Pressure dependence of Eu valence, crystal structure and electric resistivity of Eu*T*Ge$_3$ (*T*=Co, Rh and Ir)

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Strongly correlated 4*f*-electron systems exhibit a rich variety of emergent phenomena, including the Kondo effect, valence fluctuations, quantum criticality, and unconventional superconductivity. In such systems, pressure often serves as an effective tuning parameter to drive electronic instabilities and induce novel ground states. The non-centrosymmetric Eu*T*Ge$_3$ family (*T* = Co, Rh, Ir; space group I4mm) provides an attractive platform for investigating the interplay between magnetism, lattice degrees of freedom, and Eu valence evolution under compression. These compounds contain divalent Eu^{2+} ions ($4f^7$, J = 7/2) and order antiferromagnetically below ~15 K, with magnetic structures that depend sensitively on the transition-metal element [1].

We combined high-energy-resolution fluorescence-detected X-ray absorption spectroscopy (HERFD-XAS), synchrotron X-ray diffraction (XRD), and electrical transport measurements under hydrostatic pressure to probe the evolution of the electronic and crystal structures across the Eu*T*Ge$_3$ series. HERFD-XAS demonstrates a systematic pressure-induced transfer of spectral weight from Eu^{2+} to Eu^{3+} states, indicating a continuous increase of the mean Eu valence. The effect is least for the 3d compound, where the average Eu valence increases from ~2.2 at ambient pressure to ~2.25 at 40 GPa in EuCoGe$_3$ [2]. In contrast, the 4d and 5d analogues EuRhGe$_3$ and EuIrGe$_3$ exhibits a significantly stronger response, with the Eu valence reaching ~2.45 at 40 GPa [3]. These contrasting behaviors highlight the distinct influence of 3d, 4d, and 5d transition-metal electronic states on Eu valence instability. XRD measurements reveal that the non-centrosymmetric crystal structure remains remarkably robust up to 40 GPa, although signatures of a possible structural transition are observed in EuIrGe$_3$ [4]. Furthermore, equation-of-state (EOS) analysis of the pressure-dependent unit-cell volume was performed to determine the elastic properties and compressibility of the compounds.

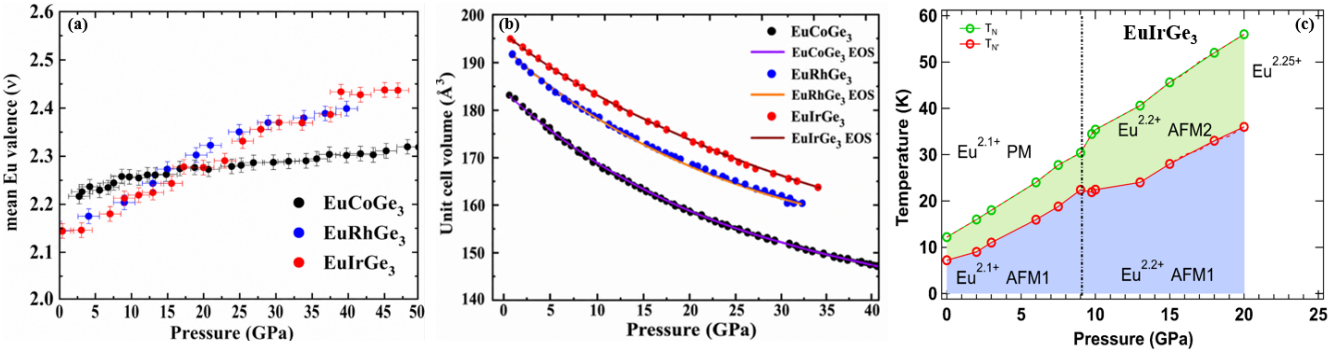

Figure 1. (a) Pressure dependence of the mean Eu valence obtained from HERFD-XAS, and (b) unit-cell volume with equation-of-state (EOS) fits for EuTGe$_3$. (c) temperature–pressure phase diagram of EuIrGe$_3$ derived from electrical resistivity measurements under pressure.

Electrical resistivity measurements performed up to 20 GPa on EuIrGe$_3$ reveal a substantial enhancement of resistivity with pressure, consistent with increased scattering from valence fluctuations and strengthened RKKY interactions. Simultaneously, the antiferromagnetic ordering temperature increases nearly fourfold, from 12 K at ambient pressure to approximately 48 K at 20 GPa. These results demonstrate that pressure drives Eu-valence evolution and strongly enhances magnetic ordering in non-centrosymmetric Eu*T*Ge$_3$ compounds, revealing a close coupling between electronic correlations, lattice compression, and magnetism.

References:

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