**Gallium Nitride, GaN**

*Jerzy Ruzyllo, Penn State University*

Red, blue, and green are the primary colors of light and by mixing them all of the colors of the spectrum, including white, can be produced. Inability to generate sufficiently intense green and blue, and consequently white, radiation by semiconductor light emitters was a "weak link" in semiconductor photonics. Mastering of the gallium nitride (GaN) technology was a key to the resolution of the problem.

As seen in Fig. 1 longer-wavelength part of the spectrum (from yellow to deep infrared) can be covered using combination of GaAs, GaP, and InP and other III-V materials. In all these cases single-crystal substrate wafers are readily available. Also, by using advanced epitaxial deposition techniques (MBE,

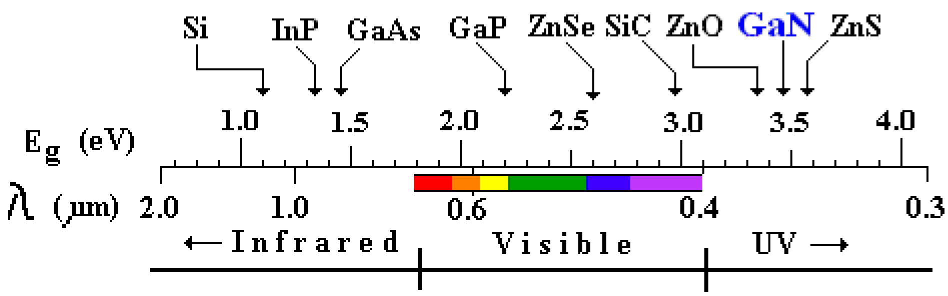


**Fig. 1**

MOCVD) extremely complex device structures can be manufactured using these materials (e.g. see SN-7) In the shortwavelength end of the spectrum (? < 0.5 µm) however, lack of substrates and inadequate manufacturing maturity of wide bandgap (Eg> 2.5 eV) semiconductors was a problem (aggravated by the fact that SiC, the best developed among wide bandgap semiconductors in Fig. 1, features indirect bandgap which makes it of limited use as an efficient light emitter).

It was not until p-type doping of GaN was demonstrated (with significant improvements in technology of Zn based II-VI compounds, Fig.1, to follow) that the long anticipated commercial manufacturing of green, blue, violet, and white LED and laser diodes could be realized. Since then GaN technology enjoys remarkable growth. As the devices are built in the GaN layers formed by epitaxial deposition lack of single-crystal GaN substrates was for quite sometime defining this growth. Alternative to free-standing bulk GaN substrates are lattice mismatched substrates mainly sapphire and SiC. In spite of the buffer layers the use of these substrates results in relatively high concentration of defects in epitaxial GaN. Still, assortment of commercial devices is built using SiC and sapphire substrates including not only photonic, but also electronic devices such as High Electron Mobility Transistors (HEMT). Incorporation of In into GaN structure ($In_xGa_{1-x}N$) allows control of emission from green to violet (high and low In content respectively). Structures consisting of GaN, AlGaN, and InGaN in turn form multi-quantum well laser diodes operating in 0.4 µm-0.5 µm regime. In addition, GaN is also used to make UV detectors that do not respond to visible light. In electronics, AlGaN/GaN heterostructures are used to manufacture high performance HEMTs.

With free-standing bulk GaN substrates made available after years of aggressive research and development, GaN device technology is rapidly moving to the next level of performance. It is at this level where outstanding physical characteristics of GaN (see www.semi1source.com/materials/) can be fully exploited.