The flying pixels

Ten years of research on polymer "explosives" have led to brightly glowing results and an intermediate victory on the way to colour screens via laser processes.

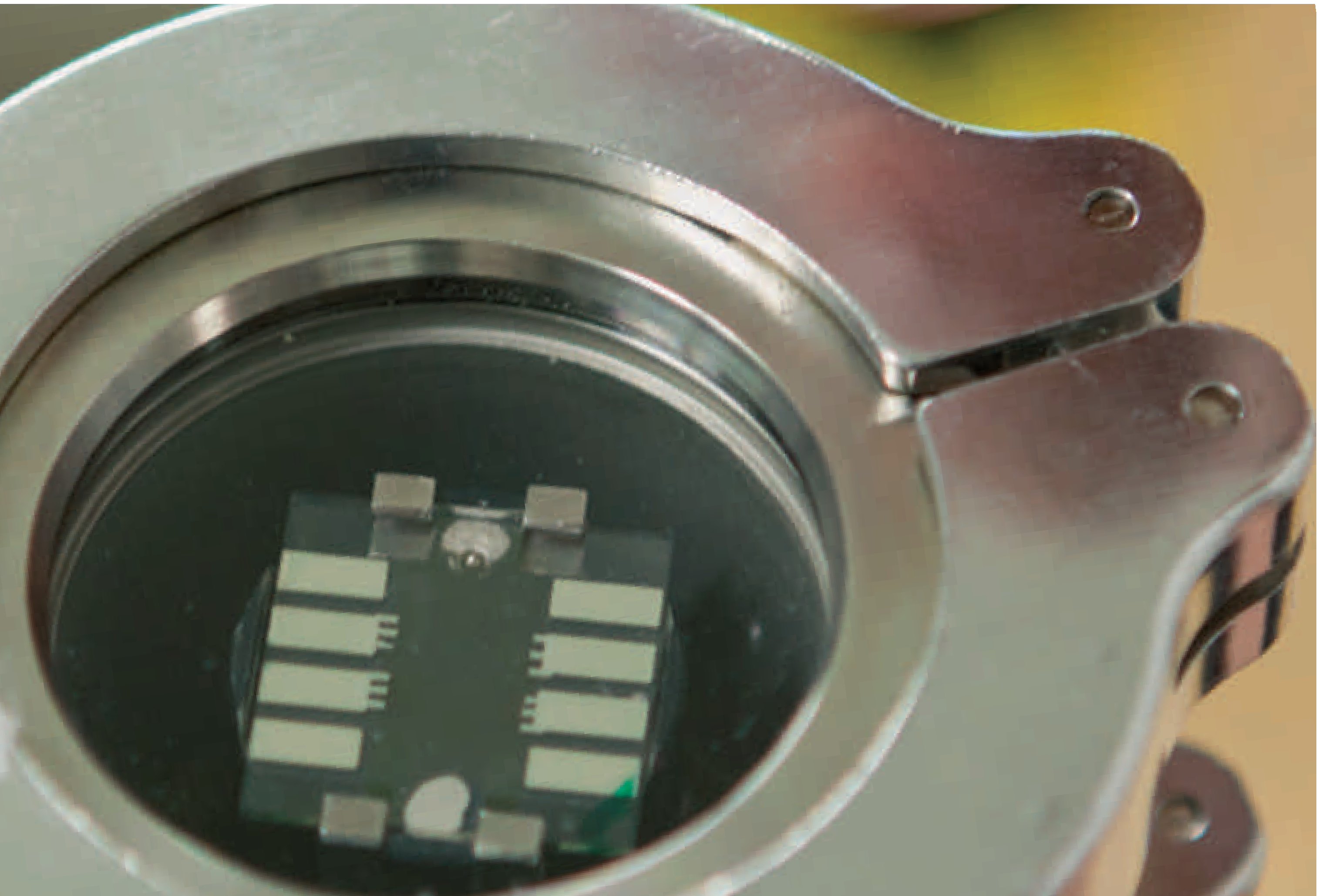
TEXT: Rainer Klose / PHOTOS: Empa

PhD student James Shaw-Stewart (left) and project manager Matthias Nagel examine the completed chip. On the plate, which is enclosed in a protective atmosphere, pixels should start glowing in three colours. If they do, the experiment was a success.

