CAPSUL

Publieke samenvatting / Public summary

Aanleiding

Crystalline silicon (c-Si) solar cells dominate the PV market due to their efficiency and scalability, but their reliance on silver (Ag) for metallization presents sustainability and cost challenges, especially for terawatt-scale deployment. Ag is both expensive and scarce, making it unsuitable for long-term, large-scale use. Copper (Cu) is emerging as a more abundant and cost-effective alternative, offering similar electrical performance. However, Cu is more prone to oxidation and degradation, requiring enhanced encapsulation solutions to ensure module durability, especially in harsh environmental conditions. In parallel, traditional encapsulant materials are often rigid, heavy, and lack sufficient UV and fire resistance. The transition to lightweight, flexible PV modules—such as those developed by Solarge—necessitates innovative encapsulation materials that offer strong barrier performance against moisture and oxygen while remaining compatible with modern, scalable solar manufacturing processes.

Doelstelling

The goal of the CAPSUL project is to develop, optimize, and validate a high-performance, lightweight encapsulation barrier film that protects Cu-based metallization in c-Si solar cells. This film, composed of PET coated with aluminum oxide (AlOx) using Kalpana Systems' patented roll-to-roll spatial atomic layer deposition (sALD) technology, will be designed to meet the specific performance and durability needs of Dutch lightweight solar module producer Solarge. AlOx is targeted due to its superior moisture and oxygen barrier capabilities,

Projectinformatie / Project information

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Algemene informatie / General information

Penvoerder / Secretariat
Kalpana Systems B.V.

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UV shielding properties, and fire resistance, which are essential for the long-term performance of flexible and urban-deployable solar modules. By combining Kalpana Systems' film production capabilities, TU Delft's fabrication and testing expertise, and Solarge's application knowledge, the project aims to create an industrially scalable, multifunctional encapsulation layer ready for integration into next-generation solar energy systems.

Korte omschrijving

Kalpana Systems will fabricate AlOx-coated PET barrier films using their patented sALD technology in a roll-to-roll process. These films will be characterized for barrier performance, aiming for water vapor transmission rates (WVTR) of 10¿4 g/m²·day and oxygen transmission rates (OTR) of 10¿³ cc/m²·day·atm. TU Delft will fabricate mini c-Si solar modules with Cu-based contacts and apply the encapsulation films in different module configurations. Four distinct architectures will be tested to understand the functional role of the AlOx-coated PET as a gas barrier, UV shield, and glass replacement. Environmental testing, including accelerated UV exposure, humidity cycling, and fire resistance, will be conducted to assess performance degradation, electrical stability, and structural integrity. TU Delft will lead testing and data analysis to determine the suitability of the encapsulation solution for long-term use in varied environments, particularly for lightweight and flexible solar modules.

Resultaat

The project will deliver a validated, high-performance AlOx-coated PET barrier film optimized for use in Cu-metallized c-Si solar cells, directly supporting Kalpana Systems' commercialization strategy. The encapsulation solution will enhance durability and environmental resistance while reducing dependence on silver, enabling cost-effective, scalable, and sustainable solar cell production. TU Delft's testing will verify the film's protective properties and functional impact across four module types, guiding future implementation

strategies. The CAPSUL project will also contribute critical research insights into Cu-based metallization and dielectric encapsulation in PV technology. As a result, the Netherlands and EU will gain a competitive advantage in the solar sector by promoting local innovation, sustainable material sourcing, and advanced manufacturing, while supporting key applications like lightweight PV modules from Solarge and flexible solar solutions aligned with national and EU green energy objectives.

De data in deze applicatie is afkomstig van de Rijksdienst voor Ondernemend Nederland (RVO) en wordt in samenwerking met de Topsector Energie ontsloten.
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