of the RMs had a significant effect on the propagation velocity. In the case of two parallel channels, when the spacing between them was small enough, local pressure waves produced by combustion of the RMs overlap in the intermediate region and direct hot gases forward, effectively increasing the propagation velocity.

The phenomena occurring in hurdle geometries are a bit more complex, as the expansion process also includes the formation and transport of hot particles from within the flame region. Researchers showed that if the hurdles are situated too closely, the expansion event is interrupted and energy push-back occurs, causing the velocity to be impeded. However, when the spacing between hurdles is increased, they could achieve a higher flame velocity even though the overall mass was decreasing. The underlying reason for this is a result of the architecture, which facilitates transport of these hot particles from hurdle to hurdle to propagate the flame. Kyle Sullivan, lead author of the article, points out "they're two very simple architectures, but the scaling behavior is opposite due to the fact that the mode of energy transport being controlled in each case is different."

This work has identified a number of critical geometric design parameters and validated the use of alternative 3D architectures in tailoring the dynamic behavior of reactive materials. As Sullivan explains, "Until now, most of the focus has been on reformulating to achieve a desired performance; what 3D printing brings to the table is the ability to use architecture to make better use of the formulations you already have."

Ian McDonald

Printed electrodes could solve issues with wearable keyboard size

Information is now accessible at the touch of a button—literally at our fingertips. Be it a smartphone, a tablet, a smartwatch, or a smart glass, compact portable electronic devices play a major role in this revolution. The future of such facile information access lies in devices that integrate with the human body and work in tandem with human physiology. For this reason, several wearable electronic devices have been developed that cover a huge spectrum of design options. Most of them rely on microfabrication techniques that essentially build tinier scaled-down versions of existing applications. This, however, will not work in making a wearable keyboard for an obvious reason: a keyboard has to be a certain size, with the ultimate limiting factor being the size of a human fingertip—roughly an area of 2 cm^2. The challenge is to create a wearable keyboard without invoking conventional microfabrication.

A research group—which includes Seiichi Takamatsu of the National Institute of Advanced Industrial Science and Technology in Japan, Esma Ismailova and George Malliaras of École Nationale Supérieure des Mines de Saint-Étienne, and their colleagues—has now reported a wearable electrode that is printed on a textile. The team reasoned that if they could create a sensor on a textile, it would make a neat wearable keyboard and entirely circumvent the need for microfabrication.

As reported in a recent issue of Advanced Materials (DOI: 10.1002/adma.201504249), the conductive organic polymer poly(3,4-ethylenedioxythiophene):poly(styrene sulfonate) (PEDOT:PSS), coated with polydimethylsiloxane (PDMS), was used to pattern electrodes. An applied load causes a change in the capacitance response of the device that can be measured with a microcontroller unit. Using a copper electrode to mimic a human finger, the researchers showed that a capacitance of 6 pF is achieved when the textile is touched, and that this response drops only to 5 pF when the textile is stretched by 20%. The device is sensitive enough to measure forces as small as 0.05 N, making these sensors reliable. Stretched beyond 40%, the electrodes lose their conductive properties.

Wearable stretchable keyboard based on conducting polymer electrodes on knitted textile. Credit: *Advanced Materials*.

The team envisions that this technology can be extended to other textiles, such as sports tights, and other applications, such as a touchpad. With no limit on the size of the electrode pattern, these devices could one day even be integrated into furniture and walls. This development has been welcomed by other researchers in the field. Margaret Frey of Cornell University said that this work "represents a significant step toward real wearable technology. With the interface incorporated directly into the knit fabric, the soft, flexible, and breathable aspects of a comfortable and functional garment are maintained."

Vineet Venugopal

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