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Two-dimensional Confinement of Heavy Fermions in Artificial Superlattices[1]

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Low dimensionality and strong electron-electron Coulomb interactions are both key parameters for novel quantum states of condensed matter. A metallic system with the strongest electron correlations is reported in rare-earth and actinide compounds with f electrons, known as heavy-fermion compounds, where the effective mass of the conduction electrons are strikingly enhanced by the electron correlations up to some hundreds times the free electron mass. To date the electronic structure of all heavy-fermion compounds is essentially three-dimensional. We realized experimentally a two-dimensional heavy fermion system, adjusting the dimensionality in a controllable fashion. We grew artificial superlattices of $CeIn_3(m)/LaIn_3(n)$, in which m-layers of heavy-fermion antiferromagnet $CeIn_3$ and n-layers of a non-magnetic isostructual compound $LaIn_3$ are stacked alternately, by a molecular beam epitaxy [1]. By reducing the thickness of the $CeIn_3$ layers, the magnetic order was suppressed and the effective electron mass was further enhanced. The Néel temperature becomes zero at around $m = 2$, concomitant with striking deviations from the standard Fermi liquid low-temperature electronic properties. Standard Fermi liquid behaviors are, however, recovered under high magnetic field. These behaviors imply new "dimensional tuning" towards a quantum critical point. We also succeeded to fabricate artificial superlattices of a heavy fermion superconductor $CeCoIn_5$ and non-magnetic divalent Yb-compound $YbCoIn_5$. Superconductivity survives even in $CeCoIn_5(3)/YbCoIn_5(5)$ films, while the thickness of $CeCoIn_5$ layer, 2.3 nm, is comparable to the c-axis coherence length $\xi_c \sim 2$ nm. This work has been done in collaboration with Y. Mizukami, S. Yasumoto, M. Shimozawa, H. Kontani, T. Shibauchi, T. Terashima and Y. Matsuda.superconductivity is realized in the artificial superlattices.

[1] H.Shishido *et al.*, Science **327** 980 (2010).

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