

Industry Acting to Reduce Greenhouse Gases

Semiconductor manufacturers use a variety of high global warming potential (GWP) gases to process wafers and to rapidly clean chemical vapor deposition (CVD) tool chambers. Processes use high GWP fluorinated compounds including perfluorocarbons (e.g., CF₄, C₂F₆ and C₃F₈), hydrofluorocarbons (CHF₃, CH₃F and CH₂F₂), nitrogen trifluoride (NF₃) and sulfur hexafluoride (SF₆). Semiconductor manufacturing processes also use fluorinated heat transfer fluids and nitrous oxide (N₂O).

Of these, the semiconductor industry naturally tends to focus its attention on CF₄ since it is one of the worst offenders, with an atmospheric half-life of 50,000 years. “CF₄ the hardest to get rid of and it's one of the worst global warming gases,” said Kate Wilson, VP Marketing, Subfab Solutions – Semiconductor Division of Edwards. “We tend to use that as an indicator of how much of the other global warming gases, as well, are being emitted by the industry. If we're dealing with that (CF₄) well, we tend to be managing the rest of the gases pretty effectively.”

According to the Environmental Protection Agency (EPA), estimating fluorinated GHG emissions from semiconductor manufacture is complicated and has required a significant and coordinated effort by the industry and governments. It was historically assumed that the majority of these chemicals were consumed or transformed in the manufacturing process. It is now known that under normal operating conditions, anywhere between 10 to 80 percent of the fluorinated GHGs pass through the manufacturing tool chambers unreacted and are released into the air.

In addition, fluorinated GHG emissions vary depending on a number of factors, including gas used, type/brand of equipment used, company-specific process parameters, number of fluorinated GHG-using steps in a production process, generation of fluorinated GHG by-product chemicals, and whether appropriate abatement equipment has been installed. Companies' product types, manufacturing processes and emissions also vary widely across semiconductor fabs.

The good news is that many companies in the semiconductor manufacturing industry have successfully identified, evaluated and implemented a variety of technologies that protect the climate and improved production efficiencies. Solutions have been investigated and successfully implemented in the following key technological areas:

- Process improvements/source reduction
- Alternative chemicals
- Capture and beneficial reuse
- Destruction technologies (known as abatement)

In 2011 the industry set new targets for 2020, which it summarizes as:

- The implementation of best practices for new semiconductor fabs. The industry expects that the implementation of best practices will result in a normalized emission rate (NER) in 2020 of 0.22 kgCO₂e/cm², which is a 30 percent NER reduction from the 2010 aggregated baseline.

- The addition of “Rest of World” fabs (fabs located outside the World Semiconductor Council (WSC) regions that are operated by a company from a WSC association) in reporting of emissions and the implementation of best practices for new fabs.
- NER based measurement in kilograms of carbon equivalents per area of silicon wafers processed ($\text{kgCO}_2\text{e}/\text{cm}^2$), which will be the single WSC goal at the global level.

“We're finding as we get down to the lower levels and different things come up as the highest priority in the fab where we're moving into more and more sort of lower usage processes, which are requiring abatement now in order to get those levels down to meet the targets of 2020 in the industry,” Wilson explained.

The main area for potential improvement now is etch, especially in older 200mm fabs where etch processes may not have been fitted with PFC abatement devices. This is particularly true for etch processes making extensive use of CF_4 . “The area where we still have the most gaps is clearly etch,” Wilson said. In CVD processes, most of the benefit was done by material shifts rather than actual abatement, although we clearly do need to abate the other gases in those processes. For the etch side, there are still quite a few customers that really only do the toxic emission abatement rather than the global warming gas emission abatement. But we do see, across almost all of our customer base, people have either fairly recently moved to fully abating all the PFC type gases or will be shortly.”

Wilson said some other gasses have been coming up more recently in terms of things like N_2O , which people are putting more focus on now as it's becoming a larger part of the fab footprint of global warming materials.

For PFC abatement, Edwards offers the Atlas range of products, which destroys PFCs by burning them. This is followed by a wet scrub of the byproducts. This works quite well, but Wilson cautions that it can be tricky for some processes, such as chamber cleans with NF_3 . “If the burn is not correct and you get too hot, there's actually the potential to create PFC's. And so, it is quite critical to have well-controlled burn technology to make sure that you don't actually cause issues where we didn't have them before.”

Wilson said another area where they have seen some issues with PFCs being created is with processing of carbon-doped materials, such as low-k dielectrics. “When they do the chamber clean, they're cleaning off predominately silicon dioxide but there's carbon in there so that can create PFCs and CF_4 as well so there's a requirement to look at abatement in those areas,” she said.

Another piece of good news is that no company in the supply chain is waiting for legislation to be enacted before they act themselves. “Right from consumers to the consumer manufacturers, the car manufacturers, consumer electric manufacturers, our direct customers, the equipment manufacturers plus the major players within semiconductor and flat panel display, it seems that at every level there's a commitment that this is the right thing to do,” Wilson said. “At every level people are pushing to get the requirements more stringent and it's almost not about legislation anymore, it's about everybody actually thinks it's a good idea and that want to do it.”