Disorder Induced Orbital Glass State in $FeCr_2S_4$

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Effect of disorder on orbital state in spinel $FeCr_2S_4$ has been investigated with the substitution of Cr by Al, Ga, and Fe, respectively. For polycrystalline $FeCr_2S_4$, being related to orbital ordering transition around 9 K, temperature dependence of magnetization shows a step-like transition, and specific heat displays a well-defined λ-type anomaly correspondingly. However for single crystal and the doped $FeCr_2S_4$ samples, the step-like transition in magnetization disappears, and the λ-type anomaly of specific heat is replaced by broad hump. Moreover, the specific heat obeys a T^2 dependence at temperatures below 2 K, suggesting the formation of orbital glass state in these samples. In consistent with different orbital states, the resistivity at low temperature can be better fitted with thermal activated model for polycrystalline $FeCr_2S_4$ sample, and better described by Mott's variable-range hopping expression for the others. All these results imply that the disorder induces orbital glass state in $FeCr_2S_4$.