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A Study Of The Isotope Effect In Superconductors With Emphasis On The Alpha Index

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A Study of the Isotope Effect in Superconductors with Emphasis On the Alpha Index

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Abstract
This study investigates the isotope effect in superconductors, focusing on the alpha index (α), which quantifies the dependence of the critical temperature (Tc) on isotopic mass (M). While the Bardeen-Cooper-Schrieffer (BCS) theory predicts α = 0.5 for phonon-mediated Cooper pairing, significant deviations in materials such as Uranium ($\alpha \approx$ -2.00) and other superconductors such as Os and Ru ($\alpha \approx$ 0.00) challenge conventional frameworks. This work addresses these discrepancies by developing a novel analytical model that integrates lattice dynamics, Coulomb interactions, and energy-state symmetry to relate α, Tc, M, and bulk modulus (B). The model, derived from classical mechanics and quantum principles, posits that thermal energy equivalence between lattice phonons and electron kinetic energy at Tc yields the relationship; Mˆ(-α) Tc $\propto$ K.B, bridging gaps between BCS theory and anomalous superconductors.
Experimental validation using data from nine elemental superconductors (Zr, Sn, Hg, Cd, Mo, TI, Os, Ru, U) confirms the model's predictive power. Key findings reveal that deviations in α correlate with lattice stiffness (B) and anharmonic phonon effects, offering insights into unconventional superconductivity mechanisms. For instance, uranium's negative α (α = -2.0) and high B (˜100 GPa) suggest non-phononic pairing dominated by electronic correlations. Conversely, conventional superconductors like Pb (α = 0.49) align closely with the model's predictions.
This study advances the understanding of the isotope effect by unifying nuclear mass, lattice rigidity, and electron-phonon coupling into a single framework. It provides a predictive tool for tailoring High-Tc materials, such as hydrogen-rich superconductors, and highlights the role of lattice anharmonicity in next-generation quantum materials. The results hold implications for applications in energy transmission, medical imaging, and quantum computing, while offering a pathway to reconcile classical and quantum descriptions of superconductivity.

Keywords: Isotope effect, Alpha index, Critical temperature, Bulk modulus, BCS theory, Phonon-mediated pairing.

References:

Bardeen, J., Cooper, L. N., & Schrieffer, J. R. (1957). Theory of Superconductivity. Physical Review, 108(5), 1175–1204.

Tinkham, M. (2004). Introduction to Superconductivity (2nd ed.). Dover Publications.

Geballe, T. H., Matthias, B. T., & Compton, V. B. (1966). Superconductivity. Reviews of Modern Physics, 38(1), 1–35.

Boeri, L., & Bachelet, G. B. (2019). Anharmonicity and the isotope effect in High-Tc superconductors. NPJ

Quantum Materials, 4(1), 1–8.
Maxwell, E. (1950). Isotope Effect in the Superconductivity of Mercury. Physical Review, 78(4), 477.
Kittel, C. (2005). Introduction to Solid State Physics (8th ed.). Wiley

Abstract Category

Materials Physics

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