The study of the historical development of glass in ancient times

Dr. Shaimaa salama Ibrahim desoki
Lecturer in glass department-faculty of applied arts-Helwan university
shaimaasalama28@gmail.com

Abstract:

This paper discusses historical development of glass in ancient times, identify the most important characteristics of glass in every era of time, through the study of their properties, chemical composition of the types of glass and production methods, through the study of some archaeological models of global museums to reach the most distinctive characteristics of each era ,The aim of this paper is to explore these aspects by using a combination of focused studies and case studies in various ancient and historical periods. Each case study in ancient Egyptian period, Roman Middle East, and the Islamic world.

Key words: historical development of glass, Ancient Egyptian, Roman glass, Islamic glass, chemical composition, glass techniques.

الملخص:

يتناول البحث دراسة التطور التاريخي للزجاج في العصور القديمة، وتحديد أهم خصائص الزجاج في كل عصر، من خلال دراسة خواصها والتركيب الكيميائي لأنواع الزجاج وطرق الإنتاج، وذلك من خلال دراسة بعض النماذج من المتاحف العالمية وصولا إلى الخصائص الأكثر تميزا في كل عصر ، **ويهدف البحث:** لاستكشاف هذه الجوانب باستخدام مزيج من الدراسات المركزة ودراسات الحالة في مختلف الفترات القديمة والتاريخية تحديدا في العصر المصري القديم، العصر الروماني، العصر الإسلامي .

الكلمات المفتاحية: التطور التاريخي للزجاج، الزجاج في العصر المصري القديم، الزجاج الروماني، الزجاج الإسلامي، التركيب الكيميائي، تقنيات الزجاج.

I.INTRODUCTION

Ancient Egyptian Glass

As early as the third millennium B.C., craftsmen in Mesopotamia discovered how to glaze jewelry and small objects with colored glass. The new material joined other vitreous glazes, like faience, as a less expensive substitute for rare and precious stones, such as lapis lazuli. Subsequent developments, especially the use of simple molds, enabled craftsmen to form objects entirely from glass.

In all likelihood, the Egyptians learned glassmaking from their Asiatic neighbors, possibly from captives taken during Egyptian military campaigns in the East under the eighteenth-dynasty pharaoh Thutmosis III (1490–1436 B.C.). The glass industry, once transplanted to Egypt, grew vigorously, fueled in part by the abundance of the raw materials required to manufacture glass. Egyptian workshops not only produced a variety of wares for consumption by the royal court and aristocrats, who could afford such luxuries, but also exported large quantities of raw glass.

Figure (1): one of the earliest Egyptian glass vessels about 1425 B.C, height 8.7 cm., British museum, Uk.

This jar is one of the earliest Egyptian glass vessels to have been found. The few glass beads of the Old Kingdom (about 2613-2160 BC), made a thousand years earlier, The Egyptians began producing glass in quantity in the New Kingdom (1550-1070 BC). The technique was perhaps brought to Egypt by Syrian craftsmen, as its introduction seems to coincide with the successful Syrian campaigns of Thutmose III. Glass was produced by heating quartz sand and natron until they were molten, adding a color agent such as a copper compound for blue and green. To make a glass vessel, a core of sandy clay was molded over the end of a metal rod to form the interior shape. The rod was dipped into the molten glass and spun to coat the core. The craftsman added details such as handles and bases using tongs, while the glass was still hot. The color of this vessel probably imitates turquoise, the yellow and white represents gold and silver. The tamarisk trees, dots and scales, and the name of the king are enameled, the earliest known example of this technique in Egypt.

II. Ancient Egyptian glass Chemical composition

The ancient Egyptian glass basis of sodium and calcium silicate, which looks like a modern ordinary glass in the nature of the materials used in the installation is that the proportion of material in both different if the glass talking contains a high proportion of silica and calcium oxide, and the ratio is less than calcium oxide and the ratio of less than less than iron oxide and aluminum alkali also does not contain any alkaloids, as it does not contain magnesium oxide or magnesium oxide to the glass industry requires a fusion to the glass industry require fusion at a temperature between 1400 and 1500 degree cellulose to a string of vitrified material and the oxide alkaline and alkaline mud but if we want to get on the glass of a particular kind, it enables us to add various auxiliaries for this group this mixture is gradually under the influence of heat through the formation of sticky paste continue formed between 650 and 1000 degrees cellulose .

III. Glass production:

The ingredients were ground as finely as possible and mixed. Fritting required only a relatively low temperature (at least 800 °C), but the mixture had to be stirred for hours to achieve consistency. The frit, after removing and discarding unmelted sediments which had collected at the bottom and the vesicular mass of the top, was ground up, melted at up to 1100

°C and then poured into molds or ground up again, so that the resulting glass particles could be worked over an open fire. The proximity to the fire and lack of protective measures could cause eye and skin problems for the worker.

