PROTECTING SEMICONDUCTOR OPERATIONS WITH CHEMICAL-RESISTANT COATINGS

How to Ensure Profitability by Defending Assets, Floors and Secondary Containment Areas Against Corrosion

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By Tim McDonough, Construction Solutions Executive, and Mark Wafford, Construction Solutions Executive, Sherwin-Williams Protective & Marine

Corrosion and semiconductor fabrication don't mix. Even the tiniest speck of contamination from corrosion in a clean zone could ruin an expensive wafer batch and harm a facility's bottom line. Because corrosive threats abound throughout a typical fabrication facility, mitigating them is a priority to help ensure profitable operations.

In many facility environments, harsh chemicals can attack steel, concrete and flooring substrates, presenting the danger of the resulting paint flakes, rust particles and dust entering clean zone airstreams and affecting production. There is also an inherent risk that corrosive chemicals could damage and breach secondary containment systems if a leak or spillage occurs.

These threats mean corrosion can be costly – from lost wafer batches to severe facility damage. Fortunately, the threats can be minimized, and at a relatively low cost compared to the risk of facing expensive manufacturing and productivity losses. The solution is to invest in chemical-resistant coatings (CRCs) that keep corrosion at bay for the long term **(Figure 1)**. Such solutions should also have low volatile organic compound (VOC) and off-gassing levels to reduce the risk of particulates getting into the air. Using CRCs that combine these properties ensures long-lasting durability to extend maintenance intervals for semiconductor fabricators and thereby help them reduce overall operational costs.

***Figure 1**. Semiconductor fabrication facilities should invest in chemical-resistant coatings (CRCs) that keep corrosion at bay for the long term to avoid the risk of unplanned maintenance shutdowns and the associated losses.*

CURBING CORROSION AND VOCS

Corrosive materials used throughout semiconductor fabrication operations can cause severe damage to anything they contact – from walls and steel columns to floors and secondary containment areas. Therefore, it is especially important for fabrication facilities to specify suitable CRC systems to protect their operations. Addressing CRC specifications is best done during the design phase of the project, so a facility can start off on the right foot. It is also possible to adjust specifications for existing facilities to realize better outcomes following maintenance activities.

In either case, facility owners should work with a qualified coating supplier to identify, qualify and approve appropriate CRCs to withstand the different traffic, moisture-mitigation, chemical, UV and static control exposures anticipated at the facility. The supplier should be able to tailor CRC systems to the facility's specific needs, while protecting assets against their most severe anticipated exposures.

CRCs are used in both clean and non-clean zones throughout a semiconductor fabrication facility. They must meet especially stringent emissions guidelines in clean zones to prevent contamination exposures to sensitive equipment and avoid costly shutdowns. That means using CRCs that have low VOC levels when applied and very little to no off-gassing after they cure. These parameters minimize the amount of vapors and particulate contaminants that could enter the cleanroom air system and work their way into wafer deposition chambers and other areas that must be devoid of particles in the air to maintain semiconductor quality.

CRCs that have been qualified, tested and approved for use in clean zones may be used on structural steel (**Figure 2**), walls, ceilings, floors and various assets housed inside. This includes many high-solids and ultra-high solids waterborne CRCs, as water-based chemistries typically have the lowest VOC emissions. High-solids, solvent-based CRCs with minimal off-gassing are also used often to provide additional protection against aggressive chemical exposures.

***Figure 2**. Structural steel used in semiconductor fab operations should be coated with CRCs that have been qualified, tested and approved for use in clean zones.*

FIGURING OUT FLOORING

Protecting flooring from deterioration is another critical function of CRC systems. Resinous flooring materials must be compatible with any production or cleaning chemicals that could come into contact with them. Otherwise, the poured-in-place flooring may discolor at best or physically deteriorate at worst. Discoloration is an aesthetic issue that shouldn't affect production operations, but it's still undesirable for a bright white floor to turn yellow. Deterioration is more concerning, as it could lead to particulate contamination issues due to bits of broken-down flooring material being lifted into the airstream.

