3D-printed insoles measure sole pressure directly in the shoe

03-21-2023

Empa
Materials Science and Technology

For sports and physiotherapy alike

Researchers at ETH Zurich, Empa and EPFL are developing a 3D-printed insole with integrated sensors that allows the pressure of the sole to be measured in the shoe and thus during any activity. This helps athletes or patients to determine performance and therapy progress.

The personalized insole with integrated sensors can measure the pressure of the sole in the shoe during different activities.
Image: Marco Binelli, ETH Zurich

In elite sports, fractions of a second sometimes make the difference between victory and defeat. To optimize their performance, athletes use custom-made insoles. But people with musculoskeletal pain also turn to insoles to combat their discomfort.

Before specialists can accurately fit such insoles, they must first create a pressure profile of the feet. To this end, athletes or patients have to walk barefoot over pressure-sensitive mats, where they leave their individual footprints. Based on this pressure profile, orthopaedists then create customised insoles by hand. The problem with this approach is that optimisations and adjustments take time. Another disadvantage is that the pressure-sensitive mats allow measurements only in a confined space, but not during workouts or outdoor activities.

Now an invention by a research team from ETH Zurich, Empa and EPFL could greatly improve things. The researchers used 3D printing to produce a customised insole with integrated pressure sensors that can measure the pressure on the sole of the foot directly in the shoe during various activities.

“You can tell from the pressure patterns detected whether someone is walking, running, climbing stairs, or even carrying a heavy load on their back - in which case the pressure shifts more to the heel,” explains co-project leader Gilberto Siqueira, Senior Assistant at Empa and at ETH Complex Materials Laboratory. This makes tedious mat tests a thing of the past. The invention was recently featured in the journal Scientific Reports.

One device, multiple inks

These insoles aren’t just easy to use, they’re also easy to make. They are produced in just one step – including the integrated sensors and conductors – using a single 3D printer, called an extruder. For printing, the researchers use various inks developed specifically for this application. As the basis for the insole, the materials scientists use a mixture of silicone and cellulose nanoparticles.

