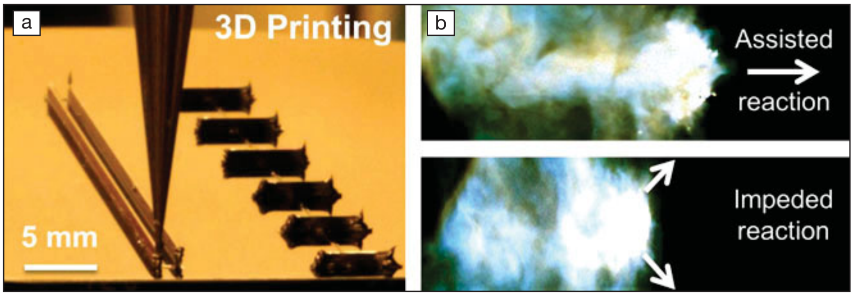
In solar cells, energy is lost due to the cooling of electrons (hot carriers) excited by supra-bandgap photons. The rate at which the hot carriers cool determines whether they can be used to boost the solar-cell efficiency or not. A few groups have used transient absorption (TA) spectroscopy to examine charge-carrier cooling properties of perovskites. In a recent *Nature Communications* article (DOI: 10.1038/ncomms9420), a team of researchers led by Felix Deschler at the University of Cambridge observed a phonon bottleneck phenomenon. In this phenomenon, phonons (heat-carrying quasi-particles) that are formed while the charge carriers cool cannot decay quickly enough. Instead, they re-heat the charge carriers, slowing down their cooling rates.

Matthew Beard and his colleagues at the National Renewable Energy Laboratory also observed this bottleneck in lead iodide perovskites, suggesting that the material could have a theoretical efficiency limit much higher than that of current solar-cell technologies. They found that the phonon bottleneck slowed down charge-carrier cooling by three to four orders of magnitude. So the carriers retain their initial energy for much longer periods of time. This extra energy could potentially be tapped in what is called a hot-carrier solar cell. The results were published recently in *Nature Photonics* (DOI: 10.1038/nphoton.2015.213).

In a promising advance for nanoscale optoelectronic devices, researchers made atomically thin two-dimensional (2D) sheets of organic–inorganic hybrid perovskites. The high-quality single-crystalline 2D $(C_4H_9NH_3)_2PbBr_4$ sheets, which the researchers grew directly from solution, had well-defined square shape and large size. The materials exhibited efficient photoluminescence, and the researchers were able to tune the emission color by changing sheet thickness and material composition. Peidong Yang and his colleagues from the University of California–Berkeley, and ShanghaiTech University in China reported the advance in a recent issue of *Science* (DOI: 10.1126/science.aac7660).

3D printed architectures impart additional control over reactive materials



(a) A three-dimensional printed channel (left) and hurdle (right) architectures composed of silver nanoparticle ink before deposition of the reactive material. (b) Snapshots of the propagating flame being assisted (top) or impeded (bottom) by the architecture. Credit: *Advanced Materials.*

Reactive materials (RMs) are a class of composite materials that, when ignited, produce a sudden release of energy in the form of heat and pressure. Their performance, which can vary based on the choice of constituent materials, is typically midway between that of a propellant and an explosive. This makes them ideal for use in applications that rely on a quick, precise burst of energy such as ejector seats and airbags—situations where fractions of a second can make a world of difference. Recent advances in RM technology have largely focused on improving formulations, for example by altering the size, morphology, assembly, and ratios of the reactive particles. However, while effective in tailoring reactivity, many of these practices are limited by processing constraints or by diminishing returns in performance.

Christopher M. Spadaccini at Lawrence Livermore National Laboratory, Jennifer A. Lewis at Harvard University, and their colleagues have introduced a method of tuning the reactivity of RMs through three-dimensional (3D) printed structures. Their work, published in a recent issue of *Advanced Materials* (DOI: 10.1002/adma.201504286), makes use of modern-day 3D printing techniques to create unique 3D RM architectures that offer an added degree of tunability in energy transport.

The researchers used Al/CuO (thermite) as the reactive material in this work. They evaluated two device architectures, “channels” and “hurdles,” which offer differences in the orientation of the product expansion relative to the direction of intended propagation. First, a custom electrode is 3D-printed with a concentrated silver nanoparticle ink to define the architecture. A conformal film of Al/CuO nanoparticles is then deposited directly onto the printed electrodes through an electrophoretic deposition process.

The researchers studied the combustion process by monitoring the linear flame propagation velocity, a commonly used metric for comparing reactivity, using high-speed videography and varying device architectures, film thickness, and spacing between structures. They found that the orientation and spacing 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.

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

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.

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