

BCS Extensions: Superconductivity in Varied System

Fiona Gallagher*

Department of Pharmaceutics, Trinity College of Pharmacy, Dublin, Ireland

Introduction

This paper explores the interplay between charge density waves, the pseudogap, and superconductivity within a generalized BCS-like framework. It highlights how these phenomena compete and coexist, offering insights into complex materials like cuprates and transition metal dichalcogenides. The formulation provides a unified description of these coupled orders, going beyond simple mean-field approximations [1].

This article investigates multi-gap superconductivity in strongly correlated systems, moving beyond conventional BCS predictions. It reveals how strong correlations lead to deviations from standard BCS behavior, particularly in the gap structure and critical temperature. The formulation considers interactions that are not captured by simple mean-field BCS theory, providing a more comprehensive understanding of unconventional superconductors [2].

This study develops a BCS-like theoretical framework for triplet pairing in quasi-one-dimensional lattice systems. It investigates the conditions for realizing unconventional superconductivity with particular focus on the formation of topological phases. The formulation clarifies the role of lattice geometry and electron interactions in stabilizing triplet Cooper pairs, potentially leading to topological superconductors [3].

This work applies a BCS-like theoretical description to analyze the superconducting characteristics of iron-based superconductors. It investigates the gap structure and its anisotropy, providing a framework to understand the complex pairing mechanisms in these unconventional materials. The formulation highlights how specific electronic features contribute to the observed superconducting properties, offering insights crucial for material design [4].

This paper investigates the BCS-BEC crossover phenomenon in a two-dimensional Fermi gas, specifically focusing on systems with p-wave interactions. It uses a BCS-based formulation to describe the transition from a Bardeen-Cooper-Schrieffer superfluid to a Bose-Einstein condensate of molecules. The study highlights the distinct features of p-wave pairing in two dimensions and its impact on the ground state and superfluid properties [5].

This article presents evidence for BCS-like superconductivity in bilayer graphene, specifically under conditions of twist angle disorder. It describes a formulation where localized electron states, induced by disorder, can lead to pairing interactions resembling those in conventional BCS theory, despite the unconventional nature of the material. The work sheds light on how disorder can unexpectedly facilitate superconductivity in low-dimensional systems [6].

This paper proposes a BCS-type model to describe high-temperature superconductivity in cuprates. It extends the conventional BCS formulation by incorpo-

rating strong electron correlations and anisotropic pairing symmetries relevant to these materials. The model aims to explain the high critical temperatures and other anomalous properties observed in cuprate superconductors, providing a theoretical basis for their complex behavior [7].

This research investigates BCS pairing in strongly interacting matter, such as that found in neutron star cores, moving beyond the traditional weak coupling limit. The formulation extends BCS theory to account for strong-force interactions between nucleons, crucial for understanding phenomena like neutron superfluidity and proton superconductivity in extreme astrophysical environments. It provides a more robust description of gap formation under such conditions [8].

This paper employs an extended BCS approach to study superconductivity within the two-dimensional Hubbard model, a fundamental model for strongly correlated electron systems. The formulation goes beyond simple mean-field BCS by incorporating effects of strong electronic correlations, shedding light on the pairing mechanisms and superconducting phase diagram in such models. It offers insights into the interplay of magnetism and superconductivity [9].

This study develops a finite-temperature BCS-like theory to describe superconductivity in topological Dirac semimetals. The formulation accounts for the unique electronic structure of these materials, predicting how superconducting properties evolve with temperature. It provides a theoretical framework for understanding the interplay between topology and superconductivity, offering insights into potential applications of these exotic materials [10].

Description

Recent studies widely adapt and extend the Bardeen-Cooper-Schrieffer (BCS) theoretical framework to understand complex superconducting phenomena across various materials and conditions. These investigations often move beyond simple mean-field approximations to capture the nuanced behaviors observed in modern condensed matter systems and extreme environments. For instance, the interplay between charge density waves, pseudogaps, and superconductivity in materials like cuprates and transition metal dichalcogenides is explored within a generalized BCS-like theory, offering a unified description of these coupled orders [1].

