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Investigating the History of Making Islamic Glass in the 5th and 6th Centuries of the Islamic Era

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Abstract: In the 5th and 6th centuries A.H., glassmaking in the Islamic era reached its peak of growth and prosperity in Islamic lands and was accompanied by innovations in the field of construction and decoration, which became the inspiration for glassmaking in the world after this period. This article aims to introduce and categorize innovations in the methods of producing and decorating glass products from the fifth and sixth centuries of Hijra. This research is descriptive-analytical with a library method. The results show in the 5th and 6th centuries of Hijri, Islamic glassmaking underwent significant transformation and innovation, evident in four key areas: color and raw materials, form and manufacturing methods, decorations, and applications. Islamic glassmaking in Iran, Iraq, Syria, and Egypt exhibited distinct technical features compared to the preceding era, which in Iran ceased with the Mongol invasion in the 7th century AH, subsequently shifting to the glassmaking centers of Iraq, Syria, and Egypt.

Keywords: *Islamic, Glass Making, History, Iran.*

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Introduction

The production of glass from raw materials is called glassmaking, and the transformation of objects from their original shape (glassmaking) is called glassworking. In fact, two different processes are considered in the industry of the ancient world, which existed in different times and places (Antonaras, 2018: 6). Glass is also known by other names such as crystal, enamel, and mirror. In the past, until the age of Zakaria Razi, glass was considered to be one of the metals, but Razi placed it in the classification of stones (Shishegar, 2005: 165). Glass is a mineral product resulting from cooling in such a way that the molten material turns into a solid and strong material as a result of cooling without crystallization (Rahimi, Matin, 2003: 401). The rapid cooling of the molten material causes the irregular and random distribution of the atoms that make up the melt to remain the same because in this case there is not enough time for the atoms to arrange themselves in a regular manner (Mirhadi, 2002: 12). This statement means that unlike all other solids, glass does not have a regular and uniform internal structure. The main difference between the solid and liquid state of any specific substances, for example, ice and water or molten iron and solid iron, is the existence of a symmetrical and regular structure in solids, which is called a crystal. However, as the temperature rises to the point of melting, the internal order of matter is disturbed and the body becomes amorphous and irregular in terms of its internal structure. Glass is the only amorphous solid, that is why it can be considered as a virtual solid. This unusual feature in the internal structure of glass determines many of the characteristics and properties of this widely used material (Akbarzadeh , 1993: 12). As a comprehensive definition for glass, it can be said that it is an inorganic, synthetic, amorphous substance that is liquid when heated and solid when cold, and transparent or semi-transparent that allows light to pass through. Its composition includes silica in the form of sand (as a raw material), alkali in the form of sodium, potassium, etc. as a flux, lime and lead oxide as a strengthening agent, and metal oxides to create various colors (Shishegar, 2005: 165-166). The word glass is commonly used for a semi-transparent and brittle material that is used to make containers and many other objects. More correctly, glass refers to a state of matter that has an irregular chemical structure, or in other words, crystalline. Many types of such glasses are known, which are both inorganic (such as compound glasses and enamels, and even rare metallic glasses) and organic (Davison et al, 2012: 1). The Islamic era is one of the flourishing and growing periods of Iranian art, an era in which various arts were formed, developed and changed according to Islamic thinking. The works of the Islamic era are kept in the museums of Iran and the world. The Islamic era produced valuable glass containers with innovative dimensions in construction and decoration, and the developments in this field were so many and diverse that the production of glass in contemporary Iran is largely unknown. The necessity of studying and investigating technical innovations developed in this field is one of the main research needs in the field of glass production in different eras, which is the focus of this article. During the fifth and sixth centuries of Hijri, glassmaking in the Islamic era reached the peak of growth and prosperity in the development of construction and decoration methods. Most of the practical works of Islamic glassmaking were produced earlier in the Sassanid period, and one can see the unbroken continuity of glassmaking before and after Islam. The Arab conquerors mostly refrained from destroying the advanced local industries and instead, they intelligently used them in making their products. It can be said that Sasanian glassmaking gradually changed to Islamic glassmaking in the first and second centuries of Hijri" (Ricke, 2002: 39). Islamic glassmaking in the 5th and 6th centuries of Hijri coincides with the rule of the Seljuks in Iran and Iraq and the Fatimids period in Egypt and Syria. By studying the main bases of glass making in Islamic lands in this historical period, it can be said that the Seljuk, Fatimids, Ayyubids and Mamluk governments are considered to

be the main claimants of Islamic glass making in order to access valuable financial and human resources obtained as a result of the legacy of the past. they become Commonalities in the form, methods of making and decorating Islamic glass works can be seen in the geographical scope of Islam, which indicates a kind of artistic eclecticism in this historical period. "The similarity between the possible glass belonging to Iran with the glass of Iraq and Egypt was to influence the unity of the Islamic caliphate, which was common in the Islamic world" (Charleston, 1990, 71).

