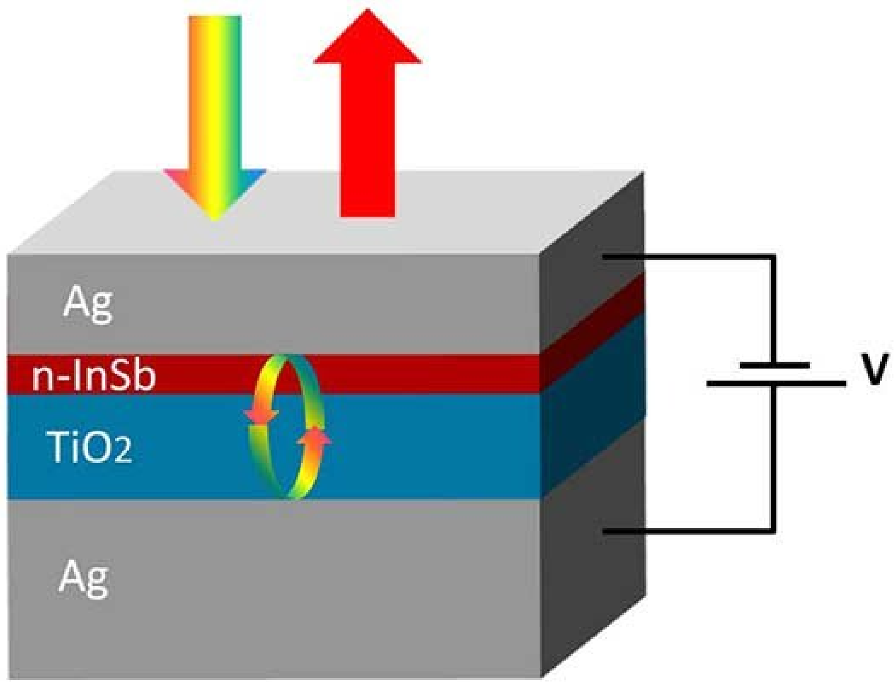
Researchers get on consumers' wavelength with InSb technology

April 30 2018, by Taralyn Caudle



Schematic structure of an electrically tunable perfect light absorber.

The technology for controlling light absorption at selected wavelengths in nanostructures has garnered much attention in recent years; however, dynamically tuning absorption wavelengths without also changing the geometry of their structure has been somewhat elusive. A recently published paper in *Scientific Reports* by Dr. Don Gregory, distinguished professor in the Department of Physics and Astronomy at The

University of Alabama in Huntsville (UAH), and his Ph.D. student, Seyed Sadreddin Mirshafieyan, proposes a solution for doing just that.

Their paper, "Electrically tunable perfect light absorbers as color filters and modulators," theorizes how voltage, when applied to a nanocavity structure made of an epsilon-near-zero (ENZ) material such as indium antimonide (InSb), allows for real-time manipulation of absorption wavelengths and device colors, which could lead to significant advances in displays, switching, sensors, and spectral analysis.

State-of-the-art technology in color filters uses what's known as a Fabry-Perot nanocavity made up of thin semiconductor and metal films to absorb light at selected wavelengths. Dr. Gregory describes this nanocavity as analogous to having two mirrors, one highly reflective and the other partially transmitted, with light entering the partially transmitting mirror and bouncing off the perfectly reflecting mirror. "If the mirror spacing is just right, you get constructive interference between light traveling in the two different directions," he says. "That means that you can pick what wavelength gets reflected from that surface." In other words, the absorption wavelength – or the color that gets reflected back to the eye – is controlled by the thickness of the nanocavity.

Until now, that thickness has been determined by fixed layers tuned for one particular color or another. "That means for a particular layer of thickness and a particular number of layers, you get a particular color reflected from that combination," Dr. Gregory explains. "You have to change the thickness of the layers to get a different color, but the idea in this paper is that we can build these different materials and electrically control the light that's reflected back. So we could tune it for green light, blue light, red light by changing the voltage across the layers."

