

# Same sun, more power

KhepriCoat™ - the best-performing  
anti-reflective coating for solar cover glass



# Boost module efficiency

Maximize light transmission by minimizing reflection

**Over recent years, global demand for sustainable energy has grown steadily – and is certain to continue growing. As a result, solar energy systems will play an increasingly central role in the energy economy of the future. And as the technology becomes more efficient, their role will become even more critical. To help boost the price/performance ratio of solar energy systems, DSM is developing new breakthrough technologies – technologies such as KhepriCoat™. Set to contribute significantly to the hunt for grid parity, KhepriCoat™ is the best-performing anti-reflective coating technology for solar cover glass on the market. By transmitting more light, it boosts module efficiency significantly.**

## Minimum reflection, maximum transmission

Wherever glass meets air, about 4% of the light hitting the glass at a perpendicular angle is reflected. And that percentage rises steeply as the light's angle of incidence increases. Obviously, for solar energy systems, reflected light represents a wasted opportunity. KhepriCoat™ minimizes this effect. In fact, it delivers a record-breaking performance in terms of light transmission, beating all other AR coatings on the market today. Plus, it is mechanically robust and highly durable – essential properties for this outdoor application.

## Advantages at a glance:

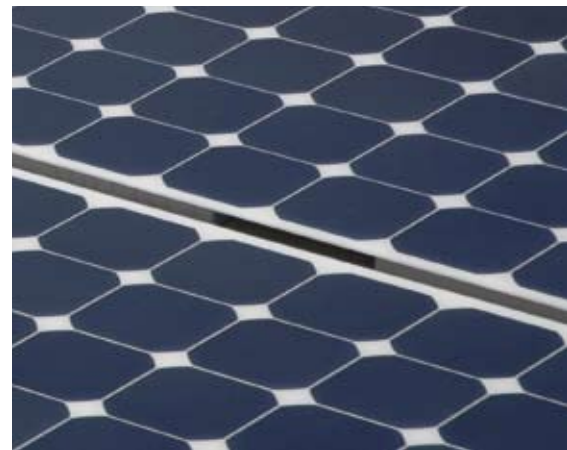
- KhepriCoat™ maximizes light transmission by minimizing reflection.
- KhepriCoat™ can be used on solar cover glass for both photovoltaic modules and solar thermal modules and can be applied on one or both sides of the glass.
- KhepriCoat™ is tough and durable and meets all industry standards
- KhepriCoat™ adds significant value by improving the price/performance ratio.

## Why KhepriCoat™ is different AR coatings are turned inside out

KhepriCoat™ is a completely new technology. To achieve this breakthrough, DSM has turned the structure of traditional nano-porous sol-gel coatings “inside out”, enabling KhepriCoat™ to deliver a unique combination of mechanical and optical properties.

## Traditional coatings

The cost price of solar panels is under constant pressure. As a result, when it comes to AR coatings, manufacturers must use single-layer systems to remain cost-effective. Whilst traditional single-layer AR coatings can be applied in a single-step process, they are limited in the optical benefits they can deliver, due to the way they are structured.



# Why KhepriCoat™ is different

## AR coatings are turned inside out

Traditional single-layer AR coatings consist of solid silica nano-particles “glued” together with a binder so that the spaces between the particles act as nano-pores (see figure 1). Use too much binder, and this reduces the nano-porosity – and thus the AR performance – of the coating. Use too little binder, and this leads to poor mechanical strength and low durability.

What’s more, the structure’s open surface (see figure 1) makes the silica layer of the coating vulnerable to hydrolysis when exposed to extreme weather conditions. And this causes a sharp deterioration of both the optical and mechanical properties.

**KhepriCoat™ avoids this trade-off between optical and mechanical properties by turning the structure of the coating inside out. Instead of being formed in the spaces between solid nano-particles, the nano-pores in KhepriCoat™ are actually inside hollow particles.**

DSM uses core-shell particles that consist of a polymer core and a silica shell. In the coating stage, a 100-150 nanometer layer of these particles is deposited on the surface of the glass. Next, the spaces between the core-shell particles are completely filled with a solid silica binder. At the thermal-hardening stage, the polymer cores of the particles are removed, leaving a silica layer with a high proportion of binder and high internal nano-porosity (figure 2).

This nano-pore/binder ratio ensures KhepriCoat™ delivers both outstanding optical and mechanical properties. And because it has a very smooth, “closed” surface (see figure 3), the risk of hydrolysis is sharply reduced, enabling KhepriCoat™ to withstand extreme weather conditions and making it ideal for solar-cell cover glass. In addition, the coating’s properties can be tailored to suit a variety of different module types.