In a brief explanation, we will examine the bases of glass making in the Islamic era in the 5th and 6th centuries of Hijri. "The arrival of the Seljuqs in Iran in the fifth century of Hijri led to the development of all kinds of arts, including watercraft. Archaeological reports state that the cities of Neishabur, Gorgan, Ray, and Saveh were active in the manufacture or trade of water bottles (Shishegar, 2013). The glass making of this period is in Neishabur" (Dimand, 2013 238). The methods of making in this era were two methods of blowing in a mold and free blowing, and with the change in the type of mold and making it into several pieces, more complex and diverse designs can be seen on the works. The works obtained from the excavations of Neyshabur and Samarkand (one of the big glass making centers of their time) show that they either had a similar style to each other, using the method of blowing in a mold or free blowing with a variety of cut, molded and added decorations. (Akbarzadeh Kardamahini, 2013 31). "During the Seljuk era and until the Mongol invasion, very beautiful glassware and dishes came out of the Gorgan glass furnaces, which were as thin as paper and sometimes enamel. Sometimes they were shaved and carved" (Galak and Hiramoto, 1355 103). Therefore, Identifying and classifying glassmaking technical innovations in different eras is the goal of this article. In this regard, the question was raised that which technical developments have taken place in the field of glass products manufacturing and decoration in Islamic lands? what technical changes have occurred in the glassmaking industry during the 5th and 6th centuries A.H., and the glass decorations that are seen in Islamic countries? Can they be considered as characteristics of Islamic glass? How have the evolutions of glassmaking been formed in different historical periods in Iran?

Research method

Research method: This research is based on the purpose of applied research and the nature and method of historical-analytical research. Also, library and inductive methods have been used to collect data. Given the many examples, of Islamic glass containers kept in museums in Iran and other parts of the world, the statistical population studied was selected from several Islamic glass works by the preferential sampling method, whose innovative dimensions are one of the main dimensions according to the authors. Since the research variables are relics of the past, by studying the history of Iranians in different historical periods, knowledge of the social, cultural, and political context governing the time of glassmaking was obtained. Also, by examining the samples, the shape, and the method of making glass and glass containers, the findings of the field study on the one hand and library documents on the other hand were analyzed, and finally, a conclusion was drawn.

Research Background

Studying and researching in the field of Islamic glassmaking has always been accompanied by problems such as the lack of sufficient resources and the lack of access to accurate information of the works. By examining the studies, it was found that this field has been the focus of many Islamic art researchers, who have often introduced, identified, and in some cases identified the specific characteristics of these works. One of the reference sources used by Islamic art researchers is the two-volume book Mittelalterliche Glaser und Steinschnittarbeiten aus dem

Nahen Osten, which introduces and examines the glass works of the Islamic era (Lamm, 1931), although this book is not available in any museums or libraries in Iran. The book "Treasures of the Fatimids" is written by Zaki Mohammad Hasan (2008), in a chapter of which the works of glass and glass stone of the treasures of the Fatimid Sultans are examined in the documents and historical sources. Also, Rahmatabadi and Jalili (2011) in an article titled "Glassmaking in Sham in the 4th to 6th centuries of Hijri, have presented historical documents and references in the field of glass making in the city of Sham. Arman Shishegar (2008) in an article entitled "Glass making industry in the Seljuk period and introducing some examples of it" examines the situation of glass workshops in the cities of Iran and introduces some works. It has introduced and studied glass works of the Islamic period. Sidney M. Goldstein (2008), in the book Glass works, has introduced glass works from Islamic periods. Stefano Carboni (2001), in the book: Glass from Islamic Lands, has introduced and classified the works of Islamic glass preserved in the "Al-Sabah" collection of the National Museum of Kuwait in the fall and winter of 2019. Likewise, Carboni and Whitehouse (2001) in the book Glass of the Sultans, introduced the glass collection of the Islamic era preserved in the Metropolitan Museum is discussed and works from the 5th and 6th centuries of Hijri. Kruger (1995) in the book Nishapur Glass at the Early Islamic Period, based on the glass findings of the Nishapur excavations, deals with all the glass-making technologies of the Islamic period, as well as many sites of the Islamic period of Iran and comparable areas from east to west related to the Sassanid period. In this regard, many sources have been introduced, which cover up to 1995 (the year of publication of this book). This book has focused on archeological study of glassmaking in the first eras of Islamic period that does not fit the discussion of this article. One of the important references is another work by Kruger and Bigalke (1984) on the subject of glass. He has an unpublished book entitled Parthisches, Sasanidisches und Islamisches Glass about the Islamic glass of the Berlin State Museum, which is especially very useful to compare the glasses of the Islamic world. In all the mentioned sources that have helped the authors during the compilation of this article, they have often introduced and reviewed the glasswork of Islamic lands. Studying the examples preserved in Islamic art collections such as the world's great museums, which were selected through the purposeful preferential sampling method, this article investigated the innovative features of glazing in the field of technical issues of construction and decoration.

