Fusion UV Systems, Inc.

UV SPECTRUM

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UV Curing: an Enabling Technology for Abrasion Resistance of Polymer Reflector for Concentrating Solar Applications

Top: ReflecTech®PLUS mirror film

Left: SkyFuel's parabolic trough collectors at the SEGSII solar plant

Clean, carbon-free power from solar energy has enormous potential to satisfy growing global demand for heat and electricity without increasing emissions of carbon dioxide and other air pollutants. Concentrating solar power (CSP) technologies are a resource-efficient form of solar energy conversion because they use mirrors or lenses to focus sunlight onto specialty materials such as evacuated thermal receivers and photovoltaic cells.

Until now, these technologies have used glass mirrors to concentrate the sun's energy. Glass mirrors are fragile and expensive to make and ship. They are very heavy, requiring significantly robust support structures to hold them and maintain the focus on the receiver. Highly reflective, lightweight, low cost, durable reflectors are needed for CSP technologies to compete for market share and for solar energy to reach its full potential.

According to Randy Gee, SkyFuel's Chief Technology Officer, "ReflecTech® mirror film is a highly reflective, flexible polymer film designed specifically to reduce the capital cost of parabolic trough CSP systems. By changing the materials used in concentrating solar energy applications, we have not only reduced the costs with no appreciable loss of solar reflectivity, but we have also increased the longevity and improved the maintenance capabilities of our products".

SkyFuel's SkyTrough® parabolic trough solar collector is the first utility-scale concentrator to use ReflecTech mirror film. ReflecTech is adhered to flat aluminum sheets to make full-aperture reflectors previously not possible. Total cost savings of about 20% result from a decreased amount of frame materials, manufacturing simplicity, transportation efficiency, and ease of field-assembly. Further savings are forecast to reach 35% by 2020, made possible by the increase in scale enabled by use of ReflecTech film.

Developing the polymer-based mirror film

ReflecTech® mirror film was developed through collaboration between ReflecTech, Inc. (a subsidiary of SkyFuel, Inc.) and the National Renewable Energy Laboratory (NREL). This collaborative research has recently produced an abrasion resistant coating (ARC) for application to polymer based mirror film. The ARC was developed to address the need for reflectors that are low in cost, high in performance and capable of withstanding the mechanical contact cleaning methods sometimes used in the CSP environment. ReflecTech film is easily produced in scalable volume at existing film manufacturers, and has the potential to dramatically increase the economic viability, and therefore market penetration, of parabolic trough solar power plants around the world.

A layer of pure silver – protected from oxidation and ultraviolet (UV) degradation by multiple layers of polymer films – provides the high reflectance of ReflecTech mirror film. The polymer mirror film has a solar-weighted hemispherical reflectance of 93% and a specular reflectance of 94% at a 25-mrad (1.4°) full acceptance angle at 660 nm. This performance is comparable to glass mirrors that are made for CSP applications.

Eliminating barriers to technical acceptance

A significant barrier to technical acceptance by solar developers and manufacturers is the question of durability under severe outdoor conditions. For any outdoor application to achieve product lifetime goals, the reflective technology must be weatherable – stable against UV light, resistant to the effects of moisture and temperature changes, and durable under high wind events. Reflector materials are tested for durability under exposure to outside environments through real time exposure and a variety of accelerated testing[1,2].

To test for weatherability, reflector samples were subjected to controlled conditions more extreme than experienced in actual outdoor environments, such as high doses of UV light, high humidity, and high temperatures. ReflecTech samples exposed to over 30 years equivalent UV dose in NREL's Ultra Accelerated Weathering System (UAWS) exhibited no loss in solar weighted hemispherical reflectance of the polymer film exposed at both 30°C and 60°C.

Samples of ReflecTech film were also immersed in water to test for delamination and "tunneling" (the separation of the polymer film layer from the silvered layer). No delamination occurred for the ReflecTech material after 60 days. The immersion test validated the resistance of ReflecTech film to excessive moisture.

Development of UV-cured, abrasion resistant coating

Contact cleaning methods commonly used for CSP systems can scratch the surface of polymer reflectors and thereby reduce specular reflectance. To overcome this obstacle, ReflecTech, in conjunction with NREL and Red Spot Paint & Varnish Co., Inc., developed an abrasion resistant coating (ARC) suitable for deposition onto polymer based mirror film. The desired ARC properties are high transparency and optical clarity, weatherability, abrasion resistance, strong adhesion to the base mirror film substrate, compatibility with high volume roll-to-roll production, and low material and manufacturing costs. The mirror film with the ARC incorporated as a top coat meets these requirements and is being commercially marketed as ReflecTechPLUS®.

According to John Clark, Fusion UV Systems representative, "SkyFuel/ReflecTech was first introduced to the details of UV curing technologies through the RadTech organization at one of the bi-annual conferences. ReflecTech was working with film converters who have Fusion's UV equipment and the company was looking for a better understanding of the technology and how it worked to optimize the process for its (ARC) abrasion resistant coating. Fusion was able to provide ReflecTech with a better technical understanding of the curing equipment and its capabilities, and offered technical support along the way to assist with its development."

Clark added, "UV curing has been widely adopted as an enabling technology in the film converting industry for over 30 years. The technology's ability to provide superior functional performance with low heat in a very small footprint and in an eco-friendly way is a big advantage."

Gary Jorgensen, SkyFuel's Principal Materials Scientist, commented that "Our collaboration with Fusion UV

Continued on p3