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Charge density wave behavior and order-disorder in the antiferromagnetic metallic series $Eu(Ga_{1-x}Al_x)_4$

The solid solution $Eu(Ga_{1-x}Al_x)_4$ was grown in single crystal form to reveal a rich variety of crystallographic, magnetic, and electronic properties that differ from the isostructural end compounds $EuGa_4$ and $EuAl_4$, despite the similar covalent radii and electronic configurations of Ga and Al. Here we report the onset of magnetic spin reorientation and metamagnetic transitions for $x = 0$ - 1 evidenced by magnetization and temperature-dependent specific heat measurements. T_N changes non-monotonously with x, and it reaches a maximum around 20 K for $x = 0.50$, where the *a* lattice parameter also shows an extreme (minimum) value. Anomalies in the temperature-dependent resistivity consistent with charge density wave behavior exist for $x = 0.50$ and 1 only. Density functional theory calculations show increased polarization between the Ga-Al covalent bonds in the $x = 0.50$ structure compared to the end compounds, such that crystallographic order and chemical pressure are proposed as the causes of the charge density wave behavior.