COETZER OPTICAL SYSTEMS (Pty) Ltd

Low Temperature Co-encapsulation Photonics Test Report

Overview

Validation of the COSINE-100U NaI(Tl) Encapsulation for Low During approximately 150 days of continuous operation at low temperature, we observed no degrad.

Key Takeaways

Low-temperature co-encapsulation methods demonstrate robust stability and performance for photonic devices, including perovskite solar cells and NaI(Tl) detectors, under cryogenic and accelerated aging conditions.Overview of Low-Temperature Encapsulation

Low-temperature encapsulation is critical for protecting sensitive photonic materials from environmental degradation, mechanical stress, and thermal cycling. Techniques often involve semi-solid polymeric composites or ethylene-vinyl acetate (EVA) layers that provide UV shielding, moisture barriers, and mechanical strain relief while maintaining optical transparency and device efficiency .

Perovskite Solar Cells (PSCs)

Recent studies have developed low-temperature, strain-free encapsulation for PSCs using semi-solid polymeric composites such as polyisobutylene (PIB) with hexagonal boron nitride (h-BN) flakes. These encapsulants are applied at temperatures between 60°C and 90°C, minimizing thermomechanical stress during lamination .

• Performance under stress: Encapsulated PSCs retained over 80% of their initial power conversion efficiency (PCE) after accelerated aging tests, including damp heat (>1000 h), light soaking (>1000 h), thermal shock (200 cycles between +85°C and -20°C), and humidity freeze (10 cycles between +85°C and -40°C), .

• Module scaling: Large-area modules (up to 150 cm^2) and perovskite solar panels (0.11 m^2) were successfully double-side laminated, achieving PCEs up to 13.2% for standard modules and 6.8% for semi-transparent wide-bandgap devices .

• UV protection: EVA-based encapsulation effectively blocks UV-induced degradation, allowing perovskite films to remain stable for over 350 hours under full solar irradiation .

NaI(Tl) Detector Encapsulation

For photonic detectors like COSINE-100U NaI(Tl) crystals, low-temperature encapsulation ensures chemical and mechanical robustness at cryogenic conditions (~−30°C). The encapsulation couples photomultiplier tubes directly to the crystal, eliminating quartz windows and improving light collection efficiency by ~50% .

• Stability testing: Modules were monitored for ~150 days at −33°C in liquid scintillator, showing no performance degradation, confirming suitability for long-term low-temperature operation .

• Cryogenic advantages: Operating at low temperatures increases intrinsic light yield and improves pulse shape discrimination, critical for high-sensitivity photonic measurements .

Key Findings

• Material selection: Semi-solid polymers with 2D fillers (h-BN) or EVA provide both mechanical strain relief and environmental protection.

• Low-temperature processing: Encapsulation at 60–90°C avoids thermal decomposition of sensitive materials like perovskites while ensuring adhesion and barrier properties .

• Long-term stability: Both PSCs and NaI(Tl) detectors maintain optical and electrical performance under extended low-temperature and accelerated aging conditions .

• Scalability: Techniques are applicable to large-area modules, semi-transparent devices, and integrated photonic systems, including building-integrated photovoltaics and IoT sensors .

Conclusion

Low-temperature co-encapsulation in photonics provides a reliable method to enhance device longevity, maintain efficiency, and protect against environmental and thermal stresses. These methods are validated for both perovskite solar cells and cryogenic photonic detectors, demonstrating their suitability for industrial-scale applications and long-term operation under challenging conditions .

Article Content

Surface Encapsulation forLow-Loss Silicon Photonics

Encapsulation layers are explored for passivating the surfaces of silicon to reduce optical ab-sorption in the 1500-nm wavelength

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This document is for preliminary research. Verify specifications against current standards, product documentation and project requirements.