Nour Ali
Licenciado em MESTRADO CERÂMICA

NEW DISCOVERIES IN USES AND APPLICATION OF EGYPTIAN PASTE IN THE ARTS

Dissertação para obtenção do Grau de Mestre em Arte e Ciência do Vidro e da Cerâmica

MESTRADO EM ARTE E CIÊNCIA DO VIDRO E DA CERÂMICA
Universidade NOVA de Lisboa | Universidade de Lisboa
<Setembro>, <2023>

NEW DISCOVERIES IN USES AND APPLICATION OF EGYPTIAN PASTE IN THE ARTS

Dissertação para obtenção do Grau de Mestre
em Arte e Ciência do Vidro e da Cerâmica

NOUR ALI
Mestre em Cerâmica

Orientadora: Doutora Márcia Gomes Vilarigues, Professora Associada com Agregação da Faculdade de Ciências e Tecnologia da Universidade NOVA de Lisboa

Coorientadores: Robert Wiley
Professor Auxiliar, Universidade NOVA de Lisboa

Júri:

Presidente: Doutora Inês Alexandra Ramalho Coutinho, Professora Auxiliar da Faculdade de Ciências e Tecnologia da Universidade NOVA de Lisboa

Arguentes: Doutor João Pedro Botelho Veiga, Professor Associado da Faculdade de Ciências e Tecnologia da Universidade NOVA de Lisboa

Doutora Marta Raquel Nunes Castelo, Professora Auxiliar Convidada da Faculdade de Belas Artes da Universidade de Lisboa

MESTRADO EM ARTE E CIÊNCIA DO VIDRO E DA CERÂMICA

Universidade NOVA de Lisboa | Universidade de Lisboa
<Setembro>, <2023>

NEW DISCOVERIES IN USES AND APPLICATION OF EGYPTIAN PASTE IN THE ARTS

Acknowledgments

First and foremost, I would like to thank my Advisors, Marcia Vilariques and Robert Wiley, for all their efforts and continued support throughout the whole process, their trust, support, and direction has been invaluable.

My deepest appreciation and thanks to Richard Meitner, for his profound insights and invaluable perspective, which have greatly enriched my thought process and hopefully my work.
And special thanks to Belen Uriel for her consistent support and her constant willingness to help.

I would like to also thank my professors throughout these two years, Marta Castelo, Pedro Fortuna, Fernando Quintas, Catarina Villamariz, Isabel Maria Damaso Rodrigues, and Ines Coutinho for all their efforts.

And of course, my biggest and deepest thanks is to Andreia Ruivo, whose support, help, and patience has been truly unmatched.

Finally, I would like to extend my deepest appreciation to VICARTE as a whole, whose system provided me with the freedom to explore and experiment, paralleled with a great support system for when I inevitably lost my focus and got derailed.

Abstract

Egyptian paste, commonly known as Egyptian faience, is a self-glazing ceramic body. It seems to have been the steppingstone into the creation of glass, positioned midway between ceramics and glass on the material spectrum. While sharing common raw materials with glass with slight compositional differences, it retains distinct ceramic traits, such as quartz inversion, creating a remarkable hybrid of these two materials. This unique combination holds the promise of compatibility between ceramics and glass, presenting exciting prospects for their integration and innovative applications.

Experimenting with different recipes and application techniques, a variation of a simple Egyptian paste recipe proved to produce very interesting results that showed stability of the two materials when combining them in different ways, most significantly, applying the mixture on to glass, a technique which I refer to as *clayzing*, which is adding a ceramic coat onto a glass substrate to color, decorate, or give it a ceramic finish.

Keywords: *Egyptian paste, Egyptian faience, ceramics, glass, clayze*

Resumo

A pasta egípcia, comumente conhecida como egípcia faiança, é um corpo cerâmico de auto-vidração. Parece ter sido o trampolim para a criação do vidro, posicionando-se no meio do espectro entre cerâmica e vidro. Compartilha matérias-primas com o vidro, com pequenas diferenças na composição, ao mesmo tempo em que mantém características distintas de um corpo cerâmico, como a inversão de quartzo, criando uma notável combinação híbrida desses dois materiais. Essa junção única promete compatibilidade entre cerâmica e vidro, apresentando perspectivas emocionantes para sua integração e aplicações inovadoras.

Ao experimentar com diferentes receitas e técnicas de aplicação, uma variação simples da receita de pasta egípcia produziu resultados muito interessantes, mostrando a estabilidade desses dois materiais ao combiná-los de diferentes formas. O mais significativo foi a aplicação da mistura em vidro, uma técnica que eu chamo de "clayzing", que consiste em adicionar um revestimento cerâmico a um substrato de vidro para colorir, decorar ou conferir-lhe um acabamento cerâmico.

