Sandia's INNOVATION MARKETPLACE

A QUARTERLY UPDATE OF AVAILABLE TECHNOLOGIES FOR INDUSTRY

Sandia's Infrared Technologies

Sandia National Laboratories

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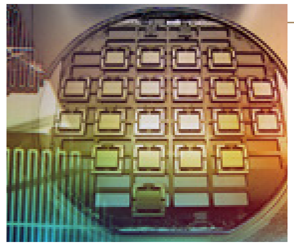
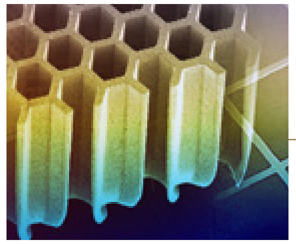
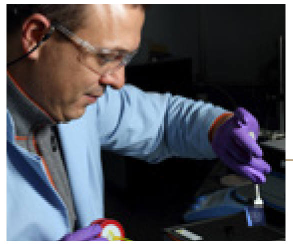
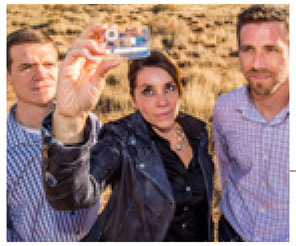






Infrared Technologies

Photodetectors are widely used for sensing light radiation or other forms of electromagnetic energy. Depending on the application, photodetectors must fulfill a variety of requirements such as measuring radiation, generating voltage, or amplifying a current. Infrared radiation (IR) is a particular region of interest since objects can continually exchange energy with the radiation field at ambient temperatures. In turn, we can study properties such as temperature and emissivity of objects within our immediate environments. Applications of IR photodetectors include: aircraft and aerospace, microelectronics, medical devices, and semiconductors. Continue reading to find out more about Sandia's IR photodetector technologies.

Lateral Conduction Infrared Photodetector *improves carrier mobility while reducing surface recombination*

Ordinary mid-infrared focal plane arrays are created from antimonide-based type-II superlattices which promise operation at higher temperatures due to the suppression of recombination. To improve on current technologies, Sandia developed a photodetector comprised of a semiconductor substrate made of gallium antimonide or alternate substrate. The layers are grown epitaxially, forming a mesa structure and superlattice that contains alternating layers of InAs and InGaSb. Along the sidewalls of the structure are impurity doped regions that allow lateral conduction of photo-generated carriers, thereby increasing carrier mobility while reducing surface recombination. An advantage of this photodetector is its ability to be used as either a single- or multi-color device while also being used to form a focal plane array that can be used in conventional integrated circuits.

Reduced Dark Current Photodetector *eliminates various noise barriers to detect near-infrared light*

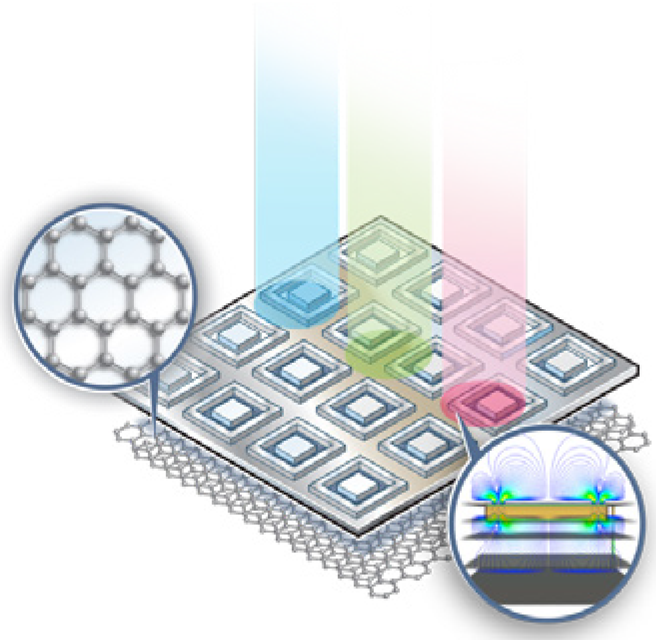
In low-light settings, the sensitivity of photodetectors can be limited by various sources of noise. This can create a dark current in the absence of any light incident on the photodetector. To overcome this barrier, Sandia created a photodetector that employs the use of a barrier layer responsible for separating the light-absorbing layer from the contact layer. The barrier produces reduced flow of minority electron carriers from the light-absorbing to the contact layer. As a result, the photodetector can detect near-infrared light with or without the use of an applied reverse-bias voltage. Sandia's photodetector eliminates surface leaking currents, decreasing the dark current and can operate in the near-infrared region of about 0.9-1.7 microns.

