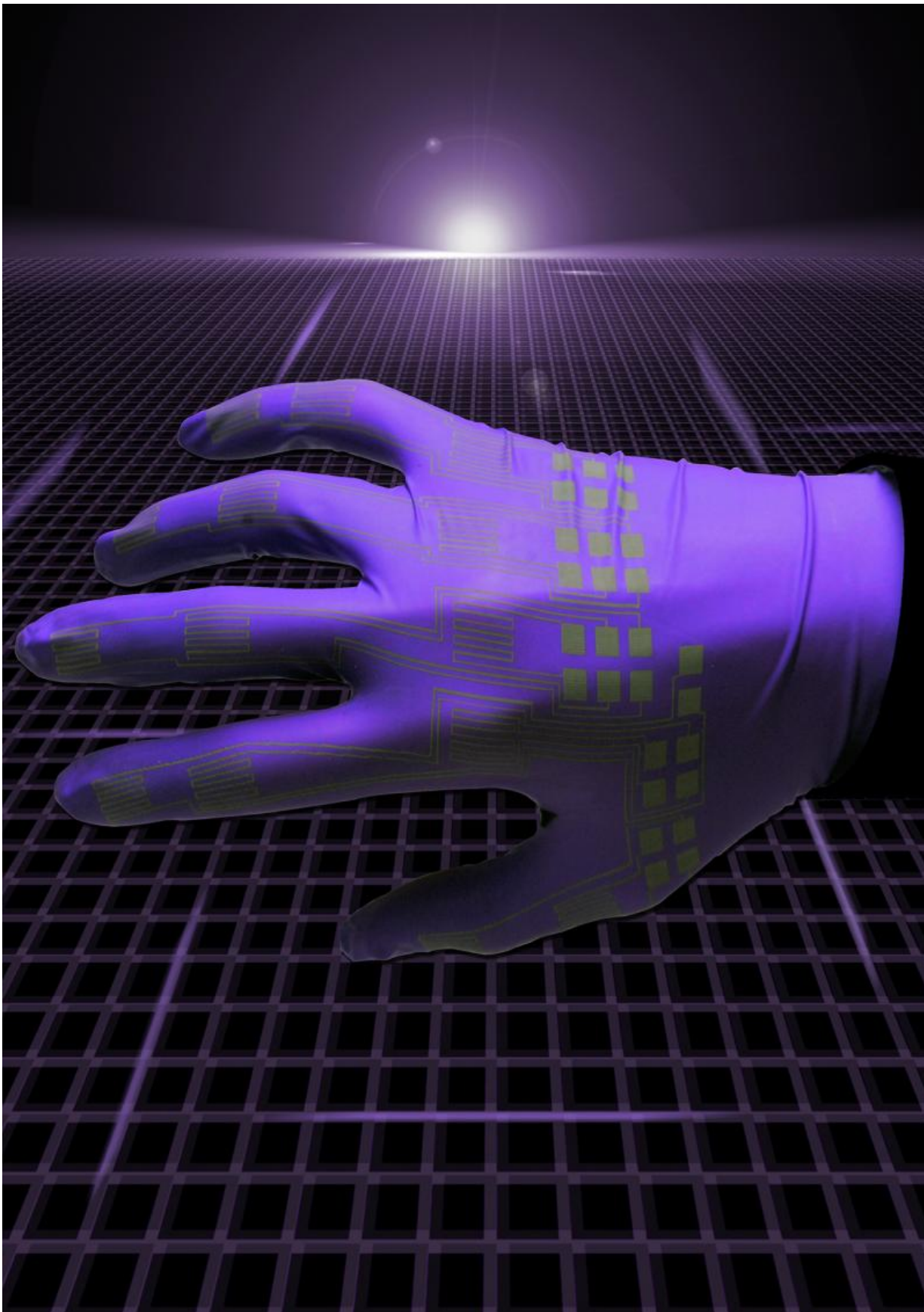


Inkjet-printed liquid metal could bring wearable tech, soft robotics

April 7 2015, by Emil Venere



This artistic rendering depicts electronic devices created using a new inkjet-printing technology to produce circuits made of liquid-metal alloys for "soft robots" and flexible electronics. Elastic technologies could make possible a new class of pliable robots and stretchable garments that people might wear to interact with computers or for therapeutic purposes. Credit: Alex Bottiglio/Purdue University