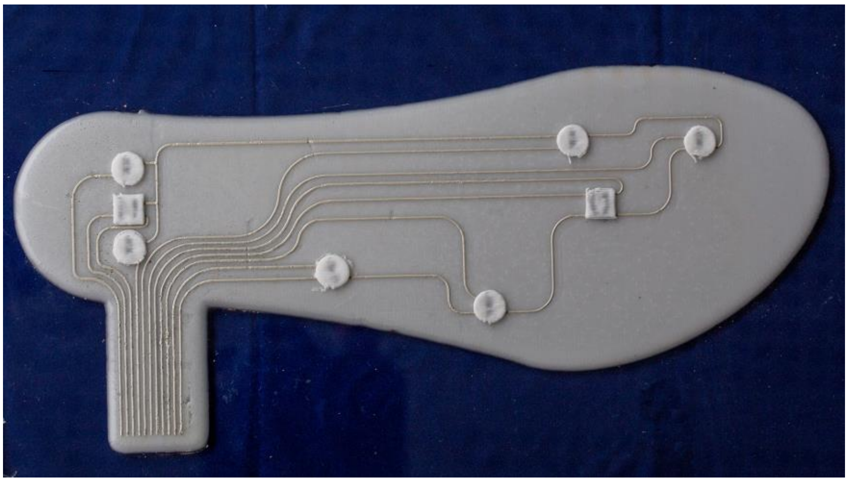
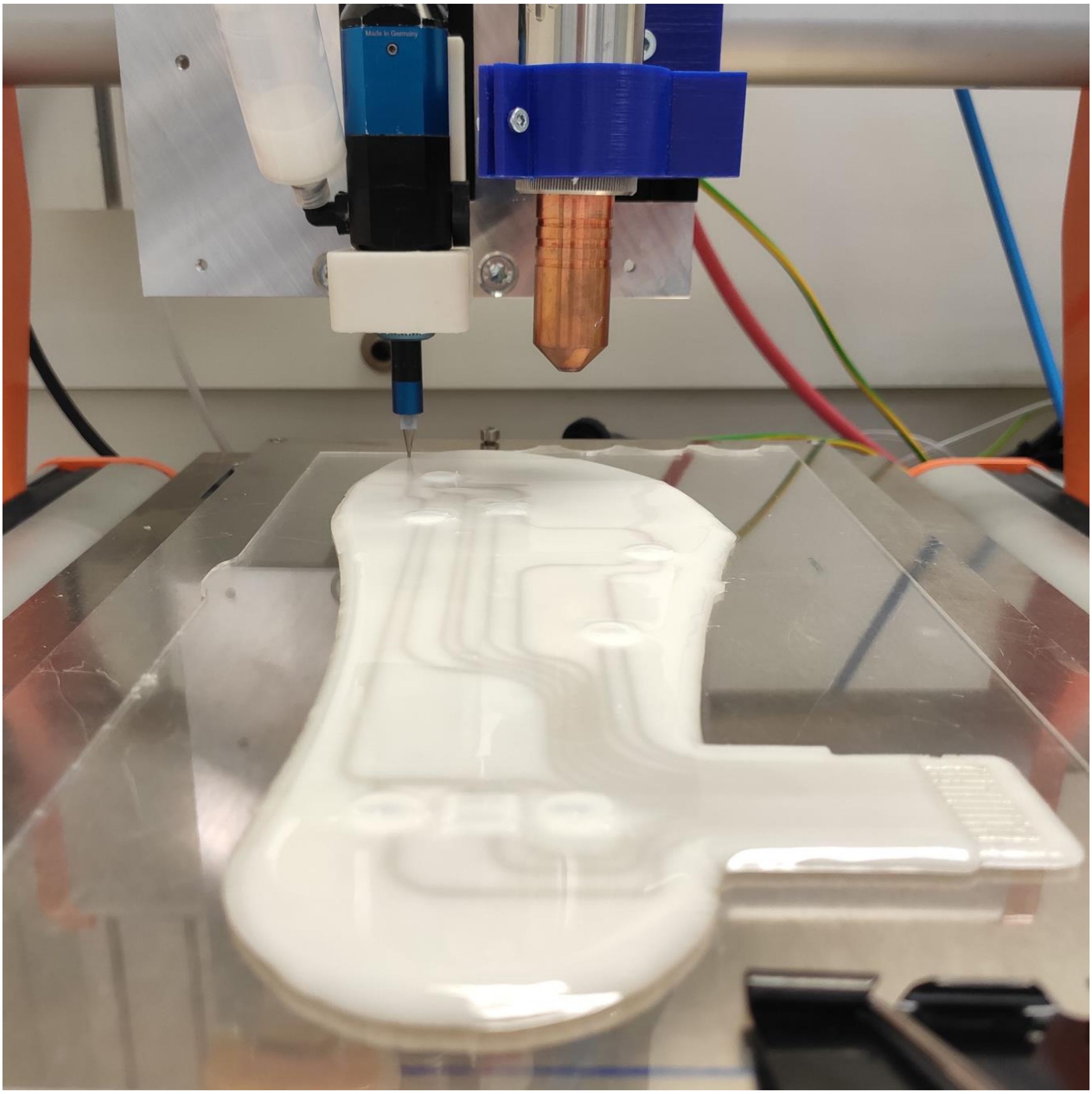


Image: ETH Zürich

Next, they print the conductors on this first layer using a conductive ink containing silver. They then print the sensors on the conductors in individual places using ink that contains carbon black. The sensors aren’t distributed at random: they are placed exactly where the foot sole pressure is greatest. To protect the sensors and conductors, the researchers coat them with another layer of silicone.

An initial difficulty was to achieve good adhesion between the different material layers. The researchers resolved this by treating the surface of the silicone layers with hot plasma.

As sensors for measuring normal and shear forces, they use piezo components, which convert mechanical pressure into electrical signals. In addition, the researchers have built an interface into the sole for reading out the generated data.



In the final step, the conductors and sensors are covered with another silicone layer to protect them..
Image: Marco Binelli, ETH Zürich

Running data soon to be read out wirelessly

Tests showed the researchers that the additively manufactured insole works well. “So with data analysis, we can actually identify different activities based on which sensors responded and how strong that response was,” Siqueira says.

At the moment, Siqueira and his colleagues still need a cable connection to read out the data; to this end, they have installed a contact on the side of the insole. One of the next development steps, he says, will be to create a wireless connection. “However, reading out the data hasn’t been the main focus of our work so far.”

In the future, 3D-printed insoles with integrated sensors could be used by athletes or in physiotherapy, for example to measure training or therapy progress. Based on such measurement data, training plans can then be adjusted and permanent shoe insoles with different hard and soft zones can be produced using 3D printing.

Although Siqueira believes there is strong market potential for their product, especially in elite sports, his team hasn't yet taken any steps towards commercialisation.

Researchers from Empa, ETH Zurich and EPFL were involved in the development of the insole. EPFL researcher Danick Briand coordinated the project, and his group supplied the sensors, while the ETH and Empa researchers developed the inks and the printing platform. Also involved in the project were the Lausanne University Hospital (CHUV) and orthopaedics company Numo. The project was funded by the ETH Domain's Advanced Manufacturing Strategic Focus Areas programme.

Source: Peter Rüegg, ETH ZÜRICH

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