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Structural phases of elemental Gallium: universal relations in conventional superconductors

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The pressure induced superconductivity in Ga-II phase of elemental Gallium (the transition temperature $T_{\rm c} \simeq 6.45$ K) was studied experimentally by means of muon-spin rotation. Experiments reveal that Ga-II is the type-I superconductor with the zero temperature ther-modynamic critical field $B_{\rm c}(0) = 64.07(1)$ mT. The analysis of $B_{\rm c}(T)$ data within the phenomenological α-model, ref [1], allows to estimate $T_{\rm c} = 6.448(2)$ K, the zero-tempeature value of the superconducting energy gap $\Delta = 1.121(1)$ meV, and the coupling strengths $2\Delta/k_{\rm B}T_{\rm c} = 4.024(2)$.

Correlations between the thermodynamical critical field $B_{\rm c}$ and the transition temperature $T_{\rm c}$ (see Fig.1) as well as between the coupling strength $\Delta/k_{\rm B}T_{\rm c}$, the ratio $B_{\rm c}(0)/T_{\rm c}\sqrt{\gamma_{\rm e}}$ ($\gamma_{\rm e}$ is the normal state specific heat coefficient), and the specific heat jump $\Delta C(T_{\rm c})/\gamma_{\rm e}T_{\rm c}$ were found to hold for varios phonon-mediated superconductors. The corresponding quantities for the pressure stabilized Ga-II phase, obtained from the temperature dependence of the thermodynamic critical field $B_{\rm c}(T)$ and of the specific heat $C(T)$ follow quite precisely the above mentioned scaling laws. These relations can be well understood taking into account strong coupling adjustments of BCS universal parameters and can naturally explain the empirical scaling of thermodynamic critical field and critical temperature of phonon-mediated type-I superconductors.

References

[1] H. Padamsee, J. Low Temp. Phys., **12**, 387 (1973).
[2] J.W. Rohlf, Modern physics from α to Z, Williey (1994).

Figure 1. Correlation between the thermodynamical critical field $B_{\rm c}$ and the transition temperature $T_{\rm c}$ in single-element superconductors (after [2]). The various Ga phases are denoted by red starts.

Position

Scientist

Primary author: Dr KHASANOV, Rustem (Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland)

Co-authors: Dr AMATO, Alex (Paul Scherrer Institut); MORENZONI, Elvezio (Paul Scherrer Institut); Dr LUETKENS, Hubertus (Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland)

Presenter: Dr KHASANOV, Rustem (Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institute, CH-5232 Villigen PSI, Switzerland)

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