Taking a performance-based approach to selecting flooring can help semiconductor facilities avoid discoloration and deterioration issues (**Figure 3**). Working with a qualified coatings supplier on such an approach will help facilities consider variables such as the location in which the flooring will be installed, as well as what traffic and chemical exposures it will encounter. These parameters can help determine if a thin-film system will suffice or if the added durability of a thicker system, perhaps containing reinforcing additives, is required to handle forklift and vehicular traffic or to mitigate especially severe chemical attacks.

***Figure 3**. Flooring throughout a semiconductor fabrication facility needs to be highly durable and rated for the traffic and chemical exposures it will encounter.*

From there, suppliers may ask about ultraviolet (UV) exposures to ensure the selected flooring won't yellow. They'll also ask about skid resistance to determine if texture is required and how much is needed to enable both personnel safety and appropriate cleanability in areas subject to washdowns.

Static control is another important consideration for various semiconductor fabrication environments with facilities and suppliers needing to determine if electrostatic discharge (ESD) dissipative or conductive flooring options are required to mitigate static electricity to protect sensitive equipment.

Finally, suppliers and facilities will determine if any waterproofing materials need to be used to ensure moisture will be contained to an area and unable to reach adjacent rooms or floors below if a breach occurs.

Following this performance-based approach allows semiconductor facilities to specify appropriate CRCs that deliver the desired properties, while also considering materials that are easy to install and maintain without sacrificing durability. Like CRCs for structural steel, walls and other surfaces, CRCs used for resinous flooring will minimize VOCs and off-gassing, with the primers, intermediate coats and topcoats used typically featuring 100% volume solids. Primers may include moisture-resistant epoxies that are designed to minimize the transmission of vapors from concrete to further protect clean zone airstreams from contamination.

Core flooring technologies used for semiconductor facilities include epoxy novalacs, which have a broad range of chemical resistance; vinyl esters, which offer even greater chemical resistance for particularly aggressive chemicals or longer exposure times; and epoxy and urethane topcoats with high wear properties and excellent abrasion resistance.

CRCs are also used below the visible, walkable flooring surfaces in various areas of semiconductor fabrication facilities. For example, they are often applied to the waffle or cheese slab structures used as part of the flooring configuration in clean zone fabrication areas for utility access and ventilation (**Figure 4**). These precast concrete structures feature square (waffle) or round (cheese) holes for that access and ventilation. Their reduced concrete surface area enables facilities to use fewer structural columns to support the flooring. Because of this limited surface area compared to a full slab, these open structures need to be protected from corrosion with CRCs to maintain their integrity if exposed to chemical attacks. Waterborne epoxies are typically used, but higher solids, solvent-based products such as polyurea may be specified instead to ensure greater durability.

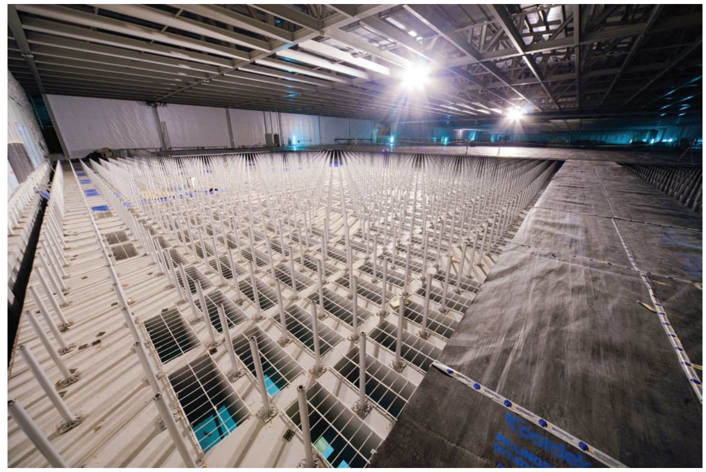

Figure 4. *CRCs are used on waffle slab flooring installations in clean zone fabrication areas to help protect the structures from corrosion and maintain their integrity if they're exposed to chemical attacks.*