Keywords: *Pasta egípcia, faiança egípcia, cerâmica, vidro, clayze*

Table of Contents

1. Introduction: New discoveries in uses and application of Egyptian Paste in Arts

1. 1 What is Egyptian Paste

Egyptian Faience, also more recently, commonly known as Egyptian Paste, can be classified as a low-temperature-fired, "self-glazing ceramic" (Nigrosh, 1980) and was known to the ancient Egyptians as tjehenet , the literal meaning of which was 'brilliant' or 'dazzling'. (IAN SHAW-PAUL NICHOLSON, 1995)

Faience originally refers to glazed earthenware that originated from a town in Italy called Faenza and spread throughout Europe during the renaissance. (Barber, 1906) Faenza also being the birthplace of majolica, which is similar in appearance to 'faience' with the main difference of it being tin-glazed. (Sparavigna & di Torino, 2014)

However, after many years of research into the material, its composition, and properties, it has been accepted that this name is somewhat deceptive, since the material is in fact not "faience" nor is it, clay based. Egyptian Faience is more commonly known as and referred to as Egyptian paste, especially among potters and the ceramic community. Nonetheless, in research papers it is still referred to as Egyptian Faience, although the name is misleading and a source of some debate. Paul Nicholson addresses this issue saying, "Sadly, a number of things have not changed since Lucas time, and most notable among these is the 'correct' use of terminology. As Lucas himself noted, 'faience' may not be the most suitable term for the material, but it is now so ingrained in Egyptological literature that it is unlikely to be superseded." (P. T. Nicholson & Shaw, 2000) referring to Alfred Lucas, (1867-1945) an Egyptologist and a pioneer in Egyptian paste research as well as the rediscovery of the faience formula. (Gilberg, 1997)

Throughout this research paper I will be referring to this material as Egyptian paste, since Egyptian paste and Egyptian faience are interchangeable and refer to the same thing. However, when referencing a paper that refers to the material as Egyptian Faience, I will also to refer to it as such.

That being said, I believe that the main issue behind the terminology debate of Egyptian paste is the usage of the term faience specifically, since the term faience not only suggests that it is clay, which it is not, it literally classifies it as a specific type of clay, a low fired, porous, earthenware clay. (O'Bannon, 1984) I will be addressing the definition of clay later in my paper in relation to my results.

"Egyptian faience is made of crushed quartz or sand with small amounts of added lime and plant ash or natron - a mineral form of hydrated sodium salts found in dried marsh or lake beds. The quartz body is coated with a soda-lime -silica glaze that is generally a bright blue or greenish color produced by the use of copper oxide additives. The vitreous glass-like glazed surface contributes significantly to the strength and durability of the surface. Analysis of ancient Egyptian faience reveals that usually it contained no deliberately added clay, however, in later periods small quantities of clay were mixed with the crushed quartz matrix to improve workability." (Jamieson, 2003)

Probably the most recognizable ancient Egyptian statue made from Egyptian paste, is Hippopotamus "William" dating to Middle Kingdom; Dynasty 12; Senwosret I to Senwosret II ca. 1961–1878 B.C. and on display in The Metropolitan Museum of Art. Figure 1.

However, it is statues and figurines, like figure 2 below that are more common as they are common funerary figurines included in most museum collections worldwide. They usually have the "nose" or other protruding parts chipped off to show the white, coarse body of the standard Egyptian paste.

Figure 1
Hippopotamus ("William") (JSTOR, n.d)

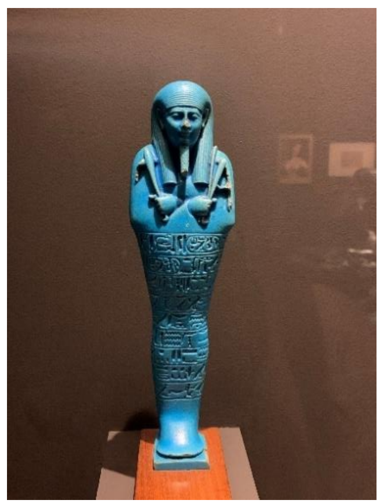


Figure 2
Funerary figurine of Nectanebo II
Funerary figurine of Nectanebo II, Egypt, Reign of Nectanebo II 360-342 BCE, Photo taken at Gilbankian museaum in Lisbon as part of a moving exhibition on Ancient Egypt in early 2023. (© Nour Ali)

1.1.1 Existing scientific research

A lot of scientific research has been conducted around Egyptian paste, especially regarding its chemical composition, and microstructure of the material to better understand its characteristics and properties. The vast majority of the research has been scientific in nature, and according to Zahed Tajeddin, this literature could be divided into three main categories, Material science and technology, Curatorial literature, and Archaeological reports. (Tajeddin, 2014) In this research I will try to be a bit more centered around the material and scientific research and therefore will be mostly focusing on literature regarding the material science and technology.

