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The Effects Copper Has on Casting Glass

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Abstract

The aim of this honors project was to discern the difference between how various types of copper reacted with glass. The two disciplines that were connected were chemistry and glassblowing. The basic components learned in chemistry were applied to glass with an end goal of a project installation that visualized the discoveries with copper. The glassblowing technique used was lost wax casting, and the two types of copper used were copper foil and fine copper metal powder. The copper was found to turn the glass into various blues with the intensity and darkness of the blues being dependent on the type of copper.

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Introduction

Glass could be dated back as far as 2500 BC, mostly in the formation of beads.[5] It was thought to have originated in Mesopotamia and traveled to Egypt. From there, the basic soda-lime-silica composition of glassmaking traveled along the coastline of what is now present-day Lebanon.[5] The art spread and the specialization of color being added to the work came later.[5] There were different processes of glass being made in history.[5] In about 100 BC, the millefiori ("thousand flowers") process was the common formation of glass in Alexandria for creating beakers and shallow dishes that made a colored mosaic effect on the glass.[5] The process included making a core shaped out of mud to which colored glass canes were attached, the piece placed in a mold with the core, and then melted in an oven which caused the rods to fuse together.[5] The Phoenicians in the beginning of the Christian area learned how to blow glass by blowing molten glass through an iron.[5] The blowing iron was a tube that was about 1.5 meters long with an end that was used as a mouthpiece to blow air and an end for molten glass to be collected, rolled, and shaped with the occasional reheating.[5] It was thought that the Romans and the Egyptians used sand mixed with silica and lime from seashells and hardwood ash as their materials for glass.[5] They would color their glass with metallic oxides such as copper because of how versatile it is.[2] Due to the ion exchange, copper in glass can occur as Copper (I) and Copper (II) with their concentrations ratios in glass being able to vary significantly depending on the method used for incorporating the metal in glass.[1] Glass was able to trap electrons that originate from Equation 1 seen below which sets the equilibrium between valence states of copper.[1]

$$Cu^{+} \leftrightarrow Cu^{2+} + e. \qquad (1)^{1}$$

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The Ion exchange mechanism of copper in glass was based on ionic conductivity of the glass with ion diffusion being able to be performed by heating the glass (thermal diffusion).[1] Copper was the choice of metal for the project because of its known success of how it interacts with glass and its easy affordability and attainability.[1]

The formation of glass was best understood through its relationship of the volume of the substance and its temperature.[3] As a liquid, the glass starts at a high temperature and the removal of heat causes the liquid to simultaneously cool and shrink in volume.[3] The transition from the glass's supercooled liquid state to its solid state is gradual and takes place over a range of temperatures called the glass transformation range.[3] Cooling the glass at a slower rate causes it to shrink at a lesser volume.[3]

This project was inspired by the works of glass artist, Irene Frolic. From Toronto, Canada, Frolic used a mixture of techniques that included lost wax casting for form and opaline, clear crystal, or copper oxide for color.[4] Many of her projects had human resemblance and were based off of humanity as she, herself, was a Holocaust survivor.[6] Like Frolic, the lost wax casting technique was used and similar to her, the final artwork installation itself took the form of the human shape as the glass became divers entering the water with the focus on the use of copper as coloring.

Lost wax casting follows the same principles of glass needing to be heated and then cooled slowly. This process has been thought to be dated thousands of years ago and still exists in the modern world today.[2] Lost cast waxing starts off by making a desired mold by sculpturing wax.[2] A second mold made up of materials such silica, vinyl, or latex is then formed around the wax mold.[2]

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Materials and Methods

For this honors project, the mixture of the second mold was made out of a combination of plaster, silica, and grog. The materials of the second mold were applied in layers to the wax sculpture in a form that starts off as a liquid but then quickly starts to harden to a solid when mixed together. The first layer was made up of a desired volume of water, fifty percent silica, and fifty percent plaster. Once this layer hardens a second and a third coat of water, fifty percent silica, fifty percent grog mixture, and about 1/3rd cup of grog were added. Once all the layers had been applied and the second mold was solid and thick enough around the first mold so that it would not crack, the molds were placed in a bin that was steamed so that the wax melted and a cavity was left where small pieces of glass that look like pebbles were placed inside the cavity to melt. To find the right amount of glass needed, the procedure of water displacement was used. To add color with copper, the raw materials were added throughout the mold with the glass pebbles. The type of casting glass used was soda-lime glass. Once the glass was added, the molds were placed in the kiln which was programmed to heat to a high temperature and then cool slowly. The program depends on the thickness of the glass as seen in Appendix B.