SHORING UP SECONDARY CONTAINMENT SYSTEMS

Excellent corrosion resistance is also particularly critical for the secondary containment systems found in semiconductor facilities. Such containment areas include concrete basins and pits that are meant to capture any corrosive fluids that may leak from a wafer deposition chamber, tubing line or primary containment system. These structures must be able to withstand the spillage of harsh, caustic chemicals for a defined period of time such that those materials don't otherwise harm the facility's operations or staff. Without secondary containment, some chemical spills run the risk of eating right through flooring, even reaching facility levels below the spill.

Primary containment systems include tanks and other vessels that store and transport harsh solvents, acids and toxic gases for semiconductor wafer fabrication. These assets are typically lined with robust CRCs designed to protect their steel or concrete substrates from their corrosive contents for long periods of time. If that primary system fails or leaks occur otherwise, secondary containment systems are there to capture any breaches.

The level of secondary containment required for an application depends on the type of chemicals used and the potential volume of spillage that may occur. In some cases, a secondary containment system might only need enough capacity to capture up to 10% of the total volume of the primary containers. In others, it may need to house 100% of the volume of the largest container or more, as certain applications also require enough capacity to handle the largest tank's volume plus that of a 24-hour rain event.

In any case, the concrete basins typically used for secondary containment must be lined with CRCs that are compatible with the harshest possible substances that could land inside. That substance might not be the leaked chemical itself, but rather that chemical plus water, as certain substances are more aggressive when diluted. Take sulfuric acid, for example, which is more caustic when diluted to a 92% concentration in a secondary containment basin containing water compared to the typical 98% concentration used in semiconductor wafer production.

The length of guaranteed containment time is also critical for secondary vessels. The norm for most lining applications is 72 hours of ensured erosion-free performance to allow facilities to remove spills before the lining breaks down. However, containment trenches may require an immersion exposure timeline exceeding six months, as they are not emptied as frequently. Any materials used to line a secondary containment vessel must offer the appropriate time of protection or longer so facilities can capture dangerous spills and remediate them before the corrosive contents can damage the lining and begin attacking the concrete substrate.

A variety of high-performance lining materials can meet even the most stringent requirements for chemical exposures in secondary containment vessels over time. Vinyl esters offer the most robust protection and are appropriate for handling highly corrosive materials like sulfuric acid and hydrofluoric acid. They are often specified for trench applications due to their long-term resistance to chemical attacks. Novolac epoxies are also commonly used due to their high chemical resistance. Some CRC formulations feature additives, such as wax or glass flakes, for added reinforcement against corrosive chemicals. The additives help to keep the chemicals from working their way through the coating to the substrate below. Secondary containment CRC systems are often built on a urethane concrete mortar basecoat, feature a chemical-resistant intermediate coat and are topped with a chemical- and UV-resistant finish coat.

COMBATING CORROSION WITH CRCS

To ensure long-term operational performance, semiconductor facilities must use an array of CRCs throughout various environments to prevent corrosion from deteriorating assets and contaminating airstreams. Selecting the most appropriate CRCs for any given environment is best done at the design stage of developing a new fabrication facility, but maintenance specifications can also be optimized later on. Regardless, it's important for specifiers, engineers, architects and facility owners to connect with coatings suppliers as early as possible to review every need and every potential exposure to ensure the most appropriate CRCs are used.

A helpful coatings supplier should be able to simplify the selection and installation processes with a facility's CRC selections. For example, they can often limit materials to a small selection of products to reduce inventory needs and installation complexity. They can also limit curing agents, perhaps to a single product, to reduce or eliminate the chance of installers making mixing errors. Most importantly, they can steer stakeholders to the optimal solutions that meet the facility's needs for long-term corrosion protection, operational longevity and profitability.

ABOUT THE AUTHORS

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