Discussion

Islamic glassmaking reached the peak of growth and prosperity in the development of construction and decoration methods during 5th and 6th century (H). Most of the practical works of Islamic glassmaking were produced earlier in the Sassanid period. You can see the unbroken continuity of glass making before and after Islam. "Arab conquerors mostly refrained from destroying the advanced local industries and instead used them intelligently in making their products. It can be said that Sassanid glassmaking gradually changed to Islamic glassmaking in the first and second centuries of Hijri" (Ricke 200239). Islamic glassmaking in the 5th and 6th centuries coincides with the rule of the Seljuks in Iran and Iraq and the Fatimids in Egypt and Syria. By the study of the main bases of glass making in Islamic lands in this historical period, it can be said that the governments of the Seljuks, Fatimids, Ayyubids and Moluccas are considered to be the main claimants of Islamic glass making due to the access to valuable financial and human resources obtained as a result of the heritage of the past. Common features can be seen in the methods of making and decorating Islamic glass works in the geographical scope of Islam, which indicates a kind of artistic eclecticism in this historical period. The similarity between the possible Iranian glass with the glass of Iraq and Egypt was to influence the unity

of the Islamic caliphate, which was common in the Islamic world (Charleston, 1990, 71). In a brief explanation, we will examine the Islamic era glassmaking bases in the 5th and 6th centuries of Hijri. The arrival of the Seljuks in Iran in the 5th century of Hijri led to the development of various arts, including glass making. Glass makers have been active in the manufacture or trade of water bottles. The discovery of glass ingots in Neishabur excavations is another confirmation of the existence of glass making workshops in Neishabur during this period" (Dimand 2008, 230). The methods of glass making in this era were blowing in a mold and free blowing, which with the change in the type of mold and making it into several pieces, more complex and diverse motifs can be seen on the works. The works obtained from the excavations of Neishabur and Samarkand, one of the big glass making centers of their time, show that both had almost the same style as using the method of blowing in a mold or free blowing with all kinds of decorations, carving, mold compression (Akbarzadeh Kurd Mohini, 1994). During the Seljuk era and until the time of the invasion, very beautiful glassware and containers came out of the glass furnaces of Gorgan, which were as thin as paper, sometimes enameled, sometimes carved and carved (Glock and Hiramoto,2010, 103). Islamic glassmaking in Egypt and Syria has more diversity in form and role. The history of glassmaking in Egypt goes back to the 18th dynasty of the pharaohs. Glassmaking in Syria has also flourished since ancient times and during Islamic ears, glass makers had definitely inherited the artistic methods of their ancestors. The fame of the Jews in the art of glassware in the cities of Tire and Antioch in the fifth century (AH) was such that the thinness of Syrian glass and its purity became a proverb. The city of Aleppo was especially famous for producing vessels and glass during the Mamluk period. Their glass products were very delicate and had beautiful decorations, and were considered among the most expensive gifts and the most beautiful products. The historical documents and the surviving works testify to the goodness and beauty of Egyptian and Syrian glass works in this period. In Nasser Khosrow's description of his trip to Egypt, between 439 and 441 AH, it is mentioned that the merchants who went to Iran, sold pearls and corals, and the Egyptians used to make transparent and very clean emerald-like glass and sold it by weight" (Qabadiani, 1997, 135), the trade of glass by weight is definitely a testimony to the development and spread of glass works in Egypt during the Islamic era. The centers of Islamic glassmaking during the Fatimid rule were concentrated in the big cities of Egypt and Syria. In the Fatimid era, Fustat was apparently one of the major centers of this industry, and the practices and styles were completed in this era, or it had a new style that was invented by contemporary Egyptian artists (Dimand 2003, 219). "so that the cities of Damascus, Aleppo, Sur and Raqqa were prominent as centers of glass making (Rahmatabadi and Jalili, 1390). With the arrival of the Mongols in Iran, the glorious era of glass making in Islamic lands began to decline" and the Islamic culture of the The Middle Ages ended with the Mongol conquest around the 7th century AH (1400 AD). The looting and destruction of the big cities of the Middle East caused suffering and sorrow in these lands. The focus of the art and culture of the old world was transferred from the East to Europe, and took the place of Syria. The influence of Islam had entered European glassmaking much earlier to the extent that the shapes and forms of glass made in Islamic countries were of great interest to Europeans. The aristocratic families of Europe considered the works of enameled glass and Islamic gilding that were brought by the Crusaders to be their most valuable possessions. Glass making in Venice benefited from the fall of the eastern states in the seventh century (AH) and the western glass producers advanced technical aspects and decorative methods, the most important of which was enamel painting with gold leaves. The formal similarities and decorative methods of Islamic glass with Roman glassmaking is evident after the decline of Islamic glassmaking (Ricke, 2020). At the same time, as the decline of Islamic glassmaking and the transfer of Islamic glass

heritage from the East to the West, extensive influences in the field of construction and decoration methods can be observed in Western glassmaking. It can be seen that Islamic glassmaking can be presented in three stages; The first stage is the engineering of raw materials and their compounds for making transparent glass. The second stage is the various methods of shaping the glass melt, which is done by the glass maker. The third stage, which is the most distinctive feature of Islamic glassmaking, is the creation of decorations on the glass. Glass works can be seen with the form of additional strips, carving, painting and gilding (Carbon and Whitehouse, 2016). In the following, these cases will be investigated in four groups of innovation in color and form, and methods of making, application and decorations.