Infrared Nanoantenna *may be coupled with various components to provide a new way to detect IR radiation*

Sandia has developed an infrared nanoantenna apparatus comprised of a photodetector with a semiconductor body, a patterned metal nanoantenna, and at least one electrode separate from the nanoantenna. The semiconductor body has an active layer that allows for plasmonic coupling with the antenna. The antenna itself is made to absorb electromagnetic radiation. The apparatus can be formed as a focal plane array with the semiconductor body divided into pixels, while the electrode captures image information. Sandia's invention opens up new opportunities within photonic devices not offered with conventional optic devices—the frequency selective surface does not adversely affect the transmission of the frequency band, thereby enhancing optical performance. In addition, infrared antennas may be electronically coupled with other components to provide new methods of IR detection and energy harvesting of IR radiation.

Frequency Selective Infrared Sensors *can be integrated and customized to fit various needs*

Sandia has developed a frequency selective infrared photodetector with a pre-determined frequency band. The photodetector is comprised of a dielectric IR absorber, an electronically-coupled electrode, and a frequency selective surface plasmonic structure (FSSP). The FSSP structure can selectively transmit radiation within the predetermined frequency band of the radiation incident on the FSSP structure, while remaining independent from the angle of radiation incidence. Sandia's photodetector can be customized and modified to suit a variety of needs, including but not limited to rectennas, focal plane arrays, and waveguide sensors.



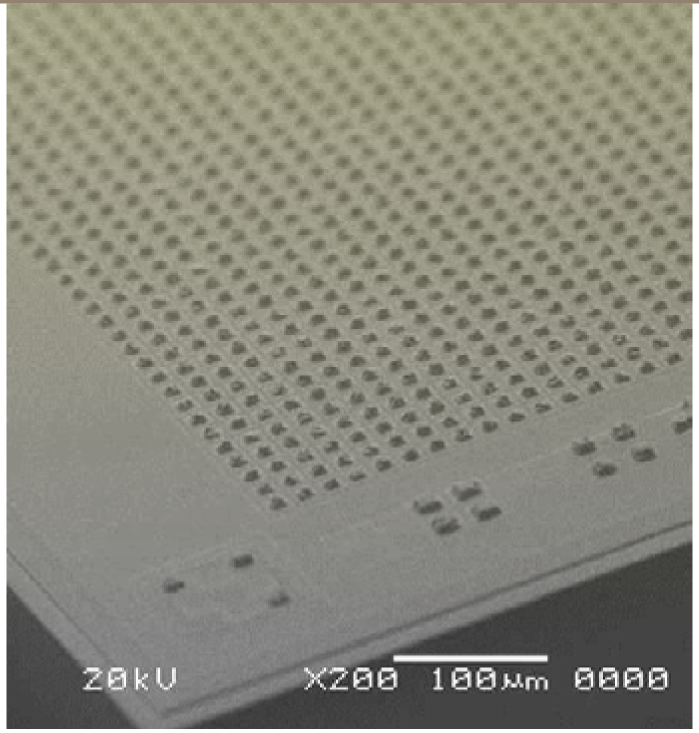
Strain-Compensated Infrared Photodetector *is comprised of multiple tensile-strained layers that increase cutoff wavelength*

Current midwave infrared (MWIR) photodetectors use a single light-absorbing layer that is constrained by its wavelength of detection, limited at 3.4 micrometers. Sandia developed a photodetector comprised of multiple tensile-strained layers made of various compound semiconductor materials. The tensile-strained layers are scattered between light-absorbing layers made from indium gallium arsenide, which allows users to increase of the amount of the element antimony within the InAsSb light-absorbing layers, thereby increasing the cutoff wavelength to around 4.5-10 micrometers at a temperature of 160 Kelvin or less. Sandia's photodetector is functional on its own, or could be combined to form a focal plane array.

Two-Color Infrared Detector

allows continuity between interfaces thereby increasing responsivity

Conventional two-color detectors utilize absorber layers that produce varying valance band energies, which can inadvertently cause discontinuity between the layers. This can reduce the detector's responsivity while promoting leakage currents. To address the shortcomings of conventional detectors, Sandia has developed a two-color infrared detector comprised of multiple layers. The first layer is an absorbance layer that exhibits the first valence band energy. A barrier layer connects the first absorbance layer while exhibiting a second valence band energy. The barrier layer also adjoining a second absorber layer creating a third valence band energy. Sandia's photodetector allows both functional and physical continuity between each interface by reducing unintentional hole barriers without the need for high doping or high bias requirements.



