

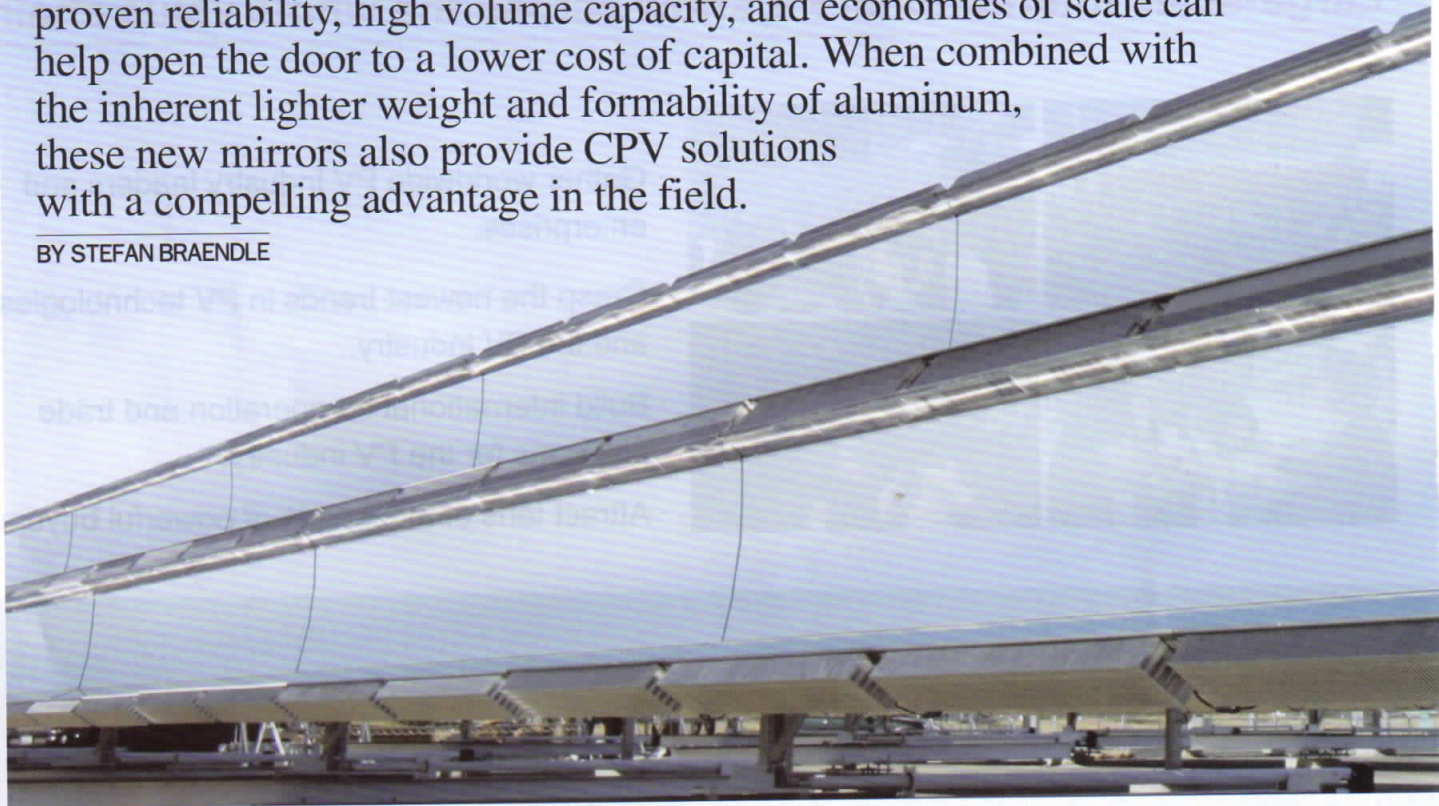
# Metal Mirrors Hold Tremendous Promise for CPV Applications



Stefan Braendle

CPV continues to make strides in technology and efficiency, but remains hampered by a lack of performance data from large projects—leading to a question of reliability and a higher cost of capital for projects. This problem can be solved by new technologies like metal mirrors that contribute to even greater efficiency gains, but whose proven reliability, high volume capacity, and economies of scale can help open the door to a lower cost of capital. When combined with the inherent lighter weight and formability of aluminum, these new mirrors also provide CPV solutions with a compelling advantage in the field.

