size could be reduced to smaller than 10 µm. Moreover, the cycle of erasing and recovery could be reproduced many times (>10 times) without a significant PL decrease. Even after the samples were stored in water or ethanol, these 3D patterns of perovskite QD-doped glasses remained rewritable.

The laser-induced in situ fabrication and decomposition of perovskite QDs in glass opens up new opportunities for various applications. Data storage is one example, with the features of saturated colour, 3D patterning and the high stability of the perovskite QDs in glass offering a long-term medium for recording memorable words. Dong and colleagues also demonstrated that the information could be encrypted. As shown in Fig. 1c, a code of '2018' was fabricated by selective laser irradiation. The code was invisible in daylight but could be decrypted under ultraviolet (365 nm) excitation to induce green PL from the laser-written QDs. After erasure and recovery, the code could be reset into '2019'. Potential applications of the technique include 3D displays, optical data storage and novel optical elements. For example, the technique can potentially be used for volumetric and holographic 3D displays if the writing and erasing time can be reduced to the microsecond scale. The combination of high spatial resolution and tunable PL emission also has the possibility to improve the capacity of data storage.

Going forward, there is still much to explore in the research of in situ fabricated perovskite QDs. First, more needs to be learnt about the chemical and physical processes that occur during the interaction between the laser and perovskites (including precursors). With that, low-temperature processes may be possible. Second, the in situ fabricated perovskite QDs in glass may be highly beneficial for functional optical systems. One possibility is to fabricate advanced micro/nano optical elements with 3D structures. Last but not least, there is plenty of room to further develop low-cost fabrication methodology with precise control.

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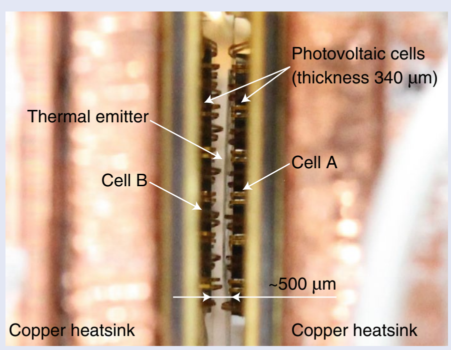
PHOTONIC CRYSTALS

Efficient thermophotovoltaics

Thermophotovoltaic systems that use a photovoltaic cell (PVC) to convert thermal radiation from a hot object into electricity are attracting attention as they potentially offer a high energy density that is comparable to a fuel cell. However, to work well, the emission spectrum of the thermal emitter should match the absorption band of the PVC. In reality, this is often not the case, because the thermal emission spectrum described by Planck's black-body radiation formula is much broader than that of the PVC's absorption, leading to inefficient operation.

Now, Masahiro Suemitsu and co-workers from Kyoto University and Osaka Gas Company Limited in Japan have developed a thermophotovoltaic system based on a custom-designed silicon (Si)-rod photonic crystal (PC) thermal emitter (pictured). Significantly, the system offers a record-high efficiency of operation (ratio of output power to ingoing heat flux) of 11.2% at an emitter temperature of 1,338 K (*ACS Photon*. https://doi.org/10.1021/acsphotonics.9b00984; 2019).

The emitter was fabricated by processing a polycrystalline Si thin film on a 500-µm-thick MgO substrate.



Credit: American Chemical Society

In order to prevent chemical reaction of Si with MgO at the high temperature of operation, a 20-nm-thick HfO_2 layer was deposited between them. Silicon rods (diameter of 360 nm, height 825 nm) were obtained by dry etching and arranged in a rectangular lattice with a lattice constant of 700 nm. "We designed the Si-rod PC in order to suppress thermal emission in the wavelength region where photons are not absorbed by the PVC", Suemitsu said.

A power generation test was implemented in a vacuum chamber. The emitter was suspended with Pt wires and InGaAs single-junction PVCs were placed either side of the emitter at a distance of less than 500 µm away. An M-shaped Pt/Ti heater was attached to the MgO substrate of the Si-rod PC. The directly generated emission from the heater was negligible with respect to that from the emitter since the heater's area is merely 0.6% of that of the emitter. The actual system efficiency gradually increased with the temperature, reaching 11.2% at 1,338 K.

"We believe further increase of the actual system efficiency is feasible," Takashi Asano of Kyoto University, who is the corresponding author of the paper, told *Nature Photonics*. The key strategies in my mind are the finding of a novel thermal radiation material, the development of a novel PC structure and the introduction of near-field thermal radiation transfer."

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