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Phase diagram and Competition between superconductivity and antiferromagnetism in $A_xFe_{2-y}Se_2$ system

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The correlation and competition between antiferromagnetism and superconductivity are one of the most fundamental issues in high temperature superconductors. Superconductivity in high temperature cuprate superconductors arises from suppressing an antiferromagnetic (AFM) Mott insulator while in iron-pnictide superconductors arises from AFM semimetals and can coexist with AFM orders. Superconductivity at 32 K is always accompanied by AFM phase with Neel temperature as high as ~550 K and local moment of $3.3\mu_B$ in iron-chalcogenide superconductors $A_xFe_{2-y}Se_2$. A natural question is whether the superconductivity and AFM microscopically coexist, or arise from the phase separation. Such different scenario raises many intriguing debates because the microscopic coexistence of superconductivity and the AFM with such high T_N will lead to a big challenge in theory. Here, we report that the superconducting transition temperature (T_C) is enhanced from 32 K to 44 K by suppressing the long-range antiferromagnetic order in $A_xFe_{2-y}Se_2$ system. It suggests that superconductivity and AFM order are correlated, and the separation of SC and AFM phase is mesoscopic rather than macroscopic, and T_C of the intrinsic superconducting phase is 44 K, rather than 32 K widely observed in $A_xFe_{2-y}Se_2$ system. These results give direct evidence for that there exists a competition between superconductivity and AFM order and the superconductivity is suppressed by the long-range AFM order. These results give a hint to gain insight into a mechanism in the high temperature superconductivity.