Strained-Layer Superlattice Focal Plane Array *reduces potential surface recombination*

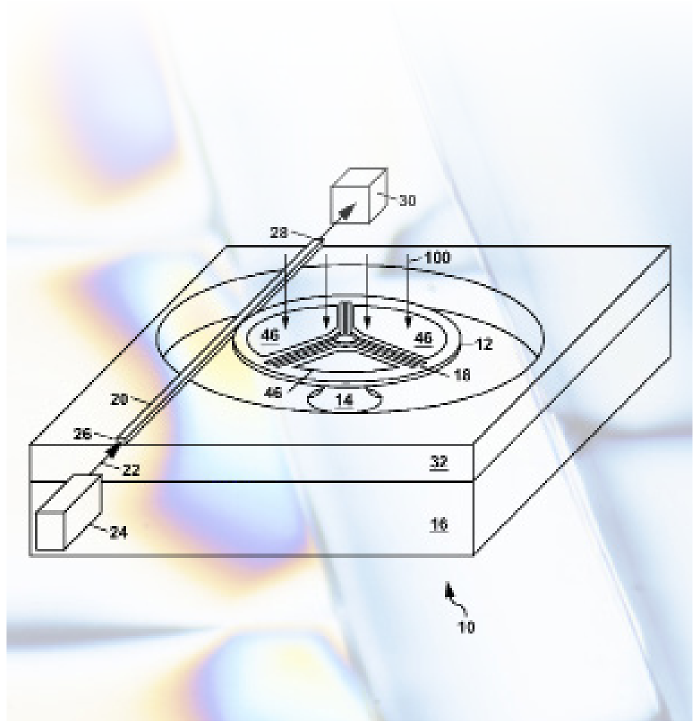
Sandia developed an infrared focal plane array photodetector that utilizes a strained layer superlattice comprised of alternating layers of InAs and InGaSb semiconductor materials. Sandia's invention improves upon current state-of-the-art technology by providing users a substantially planar geometry, allowing a two-dimensional array of photodetectors containing multiple semiconductor layers that remain continuous without a break. The present invention avoids the use of a mesa structure to isolate each photodetector element. Instead, the focal plane array uses impurity-doped regions formed within or about each photodetector for electrical isolation. As a result, the focal plane arrayremains planar, allowing the superlattice to remain unbroken and thereby reducing or eliminating any potential surface recombination. Sandia's focal plane array has applications in the wavelength range of 3-25 micrometers.

Thermal Microphotonic Sensors

represent a highly-sensitive alternative to conventional infrared imaging systems

There are various infrared imaging sensors currently on the market, including bolometers and quantum detectors. While these detectors are highly sensitive, they require a significant amount of cooling—down to cryogenic temperatures. As a result, the process of cooling down these detectors takes considerable amount of electrical power and typically requires a cryostat, which can limit the scaling of detector to larger sizes.

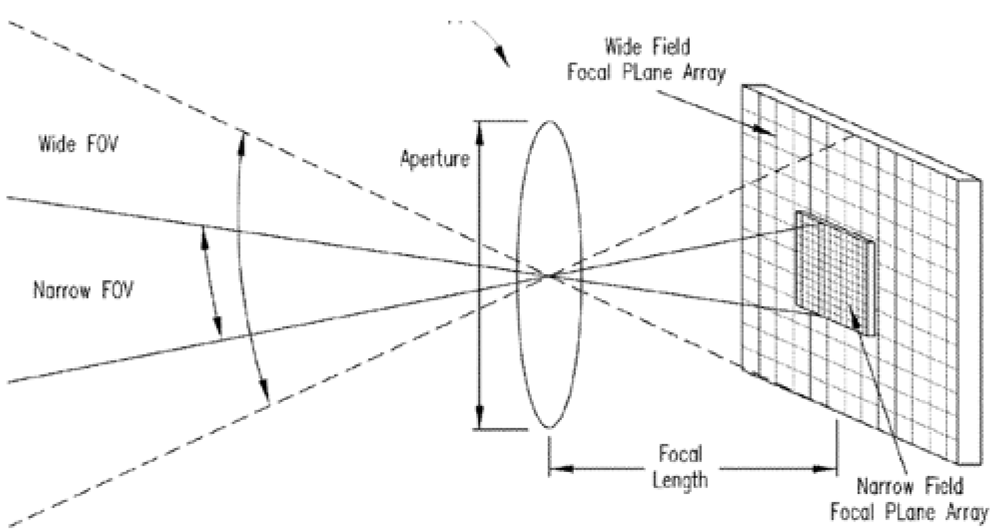
In response, Sandia developed a method to fabricate thermal microphotonic sensors onto a silicon substrate by etching an opening and a trench into the substrate, which is then filled with silicon oxide. This makes the sensor useful in detecting infrared radiation via a change in the evanescent coupling of light between the waveguide and resonator. The sensors can detect infrared radiation by using heat produced by infrared radiation to change a coupling of light between an optical waveguide and resonator. The sensors can be used singularly or be formed into an array, the latter of which is useful for infrared imaging applications.