1.1.1.1 Composition

According to Paul Nicholson and Edgar Peltenburg, a study by Vandiver in 1982 revealed that a typical Egyptian Faience body contains:

- 92–99 per cent SiO_2 (silicon dioxide)
- 1–5 per cent CaO (calcium oxide)
- 0.5–3 per cent Na_2O (sodium oxide)
- Minor quantities of CuO), Al_2O_3 TiO_2, MgO and K_2O, copper oxide, aluminum oxide, Titanium dioxide, magnesium oxide, and potassium oxide respectively. (P. T. Nicholson & Shaw, 2000)

“Unlike conventional, clay-based ceramics, the raw material of faience is a mixture of silica (quartz), alkali (soda), and lime reacted together during firing to make a new medium, quite different in nature to its constituents.” (P. Nicholson, 2009) Therefore, traditionally Egyptian paste has 3 main components: silica, alkali-flux, and lime, making it mainly a siliceous body, and very similar in composition to glass. “It seems that the production of faience was older than that of glass, with which has in common the same raw material …. Sometimes faience is considered as one of the earliest forms of glassmaking, and archaeologists suppose that faience, frit and glass were all made in the same workshop complexes. This was deduced from the marked similarity of the composition of faience and contemporary glasses.” (Sparavigna & di Torino, 2014) Seemingly, Egyptian paste was the steppingstone into the creation of glass, as it appears to be in the middle of the spectrum between ceramics and glass, having the same raw materials in common while their composition differs slightly, almost making it a hybrid of the two.
It is believed that the invention of glass is probably due to errors during the making of Egyptian faience, either by adding too much flux, or firing to a higher temperature than usual. (M. Tite et al., 2002)

In the analysis of ancient Egyptian faience in an attempt to produce most accurate reproductions, Joseph Noble notes that “Clay is not present in any appreciable quantity, and the detectable amount apparently is a result of impurities.” (J. V. Noble, 1969) In more recent recipes, Clay is added mainly as a binder to help with the plasticity and to make it more workable and therefore added in small percentages, between 10% and 20%, as mentioned in one of the earliest publications about Egyptian Paste in the Ceramics magazine, Ceramics Review, where Sylvia Hyman shares her recipe of Egyptian paste and mentions the alterations and changes she has done to a previous recipe which is to add more ball clay in an effort to increase its plasticity and therefore its workability.(Hyman, 1976) However, Hyman does mention that even after the change, that is the addition of clay, its properties and characteristics is still very different from normal clay.

Zahed Tajeddin mentions studies by (Kingery & Vandiver, 1986) that talk about adding clay as a binder to recipes and how it has been a topic of debate, due to the fact that alumina traces found in “faience” objects are too low to have any effect on plasticity. However, Tajeddin does mention other organic binders that could have been used historically, such as Gum Arabic and gum tragacanth, however, these organic binders would leave no trace after firing, making this an unsupportable theory or claim. (Tajeddin, 2014) Within Tajeddin’s research is a mention of experimental work done my Mark Eccleston in a published paper dating to 2008 which shows effects of adding gum arabic to Egyptian paste recipes and how it affects the efflorescence process.

1.1.1.2 Raw materials

Silica / Sand (SiO_2)

Silica is a glass forming oxide, with the chemical formula SiO_2, which is the chemical name for silicon dioxide. These molecules of SiO_2 form quartz crystals and occur naturally as sand and quartz pebbles in nature. Even though silica is abundantly available in nature in the form of sand specifically, it is rarely present without impurities as it is commonly found with certain levels of feldspars, kaolins and other types of clays, as well as calcium oxide and carbonate . (Medici et al., 2014) Silica is the main component of glass making and has a very high melting point of 1700 ˚ C.

Soda / Alkali-Flux (Na2O)

The soda in the Egyptian paste recipe is the flux, Alkali Flux to be specific. “The most common fluxes are alkali oxides, sodium, and potassium oxides (Na_2O, K_2O), and lead oxide (PbO). Fluxes react strongly with silica, producing homogeneous melts at a lower temperature.” (Pradell & Molera, 2020) Silicas very high melting point of 1700 ˚ C make it necessary to add a flux to lower its melting temperature into a more workable range of temperatures. (Medici et al., 2014)
The sodium oxide, soda, comes from two main sources, either plant ashes, or natron, which is a natural salt rock that is a source of natural hydrated sodium carbonate, and it has been used for many centuries in the Mediterranean and Levantine part of the world, and especially in Egypt by the ancient Egyptians as it was available abundantly in Wadi Natron and El Kab in Egypt and used by the ancient Egyptians for mumification and medicine. (Medici et al., 2014) (Tajeddin, 2014) see included references.

Therefore natron is the naturally occurring compound of sodium carbonate and sodium bicarbonate, which Joseph Noble preformed an analysis on a sample of this ancient material that was found in the embalming cache left over after the funeral of King Tut-ankh-Amun, which actually came from his embalming ceremony, it was enclosed in long thin linen bags gifted by the excavator Theodore

Davis to The Metropolitan Museum of Art in 1909. (J. Noble, 1969) below in figure 3 are the results of the components.

Analysis of Ancient Natron Mixture

Component	*% by Wt.*
Sodium chloride	30.6
Sodium sulfate	20.6
Silica (SiO_2)	10.0
Sodium bicarbonate	12.6
Sodium carbonate	4.9
Calcium carbonate	2.0
Magnesium carbonate	1.9
Alumina (Al_2O_3)	0.7
Iron oxide (Fe_2O_3)	0.3
Water	4.7
Organic matter (by difference)	11.7
Total	100.0

Figure 3
Analysis of Ancient Natron Mixture (J. Noble, 1969)

Lime (CaO)

This is basically a calcium oxide or carbonate, which is one of the most common stabilizing oxides together with magnesium and barium. (Medici et al., 2014) Calcium oxide and carbonate are very commonly available in nature, in the form of limestone or chalk.