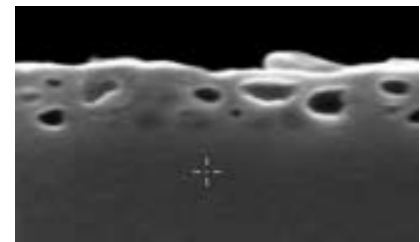


Figure 3: SEM picture of KhepriCoat™ showing the smooth silica surface and high proportion of nano-pores.

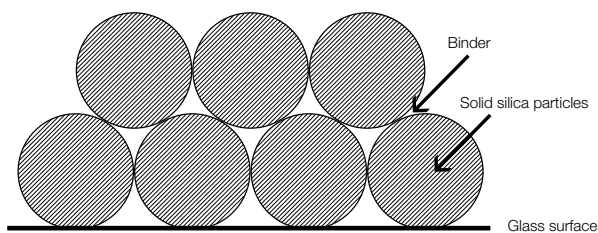


Figure 1: The structure of a traditional sol-gel nano-porous AR coating

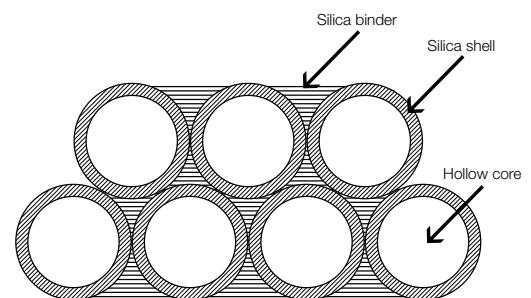


Figure 2: The structure of a single layer of KhepriCoat™

# Breaking records in light transmission

Make huge gains when the sun is high...

**Solar cover glass that is coated on both sides with KhepriCoat™ will transmit up to 7% more of the light hitting it at a perpendicular angle of incidence (see figure 4).**

**...and even larger gains when the sun is low**

And when the light's angle of incidence is not perpendicular, the improvement in transmission can be as high as 10% (see figure 5).

## Performance per system

The increase in light transmission leads to a comparable rise in the energy yield of the solar module. In practice, the actual improvement in energy yield depends on several parameters: for example, on the type of cover glass, on the type of solar cell and on the local cycle of the sun. The typical daily improvement in module efficiency will be in the range of:

- 3-4% for PV modules,
- 6-8% for solar thermal modules.

Test	Description	$\Delta T$ [%]
Transmission at normal angle	Increase in transmission per side compared to uncoated glass	+ 2.85 (TL)* + 2.35 (TE)*
Abrasion resistance (EN 1096-2)	Felt rubbing	- 0.33
Immersion test	Immersion in 85°C water for 100 hours	+ 0.22
Immersion test saline	Immersion in 35°C salt solution (50 g NaCl per liter) for 100 hours	+ 0.05
Immersion test acid	Immersion in 35°C acid solution (0.1 M H <sub>2</sub> SO <sub>4</sub> ) for 100 hours	+ 0.05
Vapour test	Exposure to water vapour	- 0.21
Damp-heat test (IEC 61215)	Exposure to 85°C, 85% humidity for 1000 hours	- 0.53
Thermal cycling test (IEC 61215)	200 cycles from -40°C to 85°C	- 0.12
Humidity-freeze test (IEC 61215)	10 cycles from 85°C, 85% humidity to -40°C	- 0.50

Figure 6: Results of the extensive testing of solar cover glass coated with KhepriCoat™.

\* TL = 400-800 nm, TE = 400-1100 nm



Figure 4: Comparing the transmission spectrum of double-sided KhepriCoat™-coated and uncoated 4mm low-iron float glass.

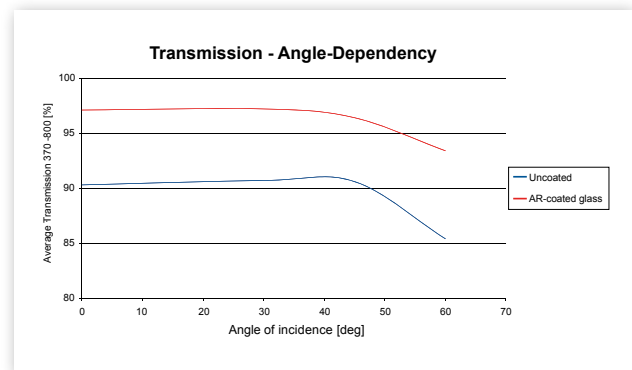


Figure 5: Comparing the angle-dependent transmission of double-sided KhepriCoat™-coated and uncoated 4mm low-iron float glass.

