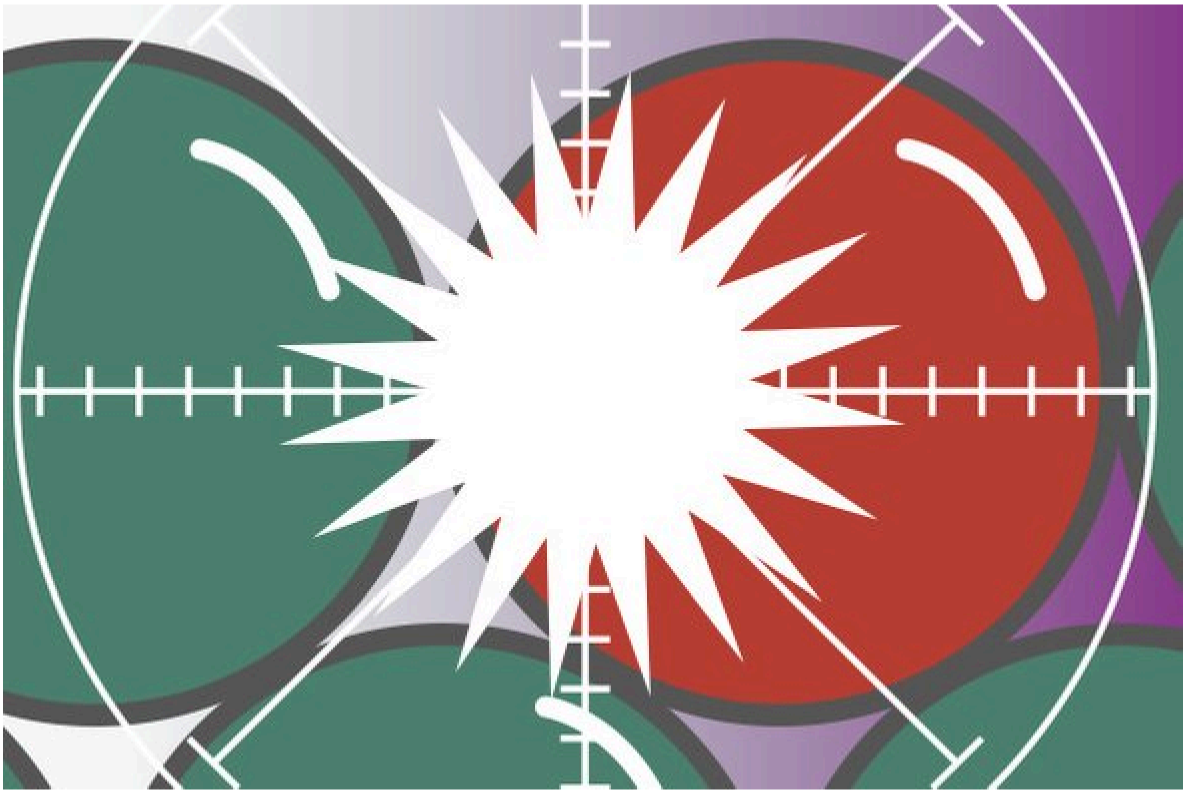
Light-controlled nanomaterials are revolutionizing sensor technology

Writing in *Scientific American* in 2007, Harry A. Atwater of the California Institute of Technology predicted that a technology he called “plasmonics” could eventually lead to an array of applications, from highly sensitive biological detectors to invisibility cloaks. A decade later various plasmonic technologies are already a commercial reality, and others are transitioning from the laboratory to the market.



These technologies all rely on controlling the interaction between an electromagnetic field and the free electrons in a metal (typically gold or silver) that account for the metal's conductivity and optical properties. Free electrons on a metal's surface oscillate collectively when hit by light, forming what is known as surface plasmon. When a piece of metal is large, the free electrons reflect the light that hits them, giving the material its shine. But when a metal measures just a few nanometers, its free electrons are confined in a very small space, limiting the frequency at which they can vibrate. The specific frequency of the oscillation depends on the size of the metal nanoparticle. In a phenomenon called resonance, the plasmon absorbs only the fraction of incoming light that oscillates at the same frequency as the plasmon itself does (reflecting the rest of the light). This surface plasmon resonance can be exploited to create nanoantennas, efficient solar cells and other useful devices.

One of the best studied applications of plasmonic materials is sensors for detecting chemical and biological agents. In one approach, researchers coat a plasmonic nanomaterial with a substance that binds to a molecule of interest—say, a bacterial toxin. In the absence of the toxin, light shining on the material is reemitted at a specific angle. But if the toxin is present, it will alter the frequency of the surface plasmon and, consequently, the angle of the reflected light. This effect can be measured with great accuracy, enabling even trace amounts of the toxin to be detected and measured. Several start-ups are developing products based on this and related approaches—among them an internal sensor for batteries that allows their activity to be monitored to assist in increasing power density and charge rate and a device that can distinguish viral from bacterial infections. Plasmonics is also working its way into magnetic memory storage on disks. For instance, heat-assisted magnetic recording devices increase memory storage by momentarily heating tiny spots on a disk during writing.

In the medical field, light-activated nanoparticles are being tested in clinical trials for their ability to treat cancer. Nanoparticles are infused into the blood, after which they concentrate inside a tumor. Then light of the same frequency as the surface plasmon is shone into the mass, causing the particles to heat by resonance. The heat selectively kills the cancer cells in the tumor without hurting surrounding healthy tissue.

For more information: https://www.scientificamerican.com/article/plasmonic-materials/