## Summary of thesis:
## Superconducting properties of heavy fermion thin films and superlattices

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The impurity effect on $CeCoIn_5$ has been investigated extensively by rare earth, *R* substitution for Ce. Two notable features have been pointed out. Firstly, non-magnetic impurities locally suppress superconductivity, generating an inhomogeneous electronic "Swiss cheese". Secondly, several groups have reported more striking and unexpected results in the case of Yb-substitution on Ce-site: the superconductivity in $Ce_{1-x}Yb_xCoIn_5$ is robust against Yb-substitution and $T_c$ decreases linearly with $x$ towards 0 K as $x \rightarrow 1$, while $T_{coh}$ remains essentially unaffected with Yb-doping. $YbCoIn_5$ is a conventional nonmagnetic metal with no superconducting transition down to 20 mK, indicating that Yb is close to divalent and in the nonmagnetic closed shell $4f^{14}$ configuration. Therefore, the robustness of the superconductivity upon Yb-substitution in $CeCoIn_5$ with unconventional pairing symmetry is extraordinary. Moreover, the lattice parameters remain roughly constant as $x$ changes until the phase separation occurs at $x \sim 0.8$, indicating the violation of Vegard's law. These results are markedly different from other *R* substituted CeCoIn*5*, in which *R* substitutions suppress the superconductivity at approximately $x \sim 0.2$-$0.3$. These anomalous behaviors have been discussed in the light of the valence fluctuations of Yb-ions. However, the electronic state of Yb in the Kondo lattice of $CeCoIn_5$ is poorly understood.

Here, we here take a different approach to studying $Ce_{1-x}Yb_xCoIn_5$ by using thin films grown by Molecular beam epitaxy (MBE) technique. In high quality $Ce_{1-x}Yb_xCoIn_5$ epitaxial thin films, Yb-ions are divalent and no signature of the valence fluctuation is observed. The Yb-substitution leads to a strong suppression of the superconductivity and Kondo coherence. The suppression of $T_c$ can be well described by AG theory. These results indicate that Kondo-holes created by Yb-ions act as nonmagnetic impurity scatters in the Kondo lattice with no serious reduction of AF fluctuations. These are in sharp contrast to previous studies performed using bulk single crystals, which claim the importance of valence fluctuations of Yb-ions. The present work also emphasizes the uniqueness of the epitaxial films in the study of the impurity effect on the *f*-electron Kondo lattices, due to the prospect of preparing highly homogeneous doped systems. These results are shown in Chapter 4.

The Rashba splitting arising from inversion symmetry breaking (ISB) has been suggested to affect the superconductivity, leading to a plethora of novel phenomena. It has also pointed out that such phenomena are more pronounced in heavy fermion system due to a strong electron correlation effect. The physics of Rashba splitting in heavy fermion system has primarily been studied using bulk crystals, where the degree of the ISB is difficult to tune because it depends on the crystal structure. Therefore, the systematic influence of ISB on unconventional superconductivity remains an open question.

Here, by using a state-of-the-art molecular beam epitaxy technology, we fabricated a new type of heavy fermion superlattices with alternating layers of heavy fermion $CeCoIn_5$ and nonmagnetic metal $YbCoIn_5$ with controlled atomic layer thicknesses: the thickness of $CeCoIn_5$ is kept to $n = 5$ for the entire superlattice, while the thickness of $YbCoIn_5$ alternates between $m$ and $m'$ from one block layer to the next, forming a (5:$m$:5:$m'$) $c$-axis oriented superlattice structure. Both the enhancement of $H_{c2\perp}(T)/H_{c2\perp}^{orb}(T = 0)$ in perpendicular field and the angular variation of $H_{c2}$ around the parallel field indicate that the ISB arising from the thickness modulation of $YbCoIn_5$ layers strongly affects the superconductivity through the suppression of Pauli paramagnetism, when $|m-m'|$ is increased from 4 to 6. This result can be understood if the Rashba splitting begins to exceed the superconducting gap energy when $|m-m'|$ reaches a threshold value between 4 and 6. These results are shown in Chapter 5.

Finally we will summarize and conclude our study in Chapter 6.