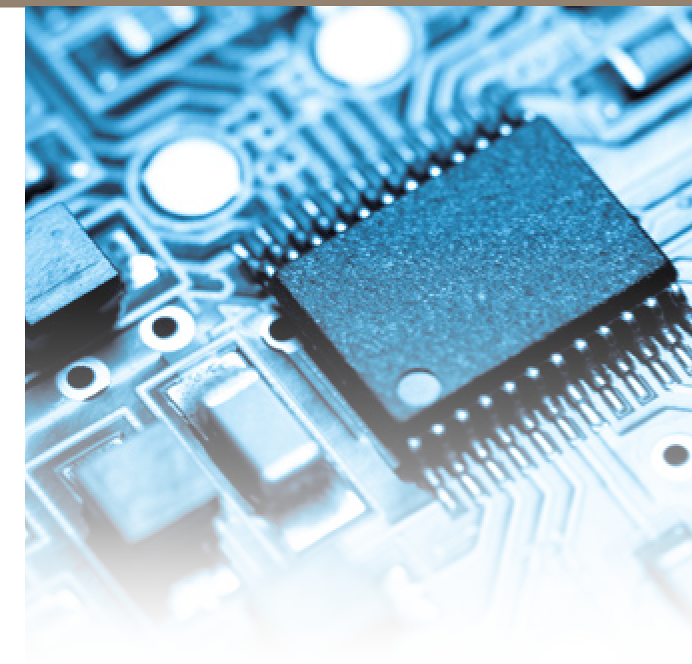


Scalable Focal Plane Array with Modular Pixel Components allows users to produce a large pixel array

Conventional imaging systems contain a focal plane array with light-sensing pixels but provide a limited field of view. In order to expand the desired field of view, the size of the FPA must be increased by increasing the size of the integrated circuitry die area to accommodate for a larger area of pixel array circuitry. However, this may pose a problem from a manufacturability standpoint, as the acceptable die yield decreases with increasing die size.

To address this problem, Sandia developed a modular, scalable focal plane array with integrated circuit dice. Each dice within the focal plane array has a given amount of modular pixel array circuitry. Arranging the dice into an array multiples the amount of modular pixel array circuitry available, thereby producing a larger pixel array without interfering with the die size. In addition, Sandia's focal plane array allows users to preserve pixel pitch by forming die stacks comprised of the pixel array circuitry die formed on a separate die with corresponding signal processing circuitry.





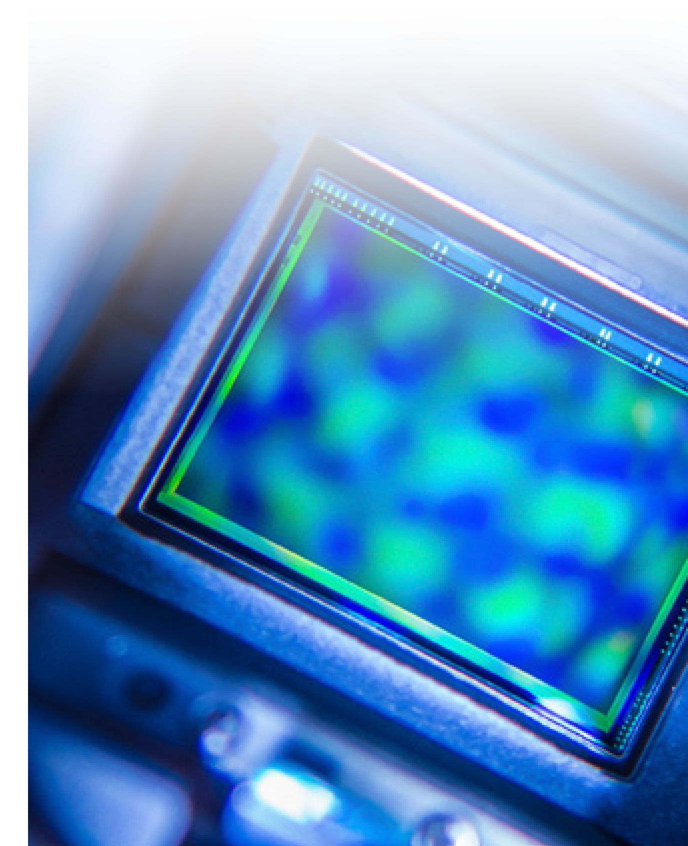
Smart Trigger Logic for Focal Plane Arrays captures light intensity data values even with continuous exposure to light

