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Claudia Ehrlich

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Hannover Messe: Smart textiles and surfaces – How lightweight elastomer films are bringing tech to life

Clothes that can mimic the feeling of being touched, touch displays that provide haptic feedback to users, or even ultralight loudspeakers. These are just some of the devices made possible using thin silicone films that can be precisely controlled so that they vibrate, flex, press or pull exactly as desired. And all done simply by applying an electrical voltage. The research teams headed by Stefan Seelecke and Paul Motzki (Saarland University) and John Heppe (University of Applied Sciences Saar) will be at the international trade fair Hannover Messe, where they will be demonstrating how their smart film actuator technology is being made even more efficient, stable, sensitive and responsive.

A research team led by Professors Stefan Seelecke and Paul Motzki from Saarland University are using a highly versatile film not much thicker than household cling film to impart new capabilities to objects while saving energy in the process. When used in wearable textiles, these films can move and press against the skin providing haptic feedback that can enhance the VR gaming experience by allowing players to feel textures, impacts and other physical sensations. When the thin polymer film is integrated into an industrial glove, it can respond to how the operator's hand and fingers move, thus enabling a computer to 'understand' specific hand motions and gestures. Applied to the top of a flat glass display screen, the film can create the transient sensation of a tactile button, switch or slider under the user's finger. Lightweight loudspeakers that use far less energy than their conventional counterparts, novel signal generators and noise cancelling textiles are just some of the other prototypes being developed by the experts in intelligent materials systems at Saarland University and the Center for Mechatronics and Automation Technology in Saarbrücken (ZeMA).

But how do they bring these films to life? 'Each side of the film is coated with an electrically conducting layer', explains Paul Motzki, Professor of Smart Material Systems for Innovative Production at Saarland University and Scientific Director/CEO at ZeMA. When the researchers apply an electric voltage to the polymer film, these electrically conducting layers attract each other, compressing the polymer and causing it to expand out sideways, thus increasing its surface area. 'By varying the applied electric field, we can control the motion of the film, essentially creating a lightweight but highly efficient actuator,' says Paul Motzki. The researchers are able to precisely control the motion of these coated films, known as dielectric elastomers (DE), and can get them to perform slow or rapid flexing movements or to vibrate at a desired frequency. Or they can make the film hold a fixed stationary position without requiring the continuous supply of electrical energy.

Using these electroactive polymer films, the research team is developing novel drive systems (actuators) that can be controlled without the need for additional sensors. 'A precise electrical capacitance value can be assigned to each deformation or change in position of the film. The capacitance data can show us how the film deforms, for example, when it is stroked or tapped by a finger. These dielectric elastomer films are self-sensing and are able to act as their own position sensors,' explains Paul Motzki. The measurement data is also used to train AI models that enable the researchers to program the motion of the film so that it flexes, holds a desired shape or oscillates at some required frequency.

The team in Saarbrücken are now taking these DE actuators to a new level and opening up a whole host of new applications. The new generation of films can be controlled even more precisely and can vibrate at even higher frequencies. One of the team's goals is to get these flexible films to oscillate at ultrasonic frequencies. A new project TransDES (Transistor structures based on flexible Dielectric Elastomer Systems), which is being funded by Saarland through the EU's ERDF investment fund, also aims to break new ground by developing elastomeric circuits for high-voltage applications. Printed circuit boards (PCBs) can be found inside most electrical devices. The technology controlling these devices - whether it's a stand mixer or a smartphone – can usually be found soldered onto flat, rigid PCBs. The research team in Saarbrücken are looking to develop lightweight, flexible PCBs that can be used in the future as low-cost flexible alternatives to conventional PCBs. The flexible circuits being developed in Saarbrücken would also come with integrated miniature, self-sensing actuators.

The TransDES project is a collaboration between Paul Motzki's team at ZeMA and Professor John Heppe's team at htw saar (University of Applied Sciences). The technology being developed in Saarland is unique worldwide and involves creating elastomeric films with novel electrode layers.

Up until now, the electrically conductive layers were made by applying powdered amorphous carbon ('carbon black') to the top and bottom of the polymer film using a screen-printing process. However, the electrical resistance of the carbon black layer is around 10,000 ohms, which is far too high if the film is to vibrate in the ultrasonic frequency range.

