# Making headway in precision therapeutics with novel fully organic bioelectronic device

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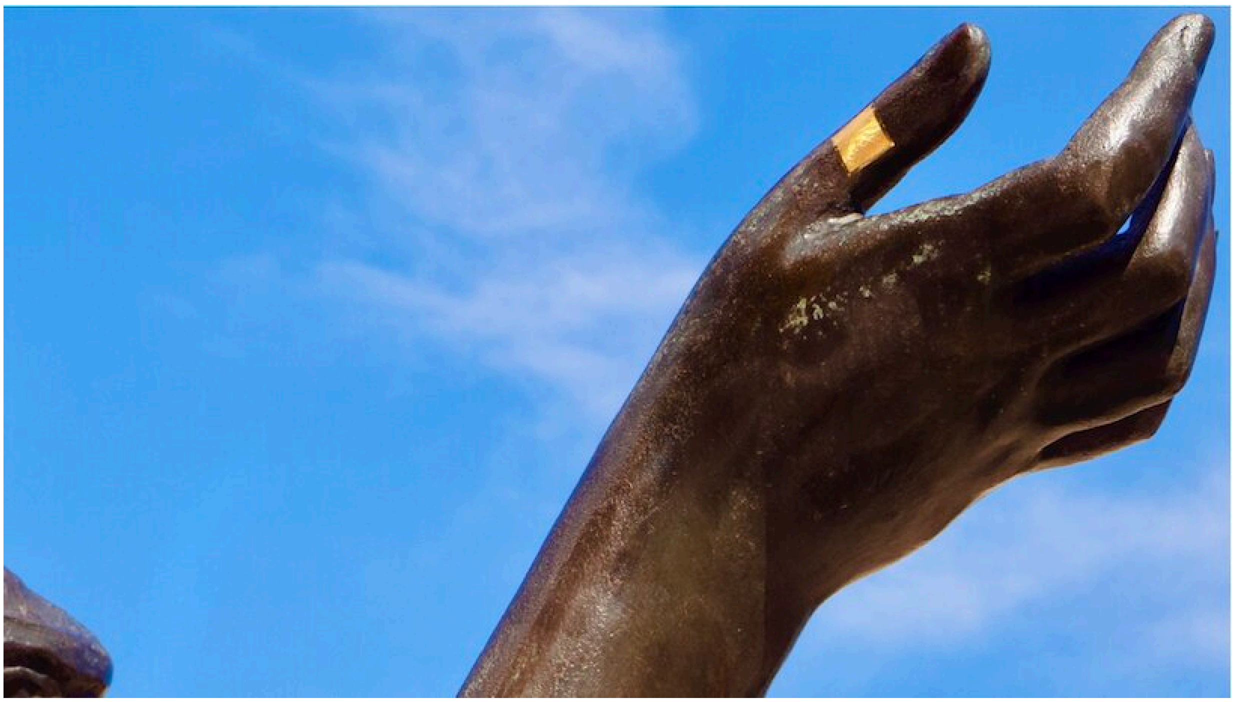

A vIGT array consisting of half a million transistors conforming to the complex curvilinear surface of the finger of Alma Mater, Columbia University's iconic stature. Credit: Dion Khodagholy,Claudia Cea/Columbia Engineering

As researchers make major advances in medical care, they are also discovering that the efficacy of these treatments can be enhanced by individualized approaches. Therefore, clinicians increasingly need methods that can both continuously monitor physiological signals and then personalize responsive delivery of therapeutics.

Implanted bioelectronic devices are playing a critical role in these treatments, but there are a number of challenges that have stalled their widespread adoption. These devices require specialized components for signal acquisition, processing, data transmission, and powering.

Up to now, achieving these capabilities in an implanted device has entailed using numerous rigid and non-biocompatible components that can lead to tissue disruption and patient discomfort. Ideally, these devices need to be biocompatible, flexible, and stable in the long term in the body. They also must be fast and sensitive enough to record rapid, low-amplitude biosignals, while still being able to transmit data for external analysis.