Theoretical foundations of research

Islamic glassmaking in Egypt and Syria has more diversity in form and role. The history of glassmaking in Egypt goes back to the 18th dynasty of the pharaohs. Glass making in Syria has also flourished since ancient times, and in the Islamic period, glass makers had definitely inherited the artistic methods of their ancestors. "The popularity of the Jews in the art of water glass in the cities of Tire and Antioch in the fifth century of the Hijri was such that the thinness of Syrian glass and its purity have been proverbial. The city of Aleppo was very famous in the production of water vessels, especially during the Mamluk period. The creations there were very delicate and had beautiful decorations and were considered among the most precious gifts and the most beautiful products" (Zaki Mohammad,2002). The historical documents and the remaining works testify to the goodness and beauty of Egyptian and Syrian glass works in this period. In Nasser Khosrow's description of his trip to Egypt between 439 and 441 A.H., it is stated: "The merchants who went to my land sold beads, combs and corals, and the Egyptians in Egypt made transparent and very pure water like emeralds and based on the weight They used to sell them" (Qabadiani, 1997,135). The trade of glass by unit of weight is certainly a testimony to the development and spread of glass works in Egypt during the Islamic era. Islamic glassmaking centers were concentrated in the big cities of Egypt and Syria during the Fatimids rule. "In the Fatimid era, Fostat was apparently one of the major centers of this industry, and the methods and styles were completed in this era. The decorations of Fatimid period glassware are either based on old designs or have a new style that was invented by contemporary Egyptian artists" (Dimand, 219 2013), so that the cities of Damascus, Aleppo, Tire and Raqqa were the centers of production. "Glass" were mentioned (Rahmatabadi and Jalili 2019). With the arrival of the Mongols in Iran, the glorious era of glassmaking in Islamic lands began to decline. "The Islamic art and culture of the Middle Ages ended with the Mongol conquest around the 7th century A.H. (1400 AD). The looting and destruction of the great cities of the Middle East caused suffering and sorrow in these lands. The concentration of the art and culture of the ancient world It was transferred from the east to Europe and took the place of Syria in the field of glassmaking. The influence of Islam had entered European glassmaking much earlier to the point where the shapes and forms of glass made in Islamic countries were of great interest to Europeans. The aristocratic families of Europe considered the works of Islamic enameling and gilding brought by the Crusaders to be their most valuable possessions. Venetian glassmaking benefited from the fall of the Eastern states in the 7th century AD, and Western glass producers learned the technical aspects and methods. Decorations, the most important of which was enamel painting with gold sheets, are evident in the form and methods of decorating Islamic glass with Roman glassmaking after the decline of Islamic glassmaking" (Ricke, 2002). Simultaneously with the decline of Islamic glassmaking and the transfer of Islamic glass heritage from the East to the West, extensive influences in the field of construction and decoration methods are observed

in Western glassmaking. "Islamic glassmaking is planned in three stages; The first step is the engineering of raw materials and their compounds to make transparent glass. The second stage is the various methods of shaping the glass melt, which is done by the glassmaker, and the third stage, which is the most distinctive feature of Islamic glassmaking, is creating decorations on the glass. Decorations on the glass are seen in the form of additional strips, cutting, painting and gilding on the works" (Whitehouse and Carboni, 2001,26). In the following, these cases will be examined in four groups of innovations in color and pattern, form and methods of construction, application and decorations.

Archaeological Evidence of Glass Furnaces

Artistic patterns in glassmaking can be compared with the discovery of glass from Mesopotamia as well as documents recorded in Rome, however, some information taken indirectly from first-hand historical sources talks about the progress of artistic works and their productions. For example, we can mention the order to make glass in Mesopotamia, which conveys the concept that there were three types of furnaces at that time (Oppenheim, 1973). In addition, the Hori Tepe Nuzi area in the north of Mesopotamia shows the first signs of vitrification in West Asia. About 11000 beads, containers and glass objects were obtained from this area. The chemical compositions of these works show that their raw materials were obtained from special sources during the second half of the 14th century BC (Schlick-Nolte and Werthmmann, 2003: 19). Also, from Amarna hill in Egypt artifacts related to 14th century BC, glass making from blue glass ingots have been identified in Al-Qantir from the 13th century BC. The glasses obtained from Ashur, Nimrud, Babylon, Eridu and Chogha Zanbil also provide us with information about the materials of the furnaces. These works show that small-scale industrial glassmaking was made on bushes in various forms (Antonaras, 2023: 7) (figure 1).

Figure 1. Remains of glass furnaces in Tell El-Amarna, Egypt (Davison, Newton ,2008: 140)

At the end of the first century AD, the use of closed furnaces with a percussive arch (which made glass melting possible) was expanded. Before this innovation, containers and glass objects were probably made in an open fire, similar to the method used by blacksmiths. (Ibid: 23). From the Roman period onwards, more evidence of glass production has been obtained. For example, the remains of a glass production workshop have been discovered from the excavations of Wadi El Natrun in Egypt. Chemical analyzes show that the glass objects produced in Egyptian workshops were not exported, but were sold as raw ingots in Syrian-Palestinian workshops of the Roman Empire (Figure 2).

Figure 2. Remains of a glass furnace from Wadi Natron in Egypt (Antonaras, 2012: 8. Fig. 3)

In addition to that, another glass workshop was discovered in the city of Rhodes, which dates back to the 4th century AD, where glass containers and beads were made. (Ibid: 7)

Also, the remains of a glass furnace from the 6th-7th century were found in the ancient site of Bata Lazer in Palestine. The excavations of this area have clarified the function of these workshops in particular. In addition to the glass-making furnaces of the ancient sites, movable works have also been found that help us to recognize the ancient furnaces. As an example, we can mention the carved clay lamp from the end of the first century AD that was found in Croatia. This object (kept in the Archaeological Museum of Split) depicts a plan of a glass workshop. This design is related to a glassmaker named Terlus sitting on the right side of the arched entrance of a glass furnace and blowing into a vessel with the help of a blow rod, while a second glassmaker named Athenaeus is on the left side of the other entrance (probably (heating room) is sitting, lifting an object to, perhaps, identify possible fractures in front of the light (Davison, 2008: 141).

