

## Growing market for LEDs fuels need for advanced abatement systems

### EXECUTIVE OVERVIEW

As the volume of compound semiconductor (CS) processing ramps up, driven primarily by demand for new light emitting diode (LED) products, manufacturers must deal with a variety of process gas abatement challenges. Indeed, many of the materials used in CS processes are particularly noxious or dangerous to handle, requiring abatement solutions that are robustly designed for both safety and reliability. At the same time, much of the increased demand is for products destined for price-sensitive consumer markets, so the pressure to reduce costs is much higher than in the high-performance and military applications that have historically been the focus of CS development.

The exploding demand for LEDs is driven by their dramatic advantages relative to other lighting technologies. Compared to incandescent bulbs, they offer lifetimes as much as 10× longer and consume less than a quarter of the energy to produce the same amount of light. Compared to fluorescent sources, they can provide a spectral distribution that is much closer to natural “white” light, which is particularly important for backlighting liquid crystal displays for flat panel TVs. The replacement of incandescent traffic lights by LEDs is frequently cited as an example of LED efficiency in an industrial application. Reduced power and maintenance costs have resulted in nearly complete replacement in only a few years.

Rising global energy costs and environmental concerns are accelerating the move away from incandescent lighting. Fluorescent sources are currently the most widely available alternative; however, the move to fluorescent tubes has also changed consumer attitudes, making them more willing to pay a higher purchase price in return for reduced lifetime costs, lower energy costs and reduced CO<sub>2</sub> emissions (20% of the world’s electricity is used for lighting). This shift in attitude will also accelerate the acceptance of LED lighting, and over time, competitive pressures to reduce purchase prices will force manufacturers to

seek every opportunity to reduce process costs. Even at a price premium, LEDs are already displacing fluorescent tubes in applications that benefit from the more natural spectrum they can provide.

Shorter wavelength LEDs (green–blue) use nitride-based materials while the longer wavelengths (red–yellow) use phosphide-based materials. Each material poses unique abatement challenges.

Phosphide processes typically use phosphine gas, which is poisonous. When phosphine passes over the wafer, it generates phosphorous, the same spontaneously combustible material used to light up tracer bullets. The primary transport gas for phosphide processes is hydrogen, also highly flammable.

Nitride processes use hydrogen and ammonia, and in addition to their flammability hazards, ammonia has a very strong, objectionable odor and is toxic. The metalorganic compounds used in both phosphide and nitride processes, typically Ga, In, and Al, are volatile by virtue of the attached methyl groups and are spontaneous combustors.

Finally, gallium arsenide wafers, though they contain arsenic, are themselves relatively

safe. However, to prevent them from evaporating, they must be heated in arsine gas (AsH<sub>3</sub>), a flammable, pyrophoric, and highly toxic compound.

### Abatement technologies

The primary components of III-V MOCVD process exhaust gases requiring abatement are hydrogen, ammonia, phosphorous, phosphine, and arsine. In addition, care must be taken not to create nitric oxide and nitrogen dioxide (i.e., “NOx”) in nitrogen-based processes. The conventional approach to exhaust gas abatement is wet scrubbing dosed with sodium hypochlorite for phosphide processes or sulfuric acid for nitrides. In phosphide processes, elemental phosphorous is conventionally removed from the exhaust stream as it leaves the process chamber to prevent its deposition in vacuum



Red, green, and blue LEDs (the “primary colors”) are increasingly being used to provide the background illumination for flat-panel displays, replacing traditionally-used CCL lamps. A big driver is for flat panel TV, where the much better “color gamut” means that colors on screen are closer to the originals. Other advantages for laptop computer applications are thinner screens, reduced weight and longer battery life.

pumps and lines using a phosphorus trap (p-trap), which requires frequent maintenance and poses a significant safety risk. Hydrogen does not dissolve in water and can be allowed to escape into the atmosphere, although it poses a safety threat from explosion over a wide range of concentrations in air.

Mike Czerniak, BOC Edwards, Clevedon, United Kingdom

# COMPOUND SEMICONDUCTORS

Combustion-based abatement provides an alternative to scrubbing: when properly controlled, it reduces noxious components to safe levels, producing harmless gases (water vapor, and nitrogen) and oxide particulates that may be removed by filtration or the facility's central scrubber. Careful management of the combustion process can prevent the formation of polluting (and closely regulated) NO<sub>x</sub> compounds. **Tables 1 and 2** list concentra-

and the periodic cleaning required to remove accumulated phosphorous from traps is a notoriously dangerous operation. High-temperature vacuum pumps and heated vacuum lines can transport phosphorous laden exhaust to the combustion chamber by minimizing the risk of condensing solids, completely eliminating the hazards associated with traps and trap cleaning.

Hydrogen poses a risk of explosion in the presence of oxygen (air) and an ignition source. These conditions can occur readily in acid-dosed scrubbers that must use plastic components prone to accumulate static charge. Combustion-based abatement oxidizes hydrogen immediately as it enters the combustion chamber, minimizing any risk of accumulation and explosion.

applications, the hydrogen and ammonia in the exhaust gas can be used as the primary fuel for the combustion process, drastically reducing fuel and utility costs. Appropriately designed systems also require no external source of oxygen or compressed air.

## Conclusion

Driven by their ability to reduce energy and therefore CO<sub>2</sub> emissions, as well as provide more faithful color rendition in display applications, manufacturing capacity for compound semiconductor LEDs is expected to expand dramatically in the coming years. Competitive forces will apply continuing pressure to reduce manufacturing costs. At the same time, the particularly noxious and dangerous nature of many of the materials used in the manufacturing process requires careful attention to safety and reliability. Combustion-based exhaust gas abatement provides manufacturers with an alternative to conventional wet scrubbing. The systems reduce the human and financial risks associated with these processes, while at the same time providing significant ongoing reductions in operating costs. ■

**MIKE CZERNIAK** received his PhD from Manchester U. He is the product marketing manager of the *Exhaust Gas Management Division of BOC Edwards, Clevedon, North Somerset BS21 6TH, United Kingdom; ph 44/0-1275-337100, e-mail Mike.Czerniak@edwardsvacuum.com.*

**Table 1. Nitride processes\***

Gas	Flow (slm)	Measured concentration
H <sub>2</sub>	320	<0.2% (<LEL)
NH <sub>3</sub>	160	<3ppm (<TLV)
NO		<25ppm (<TLV)
NO <sub>2</sub>		<2ppm (<TLV)

\*BOC Edwards Spectra G

**Table 2. Phosphide processes\***

Gas type	Flow (slm)	Measured concentration
H <sub>2</sub>	200	<0.4% (LEL is 4% in air)
AsH <sub>3</sub>	0.5	<1ppb (TLV intended to be 5ppb)
PH <sub>3</sub>	2	<1ppb (TLV is 300ppb)

\*BOC Edwards Zenith III-V

tions for exhaust gas components measured after combustion abatement.

## Safety

Combustion-based abatement eliminates two major risks inherent in scrubber based approaches: phosphorous and hydrogen. Phosphorous combusts spontaneously in air

of-ownership relative to conventional configurations. The elimination of periodic phosphorous trap cleaning typically provides an immediate 10% increase in process tool uptime and thus wafer throughput. The ability to simultaneously handle high hydrogen and ammonia flow rates from multiple process tools reduces initial capital expenditure. In many

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Info@edwardsvacuum.com • +1 978 658 5410 (US) • +(44) 1293 528844 (UK)