Products such as solar cells, flat screens and optoelectronic components require thin-film systems covering large surface areas with optical transparency and metallic conductivity. *Bild: Fraunhofer IST*

Smart coatings

Scratch-resistant plastic lenses, anti-glare displays, water-repellant fabrics – thin-film coatings make them all possible. But modern surface technology can do much more than just enhance materials. It can create new products such as CDs and flat screens and still has plenty of potential to offer. In future, thin coatings will make it possible to produce 'smart tools' and light-emitting plastic films.

Dünnschichttechnik hat längst den Weg in unseren Alltag gefunden, macht sie doch Entspiegelungen, CDs und Flachbildschirme erst möglich. Doch dünne Schichten können mehr: Schneidwerkzeug intelligent machen oder Folien zum Leuchten bringen.

Thin coatings are already part of our everyday life. They *suppress* glare, protect tools and components from *wear* and *friction*, enhance the appearance of buildings, make plastic as hard as steel and prevent food from sticking to the *frying pan*. Thermal-insulation coatings on *window glazing* help to save energy, and *impermeable* films on food packaging preserve freshness by keeping out oxygen and light. Surface engineering not only enhances many materials but also creates the basis for new products: compact discs, DVDs, flat screens, hard disks and high-speed processor chips have one thing in common: Without high-performance thin-film and surface technology, these technical *marvels* wouldn't exist. It is the CDs reflection coating which produces the sound, and without a thin magnetic coating measuring just 50 nanometers hard disks would be able to store no more than 10 megabytes of data.

To allow new developments in thin-film coating and surface technology to make the *leap* from research laboratory to industrial application, however, processes are required which make it possible to apply thin-film coatings cost-efficiently to large surface areas. And surface technology still has plenty of *untapped* potential to offer. New applications for thin-film coatings regularly *emerge*, such as the force-sensor coatings which provide a warning of wear and can thus add a 'smart' dimension to tools, components and machines.

We have all at some time *inadvertently* touched something straight from the oven, such as a hot *baking tray*, or got too close to the flame of a candle, and experienced the same reflex action: In a fraction of a second our hand pulls back in order to avoid a serious burn. "Machines and tools unfortunately do not have such reflexes. If extremely high temperatures *arise* during operation, the machine does not react but continues running," explains Holger Lüthje from the Fraunhofer Institute for Surface Engineering and Thin Films IST. This can result in serious damage to the machine. As a *precaution*, tools are therefore usually *replaced* before they really need to be – causing *downtime* and additional costs. To avoid having to replace tools until they are worn, research workers at the IST have developed smart coatings. Some of the intelligent systems consist of *tribologically* optimized *carbon* films (DLC, diamond-like carbon) with an integrated sensor function. The new, multifunctional surfaces *are referred* to as 'smart coatings'. They provide a warning when a tool needs to be replaced because of wear or indicate when a screw is no longer tight.

Thin films make components 'smart'

Lüthje explains the functioning of the *piezo-resistive* coating: "The hard film contains tiny nanoparticles and has been modified in such a way that it is not only resistant to wear and friction but also acts as a force sensor." If a force *impacts* on the hard film, the electrical resistance changes. "This makes it possible to check machine components by means of simple electrical resistance measurements," adds the head of the microengineering and sensor technology group at the IST. And, what's more, the process is cheap. While *conventional pressure sensors* can cost up to 1,000 Euros, it only costs 30 to 40 cents to coat components with force-sensor films. This means that the smart coatings are also attractive for mass products. They can increase the operating reliability of machinery, vehicles and tools.

The smart coatings have a wide *range* of applications. One example: The 'intelligent' *washer*. In order to ensure correct fitting and continuous monitoring of *safety-relevant bolt* connections in future it will only be necessary to apply a force-sensor film of hard material to the washer. "At present many bolts are *tightened* using a *torque wrench*. But this only measures the *frictional force*," explains Lüthje. The 'intelligent' washer offers a different *approach*. Here the electrical resistance only changes if a force is applied to the washer – that is, the bolt is tightened. But the smart coatings do more than make the *initial* bolt connections safer. They also permit continuous active monitoring of the bolt connection. Also with the aid of smart coatings, the instantaneous loading of sliding and *roller bearings* can be measured and the grip force of automatic assembly equipment can be continuously monitored and adjusted.