• *Innovation in the color and raw materials of glass making in many periods*

The improvement of the quality and techniques of making and decorating the glass made in the Islamic period and the variety of glass colors, which were not common before that, and in the pre-Islamic period, indicate the necessity of studying and investigating in this area as the main innovations of Islamic glass.

• *Raw materials in making glass*

In historical sources, the invention of glass has been attributed to different lands. After its origin in Syria, glass moved to Egypt and the eastern regions of Mesopotamia (Susa). In this regard, extensive research has been done in connection with Egyptian and Roman glass and its chemical similarities. Based on this, the glasses were chemically classified into two groups: silica-soda-calc and silica-potassium-calc. The most technical differences related to the glass industry are related to the type of raw materials used, the temperature of the glass furnaces and the degree of pasting, or in other words, the viscosity of the glass (Emami and Pak Gohar, 2016). By examining the raw materials in the works of Islamic glass, it is clear that almost most of the glass of the Islamic period is similar to the historical glass of Egypt, Mesopotamia, Helte and Rome, of soda lime soda lime glass, which has been revived with better quality. These glasses have well followed the traditions of glass making, i.e. the use of silica lime and soda. Silica was obtained from quartz in nature, and there were amounts of lime in the mixture of silica and soda, which was included in the composition of the raw materials for making glass" (Carboni and Whitehouse, 2001).The process of making glass requires a suitable furnace and heat, the provision of which was always accompanied by limitations, quoted by Robert H. Brill in the writings of Carboni and Whitehouse in the materials engineering department, which is a difficult process. Muslim glassmakers needed high amount of fuel to melt raw material for making glass in at a temperature of 1150 degrees Celsius. So, using the recycled glass were common in this era. The use of glass ingots or fused glass was one of the methods that had many advantages for Islamic glassmakers. Therefore, the use of ingots and its trade became popular in Islamic lands, which provided suitable platforms for the growth and development of glass making in all parts of Islamic lands.

There is evidence for the transportation of glass ingots, that the cargo of the sunken ship Serçe Limani in the century the 5th Hijri contained more than one ton of glass ingots, which was transported from the ports of Islamic countries to the Aegean Sea" (Ibid, 27). Improvement of the quality of glass raw materials and the production of glass with distinct characteristics, including sharpening are among the characteristics of Islamic glassmaking in this era. The glass used in the Islamic era, unlike the previous periods, are often transparent and have less impurities, and cutting was rarely done on colored glass (Tait, 2012, 16). The leaded glasses of Islamic lands were designed for cutting, but in none of the medieval glasses obtained by the Europeans, there is trace of carved decorations. In the lead glasses of the Islamic era, the presence of a high proportion of lead oxide significantly changed the expansion coefficient - the rate of expansion and contraction of a glass during heat and cold - and made them incompatible with glasses that have other compounds, alkalis. The case in Roman glass is different from Sasanian and Islamic glass. In Roman glass, calcium antimony is used. In Sasanian and Islamic glass, lead and tin oxides are used (Goldashtein, 2007). It seems that the use of lead in Islamic era glass is for the sharpening of works. It was done consciously by the Islamic glassmaker.

Color in Glassmaking

The main problems of glass making in the beginning was the unavailability of colorless glass,

the color of ancient glasses is one of their special features. The dull green and blue color of historical glasses can also be a proof of the erosion process in sync with natural conditions due to the presence of iron in the raw materials in the glass. Unlike ceramics, the color of glasses is consciously dependent on the baking conditions in oxide baking environments, increasing the oxygen pressure and reducing the oxygen pressure (oxygen changes by adding metals or metal oxides in the molten state. In such conditions, the amount of additives, the degree, the firing temperature and the way of using the oven in that era played a big role in the type of color created. Familiarity with many pigments based on metals or metal oxides existed only in Mesopotamia and Egypt at this time (Emami and Pakgohar 2009, 5). Due to the presence of some natural impurities, including metal oxides, such as iron, which could not be purified, the early glasses had colored tints and transparent colors were used. And the wide use of free blowing method is observed in Islamic works" 2002 Rick 39). In the composition of the raw materials of Islamic glass, the presence of amounts of manganese is debatable. Through the analysis of historical glasses, it was determined that about 0.5 to 1.5% of the composition of some Glass contains manganese, which the Islamic glassmaker consciously used as a purifier of the green color caused by the iron oxide in silica or as a neutralizer to create an amber color due to the presence of impurities (Carboni and Whitehouse, 2001, 30). In the Islamic era, with the acquisition of methods of processing and purification of raw materials, it was possible to make completely colorless glass, and at the same time, diversity can be observed in the deliberate production of colored glass. Variation in color is one of the most prominent features of Islamic glassmaking and it seems that simultaneously with the improvement of the quality of glass raw materials, it had a direct effect on the variety of Islamic works. One of the most prominent features of glassmaking in the fifth and sixth centuries of Hijri is the use of purple, azure, green and blue colors in a transparent form. Most of the band-shaped decorations that were created using a comb-like tool on the works were matte in color. The common colors in the glass of this period are pale green, purple, brown, and dark blue, and often, the works are colorless.