## Columbia researchers invent first stand-alone, flexible, fully organic bioelectronic device

Columbia Engineering researchers announced today that they have developed the first stand-alone, conformable, fully organic bioelectronic device that can not only acquire and transmit neurophysiologic brain signals, but can also provide power for device operation.

This device, about 100 times smaller than a human hair, is based on an organic transistor architecture that incorporates a vertical channel and a miniaturized water conduit demonstrating long-term stability, high electrical performance, and low-voltage operation to prevent biological tissue damage. The findings are outlined in a new study, published today in *Nature Materials*.

Both researchers and clinicians knew there was a need for transistors that concurrently pose all of these features: low voltage of operation, biocompatibility, performance stability, conformability for *in vivo* operation; and high electrical performance, including fast temporal response, high transconductance, and crosstalk-free operation. Silicon-based transistors are the most established technologies, but they are not a perfect solution because they are hard, rigid, and unable to establish a very efficient ion interface with the body. ]

The team addressed these issues by introducing a scalable, self-contained, sub-micron IGT (internal-ion-gated organic electrochemical transistor) architecture, the vIGT. They incorporated a vertical channel arrangement that augments the intrinsic speed of the IGT architecture by optimizing channel geometry and permitting a high density arrangement of transistors next to each other—155,000 of them per centimeter square.

## Scalable vGITs are the fastest electrochemical transistors

The vIGTs are composed of biocompatible, commercially available materials that do not require encapsulation in biological environments and are not impaired by exposure to water or ions. The composite material of the channel can be reproducibly manufactured in large quantities and is solution-processible, making it more accessible to a broad range of fabrication processes.

They are flexible and compatible with integration into a wide variety of conformable plastic substrates and have long-term stability, low inter-transistor crosstalk, and high-density integration capacity, allowing fabrication of efficient integrated circuits.

"Organic electronics are not known for their high performance and reliability," said the study's leader Dion Khodagholy, associate professor of electrical engineering. "But with our new vGIT architecture, we were able to incorporate a vertical channel that has its own supply of ions. This self-sufficiency of ions made the transistor to be particularly fast—in fact, they are currently the fastest electrochemical transistors."

To push the speed of operation even further, the team used advanced nanofabrication techniques to miniaturize and densify these transistors at submicro-meter scales. Fabrication took place in the cleanroom of the Columbia Nano Initiative.

## Collaborating with CUIMC clinicians

To develop the architecture, the researchers first needed to understand the challenges involved with diagnosis and treatment of patients with neurological disorders like epilepsy, as well as the methodologies currently used. They worked with colleagues at the Department of Neurology at Columbia University Irving Medical Center, in particular, with Jennifer Gelinas, assistant professor of neurology, electrical and biomedical engineering and director of the Epilepsy and Cognition Lab.

The combination of high-speed, flexibility. and low-voltage operation enables the transistors to not only be used for neural signal recording but also for data transmission as well as powering the device, leading to a fully conformable implant. The researchers used this feature to demonstrate fully soft and confirmable implants capable of recording and transmitting high resolution neural activity from both outside, on the surface of the brain, as well as inside, deep within the brain.

"This work will potentially open a wide range of translational opportunities and make medical implants accessible to a large patient demographic who are traditionally not qualified for implantable devices due to the complexity and high risks of such procedures," said Gelinas.

"It's amazing to think that our research and devices could help physicians with better diagnostics and could have a positive impact on patients' quality of life," added the study's lead author Claudia Cea, who recently completed her Ph.D. and will be a postdoctoral fellow at MIT this fall.

The researchers plan next to join forces with neurosurgeons at CUIMC to validate the capabilities of vIGT-based implants in operating rooms. The team expects to develop soft and safe implants that can detect and identify various pathological brain waves caused by neurological disorders.

**More information:** Claudia Cea et al, Integrated internal ion-gated organic electrochemical transistors for stand-alone conformable bioelectronics, *Nature Materials* (2023). DOI: 10.1038/s41563-023-01599-w

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