BY STEFAN BRAENDLE



One of the most compelling arguments in favor of Concentrating Photovoltaic (CPV) technology is its potential to significantly reduce the cost of solar power by decoupling systems from the market fluctuations of silicon and instead leveraging primary and secondary optics to boost the number of suns on a solar cell. On the flip side, many critics use this very same point as its main weakness—that the technology's complex structures and tracking mechanisms add to the total cost of systems and are less reliable over time. As a result, CPV companies are constantly searching out small and large gains in efficiency to help them achieve grid parity while searching for a low cost of capital to fund projects. Through these projects, CPV can obtain performance data over time and quiet critics.

Fortunately, new technologies are rapidly becoming available that can help CPV companies both improve their levels of efficiency but also alleviate some concerns

about the reliability and complexity of the technology. One of these is the advancement of metal reflective surfaces—or metal mirrors—and their ability to replace glass as a legacy optical system for concentrating solar applications.

#### **Inherent Advantages of Aluminum**

For decades, glass has been used as a traditional mirror technology because it was the only option available. It also boasted a high reflectivity and could withstand harsh desert climates. But new metal mirrors have been developed and tested that approach these levels of reflectivity and durability while also delivering a number of new benefits impossible with glass—an unbreakable nature, lighter weight, and formability. These advantages are due to the inherent nature of aluminum, the base material for these highly reflective and durable surfaces.

Taken together, the inherent characteristics and new performance criteria for metal

mirrors are helping CPV companies to improve efficiency, lower overall system and maintenance costs, and ensure supply at scale.

One of the obvious drawbacks of glass is its fragility during transport and handling. In order to ship glass, great care and expense must be taken to ensure that it arrives in one piece at its destination. In many cases, this can even mean purchasing or shipping more glass than needed to account for breakage. Unfortunately, this challenge does not stop with the freight. Installation, windstorms, flying debris, and any number of other hazards can lead to broken mirrors. This can significantly add to material and maintenance costs.

Aluminum is an unbreakable material, effectively eliminating all of the concerns associated with glass. In addition, special coatings make it scratch resistant and allow it to be simply and efficiently cleaned in the field.

Glass is also a very heavy material,



especially when transported in bulk. This adds time and cost to the shipping process, and can also have an impact on the amount of breakage per shipment.

Even more problematic, the weight of glass inhibits many of the new modular, solar systems being developed by innovative CPV companies. These technologies use lightweight space frames that can be placed in urban or space constrained areas such as parking garage rooftops for commercial applications. The weight of glass can place stress on these frames and it can be prohibited from use in some locations because of both weight and security concerns.

Aluminum is an inherently lightweight material that operates at a fraction of the weight of glass. It allows for cheaper and quicker shipping and packing methods, while also pairing perfectly with new, space frames that can be placed on rooftops and other challenging locations.

Finally, Glass is a rigid substance that is difficult to bend or form into certain shapes. Again, this can inhibit shipping and handling processes, making them more difficult, costly and time consuming. In addition, glass cannot be formed into a structural part of certain solar systems. In contrast, aluminum is highly formable and can actually act as part of the solar system to add strength and reduce weight in the overall system.

### Proven Performance and Durability

Despite these advantages, it is only recently that metal mirrors have been proven to meet two of the most important criteria for CPV companies: performance and durability. Take for example the recent tests conducted by The National Renewable Energy Laboratory (NREL) in the United States and the German Aerospace Center on Alanod-Solar's metal-based mirror samples of MIRO-SUN®.

NREL tested these metal-based mirror samples at three separate NREL facilities in Golden, Colorado; Phoenix, Arizona; and Miami, Florida over a period of three years. During that time, the mirrors showed an average drop of less than 1% in specular reflectance measured within a 25-mrad cone angle.

These samples were also exposed to NREL accelerated weather tests using both an Atlas Ci5000 Weather-Ometer and a BlueM damp heat oven. The Weather-Ometer exposes samples to a continuous condition of Xenon-arc light, 60°C, and 60% relative humidity. It accelerates weathering by roughly three to six times, meaning that in this 36-month test, the metal mirrors were exposed to an equivalent of nine to eighteen years of light and humidity. Over that time, the mirror performance declined between less than one and 2.3% in specular reflectance.

