Tips for Designing Clean Room Equipment

Mechanical components intended to run in clean rooms for wafer fabrication must comply with uniform industry standards that dictate the number and size of particles they can generate.

As the computer and electronics industries pack more circuits on semiconductor wafers, particle generation in the clean rooms where they are processed becomes more critical with each generation. In many applications, mechanical positioning stages are a large contributor to contamination. Suppliers are required to follow special design criteria that ensure a positioning stage's cleanliness according to certain standards.

Cleanrooms are classified as Class 1, Class 10, Class 100, Class 1000, Class 10000, & Class 100000 according to standard FED STD 209E. A Class 1 clean room, for example, is defined by the number of allowable particles per cubic foot of air, in this case, no more than 35 particles of 0.1 micrometer in diameter. Soon, a new ISO standard will likely displace the current US FED STD 209E. Table C compares the ISO classification to the FED STD. Tables A & B outline the number of particles allowed of each size in a clean room.

CLASS	**Number of Particles per Cubic Meter by Micrometer Size**					
	0.1 um	0.2 um	0.3 um	0.5 um	1 um	5 um
ISO 1	10	2				
ISO 2	100	24	10	4		
ISO 3	1000	237	102	35	8	
ISO 4	10000	2370	1020	352	83	
ISO 5	100000	23700	10200	3520	832	29
ISO 6	1000000	237000	102000	35200	8320	293
ISO 7				352000	83200	2930
ISO 8				3520000	832000	29300
ISO 9				35200000	8320000	293000

Table A - ISO Clean Room Standards

CLASS	**Number of Particles per Cubic Foot by Micrometer Size**					
	0.1 um	0.2 um	0.3 um	0.5 um	1 um	5 um
Class 1	35	7	3	1		
Class 10	350	75	30	10	1	
Class 100		750	300	100	10	1
Class 1000				1000	100	10
Class 10000				10000	1000	100
Class 100000				100000	10000	1000

Table B - FED STD 209E Clean Room Standards

ISO 14644-1	**FED STD 209E**
1	
2	
3	**Class 1**
4	**Class 10**
5	**Class 100**
6	**Class 1000**
7	**Class 10000**
8	**Class 10000**
9	

Table C – Airborne Particulate Cleanliness Class Comparison

Active Particle Generation and Prevention

Particles are generated actively and passively. Common active generators are positioning stages and other components with sliding surfaces, such as seals on linear bearing blocks, ballscrews, and metallic strip seals. In all cases, sliding motion generates particles. Eliminating them is a primary objective.

Seals that are standard on linear bearings & ballscrews are often inappropriate for clean room use. Carbon black & other particles generated by seals sliding on bearing rails & screw shafts can be a source of airborne contamination. Many manufacturers now offer “seals” that have a small clearance between the rail and seal lips, eliminating particle generation yet retaining lubricant critical to long term operation.

Mechanism lubricants can also be a source of particle generation in the form of oil vapors & droplet dispersal during the churning action of the balls in precision bearings and ballscrews. Standard lithium greases should be purged and replaced with low vapor pressure, low migration, perfluorinated grease. This type of grease aids in particle generation reduction in two ways. As a lubricant, it reduces friction and consequently the wear rate of ball & race surfaces. As a viscous fluid, it traps and holds in suspension the material ablated from the bearing surfaces.

A more significant and more difficult source of active particle generation is that of electrical cable & air/vacuum hose abrasion. When secondary stages & process tools are stacked on positioning stages, their electrical & pneumatic interfaces are in motion, creating a source of particle generation. In limited travel applications, cables are customarily looped, supported or “festooned” so that they are isolated from abrasive surfaces. As travel lengths grow, it is necessary to use cable carriers for support. In systems with cable carriers, however, particle generation occurs as a result of cables & airlines rubbing against each other, against the cable carrier, and from the cable carrier itself. The effects can be mitigated in three ways. Cable and airline jackets can be sourced with abrasion resistant and low friction materials such as teflon and urethane. Cable carriers can be contained in housings which are evacuated with a low pressure, high flow source. And finally, it is important to locate cable carriers as far away from critical process areas as possible. In this way, particles generated are swept away by clean room airflow.

Positioning stage protection systems are also a source of particles. Bellows, although often used to isolate bearings and ballscrews, generate large particles as they expand and contract. Pressure differentials within the stage cause bellows to blow air out, along with any contamination that is present. Seals made from metals or belts are not susceptible to pressure differentials during stage travel, but both slough off particles from sliding friction. Belt sealing systems have substantially lower friction than metal sealing systems, which reduces the number of the particles generated for similar move profiles. In addition, belt-sealed positioning stages are evacuated more easily to remove the actively generated particles.

Passive Particle Generation and Prevention

Passive particle generation is the result of a surface shedding particles of its surface, the shedding of a foreign material that have been trapped on the surface, or outgassing. The surfaces of choice in a clean room are ones requiring no coatings such as 300 series stainless steels, teflon, PVC or UHMW. When it is necessary to use mild or tool steels, nickel plating is recommended. Aluminum is a common material in a clean room. Type III anodizing with a nickel acetate sealing process cleans & puts a 0.002”-0.003” thick hard, corrosion resistant surface on aluminum. All black oxide coated and zinc plated screws and fasteners should be replaced with stainless steel components.

For non-work surfaces certain paints are an acceptable coating. Catalytic urethanes and powder coating produce hard, smooth surfaces. Standard enamels are usually not used because of their softer surfaces and characteristic of outgassing their volatile constituents for an extended period of time. Surfaces should be smooth, contain few joints and cracks and never be coated with textured paint. Surface irregularities trap particles that are difficult to wipe off and sharp edges snag strands of cleaning cloths.

Particle Removal

Most modern clean rooms contain filtration systems that introduce laminar-air flow from elevated work surfaces to grated floors or to exhaust ducts at wall bases. FED STD 209E specifies maintaining the flow at 90ft/min through a given cross section of the room. The ceiling to floor flow affects equipment designs two ways. First, avoid positioning components over critical work areas such as wet processing and hard disk assembly areas that produce particles or turbulence. For example, control cabinets should be lower than or equal to the height of process or assembly surfaces. Furthermore, mechanical stages should not be moved over critical surfaces. Components should be gripped from the side, keeping active mechanisms out of the laminar flow path. Moreover, grippers should be shaped to let the air flow around them smoothly. Ceiling to floor laminar flow also affects designs in another way. Devices that are known to produce numerous particles should be located as close to the flow or exhaust ducts as possible, so the normal air flow can carry the particles away easily.

Applying a negative pressure or a vacuum to contamination-prone areas is another effective way to remove particles. Consider the airflow route when drawing a vacuum on a device. For example, louvers should be covered and the covers gasketed. Air inlets should be placed so flow moves through particle-producing areas and by devices that require cooling. The exhaust should be piped out through the house vacuum system, HEPA filter system, or near the room exhaust ducts. High pressure, low-flow purge systems are typically unacceptable because the high pressure tends to produce air turbulence that can disperse particles outside the influence of the vacuum. But low pressure, high-flow evacuation minimizes air turbulence and maximizes particle exhaust.