Electronics gases: Going green

By Paul Stockman, Technology Manager, The Linde Group

The electronics industry has, since the 1990s, depended greatly on the use of nitrogen trifluoride (NF3) for its process chamber cleaning needs. When initially introduced it provided a faster way of cleaning a chamber than previous methods using sulfur hexafluoride (SF6), tetrafluoromethane (CF4) and hexafluoroethane (C2F6). In the past six years, however, we’ve seen a change in attitudes towards NF3, and its predecessors thanks to the growing understanding of NF3’s environmental impact.

From the declaration by Michael Prather in 2008 that NF3 is the Greenhouse Gas missing from Kyoto, and the report from the Scripps Institute showing the increase in measured NF3 concentrations in the upper atmosphere, followed by its addition to the UNFCCC fluorine manufacturing systems and delivery techniques. Due to its fluorine manufacturing systems and delivery techniques.

In order to fully realise all the benefits that F2 can provide, some optimisation of the process may be required— and it is likely that for each OEM, unique process optimisation will be required to deliver the best results. This can be due to a number of factors—gas flow uniformity, plasma density, chamber pressure and temperature, for example.

It is also possible in many cases to carry out the chamber cleaning with F2, without the need for an RPS unit. The RPS unit is typically only present on the process tool because it is required for the cleaning step using NF3. Most plasma deposition processes use an in-situ method to generate the plasma and this same system can be used with F2, with no obvious adverse effects on the chamber hardware, thus simplifying the process tool.

In some cases the cleaning can also be carried out thermally without the use of plasma. All these benefits help reduce the amount of time the process tool is unavailable for production, thus improving overall productivity and helping to lower costs.

A call to action
Linde Electronics has pioneered the use of molecular fluorine as a replacement for high GWP fluorinated cleaning or etching gases, such as NF3 and SF6, which are routinely used in the manufacture of semiconductors and flat panel displays. It can also be used to replace chlorine trifluoride (CFC3) for similar cleaning applications.

The global warming potential of greenhouse gases (GWP) is 17,200 times greater than carbon dioxide (CO2) for NF3 and 22,800 times greater for SF6. However, whilst it may not be as simple as replacing one gas with another, the benefits that can be gained are significant.

Business process and operational cost, two areas that must remain core concerns in the competitive electronics industry.

Cost
On a molecule basis, F2 price can be very competitive with NF3, particularly at the large scales used for chamber cleaning in a large 300mm wafer fab.

There is also a reduction in the mass of gas required—80kg of F2 delivers the same amount of F-atoms as 109kg of NF3. You are not buying and transporting N atoms, which play no role in the cleaning process and in fact hinder the efficiency of the cleaning process.

Fluorine can also help improve factory productivity (thus lowering overall manufacturing costs) due to its up to 5x faster cleaning rate.

Process benefits
Fluorine allows for significant throughput improvements over NF3, in many cleaning processes. The NF3 based cleaning process typically uses a remote plasma source (RPS) to activate NF3, but the F-N bond requires more energy to break than the simpler F-F bond and thus for a given RPS unit, higher flows of F2 can be used compared to NF3, which allows for shorter cleaning times.

Alternatively, for the same flow of F molecules, significantly lower power can be used with F2, thus helping reduce power costs and also improving the reliability of the RPS units.

It has also been observed that the temperature of the reaction chamber typically increases during cleaning with NF3. This is not unexpected—the recombination mechanism for NF3 can release significant amounts of heat energy but also more energy is required by the RPS unit to activate the same number of F atoms, and some of this power is dissipated as heat in the plasma. For a high temperature deposition process this effect may not be particularly significant, but for the newer low temperature process, accurate control of the process temperature is critical. Consequently, with NF3, additional recovery time may be required before subsequent wafers can be processed.

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Environmental impact
To minimise NF3 process emissions, most manufacturers have installed high performance scrubbing systems. However, there still exists the risk of emissions during the whole production, transportation and use lifecycle. In 2008, Linde Electronics was quoted within the pages of gasworld saying, “You can mitigate something with a high global warming potential but if your alternative has zero global warming potential, it is fundamentally better.” Supporting F2 in the semiconductor and other electronics manufacturing industries is Linde Electronics delivering on that message.

NF3 has a GWP 17,200 times greater than carbon dioxide (CO2). Molar powers in the very reactive molecules, there is very low concentration of the gas in exhaust streams, making it much more straightforward to abate. F2 can also be generated on-demand and onsite from anhydrous HF and then consumed and abated at the same site, thus eliminating much of the risk of undesired emissions and lowering the total carbon footprint associated with the manufacturing, transport and disposal of NF3 cylinders.

Across the entire value chain, in moving our customers to F2 processes, Linde has eliminated 35,000 tonnes of CO2 from the cleaning gas supply chain per year. However, the benefits of moving to F2 go beyond its reduced environmental impact to improving overall productivity and helping to lower costs.

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