Investigating Quantum Transport and Magnetic State Evolution for Advanced Renewable Energy Applications in RAlSi (R =rare earth element) Weyl Semimetals

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Abstract:

Weyl semimetals, particularly the RSiAl family (R = rare earth elements such as Ce, Pr, Nd, Sm, Gd), have emerged as promising candidates for next-generation electronic and spintronic devices due to their unique topological properties and robust quantum effects, such as the topological Hall effect and Shubnikov-de Haas oscillations [1-3]. These materials exhibit exotic electronic states, including type-II Weyl points and strong spin-orbit coupling, which can be harnessed to develop novel functionalities in energy-efficient technologies. In this work, we investigate the electronic and magnetic properties of the RSiAl system, exploring how these topological materials can be utilized in renewable energy applications, such as spin-based thermoelectric devices and energy-efficient data processing. The high mobility, non-trivial Berry phase, and low carrier density in these compounds contribute to enhanced thermoelectric performance and offer pathways for improving energy conversion efficiency. We present a detailed study of the magnetotransport properties across various temperatures and magnetic fields, highlighting the role of quantum oscillations and weak antilocalization effects in optimizing device performance. Additionally, we discuss how the unique band structures of Weyl semimetals could be leveraged to create low-power spintronic devices, potentially paving the way for breakthroughs in sustainable energy technologies. Our findings suggest that the RSiAl compounds, with their combination of topological characteristics and tunable electronic properties, hold significant potential for integration into renewable energy technologies, thereby contributing to the advancement of sustainable and energy-efficient materials.