specialfocus

Chemical process and plastics

PLASTICS IN CHEMICAL PROCESSING

by Newell Rollins and Doug Hodge

Thermoplastics are becoming the material of choice for more and more chemical process applications, not just because of the affordable cost and ease of installation but also for their superior broad spectrum chemical resistance and long-term system design capabilities. Unlike their metallic counterparts, thermoplastics and thermosets like PVC, CPVC, PP, ABS, HDPE, PVDF, ECTFE and FRP have no given wall loss over time and do not need to be oversized to allow for scale buildup.

Plastics have proven themselves time and again in all types of chemical applications. Examples of how plastics are being used can be found in the municipal water and wastewater industry. Most of the chemicals used to treat drinking water and wastewater are stored and delivered in plastic materials. Sodium hypochlorite, sodium hydroxide, sodium bisulfite, hydrofluosilisic acid and potassium permanganate just to name a few are all stored and delivered in plastics.

A delivery system for sodium hypochlorite would begin at the bulk storage tank which would be either HDPE or FRP. All of the vents, fill piping and output piping would be schedule 80 PVC. The level controls are contained in plastic. The pumps that deliver the chemical can be magnetic drive plastic head style pumps. The cement used to install the piping is specifically formulated for chemical applications. This type of delivery system is typical for almost all of the chemicals used in water and wastewater treatment.

Captor tanks

Chemical manufacturing and custom chemical blenders all use many types of thermoplastics in their processes because of the superior chemical resistance. The majority of drain-waste-vent waste systems in chemical and manufacturing plants as well as schools, laboratories, hospitals, research facilities and universities because of the nature of the waste that piping will encounter are some type of thermoplastic material such as polypropylene or PVDF.

There are many chemicals that can only be stored and transported in plastic materials so the use of HDPE or FRP bulk storage tanks and day tanks as well as the piping, valves, level controls, flow meters, pressure gauge fittings, temperature gauge fittings, pumps, oxidation reduction potential, conductivity, resistivity, pressure differential fittings and filtration components are all going to be made of some type of plastic.

All of the major aquariums throughout the world have miles of plastic pipe and fittings carrying both fresh and salt water as well as the chemicals that are used to treat the water to keep the animals safe and healthy.

Renal care facilities, pharmaceutical, biopharm and medical research facilities utilize plastics for both high purity water delivery and DWV waste systems.

The proper choice of material for an application as well as design and installation techniques will ensure a long-term well-performing system. Doug Hodge will now discuss the considerations that pertain specifically to the choice of plastics for high purity chemical applications.

Challenges in high purity chemicals

In the high purity semiconductor industry, fluoropolymer plastics have been required for aqueous chemicals, solvents and process slurry for more than 40 years. In order to achieve acceptable process results, chemicals must have less than 100 parts per trillion (ppt) total contamination from the piping system. Valves, fittings, tubing, filters and inline instrumentation must be pristine right out-of-the-box to meet these requirements.

As these elements have matured to parts per trillion purity requirements, the defects being considered today have evolved to the point at which molecular contamination and other elements of process are coming under ever-increasing scrutiny. It is for this reason the semiconductor industry is being challenged to push the envelope with regards to construction materials and the resulting point-of-use purity levels over a wide range of bulk and specialty chemicals.

Fluoropolymer resins are used in high purity components in semiconductors for their resistance to corrosive acids, being inert to common process chemicals and having minimal contamination to flow. Because metal particles contribute the deadliest types of contamination to a semiconductor chip, perfluoroalkoxy (PFA) fluoropolymer resin has provided the best overall material solution. Other fluoropolymers, such as PVDF, PTFE, ETFE, TFM and more are used commonly in systems; however, they have greater material or cost issues. PFA is still the leader.

Piping components, such as valves, fittings, pipe and tubing, filtration elements and housing and instrumentation are completely constructed from high purity fluoropolymers. Even if metal is required, such as a pneumatic valve spring, it is sometimes coated with a fluoropolymer so no metal is exposed to corrosive fumes that might migrate into the flow stream.

Purad® ultra high purity PVDF piping and diaphraghm valves by Asahi/America

Worker in protective gear using the Asahi SP-110S IR Fusion tool

Other polymers and elastomers are used in high purity flow streams, but each part is evaluated and tested before use. Materials and manufacturing processes are closely scrutinized at each step in the supply chain — from raw material to finished product. The suppliers in this industry are being challenged by the chip makers to meet ever-exacting standards.

Manufacturers install expensive facilities systems to meet a variety of high purity requirements for microelectronics, medical devices and pharmaceutical industries. State-of-the art clean rooms, ultrapure water systems, and sophisticated instruments for measuring micro particles and metal and ion contamination are all part of the high purity game. Can the bar be raised in the semiconductor segment? With increasing numbers and volumes of chemicals required to support processes that are defined in line widths as small as 0.020 microns, the semiconductor fabrication engineer considers the effects that chemical solutions and chip processes have on the yield.

For a few top-end chip makers, there is a next step up. A new US$4.4 billion initiative by a select group has formed at Sematech in Albany, NY, USA, in a consortium to develop the next level. What does that mean for plastic materials and component manufacturers? The most critical issue is use of larger quantities of chemicals. The quantities of high purity chemicals required by today's state-of-the-art semiconductor manufacturers present some major challenges. From an engineering perspective, most of the component and equipment designs available to this market are typically geared toward smaller flows, not the next generation, high volume chip manufacturer or high volume producer. Manufacturers in the liquid chemical industry expect upsizing of all components, but do not foresee material purity issues to jump significantly.

The primary challenge involved with developing and maintaining a large scale chemical purification process is analytical. Detection limits must be driven down to a low enough value so that analysis can reveal subtle variations on the order of 1 ppt. Achieving and maintaining best-in-class analytical capability is key to meeting this evolving requirement and the benefits are twofold.

Once variability of the process is known, its causes can be investigated and eliminated. A direct correlation can often be shown between analytical capability (detection limit) and reported product quality. In many cases, a process can be much cleaner than a producer's ability to measure and the direct result of improving detection limits is the ability to see and report the improved data. This instrumentation is one of the greatest challenges in moving to the next level.

Application-specific products are still frontiers in the high purity markets with room to improve. Processes are pushing the boundaries for high temperature chemicals (up to 356°F/180°C) in components such as valves and fittings. Higher temperatures speed up the production process of making semiconductor wafers. Certain specialty solvents used in semiconductor processes are extremely aggressive and may be flammable. Historically, these chemicals are piped through electropolished stainless steel tubing. As the industry goes to the next level, this may not be acceptable. New solutions in plastic materials will be the answer.

Some point-of-use liquid flow control requires extremely low flow requirements (< 5 ml/min). Accuracy and repeatability are critical in the smaller line widths. Measurement and control solutions are limited by the high purity plastic materials and cleanliness requirements.

Certain corrosive chemicals easily permeate PFA tubing and components causing damage to the surrounding environment. Some component makers are presently developing products to minimize or stop this effect, saving equipment and facilities from costly damage.

According to Moore's Law, the number of transistors on a chip roughly doubles every two years. As the semiconductor industry has evolved with their innovative products, they continue to push this law forward. The manufacturers of high purity components and materials are a critical part of this history and will continue to be as it evolves. ■

Newell Rollins is national technical manager and Doug Hodge is managing director of pure systems for Harrington Industrial Plastics LLC, 14480 Yorba Avenue, Chino, CA 91710-5766 USA; (909) 597-8641, fax (909) 597-9826, e-mail info@hipco.com, www.harringtonplastics.com.