• *Innovation in the Form and Methods of Making Glass in the Islamic Era*

A huge part of the innovations that took place in the 5th and 6th centuries of Hijri were in the field of diversity in the form and methods of making glass, which are mentioned in this section.

• *Incalmo*

In this period, a group of dishes is designed and made in the "incalmo" or semi-finished style. A group of tanks and 2-color jars that were made in a semi-finished way; This method consists of blowing into a mass of partially swollen glass, and before it is fully swollen, it returns to the molten pool to add another amount of glass, which is often of a contrasting color. Making these samples is much more difficult than the samples, Monochrome is similar to them. This tactic allows the glassmaker to decorate the lower part of the vessel before adding the upper part with molded and polished patterns. This group of vessels is often a combination of colorless glass and colored glass (pink, green), or it is turquoise. Most of the works made in this way belong to Egypt and Syria, which were executed in the cities of Cairo, Fustat and Al-Mina in Syria in the 4th to 6th centuries of Hijri (Goldashtain 2007, 64). Using the Incalmo method, which seems to be one of the construction and decoration methods is seen, for the first time, in Islamic glassmaking. "Islamic glassmakers were technically very skilled in full or partial coating, as well as the complex processes of fusing glass pieces with contrasting colors. This method of making glass became common in Roman glassmaking in later periods. In the following centuries, with the transfer of this method from Islamic glassmaking to Western glassmaking, Incalmo is considered as one of the mysterious methods of Murano glassmaking (Figure 3-4).

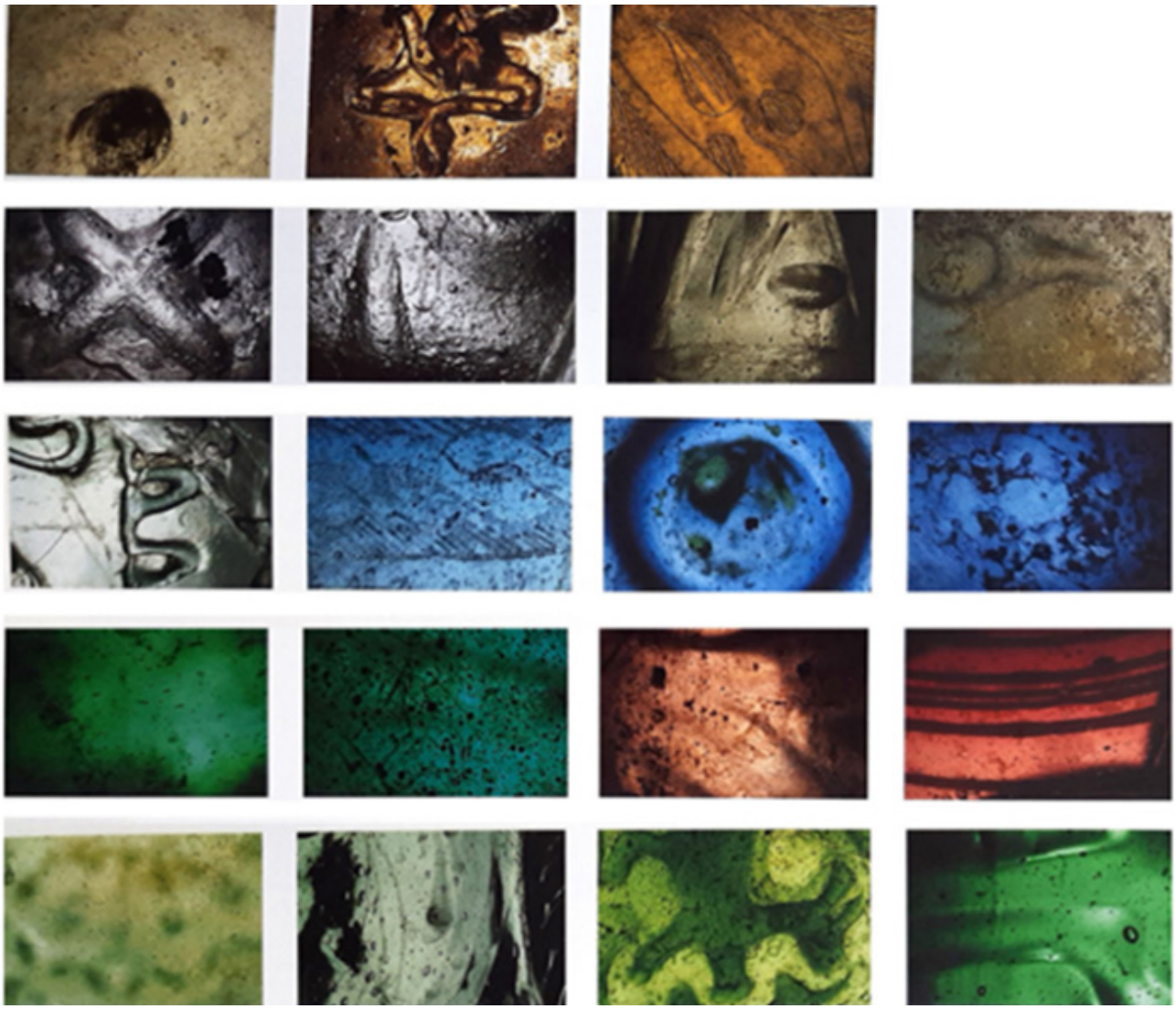

Figure 3: Color spectrums in the glass of Islamic lands (Carboni, 2001)

