Wireless drug patch shows promise as chronic disease treatment delivery system

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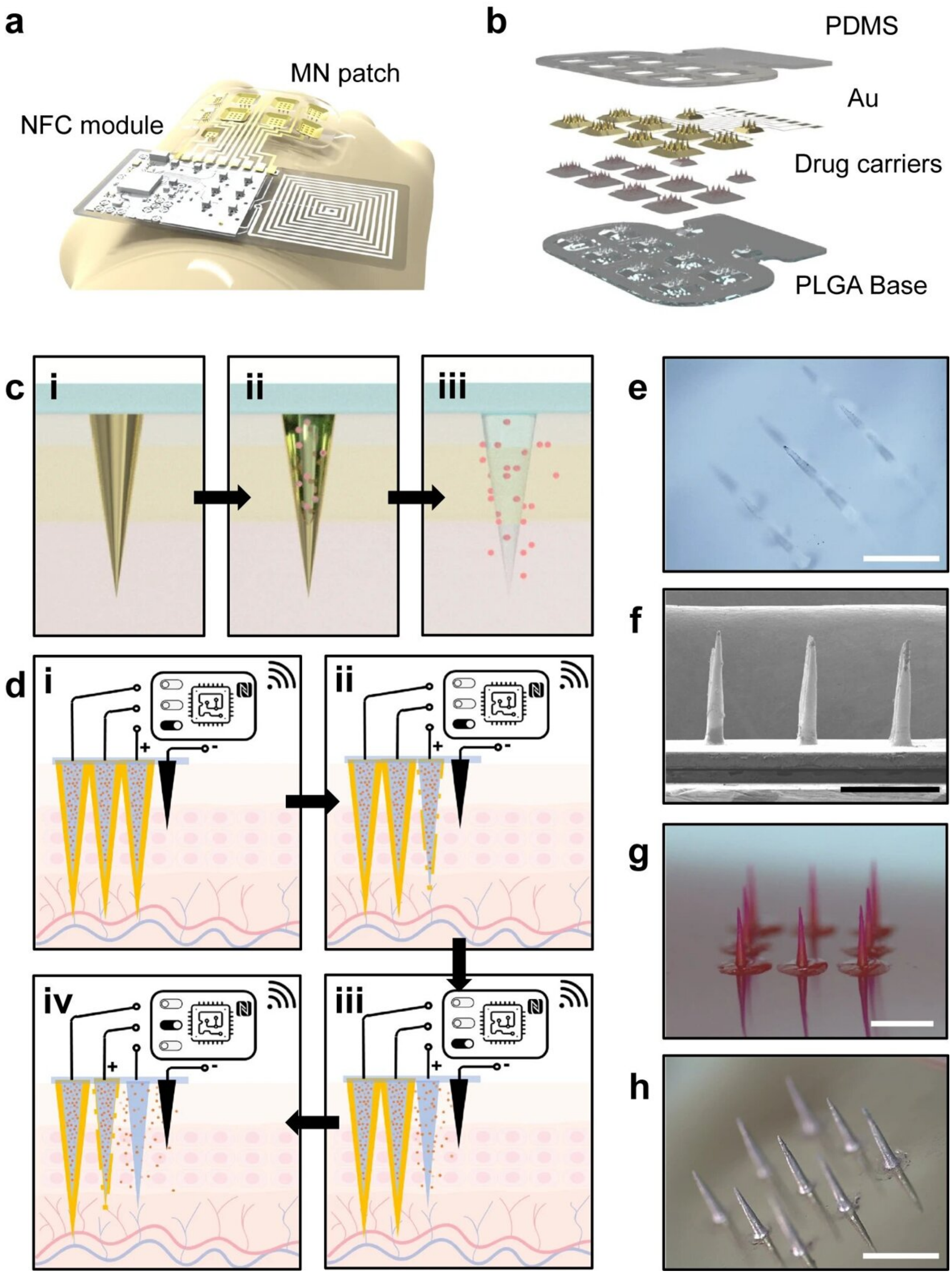
a
MN patch
NFC module
b
PDMS
Au
Drug carriers
PLGA Base
c
i
ii
iii
d
i
ii
iii
iv
e
f
g
h

