Expanding use of hydrogen in the electronics industry

By Dr. Jean-Charles Cigal

Hydrogen (H_2) is used extensively for electronics manufacturing in the semiconductor, display, LED, and photovoltaic application segments. This most simple of molecules exhibits unique properties: it has excellent heat transfer capabilities and is an efficient reducing and etching agent. The four main ways hydrogen is used are:

- **Annealing:** Silicon wafers are heated to temperatures over 1,000 C in order to repair, or anneal, the crystal structure. Hydrogen transfers the heat uniformly to the wafer, assists the reconstruction of the crystal structure in the final surface layers, and reacts to remove any oxide.
- **Epitaxy:** Hydrogen is used as a reducing agent in many chemical reactions, especially when new crystalline films are being deposited, which is called epitaxy.
- **Deposition:** Hydrogen can also be directly incorporated into thin films to make them less crystalline. This is often done with silicon thin films to make the layer more electrically insulating.
- **Stabilizing:** The addition of hydrogen also extends the shelf life of important electronic chemicals like diborane (B_2H_6) and digermane (Ge_2H_6), which otherwise slowly decompose.

Hydrogen is an extremely flammable material that burns with a colorless flame and forms explosive mixtures with air over a wide range of concentrations. Strict regulations regarding transport and storages apply, but vary according to country or region.

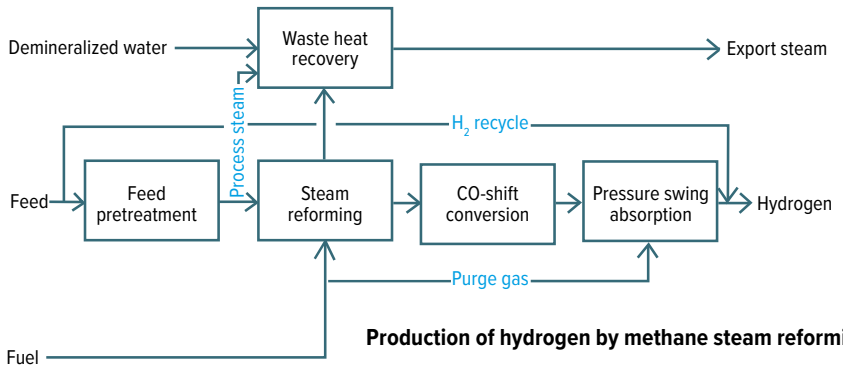
Hydrogen is widely used in many industries outside of electronics such as petrochemicals, glass, food, refining, and fuel cells and is distributed all over the world. It is commonly generated at large plants and distributed either over short distances by pipeline or by truck fleet. Bulk hydrogen can be supplied in high pressure gas tube trailers, or where permitted as in the US and Europe, by cryogenic (liquid) trailers, which maximizes the transportable volume.

There are two primary ways hydrogen is produced for electronics. Small volumes can be produced by the electrolysis of water to yield both oxygen and hydrogen. For higher volumes, steam reforming is economically advantageous. Natural gas (CH_4) and steam are heated to form syngas (a mixture of hydrogen and carbon monoxide). The syngas is then separated to give hydrogen.

$$CH_4 + H_2O \rightarrow CO + 3\,H_2$$

The carbon monoxide can then be further reacted (shifted) with the steam to yield additional hydrogen.

$$CO + H_2O \rightarrow CO_2 + H_2$$



Production of hydrogen by methane steam reforming

A new application of hydrogen in the semiconductor industry is extreme ultra-violet (EUV) lithography. Lithography is the process where the pattern for semiconductor chips is transferred from a master, called a mask, to the silicon wafer using light. During EUV light production, tin droplets are shot with a laser, which causes them to emit UV light. This leads to the unwanted deposition of tin debris in the light collector, and the chamber needs to be cleaned regularly. Large flows of hydrogen are used to react with the deposited tin to form tin hydride (SnH_4), which is volatile and is removed using a vacuum pump.

EUV hydrogen demand, in combination with increased use of other processes for advanced semiconductor manufacturing such as epitaxy, is creating significant hydrogen requirements at new fabs. On-site generation should be considered, particularly in areas where liquid hydrogen transportation is not permitted or sufficient bulk hydrogen is not available.

Linde recently introduced a compact hydrogen generator line called Hydroprime®, based on methane steam reforming technology, which is particularly suited for semiconductor industry needs. The generator can produce ultra-high purity hydrogen (99.999+%) at 13.8 bar, reducing the need for product compression in most uses.

The decision whether to choose on-site generation and supply to replace a packaged material supply scheme must be taken after considering an evolution of business model from OPEX to CAPEX. Standard supply by package (cylinders and trailers) mainly incurs operating costs. An on-site generation scheme requires a larger share of capital expenditure. The design, including production volume, footprint, and purity must be specified. Linde works with customers to ensure and optimize hydrogen supply using integrated on-site production, bulk back-up, and purification. SGR

About the Author

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