

Application Note

What Is InGaAs?

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InGaAs, or indium gallium arsenide, is an alloy of gallium arsenide and indium arsenide. In a more general sense, it belongs to the InGaAsP quaternary system that consists of alloys of indium arsenide (InAs), gallium arsenide (GaAs), indium phosphide (InP), and gallium phosphide (GaP). As gallium and indium belong to Group III of the Periodic Table, and arsenic and phosphorous belong to Group V, these binary materials and their alloys are all III-V compound semiconductors.

Why go to all the trouble?

To a large extent, the electrical and optical properties of a semiconductor depend on its energy bandgap and whether the bandgap is "direct" or "indirect." The energy bandgaps of the 4 binary members of the InGaAsP quaternary system range from 0.33 eV (InAs) to 2.25 eV (GaP), with InP (1.29 eV) and GaAs (1.43 eV) falling in between. At SUI we emphasize photodetectors, so we care most about the optical properties of semiconductors. A semiconductor will only detect light with photon energy larger than the bandgap, or put another way, with a wavelength shorter than the cutoff wavelength associated with the bandgap. This "long wavelength cutoff" works out to 3.75 μm for InAs and 0.55 μm for GaP with InP at 0.96 μm and GaAs at 0.87 μm .

By mixing two or more of the binary compounds, the properties of the resulting ternary and quaternary semiconductors can be tuned to intermediate values. The challenge is that not only does the energy bandgap depend on the

alloy composition, so also does the resulting lattice constant. For our four friends, the lattice constants range from 5.4505 \AA (GaP) to 6.0585 \AA (InAs) with GaAs at 5.6534 \AA and InP at 5.8688 \AA . The relationship between the lattice constant and the long wavelength cutoff of the 4 ternary alloys in the InGaAsP family are shown in Figure 1.

Let's get back to InGaAs...

The InAs/GaAs alloy is referred to as $\text{In}_x\text{Ga}_{1-x}\text{As}$ where x is the proportion of InAs and $1-x$ is the proportion of GaAs. The lattice constants and long wavelength cutoffs of these alloys are depicted as the red lines in Figure 1. The challenge is that while it's possible to make thin films of $\text{In}_x\text{Ga}_{1-x}\text{As}$ by a number of techniques, a substrate is required to hold up the thin film. If the thin film and the substrate do not have the same lattice constant, then the properties of the thin film will be severely degraded.

For lots of reasons (call us to chat if you'd like to learn more), the most convenient substrate for $\text{In}_x\text{Ga}_{1-x}\text{As}$ is InP. High quality InP substrates are available with diameters as large as 100 mm. $\text{In}_x\text{Ga}_{1-x}\text{As}$ with 53% InAs is often called "standard InGaAs" without bothering to note the values of " x " or " $1-x$ " because it has the same lattice constant as InP and therefore the combination leads to very high quality thin films.

Standard InGaAs has a long wavelength cutoff of 1.68 μm . Mother nature smiled on this material because it is sensitive to the wavelengths of light that suffer the least signal dispersion and transmit furthest down a glass fiber (1.3 μm and 1.55 μm), it detects "eye-safe"

lasers (wavelengths longer than 1.4 μm), and it is the optimum wavelength band for detecting the natural glow of the night sky. Our core product lines are based on PIN and avalanche photodiodes and photodiode arrays made from standard InGaAs. Take the time to browse through the rest of our site to learn about our many offerings including area and line scan cameras, one and two dimensional focal plane arrays, and high-speed photodiodes and receivers.

So what is "extended wavelength" InGaAs and why bother?

Standard InGaAs has a long wavelength cutoff of 1.68 μm . Many applications require the detection of light with longer wavelengths. An important example is the ability to measure moisture content in agricultural products by measuring water absorption at 1.9 μm . Another example is "LIDAR" (light detection and ranging), used in airplanes to detect clear air turbulence. LIDAR systems often use lasers that emit light with a wavelength of 2.05 μm . $\text{In}_x\text{Ga}_{1-x}\text{As}$

$_x\text{As}$ with a longer cutoff is called "extended wavelength InGaAs."

All we have to do is add a little more InAs to the mix, right? It's not so easy. This increases the lattice constant of the thin film, which causes a mismatch with the substrate, and this reduces the quality of the thin film. We've put a lot of work into learning to grow high quality extended wavelength InGaAs (again, call to chat), and this is reflected in our product offerings. The results of our efforts are summarized in Figure 2. Figure 2 shows the quantum efficiency of standard InGaAs in blue together with the quantum efficiencies of two extended wavelength alloys, $X=0.74$ (green) and $X=0.82$ (red). The spectral response of silicon is also shown. As we like to say, " $\text{In}_x\text{Ga}_{1-x}\text{As}$ starts where silicon leaves off."

