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SPSTM observation of quantum fluctuation-driven plaquette antiferromagnetic order and enhancement of superconductivity by interfacial phonons in bulk form of Fe-based superconducting monolayer sandwiched by perovskite layers

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The symmetry requirement and the origin of magnetic orders coexisting with superconductivity have been strongly debated issues of iron-based superconductors (FeSCs). Observation of C4-symmetric antiferromagnetism in violation of the inter-band nesting condition of spin-density waves in superconducting ground state will require revolutionary change in understanding of the mechanism of FeSC. The superconducting material Sr_2VO_3FeAs, a bulk version of monolayer FeSC on a perovskite layer, with magnetism (TN ~ 50 K) and superconductivity (Tc ~ 37 K) coexisting at parent state has no reported C2 structural distortion and thus makes a perfect system to look for C4 magnetism1-3. Based on variable temperature spin-polarized scanning tunneling microscopy (SPSTM), we discovered a minute C2 orthorhombic distortion below 150 K and the coexistence of C4 plaquette antiferromagnetic order and superconductivity below Tc. This C4 symmetric order, observed with atomic resolution for the first time in any FeSC under Tc, is a robust ground state originated by exchange interaction of local Fe moments and selected by quantum fluctuations and quantum order by disorder mechanism4. Its existence in the superconducting ground state with fairly high Tc and the inconsistency of its dual Q wavevectors with nesting condition implies that the nesting-based C2 symmetric magnetism is not a unique prerequisite of high-Tc FeSC. Furthermore, the plaquette antiferromagnetic domain wall dynamics under the weak influence of spin torque effect of spin-polarized tunneling current are fully consistent with theoretical simulation based on the extended Landau-Lifshitz-Gilbert equation.

Also the physics at the interface between monolayer iron-based superconductor (FeSC) and perovskite substrate has received considerable attention due to the extremely high Tc of 100 K found recently in monolayer FeSe on $SrTiO_3$ substrate. It has been found that forward-scattering interfacial phonons coupled with the Fe-layer electrons can enhance superconductivity from almost any kind of preexisting electron-based pairing, initiating the searches for more chemically robust and widely applicable bulk versions of monolayer FeSC on perovskite layer harboring interfacial phonons. In an effort to look for such a bulk version of interfacial phonon enhanced FeSC heterostructure systems, we have studied a parent-compound superconductor Sr_2VO_3FeAs, the only currently known self-assembled bulk example of monolayer FeSCs on perovskite layers with substantially high Tc ~ 37 K. Our spectroscopic imaging scanning tunneling microscopy (SISTM) study shows clear replica-band signatures characteristic of forward-scattering phonons coupled strongly with the Fe layer electrons. To verify that the forward-scattering phonons indeed can enhance superconductivity, we showed that the quasiparticle interference on regions of high superconducting gap have larger coupling parameter g2(0) based on the symmetric Fe band shift around the Fermi energy, as well as larger Fano peak width proportional to the coupling of the localized V electrons and the Fe electrons. Our discovery of g2(0) enhancing ΔSC reveals the first direct evidence of phonon-enhanced superconductivity in a bulk FeSC heterostructure system.