The transparency of the end product was affected by the amount of bubbles included in the glass. This could be reduced by vigorous stirring during fritting and the addition of antimony trioxide (Sb_2O_3), but there is no proof that this was done intentionally during the New Kingdom. Impurities which affected the clarity could be neutralized by additives.
carbon dioxide and water vapor during heating, as well as get rid of the Salafist class filled with dirt, which reviews the bottom of the pot and glass require fusion at a temperature between 1400 and 1500 degrees cellulose.

IV. <u>Techniques:</u>

Core-forming: technique The manufacture of vessels or objects by trailing molten glass around a core of clay, mud, sand, and organic material made in the shape of the desired vessel. Threads of colored glass are usually trailed onto the surface for decoration. The exterior surface of the vessel is smoothed by marveling while the glass remains hot and pliable. Finally, the core is removed after the vessel has been given ample time to anneal

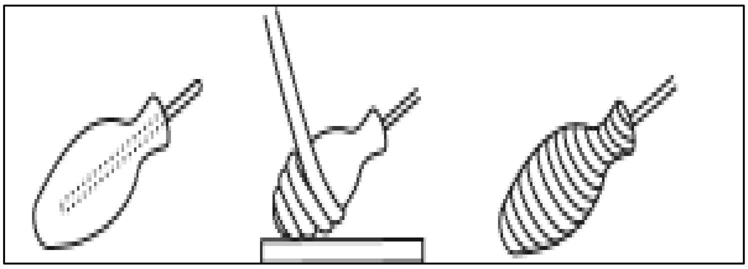

Figure (2): core-forming technique.

Casting techniques: Casting glass into molds was only of minor importance during the New Kingdom, but continued to at least a small extent after core-forming had been abandoned due to the introduction of **glass blowing** under the Romans.
Casting is a technique of pouring hot glass into a mold. After the glass cools, glassmakers use various grinding and cutting techniques to refine the vessel's form and decoration. Any of several glassmaking techniques involving the use of single (open), multipart (closed), or former molds.

Figure (3)*: Amber Bowl with White Ridges*, Roman, 1–100 C.E., cast glass 4-1/16 inches in diameter (The J. Paul Getty Museum, 2003.475).

V. Ancient Rome Glass:

It wasn't until around 300 BC that the Syrians invented the blowpipe which formed the foundation for the craft of glass blowing. During the Roman Empire, new techniques and experimentation began and these techniques are still used in glass blowing today. Roman craftsmen often used molds in conjunction with glass blowing to form new shapes and vessels. They also experimented with colors and adding gold and silver inlays to glass objects. Glass enameling later perfected by the glass blowers in the Middle East and Egypt began during the time of the Roman Empire.

form popular in the mid- to late first century A.D. and well represented among the finds at archaeological sites in Italy and elsewhere in the Roman world is the so-called lotus beaker. The name of this type of vessel derives from the relief decoration of protruding knobs, commonly identified as a lotus bud motif. Five rows of knobs protrude from the body of this fairly small example, with raised circular dots appearing in the spaces between the knobs. The size of the vessel, the absence of relief decoration toward the top of the body, and the slightly splayed rim may indicate an intended function as a drinking vessels Figure (4).

Figure (4) *Lotus Bud Beaker,* Roman, Eastern Mediterranean, 1st century C.E., mold-blown glass, 8-3/8 inches (The J. Paul Getty Museum, 2003.320).

VI. Chemical Composition

Ancient Roman glass can be classified as soda-lime glass. It was made from silicon, sodium and calcium oxides, with the addition of potassium, magnesium and aluminum oxides. In some Roman glass there's a characteristic pale blue-green color caused by iron oxide; an impurity, Roman glass has also been shown to contain around 1% to 2% chlorine, this is thought to have originated either in the addition of salt (NaCl) to reduce the melting temperature and viscosity of the glass, or as a contaminant in the natron.

Colors. All colors in roman glass were determined under the same circumstances, by day light. because the degree of transparency affects the perception of color, the glass is called transparent, translucent, or opaque depending on the amount of light transmitted. Black glass was not made by ancient roman glassmakers; glass appearing black is always a translucent dark color such as purple, green, blue or brown color.

Table 1: chemical analysis of some colored roman glasses.

