INTERNATIONAL MOLYBDENUM ASSOCIATION
THE VOICE OF THE MOLYBDENUM INDUSTRY

Melting glass with molybdenum

We prize glass because of its clarity and beauty, and also for its immense versatility. Molybdenum components help to make the glass and glass products used every day. Moly's high strength at the high glass melting temperature and its resistance to corrosion by molten glass make it the ideal material for this purpose.

Human beings' use of glass predates historical records, going back to the days when primitive peoples used obsidian glass formed naturally from lava for knives and cutting implements. In its progression from ancient history to modern times, glass has shown its utility in countless applications and has become indispensible to everyday life. Today, molybdenum is just as indispensible to glassmaking.

Early glassmaking

Archaeological evidence suggests that the first 'manufactured' glass globules were formed serendipitously in cooking fires. The early humans who discovered these globules probably used them for decoration. Archaeologists think that the first intentionally created glass products appeared 3,000–3,500 BCE in Mesopotamia (modern Iraq and northern Syria). Early glassmakers could not create enough heat to work their glass easily, but with the invention of the blowpipe in Babylonia (modern southern Iraq) in about 1,500 BCE, glassmaking became an important technology. Artisans made most objects for decorative or utilitarian purposes, but they always dreamed of creating windows from their materials. The Romans attempted to make windows by flattening globs of hot glass, but the resulting product was too thick and not clear enough to be a good window.

A glass head thought to be of King Amenhotep II, dating to about 1,500 BCE.
© Corning Museum of Glass

It was not until the 15th century CE that glassmakers in Venice created the first clear glass called 'cristallo', but glass windows remained a luxury because of their cost. The Industrial Revolution greatly increased the ability of manufacturers to melt glass and in 1902 Emile Foucalt of Belgium invented the sheet glass drawing machine, making mass production of window glass possible.

Electricity is introduced

With the advent of electric power, engineers began designing electric furnaces to replace coal or gas fueled furnaces traditionally used to melt glass. Early design attempts relied on electric arcs and radiation to heat the glass, but the technologies did not find wide acceptance. In the 1950s, researchers discovered that molten glass conducts electricity, and that molybdenum metal electrodes could heat glass directly by passing electric current through the molten glass bath. Molybdenum electrodes began to be used to boost the power and production of conventional fossil-fired furnaces. All electric furnaces using molybdenum electrodes soon followed.

Advanced furnace designs

Increased use of electric furnaces in modern glassmaking has also increased the use of molybdenum. Advances have been largely related to electrode design. Side-entry and bottom-entry designs are used, as well as electrodes suspended into the glass tank from above. Molybdenum stirrers help to homogenize the melt. The molten glass bath protects these molybdenum components from the rapid oxidation that would occur at that temperature in air, so that they provide long and reliable life. Designers use inert cooling gases or water cooling to protect the portion of the electrode outside the glass bath from oxidation.

Molybdenum components also protect furnace refractories from wear and erosion as 'armor' covering the refractory brick in vulnerable areas. Advanced coatings allow these components to resist oxidation even when being brought to temperature on a cold start with no molten glass to protect them.

There is always competition

Few other materials can match molybdenum for the job. Platinum heads the list of molybdenum's competitors. It is ideal as a glass electrode in many aspects, but it is very soft and very expensive! It is used only where nothing else will do, often as a cladding material on molybdenum components like stirrers. Tin oxide has limited use because it is fragile. It is found in small furnaces and in furnaces melting glass compositions that are oxidizing to molybdenum. Carbon is another candidate but it is also fragile and can support only low current ›

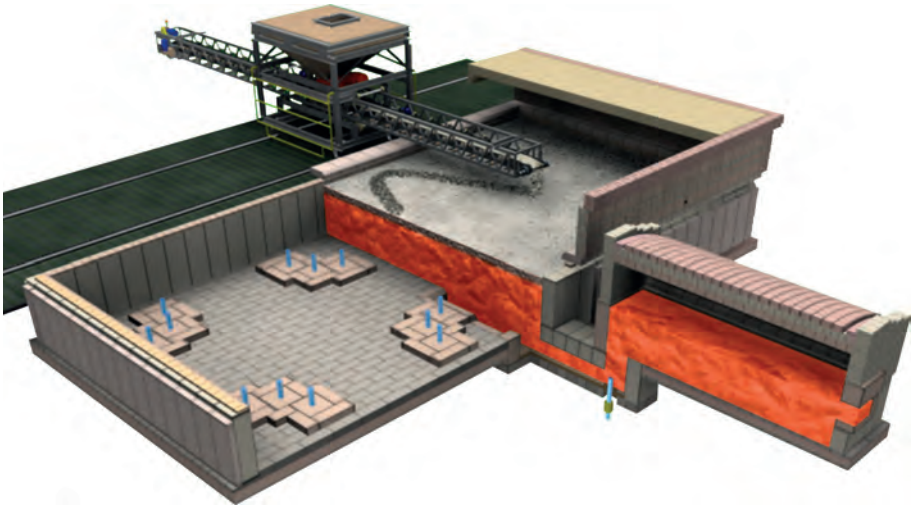
densities that require large electrodes; it suffers from oxidation problems of its own. Sometimes nickel alloys like Inconel® are used but they suffer from low strength at temperatures above 1200 °C (the most common glass, soda-lime glass, melts in the range of 1500 °C), and the electrodes sag and droop during use.

Molybdenum is the material of choice for electric and electric-boost fossil-fired furnaces. It is strong and sag resistant at temperature, resistant to thermal shock, chemically compatible with a wide array of glass compositions, and resistant to corrosion and erosion. These advantages make molybdenum the hands-down winner for electric melting when viewed from the standpoint of total-life cost, even though it is initially more expensive than all the alternatives except platinum.

Molybdenum-made glass is an important part of our world

Glass made with molybdenum electrodes is part of everyday life. It is used for mirrors, the windows that brighten homes and workplaces and provide safety in cars, glass bottles and the ubiquitous flat-panel displays of televisions, computers, tablets and mobile phones. Glass is even used for the optical fibers that support high-speed internet networks, and the panels critical to efficient solar power generation. All of the technologies above and many more are enabled by glass products made with the help of molybdenum glass-melting electrodes. (John Shields)

The New Beijing Poly Plaza has one of the largest cable-net glass curtain walls in the world. It allows a clear view of the surrounding city.



Glass furnaces often use the bottom-entry electrodes, shown as vertical blue components in this cut-away view. The open-top design uses the insulating properties of the raw material to improve thermal efficiency. © Toledo Engineering Company, Inc.

The author expresses his gratitude to Mike Friess, Senior Director, Project Management and Brian Naveken, Design Engineer at Toledo Engineering Co. for discussions regarding electric furnace design philosophy and material choices.