



Q & A

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Q How would you describe the current state of the LED industry?

A The global LED industry has grown very fast since 2010. The quantity of MOCVD tools installed worldwide by Q1'14 has exceeded 2,700 sets; this number was less than 1,000 in 2009.

Display backlighting and general lighting are the two biggest application markets for LED. With the saturation in display backlighting, especially for TV, where LED penetration will reach 98% in 2014, the future growth of the LED market will, to a large extent, depend on further development in general lighting. LED lighting is still at an early stage of adoption. It accounts for a small but increasing share of the total lighting market. Rising electricity prices, mounting concerns about climate change, and the desire for energy independence are driving the global lighting market to shift toward energy-efficient light sources: LED-based lighting products.

It is estimated that the global lighting market generates an annual revenue of nearly \$100 billion; LED products accounted for 18 percent of lighting revenues in 2013. We believe that LED's share will keep increasing in the years to come. The industry's future is bright, but it is experiencing painful overcapacity. Current LED capacity installed in the world is enough to meet the global demand by 2018, so market consolidation is unavoidable and harsh.

Only providers that have good channels to the end market with continuous innovation in high-performance, cost-competitive products will eventually survive and enjoy a profit. Half of LED makers may disappear in the next five years in the shakeout as the market matures.

Increased adoption driven by continuous cost reduction and improved consumer awareness represents an enormous energy savings opportunity for the world and an enormous market opportunity for LED lighting manufacturers and component and materials providers.

Q Are LED chipmakers concerned about quality of gases supplied in the industry? Or is price their primary concern?

A Yes, LED chipmakers are very sensitive to material purity because unexpected impurities lead to declined device performance and/or early failure. For example, ammonia (NH₃) gas used to react with Trimethylgallium (TMGa) to form Gallium Nitride (GaN) layers in LED chip making. The LED industry demands highest product purity (7N, i.e. 99.99999%) with lowest impurity - especially of moisture (some customers require that moisture level be below 50 ppb).

Q Are you developing new sources, or new technologies to deliver them?

A Linde has developed and delivered the best-in-class ultra-high purity ammonia supply solution. This meets the critical demand of global top LED customers to achieve the highest ammonia purity at a stable high flow rate (3000 slpm), but with lowest moisture impurity (<20 ppb). At the same time, Linde's small scale SMR (steam methane reformer) hydrogen (H₂) plants make a switch from trailer supply to onsite generation economically viable for small fabs (approximately 50% of the size of conventional hydrogen plants).

Customers get benefits of simplified supply chain and lower unit costs without the need to use electrolyzers.

Q How does Linde set itself apart from the competition?

A Linde provides turnkey solutions with a full product portfolio - gas, engineering, and service - reducing, for customers, complexity and interfaces with multiple suppliers. Linde also has local production facilities of ultra-high purity ammonia in China, Taiwan, and Korea, where around 80% of global LED production capacity has been built. Linde is leading in technology - our NH₃ supply system with stable high flow and low moisture is the best in the market. We also have an on-site NH₃ purification solution available for demand of over 1000 tonnes per annum.

Q Do you believe that competition for sales is fiercer than ever, given the launch of materials suppliers in China and USA entering the market?

A There are a few local producers and suppliers of ammonia in China and Taiwan. LED customers choose Linde because of superior technology for gas purification and delivery, security of supply running three high-purity ammonia plants in Taiwan, Korea, and China, turnkey capabilities including gas supply, hardware installations, and operation and maintenance from a single supplier.

Q What are your biggest selling products into this industry? Why?

A The top three products that Linde sells to the LED industry are ultra-high purity ammonia and H₂ and N₂ gases. These are the major gas molecules in the process of epitaxy wafers, which is the most important process among all the LED chip processes. Linde is a global supplier of ultra-high purity ammonia purification with a lot of H₂ and N₂ resources near leading LED manufacturers in Asia and Europe.