The BlueM oven applies an even more intense testing protocol, exposing samples to a continuous condition of 85°C and 85%

## Aluminum-based metals mirrors are well suited for concentrating solar applications because of their proven durability and sustained level of specular reflection.

sured samples show solar weighted direct reflectance values of 0.868-0.883 as measured with the URA within an acceptance angle >25 mrad in the spectrometer. The optical analysis of the beam spread distributions shows furthermore that most of the reflected energy can be captured within a radius determined by a standard deviation of 0.67-1.20 mrad, corresponding to a target radius of 2-4 mrad. This shows that the analyzed materials can be used in concentrating solar power applications."

These tests jointly establish new performance benchmarks for aluminum front-sided mirrors for solar applications. Taken together, these tests and reports show that aluminum-based metals mirrors are well

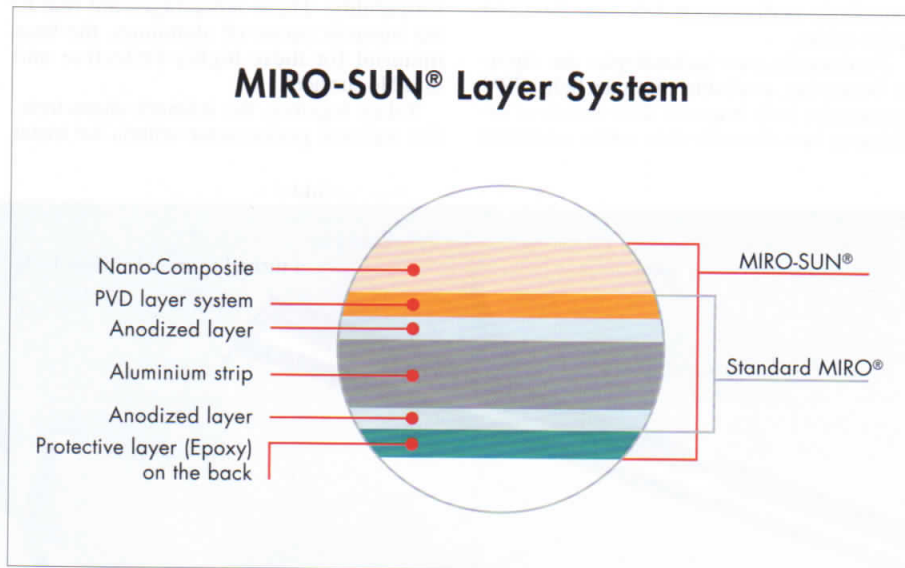


Figure 1. Cut-away of Alanod-Solar metal mirror (Source: Alanod-Solar)

relative humidity without light. Over the accelerated test period, which may simulate as much as 25 years of real world exposure, the samples maintained a very high specular reflectance value.

Overall, the test results demonstrated an outstanding degree of consistency and high-level performance during rigorous real world and accelerated weathering tests. There are no known similar results for any other anodized aluminum front surface mirrors, making these metal mirrors the definition of performance for this category.

German Aerospace Center (DLR) measured Alanod-Solar metal mirrors for spectral specular reflectance using a Perkin-Elmer Lambda 950 spectrometer with a Universal Reflectance Accessory (URA). Absolute measurements were taken in three positions, rotated each time by 45 degrees. The average and standard deviations of the three measurements was used for further evaluation. The results were weighted with the solar spectrum of ASTM G173-03 at air mass AM 1.5 to produce the solar weighted specular reflectance in the range from 250-2500nm.

According to the DLR report, "The mea-

sured samples show solar weighted direct reflectance values of 0.868-0.883 as measured with the URA within an acceptance angle >25 mrad in the spectrometer. The optical analysis of the beam spread distributions shows furthermore that most of the reflected energy can be captured within a radius determined by a standard deviation of 0.67-1.20 mrad, corresponding to a target radius of 2-4 mrad. This shows that the analyzed materials can be used in concentrating solar power applications."

### Manufacturing Facilities and Processes

With all of these advantages over glass, aluminum-based metal mirrors become a very compelling alternative for most CPV companies. One further argument in its favor is its ability to be easily and cheaply produced at high volume. This lends itself to modern mass production methods that can easily scale to meet demand.