Under Dr. Gregory's supervision, Mirshafieyan has modeled a structure capable of being electrically tuned for different absorption wavelengths and a first draft of his Ph.D. dissertation has been completed.

The structure comprises an ultrathin, nanometer-thick ENZ material called InSb and a titanium dioxide (TiO_2) layer sandwiched between two silver mirrors. The total thickness of the device including the mirrors, InSb, and TiO_2 is less than 200 nm, which is 500 times thinner than human hair. InSb is a III-V semiconductor whose carrier density (when it is doped) is ideal for electrically induced carrier modulation, making it behave more like a metal under the right applied voltage. Aware of several previous but often incomplete attempts to achieve electrically tunable perfect light absorbers, Mirshafieyan notes, that "researchers have already shown that if you change the thickness of the cavity, you can change the color, but that is difficult in real-time display applications because the thickness of each pixel is fixed. We want to change the color of each pixel dynamically without physically changing the thickness of that pixel."

With these materials, the index of refraction changes with the doping that's used inside the material, which Dr. Gregory explains is how many electrons or holes you've added to the basic semiconductor material. "So, you can change its conductivity, its resistivity in the making of the material or you can do it with applied voltage," he says. "You don't have to physically change the separation between mirrors." This can be more difficult than it sounds depending on the circumstances. "It's easy enough to do it in the lab with two mirrors. We can change the spacing between the mirrors and we can get different color light reflected," he says. "But to have two mirrors that are fixed and then changing the index of refraction of the material inside, electrically, in real time, that's tough."

This doping also means there is no need for nanopatterning or the creation of additional exotic materials, and it's this distinction that separates Mirshafieyan's structure from previous iterations that called for changes in structural geometry – a distinction that also has implications for the telecommunications industry.

Being able to change the index of refraction easily with a low applied voltage also helps explain why the use of InSb as opposed to say, silicon, may prove a better material option in the telecommunications or switching industry. Applying voltage to switches with an active layer of InSb increases the carrier density, and consequently, the permittivity, which leads to a greater change in refractive index. "It's the difference between off and on that really matters," says Dr. Gregory. "We get much higher difference between off and on, which means that we can run with a much lower error rate. And error rate is everything in telecommunications." The result, therefore, is very high speed switching.

Silicon, on the other hand, does not produce much change in index with an applied voltage. Even with the addition of other materials designed to improve switching, silicon can't currently match the fidelity of InSb.

Dr. Gregory also anticipates that this technology could replace silicon in switching altogether. And while the use of InSb isn't necessarily cheaper, it could prove more cost effective in the long run because of improved bit error rates, which people would be willing to pay for.

As for display applications, this technology could generate even thinner and faster displays than are currently on the market, without the same quality control issues.

Current LCD and LED technology consists of several different components besides the liquid crystal itself. "And each stack has a thickness," says Mirshafieyan. "But with InSb technology, you can combine everything. It is itself a color filter." As a result, a much thinner, faster, higher-resolution display is possible.

"If you've ever tried to watch a hockey game on a liquid crystal TV, you can't follow the puck on the ice at all, and that's because the TV can't run at high-enough rates," says Dr. Gregory. This is because of the image distortions created by the variation in the layers of many liquid crystal displays and the basic reaction speed.

However, these quality control issues could be eliminated with the technology that Dr. Gregory and Mirshafieyan are proposing because it would allow for decreased pixel size. "We can create very small pixels with this technology because it doesn't have any nanopatterning that limits the fabrication process," Mirshafieyan says. "We can make ultra-ultrasmall pixels with distinct colors and that will improve the quality of the display well beyond what's available now."

More information: Seyed Sadreddin Mirshafieyan et al. Electrically tunable perfect light absorbers as color filters and modulators, *Scientific Reports* (2018). [DOI: 10.1038/s41598-018-20879-z](https://doi.org/10.1038/s41598-018-20879-z)

Provided by University of Alabama in Huntsville

Citation: Researchers get on consumers' wavelength with InSb technology (2018, April 30) retrieved 10 April 2024 from https://phys.org/news/2018-04-consumers-wavelength-insb-technology.html