In a chemistry lab at Empa, two men in white lab coats lean over a tightly bolted metal cylinder with a viewing glass in its lid. "Looks useful", observes one of them. "Let's see if it worked", mumbles the other one somewhat sceptically. Shortly thereafter, the metal cylinder including its contents is mounted onto a support. The younger of the two, PhD student James Shaw-Stewart, examines the results through a spectrometer, and a smile comes across his face. Project leader Matthias Nagel is equally thrilled, gleaming with pride about what they have achieved.

The triazene polymer – an explosive plastic

What made the Empa researchers so pleased were three small spots inside the cylinder which are glowing red, green and blue. These are not conventional light-emitting diodes (LEDs) but rather the first samples of a luminous plastic, a light-emitting polymer (LEP). The special thing is the three coloured pixels were "shot" onto a carrier chip using a special method being developed at Empa in collaboration with the Paul Scherrer Institute (PSI). An explosive plastic – a triazene polymer – makes it possible. The polymer is exposed to a laser pulse, then decays within a fraction of a second and in the process generates a large amount of nitrogen. In this way, everything sitting on top of it is locally "blown away" and is propelled towards a target with high speed. And, if everything is set up properly, the layers atop remain undamaged and continue to function.



This type of “propellant” made of triazene polymers, along with all the other ballistic parameters (such as the optimum distance to the target, amount of propellant, strength of the laser pulse and air pressure in the environment), are being painstakingly investigated and optimised at Empa and at PSI. Only when everything works together perfectly do the luminous pixels arrive at the desired location undamaged. This technology is known by the acronym LIFT, which stands for laser-induced forward transfer.

But what’s the use of teaching luminous colour pixels how to fly? Well, for example, to construct a colour display with the three primary colours red, green and blue. The individual screen pixels can be applied to a surface in an elegant way using the Empa-PSI method based on a laser process, and do so with pinpoint accuracy, without any solvents and at low cost. “At this point we’ve demonstrated that the system works”, notes Nagel. “Now industry has to take over, further develop the process and bring it to the market.”

What Nagel is describing is the preliminary conclusion of a research project, which started about ten years ago and which at the same time represents a typical case of the basic research with industrial applications being conducted at Empa. Shortly after the turn of the millennium, Nagel ran across the triazene polymer, which had already been developed in the 1990s and since then has been used primarily in lithography: a laser is shot on the triazene layer, the exposed spots are exploded away locally resulting in a highly precise relief, similar to a printing plate.

Buffers and titrates for a crystal-clear, extremely thin film

The project partners Empa and PSI wanted to go a step further. What happens if the triazene layer is exposed from behind? Will this also cause the useful “micro explosions”? Success can only be achieved with hard work, in this case, a laborious, carefully conducted chemical synthesis. Although there was already a “recipe” for triazene polymers which a doctoral student at the Technical University of Munich had developed, the results were less than satisfactory. “When we duplicated the recipe, we ended up with a lumpy brown soup”, recalls Nagel. “And while that works adequately for lithography, for our experiment we needed to manufacture very defined, thin layers. This material was clearly unusable for that.”

Nagel analysed the synthesis process step by step and finally found the weak point. In the Munich recipe, at a certain point the acid was neutralised too quickly. Everything tipped over to an alkaline solution whereby an unwanted side reaction took place and led to the “lumps”. The answer was clear: buffer and titrate, which every first-year chemistry student learns and practices over and over again. If the pH value is reduced