Because multiple forms of copper were tested, more than one mold needed to be made, so an extra step was added before adding the second mold, called a rubber mold. One rubber mold allows many forms of the same desired wax figure to be made without having to take a sizable amount of time to sculpt new figurines for every casting needed. The rubber mold also allowed exact copies of the original wax mold to be made. Hot liquid wax would then

be poured into the new rubber mold and once solid, would be taken out, and the mold of plaster, silica, and grog would be placed around the wax figure.

Results

Tester pieces of four open cast pyramids were already created to see if copper leaf and copper powder would have successfully functioned in glass molds. The results were found to be successful with the pyramids. So, the research continued with the larger molds that would shape the glass into divers. With the diver molds, the copper powder formed a darker blue than the copper foil, but more clumps of copper powder could be seen in the glass where it had not melted. The more copper powder was added, the more vivid and concentrated the blue was within the glass. A version of the mold with no copper was done as well as the use of glass frit that was the color of cobalt blue. Glass frit is pre-colored glass that was commonly used to create colorful glass pieces. The differences in how the glass was affected by copper could be seen more easily when compared with the cobalt frit model and no color model. The image results are seen below in Appendix C, Figure 1.

Conclusion

The copper powder leaving dark clumps within the glass was thought to be caused by a higher melting point for the copper than the glass. The darker blue color from the powder was thought to be caused by the density of the copper as the powder was denser than the copper foil. With both types of copper, the blue inside the glass was not uniform. Rather the path of coloration from the copper could be seen and the blue had a bit of a swirl affect. If too much

copper was added, the glass would not flow properly as it was believed that the copper changed the viscosity by making it thicker and therefore more difficult to flow downwards into the desired mold. The molds came out successful with showing a wonderful representation of how the various forms of the copper affected the casting glass.

This project had been a unique experience where multiple disciplines were combined. Chemistry concepts were added to an artistic technique. In the future, more testing of various coppers such as copper metal would be a great next step to continue this subject of research.

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Bibliography

(1) Demichev, Ivan & Nikonorov, N. & Sidorov, A. Copper ion exchange in silicate glasses: A review. *Research Gate*., 2017

This was a peer review article found on research gate. The article was about a research project involving glass and copper with background information on how copper reacts with glass.

(2) Dvorak, Donna. "The Not-so-Lost Art of Lost Wax Casting." *Copper Development Association Inc.,* 2008

This online article goes in-depth on the process of lost wax casting which is a common method of glassblowing that I will be using in my honors project.

(3) "Glass Formation: Volume and Temperature Changes." *Britannica*, Britannica, Inc.

An excerpt from Britannica, the reading went into how glass and works in part with temperature and volume changes. Temperature and volume play an important part in how glass is formed and shaped for glassblowing.

(4) "Habitat Galleries: Irene Frolic." *Habitat Galleries*, Royal Oak, MI., 2021

Irene Frolic is an inspiration for my art project as I will be following a lot of similar techniques as her such as casting, the human shape, and the use of copper. This article brings background information on to exactly Irene Frolic is as an artist and person.

(5) "History of Glassmaking: Development of the Glassmaker's Art." *Britannica*, Britannica, Inc.

There has been a long history of making of glass and using it as art. This article dives into the history briefly and where it was estimated that glass originated at.

(6) Wiebe, Carol. "How to Live in The World." *Silverspring Studio*. 2010

Another article about Irene Frolic and her history of being a survivor of the Holocaust which plays a large part as innovation in her art pieces. The author admires her work and goes into discussion with her.

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Appendix

Appendix A: Timeline

Fall Semester:

November 26th – Materials gathered

November 9th - Test pyramid samples done

November 23rd - Rubber diver mold made

November 30th - Three wax divers from rubber mold ready to be cast

December 2nd - Three molds in kiln

December 7th - First part of project completed

December 13th - Project proposal, bibliography, and timeline turned in

Spring Semester:

January 11th – Start second round of casting divers and gathering materials

- test using various forms of copper

February 25th – Have divers completed and start final installation

- Results completed

March 25th – Final Installation completed

April 22nd – Final Project for 4990 completed and ready to turn in

Appendix B: Program Used for Diver Molds

Step	Time	Cum Time	Temp
1	0:01	0:01	300
2	3:00	3:01	300
3	8:00	11:00	1250
4	1:00	12:00	1250
5	0:01	12:01	1550
6	4:00	16:00	1550
7	0:01	16:01	1575
8	1:00	17:00	1600
9	0:01	17:01	950
A	6:00	23:00	950
B	15:00	38:00:00	775
C	12:00	50:00:00	500
D	4:00	55:00:00	200

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Appendix C: Image Results

Figure 1: From Left to Right – Cu powder, Cu foil, no color added, and cobalt frit