Rhodium doping of the heavy fermion compound URu$_2$Si$_2$ leads to simplification of its temperature (T) vs. magnetic field (B) phase diagram [1]. When 4% of the Ruthenium atoms are substituted with Rhodium, the hidden order (HO) phase is suppressed and a single field-induced robust phase remains in a (T, B) region centered at the quantum critical point near 35 T. In a hybridized band model picture, rhodium is believed to weaken the hybridization between the 5f quasiparticles and the conduction bands tilting the balance of the interactions in favor of a local electrical quadrupolar ordering [2][3]. Recently, rhenium doping of URu$_2$Si$_2$ has been shown to present intriguing electronic and magnetic behaviors in the 0 – 14 K temperature range [4]. Whereas a 5% substitution of Ru by Re suppresses the HO phase, ferromagnetic (FM) order develops from a 15% substitution which FM order coexists with non Fermi liquid (NFL) behavior over a wide range of Rhenium doping values. NFL behavior is often associated with the existence of a QCP but most rarely with FM order and particularly in f-electron compounds. Those recent discoveries make thus the study of the (T, B) phase diagram of URu$_2$-$_x$Re$_x$Si$_2$ of great interest; one important first step in that purpose is to determine whether the multiple field induced ordered phases observed in URu$_2$Si$_2$ and whether the QCP itself can survive to an increasing rhenium doping.

In the present series of measurements, we studied the field dependence of the magnetization in samples having nominal compositions URu$_{1.98}$Re$_{0.02}$Si$_2$, URu$_{1.96}$Re$_{0.04}$Si$_2$ and URu$_{1.90}$Re$_{0.10}$Si$_2$. The pulse field measurements were carried out in Cell 1 (50 T, mid pulse) and Cell 3 (65 T, short pulse) at NHMFL - LANL up to 42 T for several different temperatures lying between 0.5 K and 17 K using a wire-wound sample-extraction magnetometer inside which the sample of typical size 0.8 x 0.2 x 1.7 mm$^3$ is mounted and oriented such as the easy magnetic orientation axis $c$ is aligned with the field.

Above 6 K, itinerant electron magnetism manifests in URu$_2$Si$_2$ as an important jump of the magnetization at a metamagnetic transition field $B_M$ of 37.9 T [5]. As the temperature is decreased, several magnetization plateaux appear inside the metamagnetic crossover region as a signature of successive transitions between different ordered phases. In the present compounds, from the data at 11.0 K, $B_M$ as obtained from a fit of the centered position of a single broad maximum in the differential susceptibility $\chi$ is shown to move to higher fields as the Re content increases with $B_M \sim 37.9$ T at $x = 0.02$ and $\sim 39.1$ T at $x = 0.10$. In a simple qualitative picture where low Rhenium doping values just contribute in adding more electrons to the system making it more itinerant, higher fields are required to break a strengthened hybridization between the f quasiparticles and the conduction band. The opposite trend is observed in the case of rhodium doping. At 1.5 K, as can be seen in Fig.1, the plateaux-like features are less visible as the Re content increases. At $x = 0.10$, the metamagnetic transition can be followed down to lowest temperatures than in pure URu$_2$Si$_2$. All observations in this magnetization study tend to indicate that low rhenium doping values weaken the ordering at the neighborhood of the QCP.

Complementary magnetoresistance measurements must be carried out in order to obtain a complete and comprehensive (B, T) phase diagram for each Re content. The present compounds are low Rhenium-doped and do not allow us yet to address the consequence of coexisting FM order and NFL behavior on the high magnetic field magnetization curves.

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