations [1,2]. Investigating the superconducting proximity effect between 2D flakes of such a magnetic material and conventional 2D superconductors could lead to the discovery of unconventional spin-triplet superconducting states [3-5], which are beneficial for superconducting spintronics and quantum computing.

Based on this motivation, we have fabricated thin $Cr_{1/3}NbS_2/NbS_2$ bilayers and investigated their low-temperature magnetotransport properties. Studying the evolution of the superconducting critical temperature (T_c) of devices based on $Cr_{1/3}NbS_2/NbS_2$ bilayers as a function of the magnetic state of $Cr_{1/3}NbS_2$, we find that the T_c of the bilayer strongly depends on the $Cr_{1/3}NbS_2$ magnetization in a way that cannot be explained as the result of a conventional short-ranged S/F proximity effect or of stray fields. Supported by a theoretical model, we show that our results are consistent with the generation of long-ranged spin-triplet pairs forming at the interface between NbS_2 and $Cr_{1/3}NbS_2$ flakes [6].

[1] S. Tang *et al.,* Nano Lett. **18**, 4023 (2018).
[2] L. Wang *et al.*, Phys. Rev. Lett. **118**, 257203 (2017).
[3] See e.g.: J. Linder and J. W. A. Robinson, Nat. Phys. **11**, 307 (2015).
[4] R. Cai *et al.*, Nat. Commun. **12**, 6725 (2021).
[5] G. Hu *et al.*, Nat. Commun. **14**, 1779 (2023).
[6] A. Spuri, D. Nikolić, S. Chakraborty, M. Klang, H. Alpern, O. Millo, H. Steinberg, W. Belzig, E. Scheer, A. Di Bernardo, Phys. Rev. Res. **6**, L012046 (2024)