How clean can we get?

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Today, we are basically without good baselines and specifications for the quality of air in cleanrooms. Most fab engineers do not know the level, type, or quantity of contaminants that exist in their cleanrooms or what these should be by product type. With the advent of SEMI standard F21-95, some are beginning to at least take an initial look.

Without baselines, it is difficult to prove that cleanroom quality has affected yields. Furthermore, it is virtually impossible to win an insurance claim if you have a catastrophic accident in the fab. Obtaining complete baseline information and established guidelines is becoming critical as we move into even thinner films and smaller lines on expensive 300mm wafers. Specifications and more histograms relating yield to cleanroom air quality are also needed. Although large quantities of information concerning concentrations and types of materials that contaminate a cleanroom have been collected, relating them to yield still needs to be done.

With the passing years, cleanrooms have become cleaner and cleaner, but not to a satisfactory level. Industry observers debated whether a cleanroom could ever be clean enough to produce state-of-the-art chips, which led to the debate over using cleanrooms vs. total wafer environmental control.

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In the 1990s, proper gowning and cleanroom protocol became rigorously enforced. Cleanroom design and the need for cleaner, particle-free environments pushed the class levels down to <1. In fact, specifications for particles, metals, anions, cleanroom materials, and materials of construction were tightened, in some cases, to levels below what can be detected.

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Particle measurement in the 0.03–0.02μm range is required today for critical processes. These sizes are below what particle counters can "see." Processes like VPD-ICP-MS or VPD-TXRF are now used to determine the level of metal contamination on a wafer. With this information, one can see that something like 30 particles on a wafer would not be detected. Considering the quantity of metal usually seen on a wafer, one could conclude that these contaminants are there in molecular form and not as particles.

Vapors from etching and cleaning baths accumulate in the cleanroom air and can cause doping, hazing, and

film delamination problems. These can be measured to levels <0.05ppbM, but most fabs have considerably higher numbers than that. These chemicals, as well as amines from photoresist processes, can cause severe hazing. Boron from the HEPA filters can cause doping. These materials are etched out of the soft fibers that are used to make HEPA by the recirculating air that has both HF and moisture in it.

Organic contamination from the numerous polymeric materials found in a cleanroom can cause delamination, gate oxide integrity, and doping problems. On a wafer, levels of $<10ng/cm^2$ are required. Amounts greater than that have been found to cause yield problems. Organophosphates that can cause doping are also often found in materials that are used in a cleanroom.

Recently, a new contaminant of concern has entered the cleanroom picture: copper contamination. Of 100 cleanrooms studied for copper, five were found to have serious copper contamination in the air. As more copper is being used in the industry, greater amounts of copper contamination are being found.

It will be interesting to see what will happen to cleanrooms in the next few decades. Will there be people in them at all? Or perhaps a better question is, will there be cleanrooms at all? ■

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