Conventional charge-coupled devices and other photoelectric image sensors capture image data. The sensors are made into a grid containing light-sensing pixels; each grid can range anywhere form tens of pixels to millions of pixels. These light-sensing pixels are especially useful for applications such as cameras, however, continuous exposure to light (i.e. video camera) can cause difficulties in processing and transferring data from the pixels since the transmission bandwidth is limited.

To address the problem, Sandia developed an electronic device that can effectively collect and transmit focal plane array data. The current invention is comprised of a memory configured to receive light intensity data values from focal plane array pixels, in addition to a processor that analyzes the data to determine which light values correspond to which triggered pixels. Sandia's invention can be scaled to use in computer systems to effectively analyze the light intensity data and can be practiced in a variety of networked computing environments, ranging from personal computers to multi-processors systems, allowing for ease of use.

Polarization-Sensitive Image Sensor captures polarization information from infrared images

Conventional infrared imaging systems are limited by their inability to capture movement. In response, Sandia has developed a polarization-sensitive infrared imaging sensor that utilizes fiber optics. The use of fiber optics reduces the amount of cross-talk between adjacent pixels and while improving the extinction ratio of the sensor. Sandia's sensor is comprised of a two-dimensional array of polarizers that receive and filter incoming infrared light according to its polarization, which is then transmitted to an exit end of the optical fibers. The 2-D array of photodetectors that detect the filtered infrared light can then generate a polarization-sensitive image of the scene. The polarizers are placed facing a 2-D array of light retarders to minimize diffraction. Sandia's imaging system allows users to extract polarization information from an infrared image in real-time.



Thin Film Electrode Synthesis

represents a fast and inexpensive integrated power source for MEMS technology

The development of small, light-weight power sources is driven by the need for smaller electronic devices and emerging technologies, such as microelectromechanical systems (MEMS). Due to the size constraints of such a technology, there is a need to create an integrated power source that will not substantially increase the weight or size of the device. To address this problem, Sandia developed a method of synthesizing a thin film battery using alkoxide compounds. A precursor layer is formed and deposited as a thin film, then heated to 650°C to crystallize it into ceramic. Multiple layers are deposited, with each layer being approximately 500-1000 angstroms in thickness, and possess electrochemical properties. Sandia's method of synthesis represents a fast and inexpensive approach that can be conformally coated onto a variety of surfaces as a thin layer device.

