



Glass History

Stone Age

For millions of years, Natural Glass has been formed when super-high temperatures cause certain rocks to melt, fuse, and then cool rapidly. Volcanic activity, lightning strikes, or the impact of meteorites all produced natural glass. Fossil evidence shows that Stone Age humans used this glass to make tools as far back as 9,000 years ago. Obsidian, the shiny black glass formed when lava cools quickly, was widely used by ancient peoples for tools such as spearheads and cutting instruments.

Bronze age

Glassmaking dates back to at least 3600 BC in Mesopotamia. The earliest known glass objects were beads from mid-2,000 BC. Perhaps the accidental by-product of metal-working or the production of faience, this pre-glass vitreous material was made by a process similar to glazing.

The first known Persian Glass in the form of beads dates to 1600 BC. It was discovered during explorations of Dinkhah Tepe in Iranian Azerbaijan by Charles Burney. Subsequently, glass tubes belonging to the middle-Elamite period were discovered by French archaeologists at Chogha Zanbil. Mosaic Glass cups, found at Tepe Hasanlu and Marlik Tepe in northern Iran, date to the Iron Age.

Glass tubes containing kohl have been found in Iranian Azerbaijan and Kurdistan Province. Belonging to the Achaemenid period, glass vessels of this era were usually plain and colorless. By the Seleucid and late Parthian era, Greek and Roman techniques were prevalent. During the Sasanian period, glass vessels were being decorated with local motifs.

The first known methods for shaping molten glass into objects were Drawing and Casting. These techniques were believed to have first been used by Sumerians in ancient Mesopotamia (Iraq and Syria) more than 5,000 years ago. In Glass Drawing, a metal hook is used to pull molten glass out of a tank while it is a thick, red-hot liquid. The glass is drawn into long, thin strands which harden into rods or are cut into beads while still soft. In Glass Casting, molten glass is poured into a form and allowed to harden. The earliest glass molds were probably made of sand.

Glass beads and simple cast pieces dating to circa 3500 BC have been found in the region of Mesopotamia, and glassmaking instructions have been discovered in ancient Sumerian texts. This technology spread to neighboring societies via the trade routes and, over the next 2,000 years, simple glassmaking spread across Mesopotamia and the Middle East.

The earliest glass item from the Indus Valley civilization of India is a brown glass bead found at Harappa, dating to 1700 BC. This makes it the earliest evidence of glass in south Asia. Texts such as the Shatapatha Brahmana and Vinaya Pitaka mention glass, implying they could have been known in India during the early first millennium BC. Glass objects have also been found at Beed, Sirkap and Sirsukh, all dating to circa the 5th Century BC. However, evidence for widespread glass usage comes from the ruins of Taxila (3rd Century BC), where large quantities of bangles, beads, small vessels, and tiles were discovered.

The site of Kopia, in Uttar Pradesh, is the first site in India to locally manufacture glass, with items dating between the 7th Century BC and the 2nd Century AD. Early Indian glass of this period was likely made locally, as it differs significantly in chemical composition when compared to Babylonian, Roman, and Chinese glass.

Late Bronze Age

There was rapid growth in glassmaking technology during the late Bronze Age in Egypt and western Asia. Archaeological finds from this period include colored glass ingots, vessels (often colored and shaped to mimic prized carvings made of semi-precious stone), and beads.

Around 1500 BC, Egyptian glassmakers produced the first known glass containers. They would dip solid cylinders of silica paste (crushed sand and water) into molten glass, allow the glass to harden, and then break out the core. The method was improved by pouring molten glass over compacted sand forms, and further by glass pressing, where molten glass was poured into a mold and another mold pressed into it. This vast improvement over wood or clay containers was put to many uses: as bottles for perfumes, dyes, and cosmetics; and as containers for carrying and preserving food and beverages.

By the 15th Century BC, glass production was occurring throughout western Asia, Crete, and Egypt. It is believed that the techniques and recipes for the fusing of glass were a guarded secret of the palace industries of these powerful states. Therefore, glassworkers of other realms relied on imports, often in the form of cast ingots like those found on the Ulu Burun shipwreck off the coast of modern Turkey.

Glassmaking developed later in China as compared to the cultures of Mesopotamia, Egypt, and India. Imported glass objects in the form of polychrome eye beads first reached China during the early 5th Century BC. These imports created the incentive for the domestic production of glass beads.

The use of glass diversified during the Han Dynasty of 206 BC to 220 AD. During this period, the inception of glass casting stoked the production of molded items like bi disks and other ritual objects. Chinese glass from the Warring States and Han period vary greatly in chemical composition from imported glass objects, with glasses from this period contain high levels of barium oxide and lead, distinguishing them from the soda-lime-silica glasses of western Asia and Mesopotamia. In 220 AD, the Chinese lead-barium glass tradition declined, with glass production not resuming until the 4th and 5th Centuries AD.