As an example, Alanod-Solar's high efficiency metal mirrors are produced through a continuous air-to-air Physical Vapor Deposition (PVD) process that applies the super-reflective layer to coil anodized material. This leverages all of the advantages inherent in aluminum plus adds a highly reflective layer with a solar reflectance of up to 95%. Additionally, the company applies a weather-resistant nano-composite for outdoor protection using a

coil-coating process. Figure 1 shows a cut-away of an Alanod-Solar metal mirror. The company's MIRO-SUN® PV reflective material is the only surface in the solar industry specially designed and matched to the needs of silicon-based CPV (Si-PV) systems.

The primary advantage of this type of process is continuity. By avoiding batch processing, it enables an extremely high production capacity. For example, Alanod-Solar's new small commercial line commissioned at the end of last year is able to produce 30 million square feet (three million square meters) of outdoor mirror material. This is enough to power 300 MW worth of concentrating power plants.

This level of production is important for CPV's need to show success at scale. These technologies demand a supply chain and partner that enable them to achieve production targets reliably and efficiently. Many CPV companies are already turning to metal mirrors to answer their demands for performance and scale.

### Skyline Solar

Skyline Solar is a concentrating photovoltaic company using metal mirrors to help meet cost and performance goals. The company has pioneered a dramatically simplified approach to solar with just two major components that it calls High Gain Solar.

This approach centers on a High Gain solar panel and a reflective rack. Photo 1 shows the large reflective rack system

**Many CPV companies are already turning to metal mirrors to answer their demands for performance and scale.**



Photo 1. Skyline Solar High Gain Solar System

them consists of curved metal mirrors designed and manufactured by Alanod-Solar. These mirrors deliver both structural support and a lighter alternative to glass that can operate at the same performance and durability thresholds.

Skyline Solar has turned to metal mirrors as part of its reflective rack to help produce a higher energy yield at a lower cost than traditional fixed tilt PV. By using aluminum-based mirrors that can be manufactured and formed at high capacity, Skyline Solar has also designed its product to achieve a vast production scale. To facilitate this, the company recently announced a contract with COSMA International in Hermosillo Mexico, a company of the MAGNA group, to begin mass manufacturing of their HGS device.

Skyline Solar has completed a grid-connected demonstration project in San Jose, California that powers a transportation maintenance facility serving over a million residents, and recently announced that its systems provide solar power to the city of Nipton, California.

### WS Energia


WS Energia turned to metal mirror technology as a core component in its quest to design a light, easy to mount, and reliable system that would significantly enhance the annual energy yield of standard, certified modules. The resulting DoubeSun® technology is an easy to build system that has been delivered to 100 different installations and mounted by 40 different companies.

The low-concentration system uses two large Alanod-Solar metal mirrors on either side of a standard monocrystalline module, and relies on a two-axis tracking system to follow the sun and enhance efficiency. See Photo 2 below for view of a row of DoubeSun® modules. WS Energia used metal mirrors because their proven durability and ability to be effectively mass produced helped produce a more reliable overall system that could be delivered at scale.



Photo 2. DoubleSun® low concentration system

The company has also developed a higher concentration system called HSUN. This technology will be used as part of a recently announced partnership with Volkswagen Autoeuropa, the Portuguese branch of the famous German carmaker that will leverage that company's industrial experience and infrastructure to build a 10MW CPV pilot plant.

Increasingly, the data and the successful implementations in the field all demonstrate that metal mirrors offer CPV companies a compelling advantage. Their lightweight nature, inherent formability, unbreakable composition, and scratch-resistant surfaces make for a mirror that is easier to produce, ship, and install in almost any physical environment or setting, while exhibiting proven performance and durability that is on par with the best glass mirror systems. Additionally, the existing manufacturing facilities and process are important for CPV companies that must plan to deploy at scale. Taken together, these factors directly contribute to an overall cheaper, lighter and more easily produced system that also makes a compelling case for a lower cost of project capital. In short, metal mirrors will become an even more critical and credible part of innovative CPV systems and technologies. 

*Stefan Braendle is Director of Solar Applications at Alanod-Solar, the solar surfaces company ([www.alanod-solar.com](http://www.alanod-solar.com)). Braendle has twenty years of solar experience in developing and building renewable energy technologies and businesses. He was a part of the team that designed the first grid-connected and BIPV projects in Switzerland, and he built one of the first solar thermal companies in Central America and the Caribbean. He is also considered a pioneer in the field of laser welding for solar thermal applications. Braendle is a frequent author and sought-after presenter at worldwide solar technical gatherings.*