Modern surface engineering can even *endow* plastic film with light-emitting *properties*. The Bavarian company Cool-Light produces highly flexible films just one millimeter thick which emit monochromatic cold light ▶

approach	*Methode, Ansatz*
arise, to	*auftreten*
baking tray	*Backblech*
be referred, to	*werden genannt*
bolt	*Schraube*
carbon	*Kohlenstoff*
coating	*Beschichtung*
conductivity	*Leitfähigkeit*
conventional	*herkömmlich*
downtime	*Ausfallzeit*
emerge, to	*auftauchen*
emit, to	*ausstrahlen, abgeben*
endow, to	*ausstatten*
enhance, to	*verbessern*
friction	*Reibung*
frictional force	*Reibungskraft*
frying pan	*Bratpfanne*
glare	*grelles Licht*
impact, to	*einwirken*
impermeable	*undurchlässig, undurchdringlich*
inadvertently	*aus Versehen*
initial	*anfänglich*
leap	*Sprung*
marvel	*Wunder*
piezo-resistive	*piezoresistiv*
precaution	*Vorkehrung, Schutzmaßnahme*
pressure sensor	*Drucksensor*
property	*Eigenschaft*
range	*Spektrum*
repellant	*abstoßend*
replace, to	*ersetzen*
roller bearing	*Rollenlager*
safety-relevant	*sicherheitsrelevant*
scratch	*Kratzer*
suppress, to	*unterdrücken*
tighten, to	*anziehen*
torque wrench	*Drehmomentschlüssel*
tribologically	*tribologisch*
untapped	*ungenutzt*
washer	*Unterlegscheibe*
wear	*Verschleiß*
window glazing	*Verglasung, Fensterglas*

when a voltage is *applied*. The light is pleasant on the eyes and is more clearly visible than any other light source, even in dusty, smoky or foggy conditions.

The outlook is bright: Light-emitting plastic film

The just one millimeter thick rollable film has a sandwich structure *comprising* several *layers*. On the substrate film of highly transparent polyester, a likewise transparent, electrically *conductive* layer is applied. Then in the middle follows a thin, active light-emitting layer which is separated from the electrode coating by an *insulating* layer.

"The key part of the film is the front electrode. The layer of silver which has a thickness of just two nanometers conducts electricity but still lets through up to 80 percent of the light," states Matthias Fahland from the Fraunhofer Institute for Electron Beam and Plasma Technology FEP in Dresden, emphasizing the high transparency of the coating.

For *comparison*: the non-coated film lets through 88 percent of the light. The light-emitting plastic film is *supplied* in the standard pigment colors white, green, orange or blue, and by means of transmitted light virtually any color can be achieved. And the film is cool too because it converts almost all the energy (about 98%) into light and only a *minute* proportion into heat. It therefore needs only a *fraction* of the energy consumed by a fluorescent light tube. A further advantage is that the brightness of the light is infinitely adjustable.

Light-emitting plastic film opens up *amazing* opportunities for advertising, signs and lighting. Different parts of the film can be activated in alternating sequences. The new lighting technology *paves the way* for a broad range of applications – wall coverings that light up, ceilings that can glow in different colors, and animated advertising billboards. The light-emitting plastic film can also be used in safety applications, for example to indicate *reliable* escape routes.

Transparent and conductive coatings

Transparent, conductive coatings have a wide range of applications. Solar cells, flat screens, optoelectronic components and thermally insulating architectural glass require systems capable of producing large sheets of coated material possessing optical transparency and metallic conductivity. "Especially for front contacts in solar cells and for flat screens the production of large *sheets* of transparent conductor material is rapidly gaining in importance," explains Dr. Bernd Szyzska from the IST. Another application is the development of a transparent car window heating system. Thanks to modern coating technology, iced-up car windows could soon be a thing of the past.

Transparent conductors, smart coatings and antireflex solar panels are just a few examples of what thin-film coatings have to offer. Over recent *decades*, surface engineering has *evolved* as a key cross-sectional technology. It's now employed in almost all branches of industry, because the great majority of industrial products have surfaces which *incorporate* functional features. In the years to come, thin-film coatings will continue to drive forward advances in technology and change our world. ■

Transparent heating system for car windows.
Bild: Fraunhofer IST

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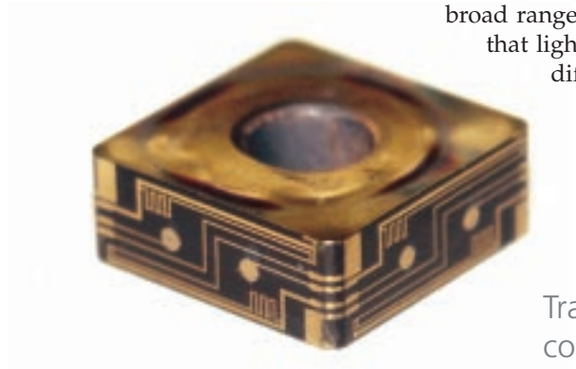

Indexable insert with integrated microsensor.
Bild: Fraunhofer IST

amazing	*toll, unglaublich*
apply, to	*anwenden*
comparison	*Vergleich*
comprising	*bestehend*
conductive	*leitfähig*
decade	*Jahrzehnt*
evolve, to	*entwickeln*
fraction	*Bruchteil*
incorporate, to	*beinhalten*
indexable insert	*Wendeschneidplatte*
insulating	*isolierend*
layer	*Schicht*
minute	*winzig*
pave the way, to	*den Weg ebnen*
reliable	*zuverlässig*
sheet	*Fläche*