Classical Antiquity

According to Pliny the Elder, Phoenician traders first stumbled upon glass manufacturing techniques at the site of the Belus River. Georgius Agricola reported a traditional serendipitous discovery tale:

“The tradition is that a merchant ship laden with nitrum being moored at this place, the merchants were preparing their meal on the beach, and not having stones to prop up their pots, they used lumps of nitrum from the ship, which fused and mixed with the sands of the shore, and there flowed streams of a new translucent liquid, and thus was the origin of glass.”

Legends aside, Modern Glass is believed to have originated in Alexandria during the Ptolemaic period (305 to 30 BC) and, later, in ancient Rome. Alexandrian artisans perfected a technique known as Mosaic Glass, where slices of glass canes of different colors were cut crossways to create different patterns. The Romans also perfected Cameo Glass, in which the design has been produced by cutting away a layer of glass which leaves the design in relief.

From across the Roman Empire, archaeologists have found glass objects that were used in domestic, industrial, and funerary contexts. Across England, Anglo-Saxon glass has been recovered during excavations of both settlement and cemetery sites. Glass of the Anglo-Saxon period was used in a range of objects including vessels, beads, windows, and jewelry.

Around 30 BC, craftsmen in Phoenicia (Lebanon and Syria) discovered that glass would inflate and take shape when they blew through a hollow metal tube into a molten lump. Now, a greater variety of wares could be produced for a greater variety of uses. Glass vessels were now inexpensive compared to pottery vessels. At this time, with Phoenicia part of the Roman Empire, the Romans embraced the new technology. Over the next several centuries, glassblowing spread throughout the empire including the Middle East, North Africa, and almost all of Europe. Glassblowing was the predominant way of making glass in these regions for the next 2,000 years.

During the Hellenistic period, new techniques of glass production were introduced. Glass began to be used for larger pieces like tableware. Techniques developed during this period include slumping viscous (not fully molten) glass over a mold to form a dish; and Millefiori (Thousand Flowers), where canes of multicolored glass were sliced, arranged together, and fused in a mold to create a mosaic-like effect. It was also during this period that colorless glass began to be prized and methods for creating it were explored.

Glass qualities like color, transparency, and heat-resistance are determined by the ingredients mixed with silica. These recipes gradually improved and, circa 100 AD in Alexandria, the manganese oxide was added to the mix. This resulted in a formula for nearly transparent glass, leading to the use of glass for windows in the most important buildings in Rome and the most luxurious villas of Herculaneum and Pompeii. Early windows were usually of cast glass, though some may have been of rolled glass. These first glass windows were thick, cloudy, and uneven but they let light in and kept weather out.

First Millenium

During the 1st Century AD, the glass industry experienced a wealth of technical changes with the introduction of glassblowing and the dominance of colorless (or aqua) glasses. Raw glass was being produced in different locations than where it was worked into finished vessels. By the end of the 1st Century, large scale manufacturing, primarily in Alexandria, resulted in glass becoming a commonly available material in the Roman world. The fall of the Roman Empire in the 5th Century marked the beginning of the Dark Ages in Europe, resulting to a cessation of progress in glassmaking.

Islamic World

By the 7th Century, Muslim empires began to flourish in Asia and Africa. Over the next several centuries, Arab artisans, especially from Syria, became the world's premiere glassmakers. Huge advances were made in cutting, engraving, and coloring techniques. Techniques were invented to paint, enamel, and gild glass. Intricately decorated, multi-colored, gilded glass pieces from this era have been found in all parts of the Arab world.

Islamic Glass carried on the achievements of pre-Islamic cultures, especially the Sasanian Glass of Persia. The Arab poet al-Buhturi (820-897) described the clarity of such glass: "Its color hides the glass as if it is standing in it without a container." In the 8th century, the Persian-Arab chemist Jābir ibn Hayyān (Geber) described 46 recipes for producing colored glass in *Kitab al-Durra al-Maknuna* (The Book of the Hidden Pearl), in addition to twelve recipes inserted by al-Marrakishi in a later edition of the book. By the 11th Century, clear glass mirrors were being produced in Islamic Spain.

Middle Ages

After the collapse of the western Roman Empire, glass making technologies emerged in northern Europe. Byzantine Glass in the Roman tradition evolved in the eastern part of the Empire. The claw beaker was popular as a relatively simple vessel that exploited the potential of glass.

