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Author: Dr. Nikolai Oh
Flexell Space Co., Ltd., Republic of Korea

Dr. In Su Jin
Flexell Space Co., Ltd., Republic of Korea
Mr. Taehun Ahn
Flexell Space Co., Ltd., Republic of Korea
Dr. Shinyoung Noh
Flexell Space Co., Ltd., Republic of Korea

NEXT-GENERATION TANDEM SOLAR CELLS FOR SPACE APPLICATIONS: ENHANCING EFFICIENCY, DURABILITY, AND COST-EFFECTIVENESS

Abstract

As the space industry transitions into the New Space era, the demand for lightweight, high-efficiency, and cost-effective power solutions has significantly increased. Traditional space-grade solar cells, such as III-V compound photovoltaics, offer excellent performance but suffer from high manufacturing costs and limited scalability. These constraints pose challenges for next-generation space missions, where cost, weight, and efficiency are critical factors. To address these issues, this study explores the development of next-generation tandem solar cells utilizing Perovskite/CIGS (Copper Indium Gallium Selenide) technology, which provides a compelling alternative for space-based applications.

Perovskite/CIGS tandem solar cells are designed to achieve an efficiency range of 28-30%, making them competitive with existing III-V solutions while significantly reducing production costs. These tandem cells offer up to 60% cost savings compared to traditional space-grade photovoltaics due to their low-temperature, scalable manufacturing processes. Unlike conventional III-V solar cells, which rely on complex and expensive epitaxial growth, Perovskite/CIGS tandem solar cells can be fabricated using high-throughput production techniques, such as solution-based processing, vacuum deposition, and roll-to-roll manufacturing. These processes enable mass production while maintaining high power conversion efficiency.

To ensure their suitability for space environments, extensive environmental durability tests have been conducted. These tests have demonstrated thermal stability from -170C to +145C, ensuring the material can withstand extreme temperature variations encountered in space. Additionally, mechanical robustness has been validated, proving resistance to launch vibrations, radiation exposure, and micrometeoroid impacts. These factors are crucial for long-duration space missions, including geostationary satellites, lunar bases, and deep-space exploration.

Furthermore, collaborations with satellite manufacturers have enabled ground-based simulations and in-orbit validation experiments, confirming the real-world feasibility of this technology. As the space industry continues to evolve, the demand for high-performance, cost-efficient, and scalable solar power solutions will only increase. This paper provides a comprehensive analysis of the efficiency, reliability, and economic advantages of Perovskite/CIGS tandem solar cells, positioning them as a transformative solution for future space missions, space-based solar power stations, and planetary exploration projects.

By advancing the capabilities of space photovoltaics, Perovskite/CIGS tandem solar cells present a breakthrough in sustainable space energy generation. Their combination of high efficiency, durability, and cost reduction makes them a strong candidate to power the next era of commercial, scientific, and

exploratory space endeavors.