Both previous main raw materials, the glass former; silica in the form of sand or quartz pebbles, and the flux; in the form of natron or plant ash, could contain small amounts of different impurities that include calcium oxide or calcium carbonate and therefore account for the traces of either that are found in historical recipes.(M. S. Tite et al., 1983) CaO or $CaCO_2$ is considered a stabilizer in this equation and in some ancient glasses studied from the eastern Mediterranean, calcium is present in the composition and is likely a result of sea shells found in the sand used for these recipes that contribute to limestone impurities. (Medici et al., 2014)

The 1-5% of CaO identified by Vandiver in 1982, could have come from two sources, depending on the silica source used it could've been added intentionally, or unintentionally as an impurity. Therefore, if the silica source was sand, then the 1-5% CaO could be an unintentional addition as an impurity present in the sand. However if the silica source had been crushed quartz pebbles then the CaO is added intentionally. (P. T. Nicholson & Shaw, 2000)

Colorant / Metal oxide

This is a coloring oxide, most commonly either CuO, copper oxide, or CoO, cobalt oxide. And the reason behind the almost exclusive use of these two oxides is the blue/turquoise range of colors these oxides produce which was the main aim and attraction in its representation or similarity to Lapiz Lazuli, (P. Nicholson, 2009). This is a very common practice historically, where ceramics or any man-made object would be made to imitate a precious or semi-precious stone to give it value like the celadon glaze in China was initially made in an effort to imitate jade.

1.1.1.3 Firing temperature

It is believed that whether the faience pieces were fired in kilns or in the open, they were fired at a range between 800 ˚C and 1000 ˚C in both cases. And since their glazed surfaces would stick to each other if they were touching during the firing it is believed that they were fired on trays or in saggars. (P. Nicholson, 2009) Originally saggars referred to containers made out of fireclay, invented in China during the Sung Dynasty, however, nowadays saggars are basically heat resistant boxes made out of refractory clay to allow for stacking, prevent pieces from touching, as well as protect the pieces inside them from the kiln atmosphere, ashes, the flame and even kiln debris. (Dodd, 1967) Figure 4 below is a drawing by Joanne Hodges that shows the structure of such saggar stacks.

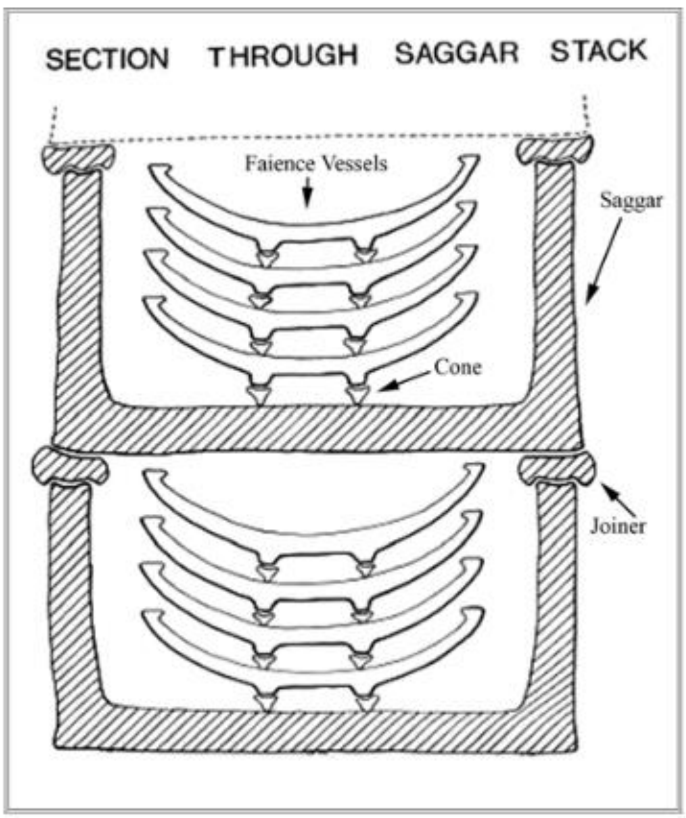


Figure 4
Reconstruction of a Roman-Period saggar stack drawn by Joanne Hodges (P. Nicholson, 2009)

2. Current knowledge on the material

There has been a lot of research done to better understand the chemistry of the material, how it works, and how it was produced.

According to Joseph Veach Noble, during the process of the analysis of the many Egyptian faience pieces that have been excavated, studied, and analyzed, it became apparent that not all pieces where produced the same way. Noble arrived at the conclusion that there three types of Egyptian faience, similar in the final outcome, but with individual characteristics suggesting that their methods of production where different. He characterizes the three types as follows, type one, the standard faience with a lustrous glaze exterior and coarse, white, gritty body. Type two, semi-glass faience with a fused vitreous mass for the body, where the color spreads through the whole piece, body, and surface. And type three is the one used for glazing the small amulets and scarabs made of steatite carving.(J. Noble, 1969) Figures 5, 6 and 7 show recipes for each of the types of Egyptian Faience that Noble mentions.

