Broken time-reversal symmetry in superconducting partially-filled skutterudite $Pr_{1-\delta}Pt_4Ge_{12}$

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Time reversal symmetry (TRS) is a key symmetry in superconductors. The violation of TRS often results in a wealth of novel properties. Here we report the synthesis and superconducting properties of the partially-filled skutterudite $Pr_{1-\delta}Pt_4Ge_{12}$. The results from X-ray diffraction and magnetization measurements show that the $[Pt_4Ge_{12}]$ cage-forming structure survives and bulk superconductivity is preserved below the superconducting transition temperature $T_c = 7.80$ K. The temperature dependence of both the upper critical field and the electronic specific heat can be described in terms of a two-gap model, providing strong evidence of multi-band superconductivity. TRS breaking is observed using zero field muon-spin relaxation experiments, and the magnitude of the spontaneous field is nearly half of that in $PrPt_4Ge_{12}$.

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