Colored solar-roof in the Netherlands

Aesthetics and efficiency combined

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Renewable energy is on the rise globally, with solar and wind becoming the cheapest way of generating energy in more and more countries, according to IEA. It is also important for many countries as a key strategy for CO_2 reduction and energy independence. However, an important question remains: where to install all the renewable energy sources which need significantly more space than fossil-based energy production? Is centralized or distributed best?

The advantage of centralized energy production by renewables is in the very low cost of big utility solar power plants compared to distributed installations. However, this advantage slowly weakens with the rising cost of distributing the centralized energy.

In addition, solar power plants are competing with the use of farmland, which directly leads to other strategic problems of the future use of land.

Distributed solar energy, for example on private or commercial buildings, has the clear advantage that energy is produced where it is also used.

A study from Fraunhofer ISE and the KIT shows the potential in Germany to be over 1000 GW of possible installations on buildings. This is important as buildings in Europe consume around 40% of the total primary energy and thus produce around 36% of Europe's greenhouse gases, according to the European commission, Energy use in buildings.

Generally, installing photovoltaics on suitable facades and roofs could therefore have a major share in achieving our goals to climate neutral economy. But do we want to live in cities with all dark facades and roofs in the future? Or a landscape with visible black areas everywhere?

Typically, the acceptance of solar in highly visible areas is rather low, which leads to a low usage of solar modules in the following three areas. Modern architecture is full of flexibility of design and colors. The use of black or dark blue solar modules leads to a low acceptance by many architects and building developers, simply because dark colors are not common in European architecture.

The usage of photovoltaics in historically preserved areas is also problematic. The spirit of old cities with a long history, like Paris, Barcelona, Milano, Lisbon, partly lies in their historic buildings and their unique appearance. If we now change this appearance significantly, their inhabitants would feel like they have lost a huge part of their culture.

A third area photovoltaics face low acceptance is in the use of daily things. This starts from solar chargers over self-powered lights and also cars. Vehicle integrated photovoltaics are becoming a hot topic, but as private cars are also a status object, optical appearance plays a key role in the purchasing decision. If the design is not taken into consideration, vehicle integrated photovoltaics can limit the acceptance of this new technology, if it brings too many changes to the optical appearance we are used to.

However, the development of smart technologies offering broad design options can help to increase the acceptance of solar technologies. A common way to increase the acceptance of solar modules is to harmonize them with the design of a building. The modules can become invisible, or they can stand out, it's up to the city planners, architects and designers to decide.

Several technologies have been developed to achieve less optical impact of solar modules. One example is dielectric stacks deposited via chemical or physical vapor deposition on glass or an additional interlayer. This can selectively reflect one part of the visible spectrum and give a bright color impression of solar modules. This usually leads to a remaining efficiency of 90% of the solar modules, but comes at a high cost of the technology.

In addition, the color typically shows a high dependency on the viewing angle. Another example is printing the module glass with absorbing pigments embedded in a binder system. This technology has the advantage of creating a huge possibility of different colors and designs, but the colors are not bright, and the module efficiency is usually greater than 80% compared to an uncolored module.

With ColorQuant™ the advantages of both systems are combined, to create high quality colors for the modern use of solar modules.

The technology is based on the principle of coloring by interference, whereby the rays of sunlight are split like in a prism. The colored layer lets through only the light that the solar cell needs to generate energy, meaning that only the wavelengths that produce the color are reflected. The result is a beautiful color effect, with minimal loss of solar module performance.

Together with our partners we validated two different routes. One way is the implementation via a ceramic glass color printed on the module glass before the hardening process. This enables a high