Applications and Industries

- Electronics
- Solar cell storage
- Wireless sensors
- Medical devices

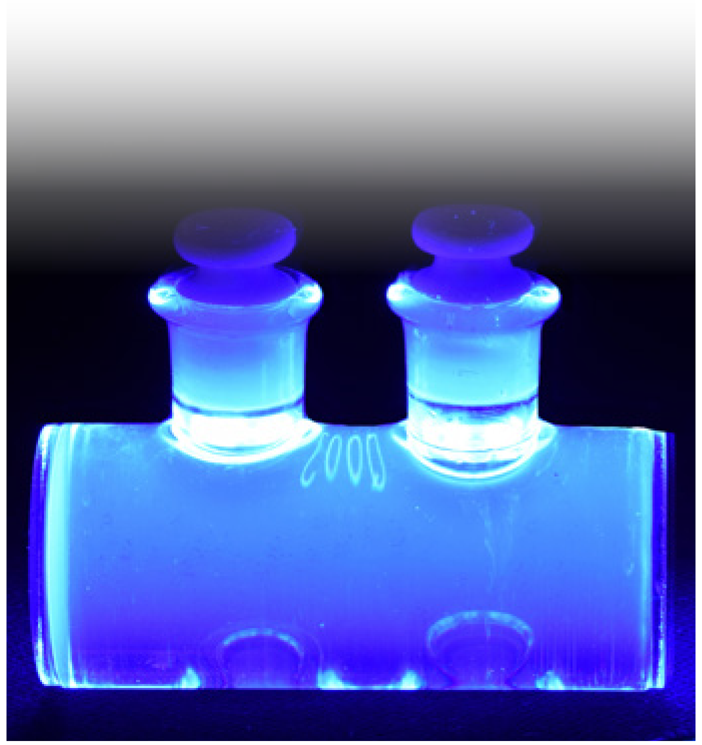
Class of Hybrid Liquid Scintillators

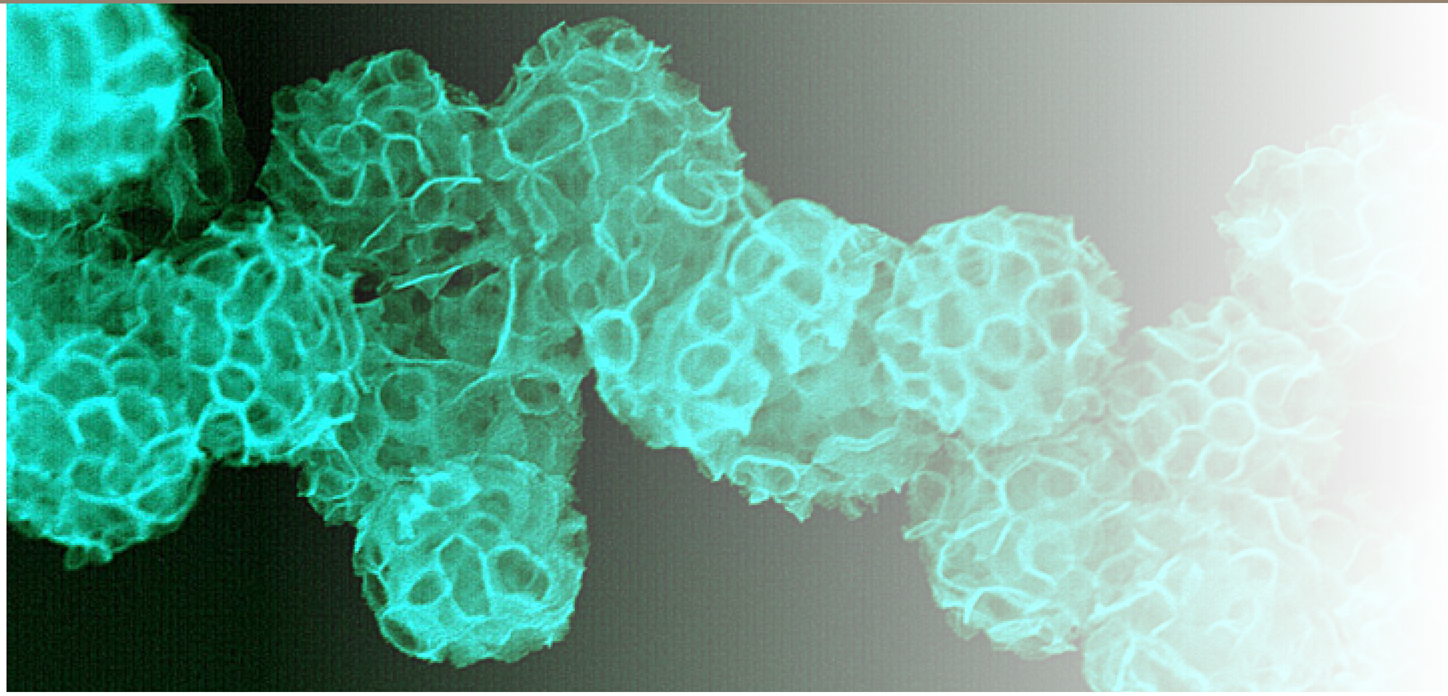
improves detection of nuclear materials while reducing costs and environmental hazards

Scintiallors exhibit the property of luminescence when excited by ionizing radiation. Sandia has developed a class of hybrid liquid scintillators for the improved detection and discrimination of nuclear threat materials. The technology is comprised of three key components: 1) at least one surfactant or emulsifier; 2) a polar hydrogen-bond solvent and; 3) at least on luminophore. One embodiment of the invention comprises a water-based mixture that enables fast neutron/gamma-ray discrimination, which can identify illicit nuclear materials. The application of water-based mixtures also enables large-scale deployment at lower cost and greatly reduces environmental hazards in comparison to traditional liquid scintillators.

Applications and Industries

- Nuclear nonproliferation
- Radiation detection
- Homeland security
- High-energy physics





Synthesized Porphyrins *are light-absorbing molecules that can be used to make nanodevices with a wide range of optical and electronic properties*

Porphyrins are a class of organic molecules comprised of four subunits of pyrrole rings, which are pentagon-shaped rings made of four carbon atoms and one nitrogen atom in the corner. They are similar to chloroplasts in its light-absorbing properties, which plays an active role in photosynthetic proteins and light-harvesting nanostructures.