# Using KhepriCoat™ in-house

And add proven value to your products

By altering the coating thickness, the optical performance of the coating can be optimized to suit different cell types.

## The best light transmission

The strongest proof that KhepriCoat™ is the best AR coating available today is that it was used by independent research institute ECN to help set a new world record for conversion efficiency in multi-crystalline solar panels. The ECN module achieved a massive 17.0%! DSM can enable you to break your own record, by helping you to optimize your KhepriCoat™ coatings to match the absorption spectrums of the specific cells you use.

## Demonstrable durability

The durability of solar cover glass coated with KhepriCoat™ has been evaluated extensively. For example, it has been subjected to damp-heat tests, humidity-freeze tests, thermal cycling tests (all according to IEC 61215) and to abrasion-resistance tests. As figure 6 shows, KhepriCoat™ surpassed all test criteria, with only minor changes in transmission being observable following these tests.

In addition, KhepriCoat™ has been tested comprehensively in-situ on life-sized modules. It passed all relevant tests conclusively and modules coated with KhepriCoat™ have received TÜV certification.

**DSM has developed state-of-the-art technologies for applying KhepriCoat™. And it is ready to supply the coating formulation and license the technology.**

## An investment that pays

DSM licenses its KhepriCoat™ technologies to glass producers and solar cover glass processors. DSM produces the coating formulation in-house and supplies it directly to its licensees. With this license, you can produce and sell KhepriCoat™-coated high-performance AR solar cover glass. The coating technology requires a much lower capital investment compared with sputtering lines. And most importantly, this investment will provide you with optimized returns, as the proven added value of glass coated with KhepriCoat™ fully justifies a premium price.



## Double-sided KhepriCoat™

A two-sided coating of KhepriCoat™ can be applied using standard dip-coating equipment (see figure 7). Typically, dip-coating speeds are in the range of 0.3-0.5 meter per minute. By coating multiple glass sheets with KhepriCoat™ simultaneously, you can achieve significantly higher effective coating speeds.



Figure 7: DSM's dip-coat unit is capable of dipping four glass sheets simultaneously

## Additional advantages:

- **There's no need to cure**  
If your solar cover glass is heat tempered after coating, there is no need for a separate curing step. As a result, you do not need to invest in special ovens, and there is no additional variable cost. What's more, without the need to handle chemicals for curing, the KhepriCoat™ technology is very safe and environmentally friendly.
- **You gain leading engineering support**  
If you are not yet coating glass in-house, DSM can supply you with a complete engineering package and the technical support you need to construct and get started with coating facilities. Get in touch, and we will help you prepare for the future.

# Choose KhepriCoat™

To make your products truly stand out

## Single-sided KhepriCoat™

One-sided coatings of KhepriCoat™ can be applied using various coating technologies, such as slot die coating, spray coating and roll coating. DSM has adapted existing slot-die-coating technology for the high-speed deposition of optical coatings on rigid substrates. This new system can even carry out inline coating at speeds as high as 20m per minute. With this technology, DSM has achieved a coating thickness of 100–150nm with a thickness tolerance of just  $\pm 2$ nm. Patents are pending for this process, and a pilot line is available at DSM (see figure 8).

## KhepriCoat™ key characteristics:

- Offers excellent optical properties in a single-layer coating
- Increases the output of PV modules by up to 4%
- Highly robust, withstands extreme weather conditions and is easy to clean
- Meets the durability criteria as specified in IEC61215 and is TÜV certified
- Can be tailored to suit a variety of different cells and types of solar cover glass
- Offers you a quick return on investment
- Is supported by a high level of design and engineering services
- Helps you to maintain or improve your position in a fast growing market by providing a differentiated product offering

**As pressure from governments and from public opinion is expected to grow in the future, project developers will increasingly ask for ever more efficient solar modules in their hunt for grid-parity. In order to help you answer this demand, KhepriCoat™ can enable you to further differentiate your business, and tailor your products to suit the rapidly growing solar cover glass market.**