Self-glazing Blue Egyptian Faience

Feldspar (ground)	40	grar
Flint (ground)	20	"
Fine white sand (ground)	8	"
Sodium carbonate	6	"
Sodium bicarbonate	6	"
Whiting	5	"
Bentonite	2	"
Copper oxide	3	"

Figure 5
Type one recipe (J. Noble, 1969)

Semi-glass Blue Egyptian Faie

Flint (ground)	20
Fine white sand (ground)	8
Sodium carbonate	3
Sodium bicarbonate	3
Bentonite	2
Copper oxide	1½

Figure 6
Type two recipe(J. Noble, 1969)

Blue Glaze for Semi-glass Faience

Sodium carbonate	35	grams
Soda ash	35	"
Kaolin	4	"
Dextine	18	"
Copper oxide	7	"

Figure 7
Type three recipe (J. Noble, 1969)

It is now also commonly known that there are three common glazing or production methods, *Application*, *Efflorescence*, and *Cementation.* (Tajeddin, 2014) (see included references)

Application is the most basic glazing technique; involving applying the glaze mixture, which is a mixture of water and glazing materials such as, quartz, colorant oxide, flux and lime. And it is applied to the faience body by pouring, dipping, or brushing. This method leaves drips, and brush strokes and an overall uneven texture on the piece making it unique to this technique and therefore recognizable. (Matin & Matin, 2012)

Efflorescence is the standard self-glazing technique researched and studied by Noble (1969), where the paste is made and formed, and then during the drying process, as the water evaporates, the soluble alkaline salts move to the surface of the faience body, creating crystals in the form of a powdery flux, which when fired melts and fuses with the silica and lime, forming a thin glazed layer. The bases of the forms made with this technique are usually unglazed due to the lack of air circulation and water evaporation which is necessary for the efflorescence to occur.

"***Cementation*** method is also a self-glazing technique. This method has been known to archaeologists since the 1960s, when its use was first recorded at Qom, an old town in Iran (Wulff et al., 1968); as such, it is sometimes referred to as the 'Qom technique'. In this method, after the object has been formed and dried, it is buried in a glazing mixture (the cement) consisting of alkalis, copper compounds, calcium oxide or hydroxide, and/or quartz. Moreover, it is generally accepted that charcoal is one of the ingredients of the glazing mixture. During the firing process (at about 1000 ˚C), a glaze layer is formed on the faience surface as a result of different reactions between the glazing mixture and the siliceous surface of the object. In this method, the alkalis and copper vaporization are crucial to the glaze formation. After firing, the partially sintered cementation mixture can be crumbled away from the object, which is now coated with glaze (Figs. 8 and 9). Cementation glazing was appropriate for small objects such as beads. It is generally accepted that this method can be recognised by uniform glass thickness (Nicholson, 1993:13;Tite and Shortland, 2008:48e49) and the absence of drying and firing marks for small objects."(M. S. Tite et al., 1983)

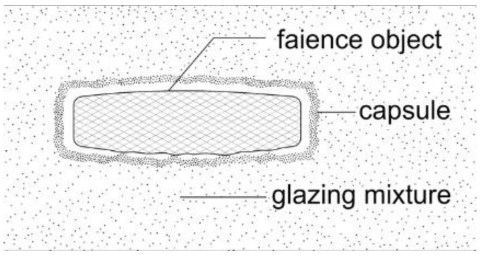


Figure 8
Schematic digram of cementation glazing. (M. S. Tite et al., 1983)

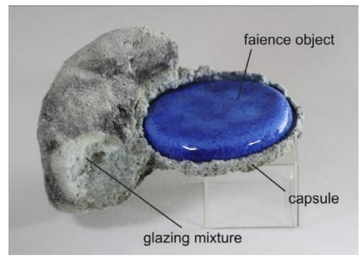


Figure 9
Object glazed by cementation, (M. S. Tite et al., 1983)

Tajeddin, presents a diagram, figure 10 below, demonstrating the three different application techniques, how, and at what stage, the outer glazed layer starts forming with each of the methods. (Tajeddin, 2014)