Figure 4: Glass pitcher made by Incalmo method (www.davidmus.dk)

• *Doubled Walled dishes with Animal Forms in the Islamic Era*

Glassmaking is one of the relatively complex traditional industries that is passed from one generation to another, and in the fifth and sixth centuries of Hijri, it developed more rapidly than other arts, and for this reason, the manufacturing methods and decoration methods were considered among the secrets of the workshops. From the creativity of Iranian glassmakers in this period is using additional stripes of two contrasting colors along the same length to make double-walled dishes with animals on the outer wall (Figure 5)

Figure 5: Flask made in the manner of animal forms (www.davidmus.dk)

• *Innovation in the Application of Glassmaking*

The diversity in the use of works is another characteristic of Islamic glass, and until now in Iran, Egypt and Syria, glass was used to make containers and practical objects. In terms of the variety of products, there are also types of vases, statues, perfume containers, and even chess pieces (Rahmatabadi and Jalili: 2011). works with applications such as lighting and scientific instruments has been found to belong to this perid. Lamps belong to the group of Mamluk art works, which are more advanced than the lighting devices of the previous periods due to the design position of the light source. In these works, in addition to the high skill of painters on blown glass, the overall form is designed in such a way that a small cylindrical tube is added inside the lamp, which makes the process of cleaning and refilling it faster. This suspended tube contains a floating wick. It is in a mixture of water and oil (Carbon et al, 2006) (Figure 6).

The use of glass in scientific instruments was used as containers, medicine horns, cupping vessels, distillation vessels, and measuring scales. The best known examples of glass weights of the Islamic period are the small circular plates used to measure the weight of coins. Most examples of weights were made in Egypt (Goldstein, 2008, 63). There are three groups of glass works with scientific uses. The first group consists of glass containers with thick walls for storing liquids or used as a container, and they are not of good quality. The glass vessels of the second group are thin-walled and decorated, which often belong to the Fatimids and Mamluks and

Figure 6: The use of glass in the manufacture of chess pieces also became common (Carboni 2001, 165-167).

were used to store perfume, oil, or mercury. The third group is glass containers with thin walls and no decorations, which are special for distillation and laboratory processes, and were mostly found in the ancient regions of Iran in the fifth and sixth centuries of Hijri. (Madison and Savage Smith 2007, 37).

• *Innovation in Iranian glasswork decorations*

The development and variety of decorations is one of the main features of the glass works of the Islamic era, which is due to technical innovations in this field. In the Islamic era, there were unique methods of decoration, which include "carved" decoration, decoration with added glass strips, feather-like decoration, pressed decoration in a mold and decoration with "added" medals. And it is enamel on glass, which was rarely used in Iran (Fukaei, 1997). Therefore, in the following, we will examine glass decorations in four groups: decoration with glass strips, added decoration by method, molding and engraving, and decoration with enamel, and painting (Figure 7).

Conclusion

The results of the research show that Glassmaking in the Islamic era, by preserving the traditions and methods of its predecessors, became indebted to developments and innovations in all its dimensions, which reached its peak due to the integration of Islamic lands and the powerful governments of the fifth and sixth centuries of Hijri. This time coincided with the rule of the Seljuqs and Fatimids, and therefore, the glassmaking bases of this era were located in the cities of Samarkand, Ray, Neishabur, Sham, Raqqa, Fostat and Al Mina in Syria. Syria is considered one of the main and most important glassmaking centers of this era due to the quality of the works, diversity in form and methods of construction and decoration. The glass of the Islamic era is of the "Sudaalim" type, and at this time, it was common to use fused glass and glass ingots to reduce fuel consumption and improve the quality of products, knowing the characteristics of glass recycling by glassmakers. The diversity and breadth of the range of colored glass commonly used in the Islamic era is another innovative dimension in this field, which has shown the growth and development of technology and material engineering in the Islamic glass workshops. Islamic glassmaking in the 5th and 6th centuries (H) had suitable platforms for transformation and innovation, and these transformations can be planned in four groups of colors and raw materials

Figure 7. Many glass containers made in different historical periods (www.Islamicartsmagazine.com)

of glass, form and methods of making decorations and applications. The study of glass works attributed to this historical period simultaneously with the improvement of the quality of raw glass materials and the variety of colors shows the diversity in the form and methods of making works and decorations and innovative use. Compared to the previous era, Egypt had distinct technical indicators, which stopped in Iran with the Mongol invasion in the 7th century AH and was transferred to the centers of glass making in Iraq, Syria, and Egypt, and later reached the west from these areas and mixed with Western glasswork experience. In the Islamic era, glassmaking, preserving the traditions and methods of its predecessors, was committed to development and innovation in all dimensions, which ended with the integration of Islamic countries and powerful governments in the fifth and sixth centuries of Hijri. Therefore, the glass foundations of that period were located in the cities of Samarkand, Ray, Nishabur, Sham, Raqqa, Fustat and Al-Maneh in Syria, which was due to the quality of the works of diversity in the form and methods of construction and decoration. It is one of the most important glassmaking centers of that time. The glass of the Islamic era was known as soda-lime glass, and at that time, the use of molten glass and glass ingots to reduce fuel consumption and improve the quality of the product, with the knowledge of the characteristics of glass recycling by glass manufacturers, the variety and extent of the range of colored glass used in the Islamic era. The title is another innovative dimension in this field, which shows the growth and development of technology and material engineering in Islamic glass workshops. By examining the results of this research, it can be said that Islamic glassmaking in the fifth and sixth centuries of Hijri was at the peak of prosperity in the field of materials, manufacturing methods, variety of forms, variety of applications and decoration, and it is one of the richest sources of growth of Islamic glassmaking in It is considered the contemporary period.