Several research efforts focus on unconventional superconductivity, where strong electronic correlations and unique material properties necessitate deviations from standard BCS predictions. This includes the investigation of multi-gap superconductivity in strongly correlated systems, where interactions not captured by simple mean-field theory significantly influence the gap structure and critical temperature [2]. Similarly, a BCS-like theoretical framework has been developed for triplet pairing in quasi-one-dimensional lattice systems, examining conditions for realizing

unconventional superconductivity with a focus on topological phases and clarifying the role of lattice geometry in stabilizing triplet Cooper pairs [3]. The superconducting characteristics of iron-based superconductors, including their gap structure and anisotropy, are also analyzed using a BCS-like description, providing insights into complex pairing mechanisms crucial for new material design [4].

The versatility of BCS-like theories extends to describing exotic states of matter and extreme physical environments. The BCS-BEC crossover phenomenon, for example, is investigated in a two-dimensional Fermi gas with p-wave interactions, detailing the transition from a Bardeen-Cooper-Schrieffer superfluid to a Bose-Einstein condensate and highlighting the distinct features of p-wave pairing [5]. Furthermore, BCS pairing is studied in strongly interacting matter found in neutron star cores, pushing beyond the traditional weak coupling limit. This work extends BCS theory to account for strong-force interactions between nucleons, which is essential for understanding phenomena like neutron superfluidity and proton superconductivity in these extreme astrophysical settings [8].

Emerging material systems also benefit from BCS-like theoretical approaches. Evidence for BCS-like superconductivity has been presented in bilayer graphene, particularly under conditions of twist angle disorder. Here, localized electron states, induced by disorder, can lead to pairing interactions resembling those in conventional BCS theory, demonstrating how disorder can unexpectedly facilitate superconductivity in low-dimensional systems [6]. To address high-temperature superconductivity in cuprates, a BCS-type model has been proposed that incorporates strong electron correlations and anisotropic pairing symmetries, aiming to explain their high critical temperatures and anomalous properties [7]. An extended BCS approach is also employed to study superconductivity within the two-dimensional Hubbard model, a fundamental system for strongly correlated electrons, providing insights into pairing mechanisms and the interplay of magnetism and superconductivity [9]. Finally, a finite-temperature BCS-like theory has been developed for topological Dirac semimetals, accounting for their unique electronic structure and predicting how superconducting properties evolve with temperature, offering a framework for potential applications of these exotic materials [10].

Conclusion

This collection of research investigates the widespread applicability and critical extensions of BCS-like theories in understanding superconductivity across diverse material systems and physical conditions. Papers delve into the complex interplay of charge density waves, pseudogaps, and superconductivity in materials like cuprates, offering a unified description beyond simple mean-field approximations. Several studies explore multi-gap superconductivity in strongly correlated systems, where conventional BCS predictions fall short, highlighting deviations in gap structure and critical temperature due to strong interactions. Specific investigations focus on unconventional pairing mechanisms, such as triplet pairing in quasi-one-dimensional lattices, which could lead to topological superconductors, and the distinct features of p-wave interactions in two-dimensional Fermi gases undergoing a BCS-BEC crossover. The BCS framework is adapted to analyze superconducting properties in iron-based superconductors, providing insights into their anisotropic gap structures and pairing mechanisms crucial for material design. Remarkably, evidence for BCS-like superconductivity is found in bilayer graphene with twist angle disorder, showing how localized electron states can facilitate conventional-like pairing in unconventional systems. Models are proposed to address high-temperature superconductivity in cuprates by incorporating strong electron corre-

lations and anisotropic pairing symmetries. Beyond condensed matter, the BCS theory is extended to strongly interacting matter in extreme astrophysical environments, like neutron star cores, to describe nucleon pairing and superfluidity under strong-force interactions. Further research uses extended BCS approaches to study superconductivity in the two-dimensional Hubbard model, elucidating the role of strong electronic correlations and the interplay of magnetism and superconductivity. Finally, a finite-temperature BCS-like theory is developed for topological Dirac semimetals, connecting their unique electronic structure with superconducting properties and potential technological applications.

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None.

Conflict of Interest

None.

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***Address for Correspondence:** Fiona, Gallagher, Department of Pharmaceutics, Trinity College of Pharmacy, Dublin, Ireland, E-mail: f.gallagher@tcp.ie

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