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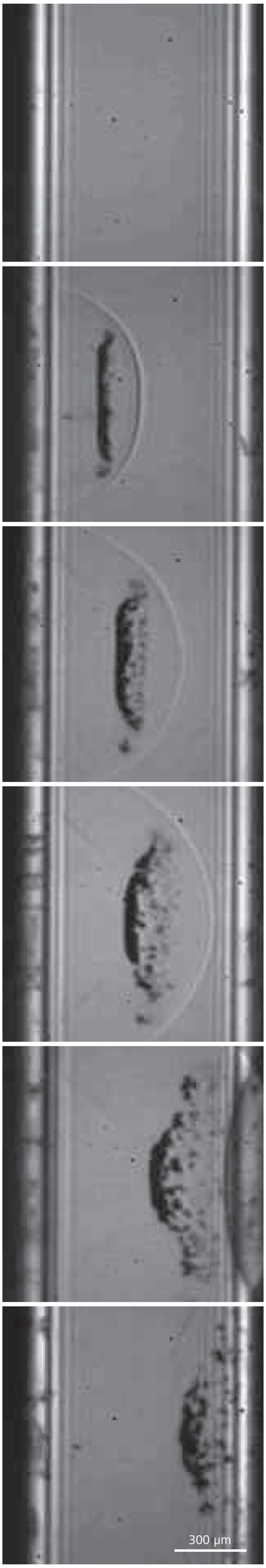

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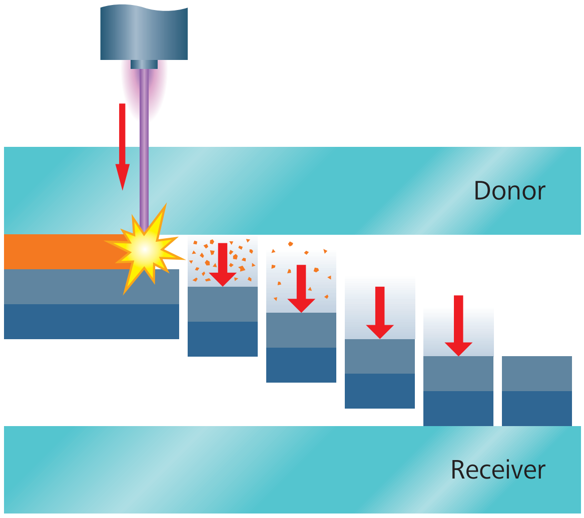

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in a controlled manner, the result is a clean triazene polymer. Now there was nothing standing in the way of an extremely thin film as clear as glass.

With material fabricated in this way, all sorts of experiments could be conducted. As early as 2006, biologists and physicists were able to catapult nerve cells onto a microscope slide for the first time using Nagel's film samples. Once the cells arrived at their target, they continued to live and even multiplied. In this way, a very gentle method for the transfer of the tiniest amounts of material was discovered.

1
A pixel as it flies by: there is a flight path of only 1 mm from the "launch ramp" on the left to the "target" on the right. On pictures 2, 3 and 4 note the pressure wave speeding ahead of the pixel pigment at the speed of sound. If you use too much triazene propellant, the pixel flies faster than sound and would be destroyed as it "passed" the pressure wave. The researchers were able to photo-document this case as well.

2
A diagram illustrating what is known as the "LIFT" process. The triazene layer (orange) is caused to explode by an UV laser pulse. Large amounts of nitrogen gas develop; the layers above break free and are pushed into the target. This method is so gentle that sensitive colour pigments and even living cells can be transported in this way.

The pixelated Easter rabbit as proof

Science, though, is far more than the art of engineering. Scientists just don't want to know that something works, they also want an explanation as to why. And so in 2007 silver layers had their turn. "Using low levels of energy of only 65 millijoules per square centimetre, we shot holes into a triazene layer upon which we had applied a layer of silver. Such weak laser light would never had been enough to vaporise the silver layer", adds Nagel. Even so, the silver on the illuminated spots disappeared. This served to prove that the triazene layer had precisely exploded away the layer of silver which sat on top of it. Nagel still carefully keeps the sample from back then in his desk; it has the image of a laughing Easter bunny made of individual, tiny pixels eluted from the reflective silver layer.

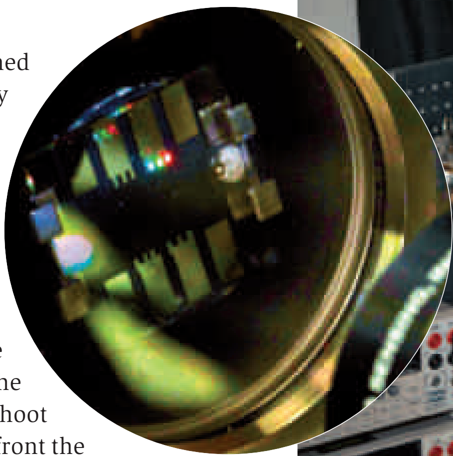
Failed shots actually prove useful

The next step was "target shooting". With Nagel's support, the PhD students Romain Fardel and James Shaw-Stewart examined the flight characteristics of the material being "shot". Again and again, they fabricated samples at Empa, made the trip to PSI where they fired laser pulses on them, then returned to Empa to characterise the results.