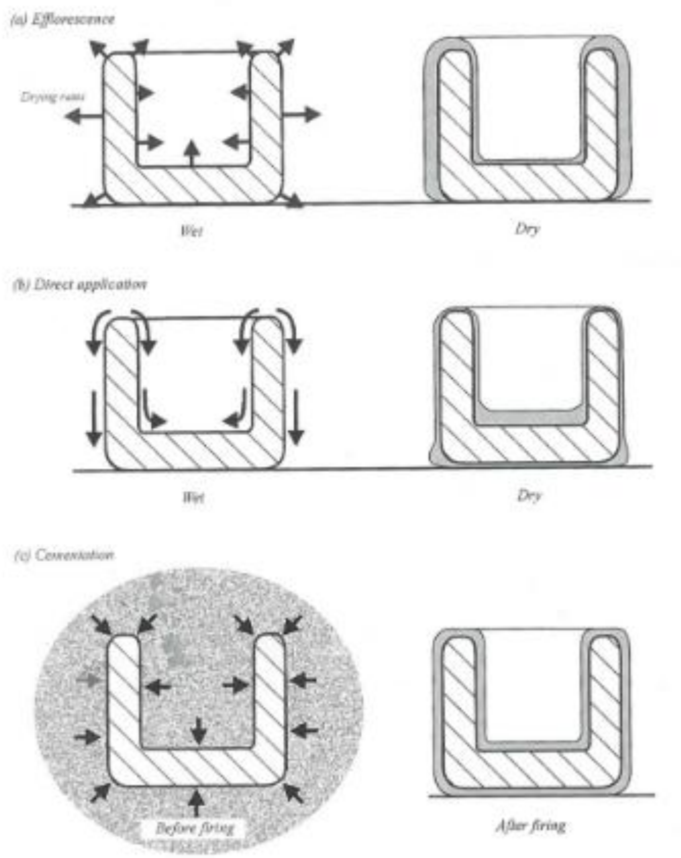


Figure 10
Illustration showing the three application methods (Tajeddin, 2014)

Figures 11, 12 and 13 below show images taken with a SEM, Scanning electron microscope, that show the microstructures created with the three glazing methods, application, efflorescence and cementation respectively. Where the light gray shows the glass phase, and the dark grey shows the silica grains. In the application method a clear distinction can be seen between the glaze and the body, with no interaction layer, while in the efflorescence method there is a clear distinction between, glaze, interaction layer, and the body which shows extensive interparticle glass. And finally in the cementation method a thin glaze layer can be seen, a wide interaction layer, and poor interparticle glass in the body. (Tajeddin, 2014)

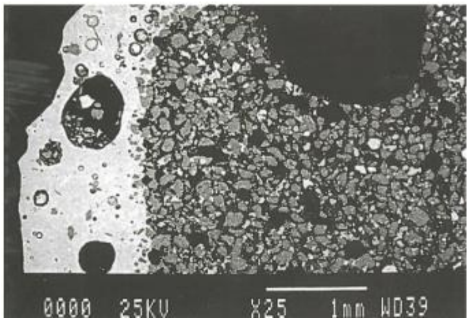


Figure 11
SEM image of application glazing (Tajeddin, 2014)

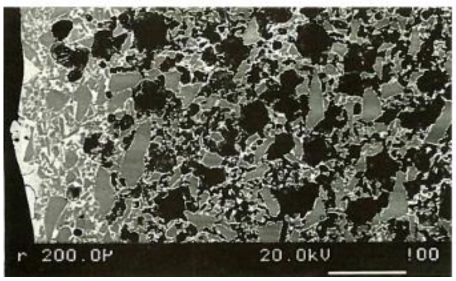


Figure 12
SEM image of efflorescence glazing (Tajeddin, 2014)

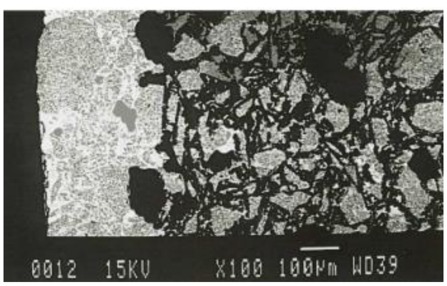


Figure 13
SEM image of cementation glazing (Tajeddin, 2014)

The nature of Egyptian paste, and its characteristics, limit the ways in which it could be used, and this is evident since the ancient times, most pieces that are made out of Egyptian paste are usually small, usually beads or molded figures, and that is mainly because the nature of the material doesn't allow for bigger constructions or hollow forms given the limitation of the material. Egyptian paste is a thixotropic material, which is described as a material "having a viscosity that decreases when a stress is applied, as when stirred." (Thixotropic Definition and Meaning | Collins English Dictionary, 2023)

When working with this material, especially in samples with less clay this is very obvious, it feels more like wet sand, that immediately starts cracking when worked or pressed.

That being said, there are a few examples of larger item, such as vessels, which are believed to have been formed or modeled with a straw core, almost like a former mold, where the object is formed around a mold made of a flexible material that is removed before firing. This forming mold is the core of the vessel which allows for the object to be formed around it and removed when the material dries and is able to hold its own form. These larger vessels were also believed to have been made in smaller sections that are joined together later. (P. Nicholson, 2009)
The biggest found Egyptian paste piece found is a Scepter currently at the Victoria and Albert museum in London and measures 2.158 m in height although this piece is made by joining smaller sections together rather than it being made in one piece. (P. Nicholson, 2009) (Figure 14)

Figure 14
Sceptre, V&A c. 1427 BC - c. 1401 BC (©Nour Ali)

2.1 Applications in artwork, and Artwork in this medium

Even though the majority of the research has been scientifically dominant, some research has been artistic in nature. However, as is the case with most artworks and artistic research, it is not very well documented nor is there a lot of literature on the process or the actual scientific studies behind the artwork and the artistic process. This might very well be due to the lack of scientific research behind the artistic process, speaking of my process and experience for example, it usually involves a lot of experimentation, and trial and error, but lacks the extensive documentation and analysis that follows the results, when something fails, I try again, and when something works, I stick to it. And according to Bray, this is true of the whole pottery and glass making developments dating back to centuries, where the whole process has been dependent on trial and error, until only recently involving some in depth understanding of the chemical and physical properties of the materials. (Bray, 2001)

Some artists have used Egyptian paste in their artwork such as Deborah Sigel, Lesley Risby, Bernadette Pratt, and Zahed Tajeddin.

