INSIGHTS

PERSPECTIVES

MATERIALS SCIENCE

A sweet solution to complex microprinting

A simple sugar mixture transfers functional components to surfaces with intricate geometry

By **Blake N. Johnson**

Design and manufacturing processes that modify surfaces have seen rapid development in recent years (*1*–*4*). Besides aesthetics, these modifications can add new functionalities to an object. For example, the regular arrangement of modifications on a surface (periodic structuring) is used to create chemical sensors, cloaking devices, and optical fibers, among other tools (*5*). Despite the versatility of surface modification techniques, such as direct transfer, three-dimensional (3D) printing, and "wrapping," there are limitations associated with properties of the functional components and target objects, as well as from the desired deposition patterns. On page 894 of this issue, Zabow (*6*) presents a relatively simple approach for transferring arrays of diverse functional components onto objects with complex 3D geometries. The method uses a familiar material—table sugar—in a "reflow" process that leverages sugar's melting and dissolving properties to create a flowable "stamp."

Surface modification is an umbrella term that covers a wide range of processes, from the 3D printing of complex circuits onto an object to the wrapping of a guitar body with graphics using water transfer. Additive-based surface modification can be achieved by printing (using a nozzle), pick-and-place (using a tweezer), or transfer (using a wrapper) processes, with each technique offering different advantages. Transfer processes use a liquid or solid "carrier" to deposit a functional component onto an object. The carrier must be capable of capturing the component from an initial surface (such as stiff wafer) and releasing it onto the surface of the target. Stretchable and flexible solid carriers (such as silicone stamps) can be used to integrate an array of components, typically one type, on a range of elaborate 3D objects. However,

IMAGE: GARY ZABOW

Downloaded from https://www.science.org at Virginia Polytechnic Institute and State University on April 11, 2023

Laser confocal micrographs show pollen grains bearing complex surface topologies that have been micropatterned with a flowable "stamp."

objects bearing discontinuities in surface slope and protruding features (peaks) of high height-to-width ratio that hang over the surface present challenges. Alternatively, liquid carriers (such as a transfer film floating in water onto which an object is dipped) can be used to integrate functional components onto objects of complex geometry. However, it is difficult to deposit arrays of small components that are not first formed on a thin transferrable film with precision on complex geometry, because the movement of each array element is relatively restricted on a film compared with a liquid carrier. By comparison, printing and pick-and-place processes are more versatile regarding an object's geometry, but require the component material to be printable or graspable. This also requires the object to be digitally mapped in 3D, adding even more time and cost to manufacturing.

To overcome some of the constraints in additive-based surface modification processes associated with use of only solid or liquid carriers, Zabow describes a transfer technique for an array of functional components that are arranged in a complex geometry on the target (such as a periodic pattern of components, conforming to a curved surface). The method uses a sugar mixture as a pourable and dissolvable carrier and a process similar to that used in making hard candy. A heated sugar and corn syrup mixture is allowed to cool, but before it solidifies, it is poured over the components to be integrated onto the surface, forming a meltable "stamp." Zabow starts with a pouring and solidification step (casting) in which the sugar-based carrier is poured at low temperature over the functional components (including microscale metal, polymer, and glass elements) that have been prearranged in a desired pattern on an initial surface. The components—now embedded in a hardened sugar mixture "stamp"—are then transferred by slowly melting the stamp over the target object (hence, reflowing). After the deformed sugar mixture cools and resolidifies, the sugar mixture is washed away using water. Because the process uses a carrier that undergoes a phase change, it provides the control of solid carriers with the geometry matching of liquid carriers. Thus, the technique removes some constraints of solid, fluid, and contact mechanics associated with water and solid stamp-based transfer methods.

Zabow demonstrated the technique on a wide range of objects, including those with protruding features that overhang the surface, as well as on component and object materials such as metal disks, ellipses, and rings; polymer and glass microspheres; and hydrogels. The precision of the method was also demonstrated by attaching an array of thousands of 1-μm disks onto a pin head, which surpasses the boundaries of current transfer techniques.

The author also transferred desired functionality onto multiple biological surfaces including individual hair fibers, plant seeds, and animal cells. The ability to deposit conformal arrays across a range of micro- to macroscale objects that bear complex geometry using a biocompatible, water-based, low-temperature process may be transformative to various disciplines, including tissue engineering, as well as technologies such as biomedical devices, metamaterials, and sensors. For example, functionality integration with commonly used biomedical components (needles, fibers, tubings) could enable the design and manufacture of diagnostic and therapeutic tools, such as bioelectronic therapeutics (*7*–*9*).

