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ARPES study on FeSe films

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The record of superconducting transition temperature (Tc) has long been 56 K for the iron-based high temperature superconductors (Fe-HTS's). Recently, in single layer FeSe films grown on $SrTiO_3$ substrate, signs for a new 65 K Tc record are reported. Combining molecular beam epitaxy and in situ angle resolved photoemission spectroscopy (ARPES), we study the ultra thin FeSe films on various substrates. We substantiate the presence of collinear antiferromagnetic order (CAF) in FeSe films, a key ingredient of Fe-HTS that was missed in FeSe before, which weakens with increased thickness or reduced strain. We demonstrate that the superconductivity occurs when the electrons transferred from the oxygen-vacant substrate suppress the otherwise most pronounced CAF in single layer FeSe. We establish the phase diagram of FeSe vs. lattice constant that contains all the essential physics of Fe-HTS's [1]. With first principle calculations, we show that the superexchange interactions across Fe-As-Fe is enhanced with increased lattice constant [2]. Therefore, with heavy electron doping, the FeSe would have been an overdoped non-superconductor likely due to the weakened spin fluctuation; however by expanding its lattice in thin films, the magnetism is enhanced and superconductivity is restored. By fabricating FeSe/STO/KTO heterostructure, we further enhanced the lattice constant of FeSe, and increased the gap-closing temperature to 70K. Two un-hybridized electron Fermi surfaces are resolved, and the superconducting gap exhibits strong anisotropy around the individual Fermi surface. This observation contradicts many existing theories on the pairing symmetry of Fe-HTS's with only electron pockets [3].

[1] S. Tan et al., Nature Materials 12, 634–640 (2013)
[2] Hai-Yuan Cao et al., arXiv:1310.4024
[3] R. Peng et al., arXiv:1310.3060