Sandia has developed a method of synthesizing metal nanostructures comprised of porphyrins. These nanostructures have wide applicability, especially in the realm of electronics due to advantages such as: increased surface area, low density, low material cost, and special optical properties. Sandia's method of growing nanoshells requires a photocatalytic reduction of metal ions at the interface between the dispersed and continuous phases of an emulsion. The emulsion droplet serves as a template for hollow-nanoshell growth. The photocatalytic reaction is carried out by a specialized porphyrin and causes subsequent growth of the nanoshells. The size of the shell is controlled by the size of the emulsion droplet, while the wall thickness depends on metal ion availability.

Sandia also created a nickel-porphyrin derivative that can be used in optical memory applications that require fast-switching times and long data-retention times. The nickel-porphyrin derivative is comprised of a low-energy-state and high-energy-state isomer while suspended in a gel or solvent matrix. The energy states are analogous to "on" and "off" switches, providing the user with the ability to controllably switch from energy state to another, making it appealing for molecular-scale optical memory applications.

Applications and Industries

- Electronics
- Microelectronics
- Photonic devices
- Electro-optical devices
- Chemical sensors

Recent Industry Impacts

Bacillus anthracis is a bacterium responsible for the disease anthrax, and is commonly found in agricultural soils all over the world. Sandia developed a portable device the size of a credit card that can detect the presence of B. anthracis spores and requires no battery and electricity to operate. Through the process of amplification, Sandia's device can detect to up to as little as one hundred B. anthracis spores. A trained technician can place a small sample swab into an amplification chamber and through the process of lateral flow assay, a colored line appears on the device to signify that the test is positive for the bacterium.

Sandia's technology was recently awarded the Federal Laboratory Consortium's (FLC) 2015 Award for Excellence in Technology Transfer. The annual award is to recognize employees of FLC member laboratories and non-laboratory staff who have accomplished outstanding work in transferring federally developed technology. In addition, BaDx was recently licensed to a New Mexico small business that specializes in the design and development of technologies for nuclear security and international safeguards.

Did you know that Sandia's decontamination foam cleaned up 53 of 56 buildings exposed to anthrax during the 2001 Amerithrax attack?

While chemical and biological terrorism recently gained attention in the past decade due in part to the 2001 Amerithrax attack, it possesses the potential to cause significant harm in modern-day society. Before the attack, Sandians Mark Tucker and Maher Tadros were quickly developing a decontamination foam, designed to neutralize both chemical and biological agents within minutes. Sandia's foam serves as a first line of defense in the event of a chem-bio attack. Aa Tadros puts it, "Whatever you do, it's best to ask very quickly. This foam can start neutralizing an agent or combination of agents right away, even before you know what you're dealing with." In laboratory tests, the foam destroyed stimulants of the most worrisome chemical agents such as VX, mustard and soman. The foam also proved to be exceptionally effective at killing anthrax, achieving what researchers called a 7-log kill—after one hour only one anthrax spore out of 10 million is alive.

It should come as no surprise then that after the 2001 Amerithrax attack, Sandia's foam was immediately put to the test. The federal government contacted EnviroFoam Technologies, a licensee of the decontamination foam, to help decontaminate the Hart Senate Office Complex and Dirkson Congressional Offices in Washington, D.C., both of which were thought to have been contaminated with trace levels of anthrax.

Since its inception, the foam has been modified to fit a variety of needs, including meth lab cleanup, mold cleanup, and much more. The foam represents a staple technology cornerstone for Sandia and will continue to have an impact for years to come.

Intellectual Property Creation

Sandia's intellectual property results primarily from R&D conducted for the government in the national security sector. We collaborate with industry, leveraging each other's strengths to develop innovative technology. We perform internal R & D directed at the most challenging issues in national security, for which breakthroughs would provide exceptional value to government and industry. All totaled, Sandia has more than 1200 patents and 500 commercial copyrights, the bulk of which are available for licensing.
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- Test and Evaluation License
- License Option
- Government Use Notice

Sandia is mandated by the Department of Energy to move its technology to the marketplace for the benefit of the U.S. economy. Given our national security focus, government is the primary customer for many Sandia licensees, but our technologies also find use in the industrial and consumer markets. Sandia issues licenses to companies ranging in size from start-ups to multinationals. Our qualification procedure considers a company's ability to bring a product to market as conveyed by their business plan, among other factors. The possibility to create a new company that can leverage our technology and achieve substantial growth is also important, given our interest in entrepreneurship.

Licensing Practices

- License term usually runs the length of the patent or copyright. Terms for Test and Evaluation licenses and License Options are limited in time.

