force microscope (CAFM) to switch the GST's phase within nanoscale areas. They changed the color of the affected area, and created images that demonstrate the working principle of a reflective micro-display.

Next, the group moved on from reflective devices to deposit ITO/GST/ITO sandwiches on transparent substrates (quartz). They modulated the optical transmission of such a stack by electrically stimulating the crystallization of the GST layer. The researchers again used a CAFM to serially render high-resolution images, now demonstrating the principle behind a transmissive micro-display. Potential uses of fast, low-power, semi-transparent displays include wavelength-tunable windows, windshield displays, or even synthetic retina devices.

The layered films are very thin, and the techniques described were also demonstrated on flexible substrates and displays, enabling the creation of PCM-based pliable, electronic paper. Harish Bhaskaran, who led the work, said, "This optoelectronic framework has many likely applications, such as ultrafast, entirely solid-state displays, or supple, 'smart' contact lenses."

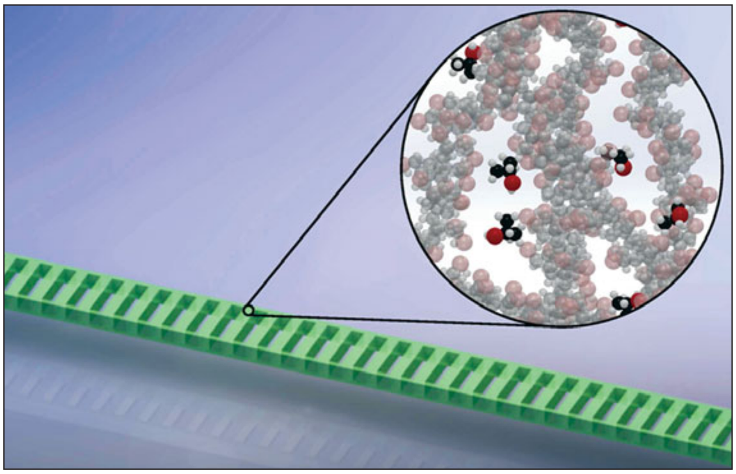
Rich Louie

Optical sensors swell when exposed to a target gas

Using microscopic polymer light resonators that expand in the presence of specific gases, Dirk Englund's research team at the Massachusetts Institute of Technology has developed optical sensors with predicted detection levels in the parts-per-billion range. Optical sensors are ideal for detecting trace gas concentrations due to their high signal-to-noise ratio, compact, lightweight nature, and immunity to electromagnetic interference.

Although other optical gas sensors have been developed before, Englund's team conceived an extremely sensitive, compact way to detect vanishingly small amounts of target molecules. As reported in the June 16 issue of *Applied Physics Letters* (DOI: 10.1063/1.4879735; 241108), the researchers fabricated wavelength-scale photonic crystal cavities from PMMA, an inexpensive and flexible polymer that swells when it comes into contact with a target gas. The polymer is infused with a fluorescent dye, which emits selectively at the resonant wavelength of the cavity through a process called the Purcell effect. At this resonance, a specific color of light reflects back and forth a few thousand times before eventually leaking out. A spectral filter detects this small color shift, which can occur at even subnanometer level swelling of the cavity, and in turn reveals the gas concentration.

"These polymers are often used as coatings on other materials, so they're abundant and safe to handle. Because of their deformation in response to biochemical substances, cavity sensors made entirely of this polymer lead to a sensor with faster response and much higher sensitivity," said PhD student Hannah Clevenson, who led the experimental effort in Englund's laboratory.



High-sensitivity detection of dilute gases is demonstrated by monitoring the resonance of a suspended polymer nanocavity. The inset shows the target gas molecules (darker) interacting with the polymer material (lighter). This interaction causes the nanocavity to swell, resulting in a shift of its resonance. Credit: H. Clevenson/MIT.

PMMA can be treated to interact specifically with a wide range of different target chemicals, making the researchers' sensor design highly versatile. There's a wide range of potential applications for the sensor, said Clevenson, "from industrial sensing in large chemical plants for safety applications, to environmental sensing out in the field, to homeland security applications for detecting toxic gases, to medical settings, where the polymer could be treated for specific antibodies."

The thin PMMA polymer films, which are 400 nm thick, are patterned with structures that are 8–10 μm long by 600 nm wide and suspended in air. In one experiment, the films were embedded on tissue paper, which allowed 80% of the sensors to be suspended over the air gaps in the paper. Surrounding the PMMA film with air is important, Clevenson said, both because it allows the device to swell when exposed to the target gas, and because the optical properties of air allow the device to be designed to trap light traveling in the polymer film.

The researchers, including Pierre Desjardins and Xuetao Gan, found that these sensors are easily reusable since the polymer shrinks back to its original length once the targeted gas has been removed.

The current experimental sensitivity of the devices is 10 parts per million, but the team predicts that with further refinement, they could detect gases with part-per-billion concentration levels.