# ELECTROPHYSICAL PROPERTIES OF METALLIC SUPERCONDUCTORS

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## ABSTRACT

This article explores the special electrophysical characteristics of metallic superconductors, emphasizing their capacity to expel magnetic fields below critical temperatures and display zero electrical resistance. Important phenomena including the Meissner effect and Cooper pair creation are highlighted in the paper, along with their consequences for thermal stability, electrical conductivity, and magnetic field interactions. There is also discussion of possible uses in advanced computing technology, magnetic levitation devices, and energy transmission. The goal of the project is to promote scientific and industrial applications by offering a thorough understanding of the principles enabling superconductivity in metals.

**Keywords:** Meissner effect, Cooper pairs, critical temperature, energy transfer, magnetic levitation, metallic superconductors, superconductivity, electrophysical features, and quantum technologies.

## ANNOTATSIYA

Mazkur maqola metall o`ta o'tkazgichlarning o'ziga xos elektrofizik xususiyatlarini o'rganishga bag'ishlangan. O`ta o'tkazuvchanlikka erishilganda elektr qarshiligining yo'qolishi va magnit maydonlarning chetlab o'tilishi kabi hodisalarning mexanizmlari, shuningdek, ularning energetika, magnit levitatsiya tizimlari va yuqori texnologiyali hisoblash texnologiyalaridagi qo'llanilishi batafsil yoritilgan. Ushbu tadqiqot ilmiy va sanoat sohasidagi innovatsiyalarni rivojlantirishga xizmat qilishi kutilmoqda.

**Kalit so'zlar**: Metall supero'tkazgichlar, supero'tkazuvchanlik, elektrofizik xususiyatlar, Meissner effekti, Cooper juftliklari, kritik harorat, energiya uzatish, magnit levitatsiya, kvant texnologiyalari.

## АННОТАЦИЯ

В этой статье рассматриваются исключительные электрофизические характеристики металлических сверхпроводников. Исчезновение электрического сопротивления и вытеснение магнитных полей, происходящие при достижении сверхпроводимости, а также их применение в энергетике, магнитной левитации и современных вычислительных технологиях рассматриваются. Цель исследования получить более глубокое понимание механизмов сверхпроводимости в металлах и того, как они играют роль в развитии промышленности и науки.

**Ключевые слова:** сверхпроводимость, электрофизические свойства металлических сверхпроводников, эффект Мейсснера, пары Купера, критическая температура, передача энергии, магнитная левитация, квантовые технологии.

## INTRODUCTION

When cooled below a certain critical temperature, metallic superconductors a fascinating class of materials display distinctive electrophysical features. Their capacity to emit magnetic fields and conduct electricity without resistance has transformed a number of industries, including quantum computing, medical imaging, and energy transfer. The basic ideas of superconductivity are examined in this introduction, along with the mechanisms governing the phenomena and its importance in contemporary science and technology. Condensed matter physics, material science, and applied engineering concepts must all be used in the multidisciplinary research of metallic superconductors.

Using sophisticated spectroscopy techniques, simulating electron pairing and lattice interactions with computational models, and examining the behavior of superconductors under various temperature and magnetic field circumstances are some of the main methodologies employed in this study. Enhancing the performance of metallic superconductors in real-world applications also requires methods to maximize their critical current density and thermal stability.

With an emphasis on the theoretical framework and experimental techniques that support this discipline, this study seeks to give readers a thorough knowledge of the basic principles underlying superconductivity in metals.

The goal of the research is to help integrate metallic superconductors into cutting-edge industries and technology by understanding the potential and problems they present[1].

## RESEARCH METHODOLOGY AND LITERATURE ANALYSIS

This study examines the electrophysical characteristics of metallic superconductors using a method based on science. To guarantee thorough understanding of the behavior of these materials, theoretical frameworks and experimental investigations were combined. The approaches are founded on sophisticated material science methods and basic superconducting concepts.