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Bibliographical References

Akbarzadeh Kurd,A., Mehini, He. 1997. Glass of Marz Bazargan Collection, Tehran, Publications of the National Museum of Iran, Freire W., 1374 Iranian Arts, translated by Parviz Marzban, Tehran.

Alkhemir, S. 2014. Light in art and science from the Islamic world, USA: Focus-Abengoa foundation.

Antonaras, A.C., 2018. A special group of early Christian glass 'gems' from Greece. Things that Travelled, p.1.

Antonaras, A.C., 2023. East of the Theater: Glassware and Glass Production.

Carboni, S. 2001. Glass from Islamic Lands. London: Thames and Hudson.

Carboni, S., Whitehouse.D, 2001. Glass of the Sultans. New York: The Metropolitan Museum of Art.

Carboni, Stefano, Marta Drexler lynn, Sidney Goldstein, Sandra Knudsen, and Jutta Page. 2006 . The Art of Glass. London: Toledo museum of art.

Charleston, R.J. and Fisher, J.E., 1990. Masterpieces of glass: a world history from the Corning Museum of Glass. New York: Harry N. Abrams, incorporated.

Davison, S. and Newton, R.G., 2008. Conservation and restoration of glass. Routledge

Davison, L., Horie, Y. and Sekine, T. eds., 2012. High-pressure shock compression of solids V: shock chemistry with applications to meteorite impacts. Springer Science & Business Media.

Dimand, M.E., 2003. Guide to Islamic industries. Translated by Abdullah Faryar, Tehran, Scientific and Cultural Publishing Company. [In Persian].

Emami, MA., Pakgohar s.,2017, Glass Wires of Chogha Zanbil; The First Signs of Glass Making in Iran in the Second Millennium BC. Sh. 5:1-15. Doi:10.29252/jr.3.1.1

Glock, G, Hiramoto, S.,2010, Passages in Iranian Handicrafts, Tehran: National Bank Publications. [Persian]

Goldstein, S. M. 2007., Glassworks, Islamic Art Collection. Trans: Soodabeh Rafiei and Gholam Hossein Mazandarani. Tehran: Karang. [In Persian].

Jenkins, M., 1986. Islamic Glass. A Brief History from Metropolitan Museum of Art Bulletin: 1-56.

Fukaei, Sh., 1996., Iranian Glass, translated by Arman Shishegar, Tehran: Cultural Heritage Publications.[In Persian].

Kruger, J., 1995. Nishapur: glass of the early Islamic period. Metropolitan Museum of Art.

Kruger, F.J. and Bigalke, R.C., 1984. Fire in fynbos. In Ecological effects of fire in South African ecosystems (pp. 67-114). Berlin, Heidelberg: Springer Berlin Heidelberg.

Lamm, C. J. 1931. Les Verres Trouvés à Suse. Syria 12, 358–367.

Madison, F., Smith.E.S., 2007, Scientific tools, translated by Gholam Hossein Ali Mazandarani. Tehran: Karang Publishing.[In Persian].

Mirhadi,B, 2002 , Culture, theory, and technology of ceramic, glass, building materials, Tehran.

Oppenheim, A.L., 1973. Towards a history of glass in the ancient Near East. Journal of the American Oriental Society, pp.259-266.

Page, J.A. and Carboni, S., 2006. The art of glass: Toledo Museum of Art. Giles.

Qobadiani, N.Kh.,1997., Nasser Khosro's travel book. Translated by Nader Vazinpour, Tehran, Scientific and Cultural Publications. [In Persian].

Rahmat Abadi, A., Jalili. M.,,2012,., Glassmaking in Shām during Fourth/Tenth to Sixth/Twelfth Centuries, Journal of History and Culture, VOL 43, (2), 69-88 .DOI: 10.22067/HISTORY.V0I0.12403

Ricke, H., 2002. Glass art: reflecting the centuries.Masterpieces from the Glasmuseum Hentrich in Museum Kunst Palast, Dusseldorf, Munich and New York: Prestel.

Schlick-Nolte, B. and Werthmann, R., 2003. Glass vessels from the burial of Nesikhons. Journal of Glass Studies, pp.11-34.

Shishegar, A.,2002, The Industry of Making Water Bottles in The Seljuk Period and Introducing Some Examples of it. the museum quarterly. Vol. 37: 24-29.

Tait, H., 2012. 5000 years of glass. London: The British Museum.

Whitehouse, D., 2010. Islamic Glasses in The Corning Museum of Glass USA: Corning Museum of Glass

Zaki Mohammad, H., 2002, Fatimid Treasures translated by Neda Golijani Moghadam, Tehran, Al-Zahra University Publications. [In Persian]