By replacing the carbon black layer with an ultrathin metal coating of higher conductivity, the researchers are aiming to create a DE actuator that can be switched on and off at an ultrafast rate. 'This will allow us to get even better performance from the film,' explains doctoral student Sebastian Gratz-Kelly. 'Even at very high frequencies, we are still able to control the entire surface of the film, not just parts of it. But the new ultrathin metal coating also means that the film actuator is more energy efficient and power losses are lower, in part because of reduced contact resistance between the cable and the film. And we're using a special laser technique that allows us to achieve a much smaller structure size within the coating,' explains Gratz-Kelly. 'Previously, when we used screen printing, the distance between the electrodes was around one centimetre. Now, the spacing between the electrodes is only a few micrometres. And this is what's making it possible for us to design elastomeric flex circuits,' adds Professor Motzki.

The challenge is that the entire film has to undergo significant stretching, but deformation of the film is hindered by the new metal coating. This is where John Heppe's team comes into play. Heppe, Professor of Physical Sensor Technology and Mechatronics at htw saar, also leads a research group at ZeMA. The two universities are working together to translate their findings into practical industrial and commercial solutions. To balance the properties of a solid metal conductive layer with those of a flexible polymer substrate, Heppe's team makes use of a special process to deposit the metal layer onto the elastomer. 'We use a material deposition technique known as sputtering. The conductive layer that we deposit on the surface of the elastomer is only ten nanometres thick, more than a thousand times thinner than a human hair,' says Mario Cerino, a research scientist in John Heppe's team.

The 'trick' the team uses is to stretch the elastomer before they deposit the ultrathin metal layer. Anyone who has ever stuck adhesive tape to an inflated balloon will know the effect. When you let the air out of the balloon, the strip of tape wrinkles. And it is the same with the elastomer film. When the elastomer relaxes, the metal layer contracts forming wrinkles. 'When we do this, we achieve a resistance of around 50 to 100 ohms over an area of one square centimetre, which is significantly lower than before,' says Mario Cerino.

The researchers are currently using the metal-coated films to develop energy-efficient and cost-effective silicone-based transistors. Transistors are electronic components that can be used to switch electrical voltages and signals on and off or to amplify them, but in this case the team wants to develop film-based transistors for switching high voltages. 'By lowering the electrical resistance, we can get more current to flow – just like a kitchen tap lets more water through, the more the tap is opened. This enables us to achieve high-voltage switching with extremely short cycle times, which can be used to control valves, pumps or loudspeakers,' explains Mario Cerino. 'We make use of a rather special property of these systems,' explains Professor John Heppe. 'If the metal-coated film is stretched more than it was during sputtering, cracks will appear in the electrode layer, which results in a large increase in the electrical resistance. So, if we stretch the film, cracks appear. If we let the film relax, the cracks close up again and the wrinkled structure returns. This allows us to switch from very low resistances to very high resistances, comparable to using a transistor as an electrical switch,' explains Professor Heppe.

The research team will be demonstrating the technology at this year's Hannover Messe (31 March to 4 April, Hall 2, Saarland Innovation Stand B10) where they will be exhibiting a new sensor element with a metal-coated film on a textile wristband. This wearable touchpad is a touch-sensitive fabric surface that can recognize shapes that are drawn on it. When someone swipes their finger across this smart textile, the pressure and direction of movement are recorded. Integrated advanced machine learning algorithms then enable the system to recognize the letters or patterns being drawn.

The Saarbrücken-based experts in intelligent material systems will also be showcasing other innovative developments that make use of these self-sensing dielectric elastomers, such as smart textiles and actuators that provide haptic feedback, energy-efficient valves and pumps, and high-performance actuators.

Saarland is funding the TransDES project with around €500,000 from state funds and from the European Regional Development Fund (ERDF).