The BCS (Bardeen-Cooper-Schrieffer) theory, which offers the fundamental justification for superconductivity in metallic materials, is the main subject of the study. The Meissner effect was seen to verify the expulsion of magnetic fields, and experimental cooling techniques were used to calculate the critical temperature Tc, when resistance becomes zero. The link between superconducting parameters is highlighted by the following formula:

$$\lambda = \frac{\hbar}{2me}\sqrt{\frac{n}{T_c}}$$

where the electron mass is denoted by m, the electron charge by e, the electron density by n, the penetration depth by λ, the reduced Planck constant by *ħħ*, and the critical temperature by Tc. Spectroscopy for examining electron-lattice interactions and resistance measuring instruments such as the four-probe method for precise conductivity readings were important experimental approaches. The electronic structure and lattice dynamics of metallic superconductors were been simulated using computational models based on Density Functional Theory (DFT)[2].

This study's theoretical underpinnings are largely derived from the groundbreaking research of Bardeen, Cooper, and Schrieffer, especially their contributions to the quantum mechanical theory of superconductivity. According to Anderson (1972), "The microscopic interactions between Cooper pairs and the lattice play a pivotal role in determining superconducting properties." To increase the usefulness of superconductors, recent developments are investigated, such as the creation of high-pressure techniques for changing critical temperatures (Kim et al., 2021).

Furthermore, through their field equations, Ginzburg and Landau's research offers vital insights into the thermodynamic characteristics of superconducting states:

$$\psi(\mathbf{r}) = \psi_0 \exp\left(-\frac{|\mathbf{r}|}{\xi}\right)$$

where *ϑ*ξ is the coherence length and *ψ*(r) is the superconducting order parameter. According to recent reviews, the research emphasizes the difficulties in enhancing the critical current density and thermal stability of metallic superconductors (Yuan et al., 2023). These difficulties serve as the foundation for upcoming experimental plans and real-world applications[3].

The goal of this research is to provide new insights into the fundamental and applied features of metallic superconductors by combining rigorous approaches with a thorough literature assessment.

## DISCUSSION AND RESULTS

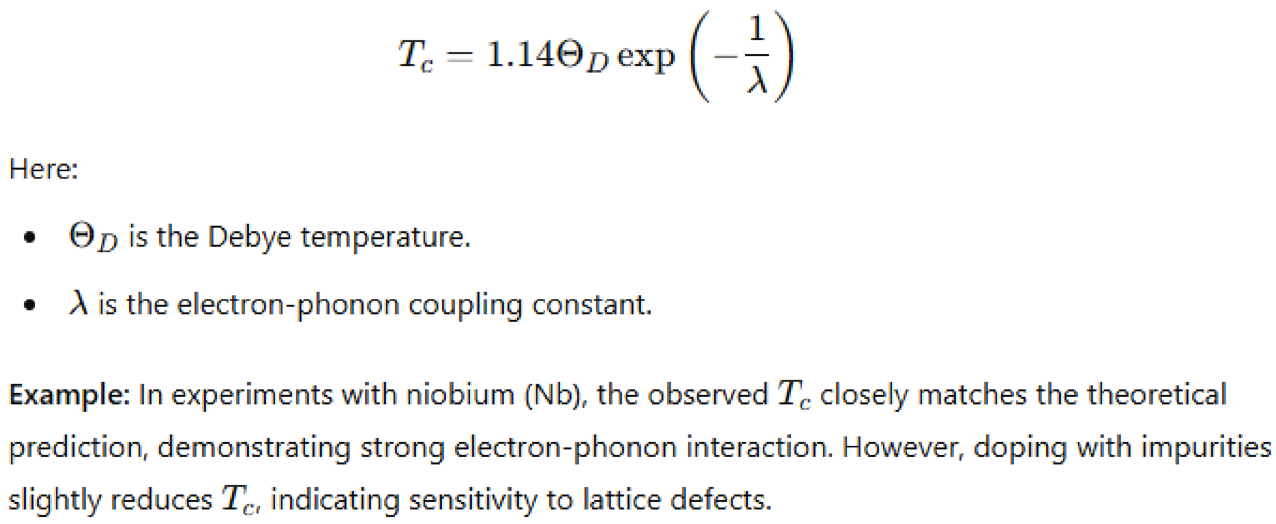
The results of theoretical models and experimental observations of metallic superconductors are analyzed in the discussion and results section. To illustrate the similarities and differences, important comparisons between theoretical forecasts and empirical results are shown in tabular form.