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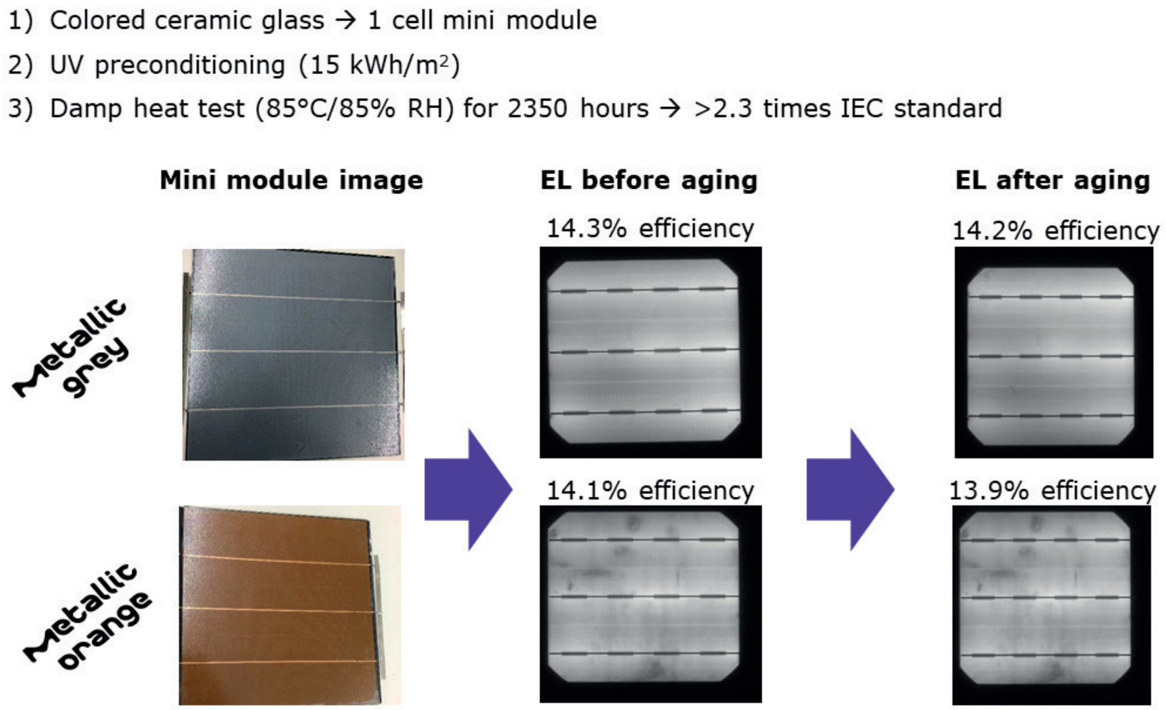
‘With over 30 years’ experience in the automotive paint industry, Merck uses its long-lasting history to develop ColorQuant™ technology as a solution to comply with the requirements of solar application and industry.’



Accelerated aging of colored solar modules

flexibility in colors and module forms, even at low project size and is perfectly suited for high end architecture and customized building integrated photovoltaics.

The glass color can be applied via screen printing or roller coating, which is a standard technology used in the European glass industry.

A second way is the implementation via a colored encapsulant. The encapsulants used are the same as the standard encapsulants used in standard photovoltaic modules, EVA for glass/backsheet modules and polyolefine for glass/glass modules. This leads to a very competitive cost structure of colored solar modules.

Due to a certain batch size for every color in production, the flexibility of colors and shapes is more limited compared to the ceramic print, making it the ideal choice for more standardized colors and modules.

In contrast to the broadly known CMYK concept used in the printing industry today, ColorQuant™ is based on RGB coloring like in modern TVs or the human eye. By a variation of the ratio of different tones the color can broadly be varied in a very wide color range, so the efficiency of solar modules typically remains above 90% compared to an uncolored module.

For more designs we can further adopt the color and even achieve bright grey colors mimicking brushed steel or aluminum, terracotta or red tiles and even golden surfaces with a remaining module efficiency above 80%. As we reflect light over a wide viewing angle the color impression stays nearly neutral, independent of the incoming light angle and the viewer’s position.

Stability and reproducibility of colors is also a key competency. With over 30 years’ experience in the automotive paint industry, Merck uses its long-lasting history to develop ColorQuant™ technology as a solution to comply with the requirements of solar application and industry.

With close quality control and dedicated processes for pigments used in the solar industry we and our partners ensure that we can reproduce the color of broken modules in facades and also ensure a good performance of colored solar modules over their long lifetime without fading colors.

Picture 2 shows the performance and electroluminescence of a light grey and terracotta colored solar minimodule after UV preconditioning and damp-heat testing for over 2000 hours without any major impact on efficiency or color.

ColorQuant™ technology offers beautiful color effects with minimal loss of solar module performance. It is validated for long-lasting use in solar applications and can be integrated in solar module technology in a cost-effective manner.

https://colorquant.ceramic-colors.de/en/

References

1K. Fath, Technical and economic potential for photovoltaic systems on buildings