Anglo-Saxon Glass has been found across England during archaeological excavations of both settlement and cemetery sites. Glass in the Anglo-Saxon period was used in the manufacture of vessels, beads, windows, and jewelry. However, the Roman departure from Britain in the 5th Century brought changes. Though excavations

of Roman-British sites revealed plentiful amounts of glass, the amount recovered from Anglo-Saxon sites of the 5th Century and later is minuscule. Apparently, the change in burial rites in the late 7th Century impacted the recovery of glass, as Christian Anglo-Saxons were buried with fewer grave goods. From the late 7th Century on, window glass is found more frequently: a direct result of the introduction of Christianity with its construction of churches and monasteries.

Glass objects from the 7th and 8th Centuries have been found on the island of Torcello near Venice. These form an important link between Roman times and the later production of glass in that city. About 1000 AD, a major technical breakthrough occurred in northern Europe: soda glass, formerly produced from white pebbles and burnt vegetation, was replaced by glass made from the much more available potash (obtained from wood ashes). From this moment, northern glass differed significantly from that made in the Mediterranean where soda remained in common use.

Up until the 12th Century, Stained Glass (to which metallic or other impurities had been added for coloring) was not widely used. However, it became an integral component of Romanesque and Gothic art. Though most surviving specimens are found in church buildings, Stained Glass was also used in grand secular buildings.

The 11th Century saw the advent of the German technique of making Sheet Glass by blowing spheres. The spheres were swung out to form cylinders, cut while still hot, then the sheets flattened. Perfected in 13th Century Venice, this Crown Glass process was used until the mid-19th Century.

Around 1000 AD, the first vision aid called a Reading Stone was invented. This was a glass sphere, laid on top of the material to be read, magnifying the letters. Circa 1284 in Italy, Salvino D'Armato is credited with inventing the first wearable eye glasses.

Thirteenth Century

Since the 13th Century, Bohemian Glass (or Bohemia Crystal) has been produced in Bohemia and Silesia (now the Czech Republic). Excavations of glass-making sites date to around 1250 AD and are located in the Lusatian Mountains of northern Bohemia.

It is not known exactly when glassmaking began in Venice, but by 1224 the city's glassmakers already had formed a guild to protect their trade. By 1291, there were so many Venetian glassmakers that their furnaces were causing fires throughout the city. In response, the city council had them all moved to the island of Murano, which became the center of luxury Italian glassmaking. Venetian Murano Glass was significantly different. The local quartz pebbles were almost pure silica, were ground into a fine clear sand, and were combined with soda ash obtained from the Levant (for which the Venetians held the sole monopoly).

The Renaissance

By the 14th Century, Venetian glassmakers were the world leaders in all aspects of the art. One of their most significant achievements was the development of the clearest glass of the time, Cristallo. This was to form the basis of a thriving export trade throughout Europe. Simple blown glasses of Cristallo were much in demand in the 16th Century. Lending itself to decoration by the engraving of delicate designs, the technique remained popular well into the 18th Century throughout Europe. Diamond-point engraving was especially practiced in the Netherlands and Germany.

Seventeenth Century

Dating back to 1620, blown Plate Glass was used in London for small mirrors and coach plates. Louis Lucas de Nehou and A. Thevart perfected the process of casting polished Plate Glass in 1688 in France. Prior to this, the mirror plates made from blown sheet glass were limited in size. De Nehou's process of rolling molten glass on an iron table made the manufacture of very large plates possible. The polishing process was industrialized around 1800 with the adoption of the steam engine to carry-out the grinding and polishing of the cast glass.

A major advance in glass manufacturing was the addition of lead oxide to the molten glass. This improved the appearance and made the glass easier to melt using sea coal as a furnace fuel; increasing its working period and making the glass easier to manipulate. Discovered by George Ravenscroft in 1674, the technique made him the first to produce clear Lead Crystal glassware on an industrial scale. Ravenscroft revolutionized the glass trade, allowing England to overtake Venice as the center of the glass industry in the 18th and 19th Centuries.

By 1696, after Ravenscroft's patent expired, twenty-seven glasshouses in England were producing his Flint Glass and exporting it all over Europe. In 1746, in response to the great success of the glass, the British government imposed a lucrative tax on it. Rather than adjust the lead content of the glass, manufacturers responded by creating highly-decorated, more delicate forms, often with hollow stems. This is known to today's collectors as Excise Glass. The British glass industry was able to repeal the tax in 1845.

By the 17th century, England was making glass in the Venetian tradition that was noted for its simplicity. Late in the 17th Century, Bohemia became a significant glass producing area, remaining important until the early 20th Century.