- Financial consideration may include an upfront license fee, annual license fee, milestone fee, or running royalty, as appropriate. We seek an equitable return to the laboratory without impeding the licensee's ability to successfully commercialize the technology.

- Performance requirements may be established to insure the licensee is diligent in their commercialization plan.

- Licenses may be limited by field of use, region, or period of restraint. Non-exclusive licenses are preferred, but we consider exclusive licenses when the business case is justified. Exclusive licensing requires a competitive assessment of potential licensees to select the one having the highest probability of success. Performance requirements are also more stringent.

- Commercial licensees must substantially manufacture their product in the U.S., given the Department of Energy's intent to provide benefit to the U.S. economy.

- The U.S. government retains a right to use the technology for government purposes.

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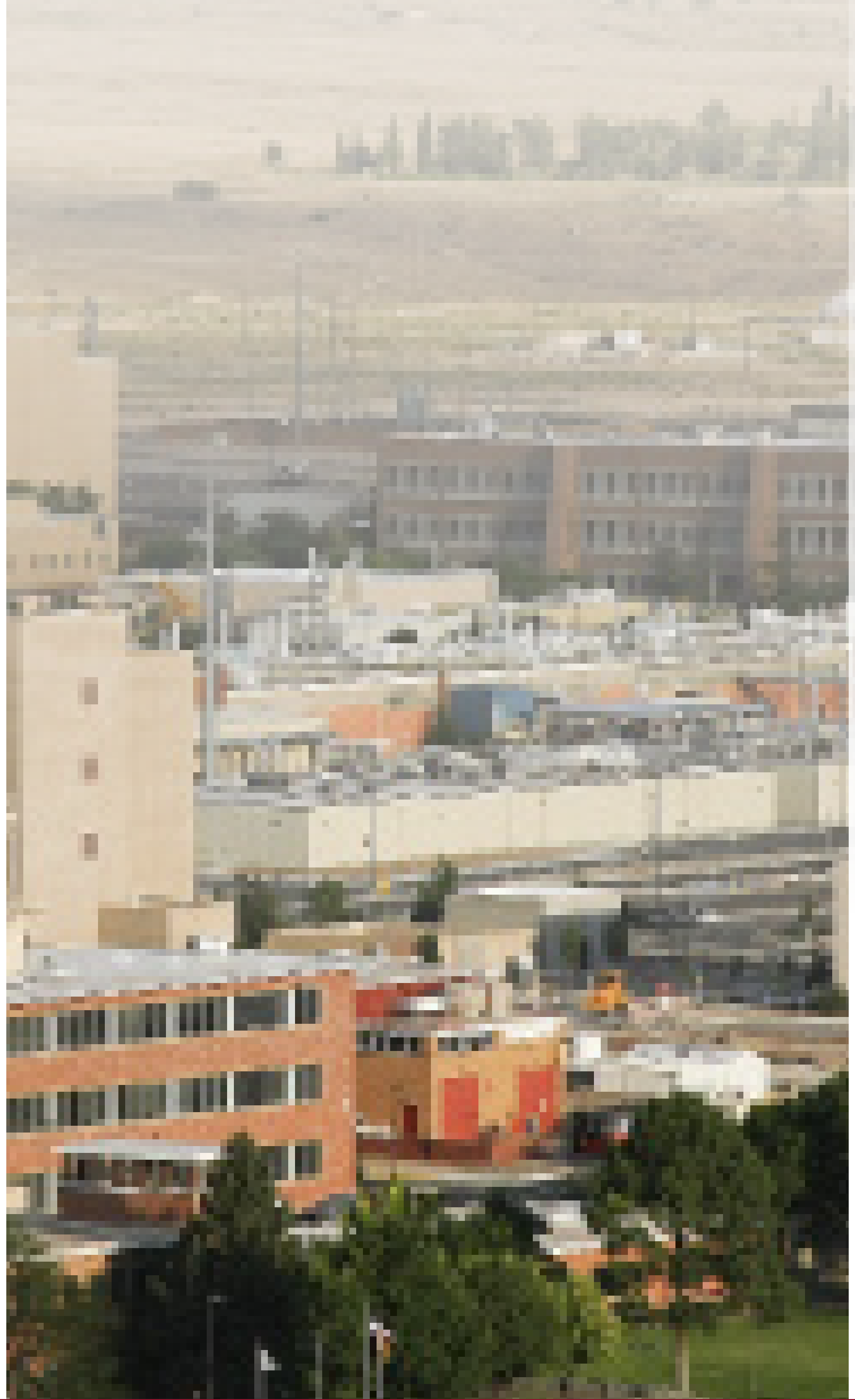

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