Both Deborah Sigel and Lesley Risby use metal as the main structure to support and form their sculptures, which they then add Egyptian paste to, Lesley Risby encases her metal nichrome wires in thin coils of Egyptian paste. And Deborah Sigel, figure 15, creates metal structures which she then fills with Egyptian paste and fires. The use of Egyptian paste in both cases is in line with what we know about the characteristics and properties of the material, and the challenges of working with it due to its non-plastic nature, and the fact that a sort of mold or structure is needed to stabilize or support the form.

On the other hand, Bernadette Pratt, figure 16, works with the material in a very different way, firing at uncommonly high temperatures of 1249 ˚C pushing the boundaries of the material closer into the glass spectrum.

Zahed Tajeddins works however covers both the scientific and artistic scopes. Tajeddin has done extensive research into the ancient making methods of Egyptian faience as part of his Doctoral thesis, which he then translates into the art pieces below in figure 17 and Figure 18.

In figure 17, the figurines where made in terracotta molds, while the “Djed”-pillar, figure 18, was made in multiple sections that were built around a core of cardboard structure filled with canes of reed, and then supported with a Styrofoam 3D printed form on the outside. Figure 19 better explains the process (Tajeddin, 2014)

Figure 15
Deborah Sigel sculpture (Cloonan, 2014)

Figure 16
Bernadette Pratt sculpture,(Pratt, 2016)

Figure 17
Group of 'Nu' Shabti sculptures by Zahed Tajeddin at V & A museum London. (©Nour Ali)

Figure 18
Faience Djed---pillar(Tajeddin, 2014)

Figure 19
Core used to make the pillar (Tajeddin, 2014)

Online recipes

There are many different recipes online, that artists have been experimenting with and using within their different practices for years, and they are all variations of the three main components I mentioned above, silica, alkali-flux, and lime, in addition to a metal oxide for the color.

Figures 20 – 23 show a few examples of recipes that would show up in a simple online search of Egyptian paste recipes.

Egyptian Paste
(from Robin Hopper)
Cone 08

Feldspar	36.0%
Silica	18.0
Kaolin	14.0
Ball clay	5.0
Sodium bicarbonate	5.5
Soda ash	5.5
Calcium carbonate	4.5
Fine white sand	7.0
Bentonite	4.5
	100.0%

Figure 20
Egyptian paste recipe(Hopper, 2015)

Egyptian Paste
Cone 016

Nepheline Syenite	25 %
Ferro Frit 3134	15
Silica	20
Sand (50-Mesh)	5
Tennessee Ball Clay #1	25
Anhydrous Borax	3
Soda Ash	4
Bentonite	3
	100 %

Egyptian paste may be colored by mixing the following into the dry body:

Deep Blue: Cobalt Carbonate	1%
Turquoise Blue: Copper Carbonate	3%
Green: Chromium Oxide	1%

Mix well and sieve to 60-mesh or finer while dry. Add a small amount of water and mix to a dough-like consistency.

Figure 21
Egyptian paste recipe(Hopper, 2015)

Egyptian Paste
(from Ceramics Today)
Cone 010 - 06

Soda Feldspar	38 %
Silica	38
Ball Clay	12
Soda Ash	6
Sodium Bicarbonate	6
	100 %

Figure 22
Egyptian paste recipe(Hopper, 2015)

Material	Amount
Nepheline Syenite	36.00
Silica	36.00
C & C Ball Clay	10.00
EP Kaolin	6.00
Soda Ash	6.00
Sodium bicarbonate	6.00
	100.00
+ Copper Carbonate	2.00
	102.00

Figure 23
*Egyptian Paste recipe (*Glazy.Org*, 2015)*

3. My interest in the topic and my aim behind this research

The question of compatibility between ceramics and glass is an ongoing one, constantly asked, researched, and experimented with. On the surface this is mainly due to the similarities of their components and basic raw materials.

The fact that Egyptian paste is a self-glazing ceramic body, with very low – to no clay content, sparked my interest to the possibility of its compatibility with glass. When I first started outlining my research and how best to go about this, I had a specific line of investigation. I wanted to research the possibility of its compatibility with glass, since on the surface, before we delve into deep research of the material, it is simultaneously both ceramic and glass. If we look at the definition, it is “a self-glazing ceramic body”, and if we look into its composition, it has all the components of modern-day glasses.

I will be dividing the body of my research into two parts, part one will be the scientific research, including methodology, options and possibilities, thought process, experimentation, and analysis, and part two will include the artistic application. In other words, part one will showcase the process of the scientific approach and data that helped carve my way into the possibilities for my applications in my artistic practice.