## DSM – the Life Sciences and Materials Sciences Company

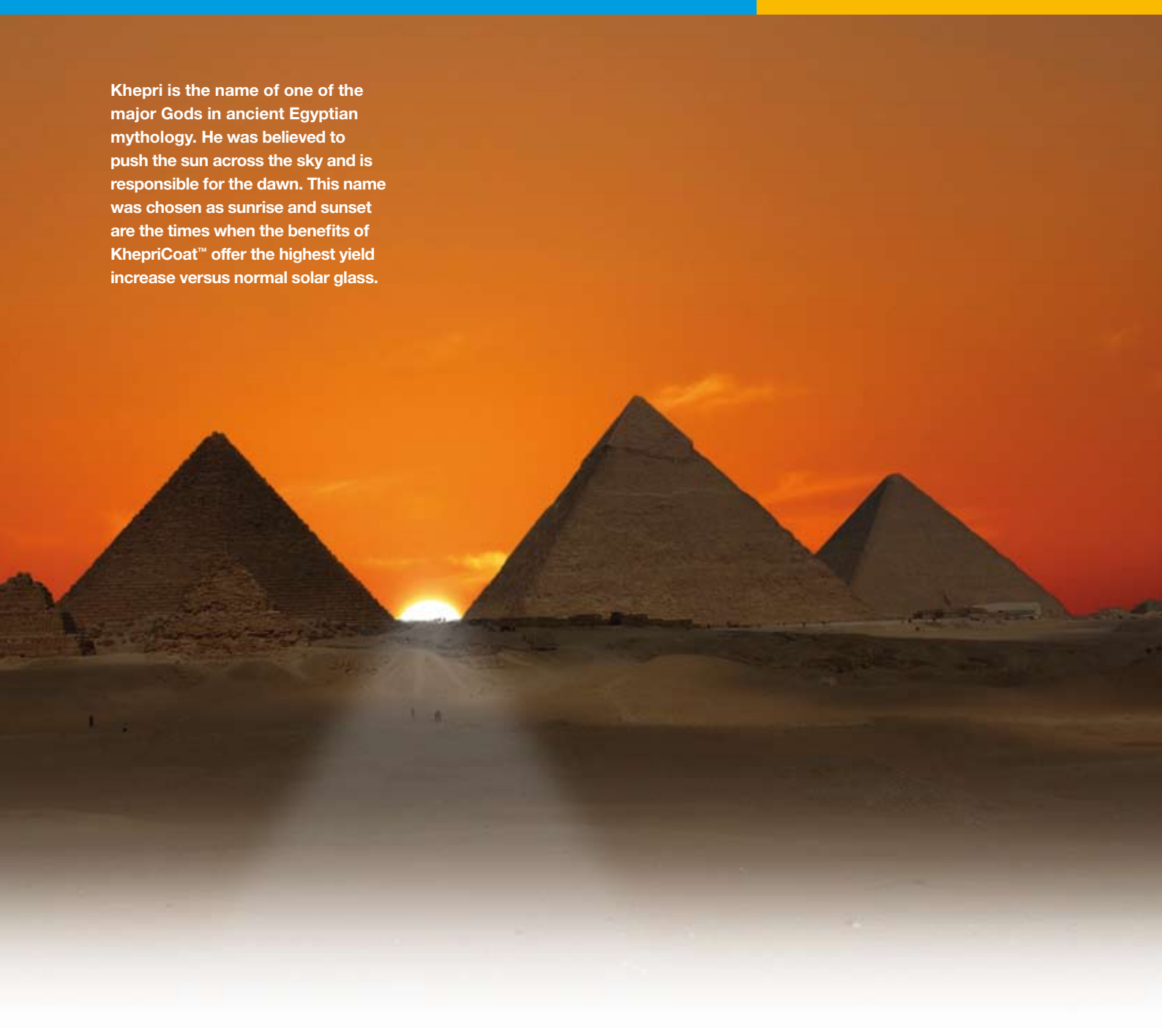
Royal DSM N.V. creates solutions that nourish, protect and improve performance. Its end markets include human and animal nutrition and health, personal care, pharmaceuticals, automotive, coatings and paint, electrical and electronics, life protection and housing. DSM manages its business with a focus on the triple bottom line of economic performance, environmental quality and social responsibility, which it pursues simultaneously and in parallel. DSM has annual net sales of about €8 billion and employs some 22,700 people worldwide. The company is headquartered in the Netherlands, with locations on five continents. DSM is listed on Euronext Amsterdam. More information: [www.dsm.com](http://www.dsm.com).



Figure 8: Pilot slot die coating line at DSM



Khepri is the name of one of the major Gods in ancient Egyptian mythology. He was believed to push the sun across the sky and is responsible for the dawn. This name was chosen as sunrise and sunset are the times when the benefits of KhepriCoat™ offer the highest yield increase versus normal solar glass.





**For more information:**

If you'd like to know more about AR coated glass and how it can help your business contact us today.

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