Eighteenth Century

Mid-18th Century England saw enameling become popular, leading to the development of Bristol Glass. Glass cutting also came into fashion at this time, with great richness of effect possible as the technique advanced. By the end of the 18th Century, as the technique further developed in Ireland, an entire surface of glass was being deeply cut to reflect light. English and Irish cut Lead Crystal was highly imitated in Europe and the US, and remains popular to this day. Waterford Crystal is a key example.

Nineteenth Century

The mass-produced glass of the Industrial Revolution dealt a blow to the artisans' craft that had been practiced for thousands of years. However, it also brought great leaps forward in glass quality.

In 1820, a process for mechanical bottle production was introduced in the US, greatly increasing the public's familiarity with and use of glass.

In 1876, John Jacob Bausch and Henry Lomb started Bausch and Lomb in Rochester, New York. They developed and refined many types of lenses for use in microscopes, eyeglasses, and magnifiers.

The Art Nouveau period introduced important techniques. Favrite Glass, invented by Louis Comfort Tiffany, was much admired and influenced glassmakers in central Europe. It coupled flowing shapes derived from naturalistic forms with a lustrous surface. The French glassmaker Émile Gallé and the firm of Daum Frères were also important designers of the Art Nouveau epoch.

Glass as a building material was introduced to the world in 1851 as the major component of London's Crystal Palace. Built by Joseph Paxton to house the Great Exhibition, this revolutionary building inspired the use of glass as a material for domestic and horticultural architecture.

In 1832, British Crown Glass became the first to employ the cylinder method to produce Sheet Glass. Produced by blowing long cylinders, this glass was cut along its length, flattened onto a cast-iron table, then annealed.

Plate Glass is produced by being ladled onto a cast-iron bed, then rolled into a sheet with an iron roller. While still soft, the sheet is pushed into the mouth of an annealing tunnel or temperature-controlled oven (called a lehr), through which it was carried by a system of rollers. James Hartley introduced the Rolled Plate method in 1847, allowing for a ribbed finish that was often used for extensive glass roofs such as in railway stations.

In 1887, the mass production of glass was developed by the firm Ashley of Yorkshire, England. This semi-automatic process used machines that were capable of producing 200 bottles per hour, far quicker than traditional methods of manufacture. Chance Brothers also introduced machine rolled Patterned Glass in 1888.

In 1898, Britain's Pilkington invented Wired Cast Glass, incorporating steel-wire mesh for safety. Commonly given the misnomer Georgian Wired Glass, it post-dates the Georgian era.

Twentieth Century

In the US in 1902, Irving W. Colburn patented the Sheet Glass Drawing Machine, making the mass production of glass for windows possible.

In 1904, a patent for a Glass Shaping Machine was granted to Michael Owen. This invention is responsible for the large scale production of bottles, jars, and other containers.

In 1915, Corning Glass made Pyrex™, the first heat-resistant glass for cookware. The name is derived from Pyro: the Greek word for Fire.

Borrowing from a French invention in 1919, Henry Ford sandwiched two layers of glass with a thin layer of cellulose between them. The resulting sheet of Safety Glass was transparent and shatterproof, and put in all Ford cars.

In 1929, the Foster Grant Company sold the first pair of sunglasses at the Woolworth's on the boardwalk in Atlantic City.

In 1926, Corning developed the 399 or Ribbon Machine to make light bulbs. Soon capable of producing 400,000 bulbs a day, it made light bulbs affordable for the average household.

Patented in 1929, Edwin Land invented the first modern filter to polarize light. This Polarizing Celluloid became the critical element in polarizing sunglass lenses that reduce light glare. Land continued to experiment with numerous types of Polaroid material in sunglasses and other optical devices and, in 1937, founded the Polaroid Corporation and used his filters in sunglasses, glare-free automobile headlights and stereoscopic 3-D photography. Nonetheless, Land is best known for the invention and marketing of instant photography.

In 1938, the Polished Plate process was improved by the UK's Pilkington by incorporating a double grinding process to upgrade the quality of the finish.

In 1959, Pilkington Brothers developed the Float Process for making Sheet Glass. Molten glass is drawn from a tank, then floated over the surface of a tank of molten tin and allowed to cool. This technique formed a continuous ribbon of glass with uniform thickness over a very flat surface. Nearly all sheet glass made today uses the Float Process.

In 1970, fulfilling an idea that had been around for decades, Corning developed a workable silica Optical Fiber. Used mostly for data transmission, this innovation jump-started the fiber-optic revolution.

Another invention of the late 20th Century is Smart glass. Coated with different substances, Smart Glass reacts to outside stimuli. Examples include: Photochromic Glass, that responds to light as in self-darkening sunglasses; Thermo-chromic Glass, that responds to heat; Electrochromic Glass, that responds to electricity where a flick of the switch can change its opacity; and other coatings which can change the color of glass.