Even failed shots helped the researchers towards their goal. Why didn't these pixels fly completely to the target? Why doesn't a thicker triazene layer produce better results? Why does overly intense laser light harm the results? Among other things, the researchers discovered that during a shot, a shock wave is created which creates problems. A laser pulse that's too intense accelerates the shot material to supersonic speed. As soon as it flies through the leading shock wave, it gets pulverised and nothing reaches the target.

Now it's industry's turn

Dozens of scientific papers were published during this time, appearing in scholarly journals such as Applied Surface Science, Journal of Physical Chemistry and even as the cover story in Macromolecular Chemistry and Physics. Now their colleagues at universities and industry should know how they will have to proceed, specifically, to properly specify the gap between the shooting position and the target so that the material doesn't stick to both sides; to shoot with reduced air pressure in order to confront the destructive shock wave; to properly gauge the laser's intensity so that the sensitive pigments continue to light up nicely even when they reach the target.



However, the proud moment that accompanies a successful experiment is also the time to say goodbye. The three glowing coloured points represented one of the last experiments for the time being in the area of flying pixels at Empa. That's because the system is now characterised and well understood. The further path to commercial applications is something industry must tackle. That's something a national research institute cannot afford – and should not have to. From these results, Shaw-Stewart will write his PhD thesis, which should be finished in the spring, and then he'll move on.

With the end of the LIFT project, project leader Nagel will also turn to new topics. He already has ideas for the next one, and he isn't worried about finding tough nuts to crack. "There are plenty of fundamental problems in the area of functional polymers", he says with a grin. Photovoltaics with organic materials are being intensively studied at Empa. "There are questions dealing with interfaces and morphologies which are not yet answered." Nagel will look for something that is not – or not yet – working, and then his research activities will start all over again. //

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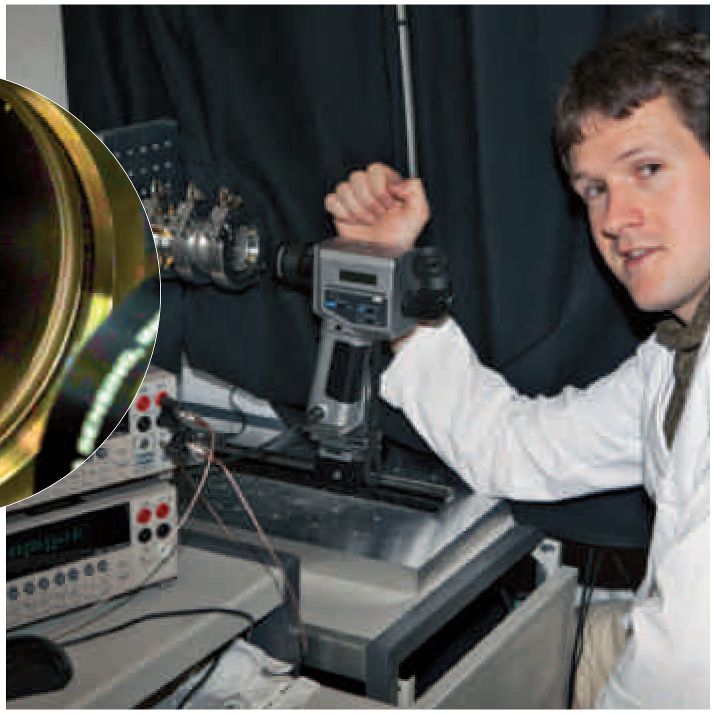

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James Shaw-Stewart prepares a sample within a protective atmosphere.

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Bingo! The pixels have reached their target in good shape and glow brightly. The Empa researcher examines the results with a spectrum analyser.

Link

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