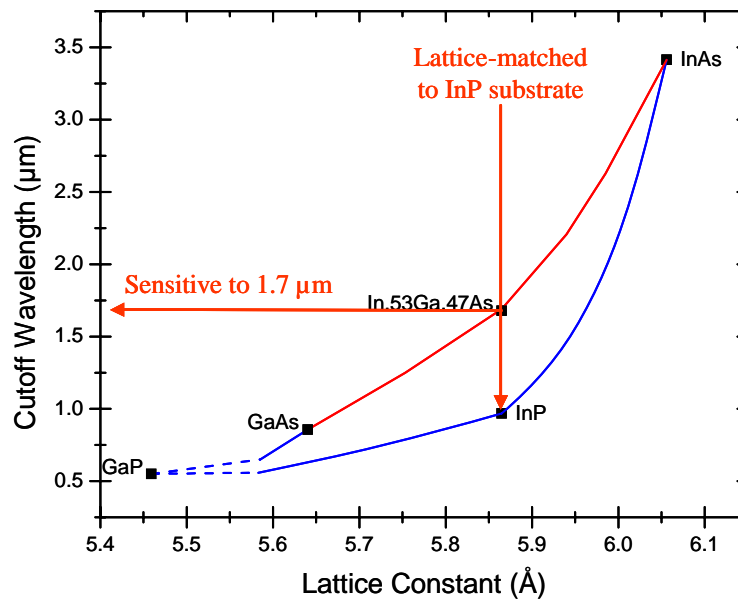


Figure 1.

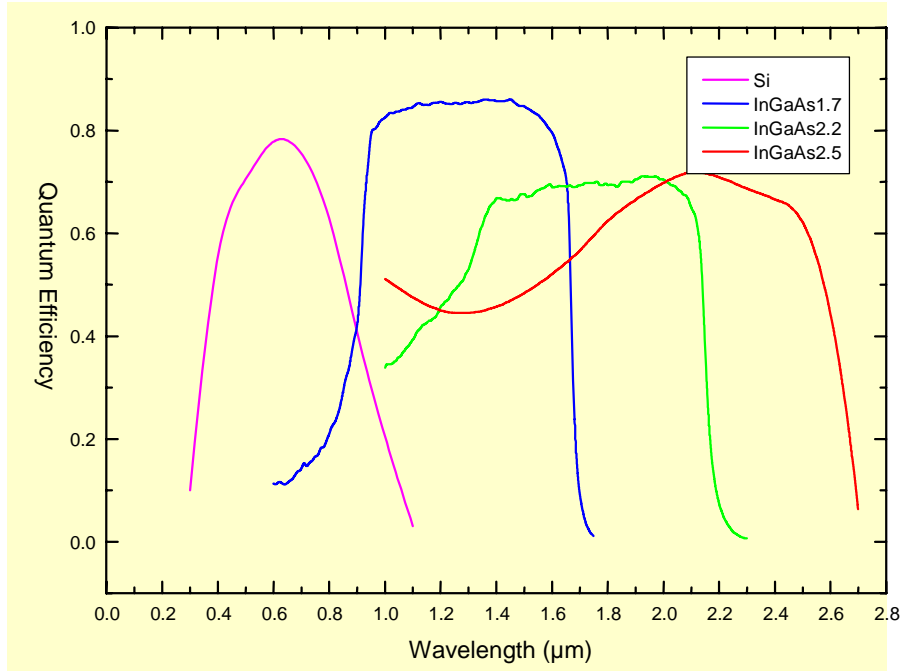


Figure 2.

If you need further technical support, please contact our sales department via email sui_support@goodrich.com or call us at 609-520-0610.

About Goodrich's SUI Team: Founded in 1991, SUI (Sensors Unlimited, Inc.) is the leading manufacturer of indium gallium arsenide (InGaAs) PIN and avalanche photodiode arrays that are used in shortwave and near infrared imaging for military, industrial, spectroscopic, machine vision, and telecommunications applications. SUI provides InGaAs photodiode array processing as a foundry service and designs custom readout integrated circuits for unique imaging applications within its ISO 9001 certified facility. For more information, visit www.oss.goodrich.com/sui.