Roman Glass	Colorant	Comment
'Aqua' .	Iron(II) oxide (FeO)	'Aqua' glass was pale blue green in color, the common natural color of untreated and early glass
Colorless	Iron(III) oxide (Haematite, Fe2O3)	Glass was produced by adding either antimony or manganese oxide. This oxidizediron (II) oxide to iron (III) oxide, which although yellow is much weaker as a colorant, Colorless so appears colorless. The use of manganese as a declarant was a Roman invention first noted in the Imperial period. Prior to this, antimony-rich minerals were used; however, r antimony acts as a stronger decolorant than manganese, producing a more truly colorless glass. In Italy and northern Europe antimony, or a mixture of antimony and manganese, continued to be used well into the 3rd century
Amber	Iron-sulfur compounds	Sulphur was likely to have entered as a contaminant of natron, producing a green tinge. The formation of iron-sulfur compounds produces an amber color.
Blue and green		Copper 2%-13% The aqua shade intensified with the addition of copper. During the Roman period this was derived from the recovery of oxide scale from scrap copper when heated. Copper produced a translucent blue glass moving towards a darker and denser
White	Antimony (such as stibnite Sb2S3)	Reacts with lime in the glass matrix to precipitate calcium antimonite crystals creating white with high opacity.
Yellow	Antimony and lead (such as bindheimite Pb2Sb2O6(O,OH	The yellow color is caused by the precipitation of opaque yellow lead pyroantimonate (Pb2Sb2O7). Yellow rarely appears alone in Roman glass, but it was used for the mosaic and polychrome pieces

VII. Techniques

Although glassmaking was invented around 3000 B.C. in the eastern Mediterranean region, glass was not widely available until the Roman period. Glass is made by melting a mixture of sand, soda or potash, and lime at approximately 700°C (1292°F). Liquid, or molten, glass is difficult to work with because it is so hot. Glassmakers use an assortment of tools but never touch their work directly. Roman glassmakers tried to find quicker, easier, and cheaper methods of creating glass objects, and they developed a variety of techniques that are still used today.

Core-formed: vessels are usually small and most often held perfume. This method was most expensive because it was very time-consuming and complex. The technique was first developed around 1500 B.C., though abandoned by 150 B.C.

Glasscasting: like core-forming, was a process developed before the Roman period. It was invented around 1400 B.C. In this process, powdered glass is placed into a hollow mold and heated in the furnace until it fuses together. After cooling, the mold is opened and an object in the shape of the mold emerges. The Romans used this technique to create ribbed bowls. These were the first mass-produced tableware.

Glassblowing: The invention of glassblowing in about 40 B.C. was the most important innovation in Roman glassmaking technology using a blowpipe. The technique was quick and easy compared to earlier processes, and glass became cheaper and more commonplace.

Mold-Blown Glass: Shortly after the invention of glassblowing, the Romans realized that if they inflated a glass bubble directly into a wooden or clay mold, vessels could be shaped and decorated in a single step. This technique allowed for a range of figural decoration.

VIII. Islamic glass:

In the Islamic world between the 9th and 11th centuries, a production model for glass can be suggested in which a number of centers manufactured raw glass partly from locally occurring raw materials, certainly for local consumption and perhaps for export to other glass-working centers.

This glassware from the Near East during the thirteenth and fourteenth centuries acquired an international reputation, so much so that in the next century the renowned factories of Venice adopted what was probably the Syrian method. Closer to home, Syrian suqs abounded with multicolored examples fabricated by local artisans who also catered to Egyptian demand, Glass mosque lamps with enamel decoration were mainly made during the Mamluk period in Egypt or Syria. They were made on commission and were presented by Mamluk sultans as gifts to Cairo mosques.

The most famous of the Museum of Islamic Art’s mosque lamps is made of honey-colored glass, with a foot shaped like an inverse chalice and a belly-shaped body that turns, above an indentation, into a long conical neck. On the body there are six eyelets laid on and pressed into escutcheon-shaped spaces. Chains were attached to these in order to hang the lamp from the ceiling. An additional funnel-shaped small oil lamp, which emitted the light, was hung within this lamp.

IX. Chemical compositions:

Most of the glass finds are soda-lime-silica glass. As a result of the chemical analysis, they have been classified into two groups by the rate of potassium content: 4 groups a shows a low content of potassium and strontium, and group B shows a high content of potassium and strontium. This distinction was presumably caused by the cases in which either natron or plant-ash was used as the supply source of alkali (potash).5 There is also some high lead glass. As for the color of the glass from Raya, the most popular is transparent pale bluish-green, which comprises about sixty percent of the whole. The second most is colorless, which is about twenty percent. Besides these, there is pale colored glass of green, blue or dark brown caused by impurities, and colored glass of deep blue, purple, or brown which is mainly in the decorative glass group.

X. Techniques:

In the 10th and 11th centuries, casting and cutting techniques reached an even higher level of achievement. And from the 12th through 14th centuries, gilded and enameled vessels took on a hitherto unseen brilliance. Glass artists created imaginative and highly schematic scenes with animals, geometric patterns, and calligraphic script painted in bright enamels. Through trade and political alliances, the new methods of ornamenting glass that had developed in the Islamic world slowly made their way to the west, giving rise to a re-emergence of glassmaking in Europe.

