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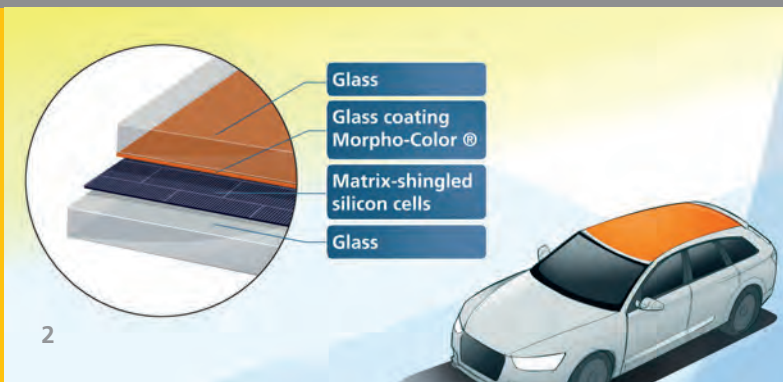
FRAUNHOFER INSTITUTE FOR SOLAR ENERGY SYSTEMS ISE



1 *Highly efficient, yet invisible solar cells in a car roof of Carlex show a high performance.*
2 *Layer structure of a colored PV car roof with matrix-shingled solar cells.*

PV FOR MOBILITY: SOLAR CELLS ACTIVATE THE CAR ROOF

According to current estimates, more than 70% of all newly registered vehicles in Germany will be electrically powered from year 2028, part of them as hybrid vehicles. Integrated solar cells can noticeably increase the range of electric vehicles.

At our Module Technology Evaluation Center Module-TEC a prototype of an innovative car roof has now been developed. The highly efficient solar cells are integrated into the shell of the vehicle. The technology applied in order to laminate solar cells into curved shapes with colored surfaces is a completely new approach.

For the integration of photovoltaics, module technology must meet special requirements:

- high efficiency to optimally use the limited available area,
- robust interconnection to reduce power losses due to partial shading
- high reliability to withstand the mechanical and thermal stresses
- invisible integration in the vehicle skin.

Powerful Solar Cells

We have developed special cell formats with largely invisible fine-line metallization and low-loss separation processes for integration. The applied cell technology based on PERC achieves efficiencies of more than 22 % in mass production at costs below € 30 per m^2. Our current developments in the field of tandem solar cells even promise cell efficiencies close to 30 %.

Efficient Interconnection

In order to achieve high efficiency on the available surface, the solar cells must be integrated as compact as possible into the vehicle shell. The cells in the car roof were therefore interconnected with the innovative matrix shingling technology. The offsetted cell strings are electrically connected by overlapping. This leaves no inactive area between the cells. Due to this topology, the power losses for inhomogeneous irradiance can be greatly reduced. The cell interconnection via electrically conductive adhesive is lead-free.

Fraunhofer Institute for Solar Energy Systems ISE
Heidenhofstr. 2
79110 Freiburg, Germany
Phone +49 761 4588-0

Photovoltaic Modules and Power Plants – Module Technology
Dr. Martin Heinrich
Phone +49 761 4588-5024
pvmod.mobility@ise.fraunhofer.de

www.ise.fraunhofer.de

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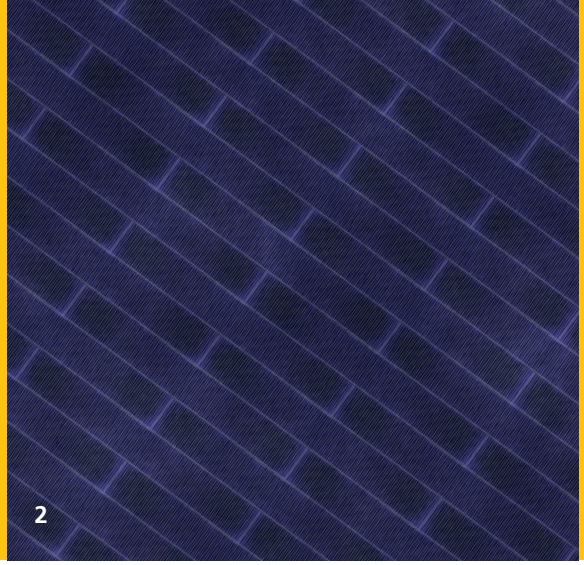

Curved Shapes
The solar cells were integrated into a standard panoramic glass roof. Lamination took place between two layers of glass with encapsulating material. The special challenge is the encapsulation in the curved glass. At Fraunhofer ISE, a process was developed to encapsulate the cells in a long-lasting manner. With a custom made form the lamination process can be conducted even with commercially available laminators.

High Aesthetics with Morpho-Color®
Car buyers have high demands with regard to design. Thus, solar cells have to be integrated completely and invisibly into the vehicle shell. At Fraunhofer ISE, we have developed an optical structure that covers the underlying solar cells. The color layer Morpho-Color® can be produced in any color with high color saturation. The coloring and intensity is maintained regardless of the viewing angle. Compared to uncoated glass, the transmission loss due to Morpho-Color® is on average only 7% relative.

Long-lasting Photovoltaics on-Board
PV modules in vehicles should have a lifetime of at least the service life of the vehicle, despite strong vibrations and shocks. The PV-car roof must meet all the requirements of a common PV module. In addition, the module is exposed to higher mechanical and thermal loads on the road and must be tested accordingly. In the test laboratories at Fraunhofer ISE, test procedures are available to meet the high loads and safety-relevant requirements in road traffic.

Promising Yield Potential
We are currently examining and measuring solar radiation on German roads in a citizen science campaign, in order to determine the realistic irradiation potential of cars even more precisely. The campaign is led by the Fraunhofer ISE and includes the irradiation measurement on about 100 vehicles over the next three years. The driving profiles, together with satellite data, are incorporated into new simulation models for solar irradiation on traffic routes. Based on these models, a car driver will be able to know how far he can drive powered by solar energy, depending on daytime and route.

As part of a research project, Fraunhofer ISE had already equipped several trucks with irradiation sensors in order to record the real solar yield potential in the commercial vehicle sector. This resulted in an average electrical output of 150 kWh/m² within one year. A truck (40 t) with about 30 m² of photovoltaic roof surface of the trailer could therefore cover 5000 to 7000 km per year with its own PV power.

Extended Range with Integrated PV
The power density of the photovoltaic car roof can reach approx. 210 W/m² and deliver sustainable electricity for up to 10 km daily. The estimate is based on solar radiation on a sunny summer day on open land in southern Germany and a vehicle consumption of 17 kWh per 100 km.

1 *Morpho-Color® allows a very wide color spectrum for PV car roofs.*
2 *Shingled solar cells in matrix structure achieve a very high efficiency.*

R&D and Services

- PV technology consulting
- development of assembly and connection technology for integrated photovoltaics
- production of module prototypes for vehicle integration
- analysis of the solar yield potential for different profiles, regions or routes
- module testing and service life analysis
- development of energy and load management as well as power electronics and battery systems
- cost analysis
- coordination and management of R&D projects with industrial partners