New research shows how inkjet-printing technology can be used to mass-produce electronic circuits made of liquid-metal alloys for "soft robots" and flexible electronics.

Elastic technologies could make possible a new class of pliable robots and stretchable garments that people might wear to interact with computers or for therapeutic purposes. However, new manufacturing techniques must be developed before soft machines become commercially feasible, said Rebecca Kramer, an assistant professor of mechanical engineering at Purdue University.

"We want to create stretchable electronics that might be compatible with soft machines, such as robots that need to squeeze through small spaces, or wearable technologies that aren't restrictive of motion," she said. "Conductors made from liquid metal can stretch and deform without breaking."

A new potential manufacturing approach focuses on harnessing inkjet printing to create devices made of liquid alloys.

"This process now allows us to print flexible and stretchable conductors onto anything, including elastic materials and fabrics," Kramer said.

A research paper about the method will appear on April 18 in the journal *Advanced Materials*. The paper generally introduces the method, called mechanically sintered gallium-indium nanoparticles, and describes research leading up to the project. It was authored by postdoctoral researcher John William Boley, graduate student Edward L. White and Kramer.

A printable ink is made by dispersing the liquid metal in a non-metallic solvent using ultrasound, which breaks up the bulk liquid metal into nanoparticles. This nanoparticle-filled ink is compatible with inkjet printing.

"Liquid metal in its native form is not inkjet-able," Kramer said. "So what we do is create liquid metal nanoparticles that are small enough to pass through an inkjet nozzle. Sonicating liquid metal in a carrier solvent, such as ethanol, both creates the nanoparticles and disperses them in the solvent. Then we can print the ink onto any substrate. The ethanol evaporates away so we are just left with liquid metal nanoparticles on a surface."

After printing, the nanoparticles must be rejoined by applying light pressure, which renders the material conductive. This step is necessary because the liquid-metal nanoparticles are initially coated with oxidized gallium, which acts as a skin that prevents electrical conductivity.

"But it's a fragile skin, so when you apply pressure it breaks the skin and everything coalesces into one uniform film," Kramer said. "We can do this either by stamping or by dragging something across the surface, such as the sharp edge of a silicon tip."

The approach makes it possible to select which portions to activate depending on particular designs, suggesting that a blank film might be manufactured for a multitude of potential applications.

"We selectively activate what electronics we want to turn on by applying pressure to just those areas," said Kramer, who this year was awarded an Early Career Development award from the National Science Foundation, which supports research to determine how to best develop the liquid-metal ink.

The process could make it possible to rapidly mass-produce large quantities of the film.

Future research will explore how the interaction between the ink and the surface being printed on might be conducive to the production of specific types of devices.

"For example, how do the nanoparticles orient themselves on hydrophobic versus hydrophilic surfaces? How can we formulate the ink and exploit its interaction with a surface to enable self-assembly of the particles?" she said.

The researchers also will study and model how individual particles rupture when pressure is applied, providing information that could allow the manufacture of ultrathin traces and new types of sensors.

More information: Boley, J. W., White, E. L., & Kramer, R. K. (2015). Mechanically Sintered Gallium-Indium Nanoparticles. *Advanced Materials*. doi:10.1002/adma.201404790

Provided by Purdue University

Citation: Inkjet-printed liquid metal could bring wearable tech, soft robotics (2015, April 7) retrieved 23 April 2024 from <https://phys.org/news/2015-04-inkjet-printed-liquid-metal-wearable-tech.html>

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