Islamic glassmakers inherited a long tradition of cold working: decorating an object by cutting, grinding, and polishing with a rotating wheel and abrasives, and by using hand-held tools. As early as the second half of the first century Islamic successors also made facet-cut objects, but in the ninth century they began to create vessels with linear decoration that included vegetal motifs, animals, birds, and inscriptions. During the ninth and 10th centuries, they produced great quantities of cut glass in several different styles.

The decorative glass makes up a little more than ten percent of all the registered glass. In the order of quantity, the excavated glass is given as follows: tooled and impressed decoration (38%); molded (14%); stained (13%); wheelcut (9%); incised (8%); stamped (3%); threaded (3%); and imbedded (2%).

This mosque lamp is an example of the fine gilded and enameled glass manufactured under the Mamluk dynasty, which ruled Egypt and Syria between 1250 and 1517. The design, dominated by a large-scale inscription in blue enamel, is typical of work produced around 1300 to 1350. The moldings below the mouth of the bottle and around the top of the high foot indicate that the form of this vessel is based on a precious-metal prototype, for which the moldings would have been structurally necessary.

Figure(5): mosque lamp ,mamluk period ,V&A Museum

in the 14th century, when Egypt and Syria were ruled by the Mamluk sultans, the glassmakers of the region produced large and magnificent lamps with enameled and gilded decoration, often including bold inscriptions in Arabic. In this example the text in blue in the upper band comes from the Qur'an, while the text in white below names the donor. He was Aqbugha, a high official at the court of the Mamluk sultan al-Malik al-Nassir Muhammad during his long third reign (1310–1340).

CONCLUSION

As a result of the above-mentioned examination, I have reached the following conclusions. The first point is:

1-ancient Egyptian one of the earliest who produced glass,The material which was intervention in the industry until late era is sand quartz and calcium carbonate and Natron or ashes of the girls and a small amount of colored materials,

15th Century B.C. ~ Glass vessels are first produced in Egypt,

500 B.C. ~ Glass vessels production begins on Roman Republic,

2-Roman glass industry sprang from almost nothing and developed to full maturity over a couple of generations during the first half of the first century A.D.Roman industry roughly coincided with the invention of glassblowing. This invention revolutionized ancient glass production, putting it on a par with the other major industries.

3- Major elements that determined the type of roman glass (typical soda-silica-lime glasses) and relative low concentrations of Mg, Ca, Al, Mn and Fe oxides were found with the exception of six samples. It is important to notice that there is a high dispersion in the major constituent compositions as a consequence of the evolution of the manufacturing processes of samples during a broad chronological range even if they are made in the same place.

4- Islamic art improved glass surface with different decorative techniques enamel, gilded, luster and cut, mamluk developing techniques from different parts of the Islamic world.

REFERENCES

1.Courtney Barman, **Glass blowing: Theory and Practice**, 1998.

2.Doreen Gail Hemp**, Process in Glass Art: A Study Of Some Technical And Conceptual**, Issue, University Of South Africa, 1995.

3.E. M. Stern, **Roman Mold-blown Glass: The First through Sixth Centuries, Rome**: L'Erma di Bret Schneider, 1995.

4.Fleming, S. J. **Roman Glass; reflections on cultural change**. Philadelphia, University of Pennsylvania Museum of Archaeology and Anthropology, 1999.

5.Frank Starr, **Art, History, Science, Literature, Social Studies, Technology,**The Corning Museum of Glass Education Dept., 1998.

6.Julian Henderson**, Ancient Glass: An Interdisciplinary Exploration**, Cambridge University Press, 2013.

7.Linda Komaroff and George Saliba , **The arts of fire : Islamic influences on glass and ceramics of the Italian Renaissance**,2004.

8.M. Dolores Petit-Dominguez, Rosario Garcia Giménez, Isabel S. de Soto, Isabel Rucandio,**Chemical And Statistical Analysis Of Roman Glass From Several North western Iberian Archaeological Sites** ,Mediterranean Archaeology and Archaeometry, Vol. 14, No 2, pp. 221-235,2014.

9.R.A. Grossmann (Richard A.) **Ancient Glass**, Yale University Art Gallery, 2002.

10. Ray Winfield, **The significance of roman glass**, JSTOR to digitize, preserve, and extend access to The Metropolitan Museum of Art Bulletin,2010.

11. Seth C. Rasmussen, North Dakota State University, Fargo, ND, **Advances in 13thCentury Glass Manufacturing And Their Effect On Chemical Progress**, Bull. Hist. Chem., VOLUME 33, 2008.