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μSR Signatures of Pseudogap and Critical Spin Dynamics in the Kondo Condensate of P-Doped Silicon

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Doped silicon offers a rich platform for exploring quantum many-body phenomena arising from the interplay of spatial inhomogeneity, magnetism, and electron correlations. At intermediate densities of magnetic impurities, phosphorus-doped silicon (Si:P) hosts a Kondo condensate, characterized by an energy gap in the electronic density of states. In this regime, randomly distributed Kondo clouds overlap and interact via Ruderman–Kittel–Kasuya–Yoshida (RKKY) interactions, yet the precise nature of its magnetic ground state remains unresolved. In this talk, I will present our study of the magnetic ground state and spin dynamics of Si:P using electron and muon spin resonance (ESR and μSR). The ESR data reveal a gradual crossover from the Korringa regime to the spin-fluctuation regime between 22 K and 150 K, with the development of Kondo-singlet fluctuations below 22 K, eventually leading to the formation of Kondo singlets below 6 K. Complementary μSR results indicate that Kondo singlets with a singlet gap Δ_{ZF} = 0.8(4) K emerge below T_{K} = 2.4 K, followed by the formation of a correlated Kondo state at T^{*} = 0.6 K, characterized by a power-law dependence, $-K_{\mu}T \sim T^{\xi}$. This Kondo condensate state exhibits a coexistence of a Bardeen-Cooper-Schrieffer-like charge gap and critical magnetic fluctuations, drawing striking parallels to the pseudogap phases observed in doped Mott insulators. These findings extend the scope of pseudogap phenomena, highlighting their relevance in the domain of doped semiconductors.

Presenter: CHOI, Kwang-Yong (Sungkyunkwan University, Republic of Korea)

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