Distinct Fe-induced magnetic states in the underdoped and overdoped regimes of La$_{2-x}$Sr$_x$Cu$_{1-y}$Fe$_y$O$_4$ revealed by muon spin relaxation

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Zero-field muon-spin-relaxation measurements have been performed in partially Fe-substituted La$_{2-x}$Sr$_x$Cu$_{1-y}$Fe$_y$O$_4$ in a wide range of hole concentration, to investigate the magnetic state induced by the Fe substitution recently suggested from the neutron-scattering measurements [1]. It has been found that a static magnetic order is formed in 1% Fe-substituted La$_{2-x}$Sr$_x$Cu$_{1-y}$Fe$_y$O$_4$ in a wide range of hole concentration where superconductivity appears in Fe-free La$_{2-x}$Sr$_x$CuO$_4$. In the underdoped regime, the Fe-induced magnetic order can be understood in terms of the concept of stripe pinning by Fe. In the overdoped regime, on the other hand, the Fe-induced magnetic order is short-ranged, which is distinct from the stripes. It is plausible that a spin-glass state of Fe spins derived from the RKKY interaction is realized in the overdoped regime. These results suggest a change of the electronic state from the strongly correlated electron state to the Fermi-liquid-like state with hole doping in La-214 high-$T_c$ cuprates [2,3].