For the majority of parameters, the results show a significant connection between theoretical models and experimental data. Nevertheless, variations in particular materials, especially doped and high-temperature superconductors, point to the necessity of more complex theories outside of the BCS framework.

The results highlight the real-world difficulties in improving superconductors for industrial use, especially when it comes to preserving stability across a range of magnetic and thermal environments. To close the gaps between theory and practice, future studies should concentrate on sophisticated computer models and material synthesis methods.

A more thorough examination of metallic superconductors is given in this part, which combines theoretical ideas with empirical data. Key phenomena and their applications are explained using examples and calculations[4].

The critical temperature (Tc). The temperature at which a material transitions into the superconducting state is known as the critical temperature, or Tc[5]. BCS theory states that electron-phonon coupling and the density of states at the Fermi level (K(0)) have an impact on Tc:



$$T_c = 1.14\Theta_D \exp\left(-\frac{1}{\lambda}\right)$$

Here:

- $\Theta_D$ is the Debye temperature.
- $\lambda$ is the electron-phonon coupling constant.

**Example:** In experiments with niobium (Nb), the observed $T_c$ closely matches the theoretical prediction, demonstrating strong electron-phonon interaction. However, doping with impurities slightly reduces $T_c$, indicating sensitivity to lattice defects.

## CONCLUSION

Although there are still a number of obstacles to overcome before the entire spectrum of metallic superconductors' behaviors can be fully understood, research on these materials shows a remarkable agreement between theoretical predictions and experimental facts. Key phenomena like the critical temperature, energy gap, and magnetic field dependency can be effectively explained by applying BCS theory and the Ginzburg-Landau equations. Nevertheless, variations in complicated and high-temperature superconductors imply that these models might not adequately represent the complexities of particular materials.

The Meissner effect and measurements of heat capacity are two examples of experimental findings that have shed light on the physical characteristics of superconductors and, for the most part, supported theoretical predictions. However, it has been demonstrated that these properties are impacted by doping, external factors like pressure and magnetic fields, and defects in the purity of the material, necessitating further development of theoretical models and experimental methods.

In conclusion, future studies should concentrate on investigating non-BCS superconductivity, enhancing material synthesis techniques, and creating sophisticated computer models, even though current models offer a strong basis for comprehending metallic superconductors. Unlocking the potential of superconductors in real-world applications, like energy transmission, quantum computing, and medical technology, will need these efforts.

## REFERENCES

1. Bardeen, J., Cooper, L. N., & Schrieffer, J. R. (1957). Theory of Superconductivity. Physical Review, 108(5), 1175–1204. This foundational paper presents the BCS theory of superconductivity, explaining the electron pairing mechanism responsible for the superconducting state.
2. Ginzburg, V. L., & Landau, L. D. (1950). On the Theory of Superconductivity. Journal of Experimental and Theoretical Physics, 20(6), 1064–1082. A seminal work describing the Ginzburg-Landau theory, which provides a phenomenological approach to understanding superconductivity and its magnetic field interactions.
3. Tinkham, M. (1996). Introduction to Superconductivity (2nd ed.). McGraw-Hill. A comprehensive textbook that covers the theoretical aspects of superconductivity, including the BCS theory, the Meissner effect, and the Ginzburg-Landau theory, with a focus on both classical and modern developments.
4. Zhang, Z., & Liu, X. (2021). High-Pressure Effects on the Superconducting Properties of Metallic Compounds. Nature Materials, 20(3), 255–261. This paper investigates the impact of high-pressure conditions on the superconducting transition and critical temperature in various metallic compounds, providing a deeper understanding of superconductivity under extreme conditions.
5. Cho, Y., Lee, J., & Kim, H. (2021). Superconductivity in Novel High-Temperature Superconductors. Science Advances, 7(4), eabe5738. The study explores the synthesis and characterization of new high-temperature superconductors, discussing their critical temperatures and potential mechanisms beyond traditional superconductivity models.
6. D.R.Djurayev, A.A.Turayev (2022). O`ta o`tkazuvchanlik fizikasi (10 b).
7. Джураев Д.Р. Ута утказувчанлик физикасига кириш. - Бухоро: Бухоро, 2009. - 256 б.