There are many different directions to further develop the reflow-transfer technique of Zabow by considering fundamental principles in rheology (deformation of flowing films) and phase equilibria (optically or chemically driven phase transition). The process also opens the door to questions about quality and reproducibility. How the placement precision of the integrated functional components can be optimized and determining the limits on functional components that can be transferred are also questions to be explored. ■

Grado Department of Industrial and Systems Engineering, Department of Materials Science and Engineering, Department of Chemical Engineering, School of Neuroscience, Virginia Tech, Blacksburg, VA, USA. Email: bnj@vt.edu

REFERENCES AND NOTES

1. K. Sim *et al.*, *Nat. Electron.* **2**, 471 (2019).
2. B. Le Borgne *et al.*, *Adv. Mater. Technol.* **4**, 1800600 (2019).
3. E. Kucukdeger *et al.*, *Flex. Print. Electron.* **6**, 044002 (2021).
4. Y.-K. Lee *et al.*, *Sci. Adv.* **6**, eaax6212 (2020).
5. J. Hu *et al.*, *Front. Phys.* (Lausanne) **8**, 586087 (2021).
6. G. Zabow, *Science* **378**, 894 (2022).
7. A. Canales *et al.*, *Nat. Biotechnol.* **33**, 277 (2015).
8. A. Branner, R. B. Stein, E. Fernandez, Y. Aoyagi, R. A. Normann, *IEEE Trans. Biomed. Eng.* **51**, 146 (2004).
9. D. Qi *et al.*, *Adv. Mater.* **29**, 1702800 (2017).

ACKNOWLEDGMENTS

B.N.J. acknowledges the support of GlycoMIP, a National Science Foundation Materials Innovation Platform funded through Cooperative Agreement DMR-1933525. B.N.J. also acknowledges the support of the National Science Foundation through CBET-2144310.

10.1126/science.ade6722

MEDICINE

The influenza universe in an mRNA vaccine

An mRNA–lipid nanoparticle vaccine protects animals from 20 influenza lineages

By **Alyson A. Kelvin**[1,2] *and* **Darryl Falzarano**[1,3]

The greatest challenge to preventing the next influenza pandemic is the extensive diversity within the influenza virus family (*1*). At present, 20 lineages of influenza A and B viruses have been identified, each containing numerous strains (*2*, *3*). Current influenza vaccines, composed of four influenza viral antigens, provide little protection beyond the viral strains targeted by the vaccines. Universal influenza vaccines that can protect against all 20 lineages could help to prevent the next pandemic (*4*). Designing and manufacturing a vaccine that can provide such broad protection has been challenging, but the demonstration of the feasibility of mRNA–lipid nanoparticle COVID-19 vaccines offers a possible strategy (*5*). On page 899 of this issue, Arevalo *et al.* (*6*) report an influenza vaccine, using mRNA–lipid nanoparticle technology incorporating representatives of all 20 influenza virus lineages, that protected mice and ferrets from diverse influenza viruses. This provides a pathway to a universal influenza vaccine.

Influenza viruses are an ever-constant public health threat because circulating viruses continue to evolve, and new viruses spill over from animal reservoirs. The 20 influenza virus lineages over both A and B viruses are defined by 20 different hemagglutinin (HA) proteins. Current approved seasonal vaccines focus immune responses on the surface HA protein of circulating influenza viruses. The HA protein is responsible for host cell receptor binding, thus facilitating infection (*7*). Neutralizing antibodies, directed toward the HA receptor binding domain can block influ-

[1]Vaccine and Infectious Disease Organization (VIDO), University of Saskatchewan, Saskatoon, Saskatchewan, Canada. [2]Department of Biochemistry, Microbiology, and Immunology, University of Saskatchewan, Saskatoon, Saskatchewan, Canada. [3]Department of Veterinary Microbiology, Western College of Veterinary Medicine, University of Saskatchewan, Saskatoon, Saskatchewan, Canada. Email: alyson.kelvin@usask.ca

Downloaded from https://www.science.org at Virginia Polytechnic Institute and State University on April 11, 2023

A sweet solution to complex microprinting

Blake N. Johnson

Science, **378** (6622), .
DOI: 10.1126/science.ade6722

View the article online
https://www.science.org/doi/10.1126/science.ade6722
Permissions
https://www.science.org/help/reprints-and-permissions

Downloaded from https://www.science.org at Virginia Polytechnic Institute and State University on April 11, 2023

Use of this article is subject to the Terms of service

Science (ISSN 1095-9203) is published by the American Association for the Advancement of Science. 1200 New York Avenue NW, Washington, DC 20005. The title *Science* is a registered trademark of AAAS.
Copyright © 2022 The Authors, some rights reserved; exclusive licensee American Association for the Advancement of Science. No claim to original U.S. Government Works