Spatiotemporal on-demand patch for wireless, active control of drug delivery. **a** Schematic illustration highlighting the construction of a wirelessly controlled spatiotemporal on-demand patch (SOP) for high-precision drug delivery. The SOP features two main components: (i) an array of drug-loaded microneedles protected by active encapsulation that exploits electrochemically triggered crevice corrosion, for on-demand drug delivery; (ii) a near-field communication (NFC) module assembled on a soft printed-circuit board, for wireless control. **b** Exploded view of the drug-delivery interface of the SOP, including a PDMS encapsulation, an electrically triggerable gold (Au) coating, drug-loaded microneedles based on poly(D, L-lactide-co-glycolide) (PLGA), and a PLGA substrate. **c** Schematic illustration showing process of electrically controlled on-demand drug delivery from an individual microneedle. (i) Standby stage where an encapsulation layer protects the microneedle from releasing drug. (ii) Transitioning stage where an electrical trigger initiates crevice corrosion of the encapsulation layer to expose drug-loaded base. (iii) Releasing stage, where the exposed base starts to release drugs. **d** Schematic illustration demonstrating the capability of spatiotemporal control of releasing profile from the SOP. (i) Deploying an SOP at the skin interface. (ii–iv) Communicating with the NFC module of the SOP enables active control of drug release for each individual microneedle. **e** Optical image of a PLGA microneedle array. **f** Corresponding SEM image with a tilted view on the PLGA microneedle array. **g** Optical image of a PLGA microneedle array loaded with Rhodamine B. **h** Optical image of a PLGA microneedle array protected with an electrically triggerable encapsulation (Au, thickness 150 nm). The length and base diameter of the microneedles in **e–h** is around 1.2 mm and 270 μm, respectively; 3 experiments are repeated with similar results for each in **e–h**; the scale bar in **e–h** is 1 mm. Credit: *Nature Communications* (2024). DOI: 10.1038/s41467-023-44532-0

University of North Carolina at Chapel Hill scientists have created a new drug delivery system, called the Spatiotemporal On-Demand Patch (SOP), which can receive commands wirelessly from a smartphone or computer to schedule and trigger the release of drugs from individual microneedles. The patch's thin, soft platform resembles a Band-Aid and was designed to enhance user comfort and convenience, since wearability is a crucial factor for chronically ill patients.

The research team, led by Juan Song, Ph.D., professor of pharmacology at the UNC School of Medicine, and Wubin Bai, Ph.D., assistant professor of applied physical sciences at the UNC College of Arts and Sciences, tested the SOP in a mouse model, using melatonin in the microneedles to improve sleep.

This research, published in the journal *Nature Communications*, opens the door to researching this wirelessly controlled patch to deliver on-demand treatments for neurodegenerative disorders, including Alzheimer's disease.

"SOP's ability to enable joint delivery of multiple drugs could address various aspects of Alzheimer's Disease, such as reducing beta-amyloid plaques, mitigating neuroinflammation and enhancing cognitive function," said Bai, a co-senior author.

The open access paper titled, "Digital Automation of Transdermal Drug Delivery with High Spatiotemporal Resolution," was co-authored by Yihang Wang of the Department of Applied Physical Sciences and Zeka Chen of the Department of Pharmacology.

Bai said the research highlights not only a multidisciplinary collaboration but also a "passionate involvement of Carolina undergraduate students," including Priyash Hafiz of the Department of Applied Physical Sciences and Brayden Davis, Will Lipman, Tian Wang, and Sicheng Xing of the UNC/NCSU Joint Department of Biomedical Engineering.

The patch, which has received a provisional patent, enables highly localized treatment—less than 1 square millimeter—of specific tissues, organs, or regions within the body, and drug release can be triggered within 30 seconds in response to an electrical signal. Patients could wear more than one patch at a time, which would reduce the need for doctors' visits or even trips to the hospital for medical attention.

"The beauty of this device is that it can house dozens, if not hundreds, of concentrated drugs and can program their sequential release automatically," said Song, who is a member of the UNC Neuroscience Center. "Rapid drug release can be crucial in emergency situations or when immediate therapeutic action is required."

The microneedles are coated with gold, which protects the drugs and surrounding tissues. When a low-voltage electrical stimulus is applied through the patch, the gold coating disintegrates, exposing the drug-loaded microneedles to the skin and initiating the controlled release of the drugs.

"This level of specificity ensures precise and customized drug delivery, catering to the needs of different conditions or specific regions of the body," said Wang. "This offers a novel approach to achieving controlled drug release through a combination of materials science and electrical engineering."

More information: Yihang Wang et al, Digital automation of transdermal drug delivery with high spatiotemporal resolution, *Nature Communications* (2024). DOI: 10.1038/s41467-023-44532-0

Provided by University of North Carolina at Chapel Hill School of Medicine