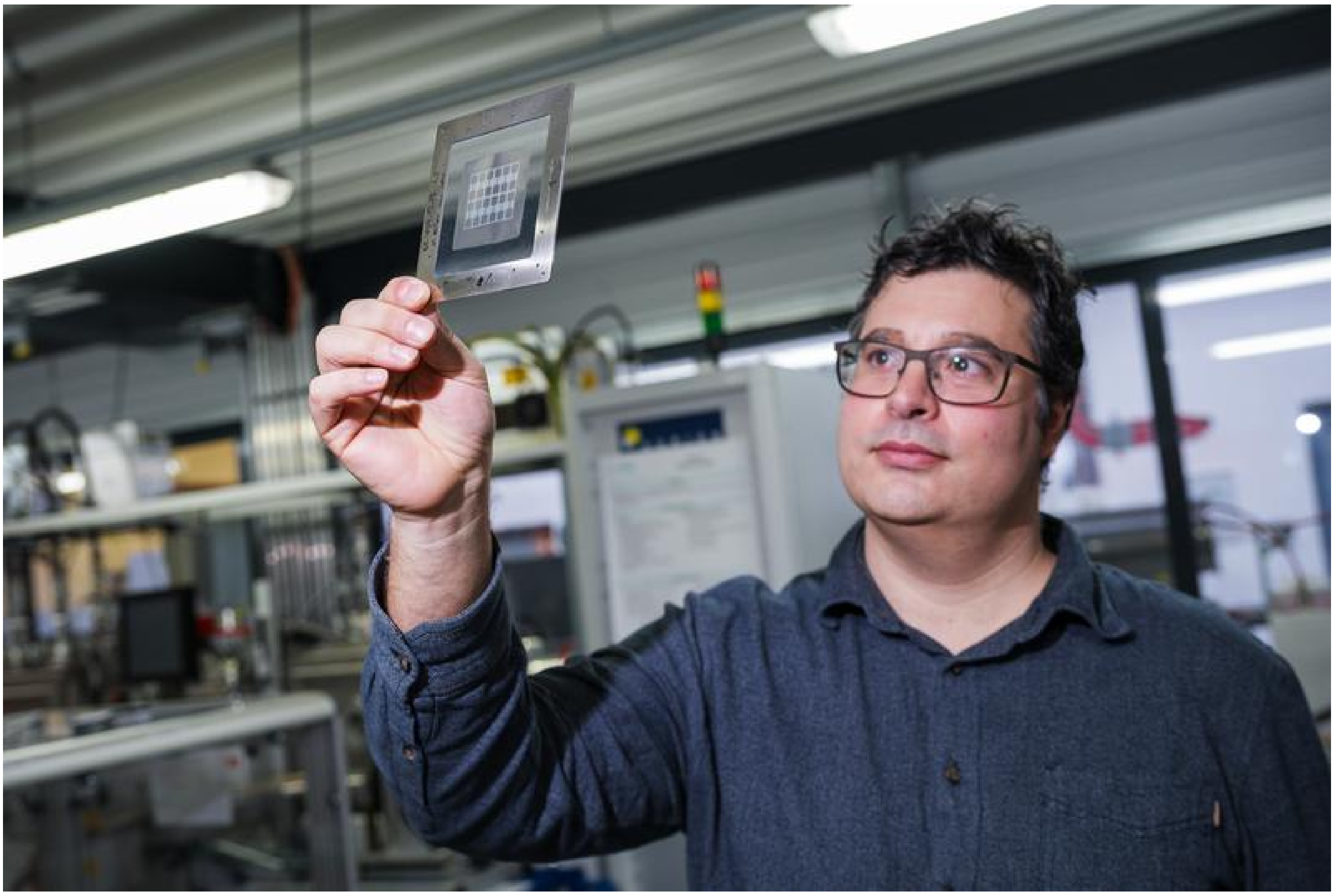
Background:
The dielectric elastomer technology continues to be developed by PhD students conducting research as part of their doctoral dissertation projects under the supervision of Professors Stefan Seelecke, Paul Motzki and John Heppe. The results have been published as papers in a variety of scientific journals. The research work has also received support from numerous sources. Funding from the EU was provided through a Marie Curie research fellowship and from the German Research Foundation through the DFG Priority Programme SPP KOMMMA. The Saarland state government has provided financial support through the ERDF projects iSMAT and Multi-Immerse, and ME Saar (the Association of Metalworking and Electrical Industries in Saarland) has funded a doctoral research scheme. To facilitate the transfer of their smart materials technology into the commercial and industrial sectors, the researchers established the company 'mateligent GmbH', which will also exhibiting at the same stand at this year's Hannover Messe.

31 March to 4 April, Hall 2, Saarland Innovation Stand B10

wissenschaftliche Ansprechpartner:
Prof. Dr.-Ing. Paul Motzki: Tel.: +49 681 85787-13; Email: paul.motzki@uni-saarland.de

URL zur Pressemitteilung: https://doi.org/10.3390/ma17235993 - Read the latest publication from the team.
URL zur Pressemitteilung: https://imsl.de – Intelligent Material Systems Lab
URL zur Pressemitteilung: https://smip.science – Chair of Smart Material Systems for Innovative Production
URL zur Pressemitteilung: https://imsl.de/projekte – Information and videos on research projects
URL zur Pressemitteilung: https://zema.de – Center for Mechatronics and Automation Technology (ZeMA)

Researcher Sebastian Gratz-Kelly shows off a sensor element created from a metal-coated elastomeric film. The touchpad, here mounted on a wristband, can recognize the pressure and direction of a finger that swipes over it.
Credit: Oliver Dietze
Saarland University



The research teams are using the films to develop low-cost transistors. Their aim is to create elastomer-based circuits for high-voltage applications. Research engineer Mario Cerino is working on the development of these novel transistor structures.
Credit: Oliver Dietze
Saarland University