4. Part one: Scientific research and Introduction to my methodology

Starting my research and this experiment, I didn’t know if the recipe would work or not, as in the ceramic community it is not uncommon to try to make Egyptian paste and not have it work. I started by picking a simple recipe, one of the many simple recipes of Egyptian paste that I mentioned above, that are available on the internet of successful reproductions used by various artists, initially this was meant as a first trial with other recipes lined up in case it didn’t work.

The research plan involved several key steps: selecting a recipe, conducting experiments with various oxides, establishing a baseline without any oxides, and firing at a range of temperatures. These temperatures encompassed both the lowest and highest firing ranges, as well as extending beyond them. Hence, the plan involved creating samples of various recipes and preparing them for dilatometry testing to determine their coefficient of expansion, or COE. “The coefficient of expansion is a number that expresses a percentage change in length, per degree change in temperature. The coefficient of expansion is determined by measuring the change in length of glass for a one-degree Centigrade increase in temperature” (Lundstrom, 1994)

The COE is what determines the compatibility between two glasses. Generally speaking, the difference between the coefficients of expansion of two glasses cannot be more than plus or minus 5. Anything with a difference of more than 5 will have immense stresses and strains inside the glass structure and be deemed incompatible, and surely cracking is to be expected at some point, even if they don’t show initially.

Since the goal was to assess compatibility with glass, specifically with the two types I had access to and was working with – furnace glass (basic soda-lime glass) and window glass – let's provide some details. The furnace glass available at VICARTE is sourced from Cristalica Studio Glass, with a Coefficient of Expansion (COE) of 98. On the other hand, the window glass, often referred to as float glass, typically falls within a standard COE range of 85-87. Figure 24 below displays the COEs of various common glasses, including float glass, for reference.

Determining the Coefficient of Expansion (COE) for various Egyptian paste recipes will provide insights into their compatibility. This information will pave the way for further experimentation, allowing us to modify the compositions of the samples to achieve a COE range that is deemed compatible.

Chart of coefficient of some glasses

BULLSEYE		90
UROBOROS	90.0 FUSIBLE	90
	96.0 FUSIBLE	96
SPECTRUM		96
BOTTLE GLASS		89–92
PYREX		32
FLOAT PLATE		85-87

Figure 24
COE of some common glasses (Lundstrom, 1994)

4.1 Starting recipe

I chose my initial recipe based on three primary factors: simplicity, the availability of raw materials required by the recipe, and the firing temperature. The ceramic community is diverse and spread across the globe, and some recipes may include raw materials and terms specific to certain regions and countries, making replication challenging. This situation is reminiscent of attempts to recreate ancient recipes, as seen in the initial research on Egyptian faience, where replicating ancient Egyptian recipes posed similar challenges.

For my choice of recipe, I opted for the one featured in Robin Hopper's article, published in 2015 in the online ceramic publication, Pottery Making Illustrated. You can find the recipe in Table 1.

Table 1

Initial Egyptian paste recipe. (Hopper, 2015)

Soda Feldspar	38%
Silica	38%
Ball Clay	12%
Soda Ash	6%
Sodium Bicarbonate	6%

In its simplest form, an Egyptian paste recipe is sand, soda/natron and lime/calcium. And this is how it translates into the recipe I picked.

Silica provides the SiO_2 from quartz pebbles or sand,

Soda Feldspar is one of the three types of felspars, sodium, calcium, and potassium, with the chemical formulas, ($Na_2O.Al_2O_3.6SiO_2$), ($CaO.Al_2O_3.2SiO_2$), and ($K_2O.Al_2O_3.6SiO_2$), respectively. These feldspars are rarely found in their pure form, and commercial felspars usually contain all three. (Rogers, 1995) Therefore, the soda felspar would provide some sodium, alumina and small amounts of calcium.

Soda Ash and sodium bicarbonate would provide the alkali-flux present in the natron. And ball clay, which is a sedimentary clay, that is finely grained and mainly consisting of kaolin, known for its plasticity (Dodd, 1967), with the general chemical composition of "SiO_2 − 53.3-61.2%, Al_2O_3 − 24.3-32.5%, Fe_2O_3 − 1.2-1.7%, TiO_2 − 1-1.1%, CaO − 0.2-0.3%, MgO − 0.2-0.4%, K_2O − 0.3-1.3%, Na_2O − 0.1-0.3%" (Wypych, 2016) would be a source of some calcium, alumina and probably any other impurities. Although it is possible that the addition of ball clay in this recipe is purely to make the recipe more plastic and the paste more workable.

4.1.1 Oxides

I decided to start with copper oxide, as a baseline for my research while simultaneously trying a few other oxides to try for a wider range of colors and see how the properties of the Egyptian paste might change with the different oxides, so I decided to also try chromium oxide, iron oxide, and manganese dioxide. And as most recipes call for almost the same percentage range of oxide, which is 1%-5%, I decided to go with 2%.

Cu_2O 2% - copper oxide

Cr_2O_3 2% - chromium oxide

Fe_2O_3 2% - iron oxide

MnO_2 2% - manganese dioxide

The oxides were added individually and as an addition to the initial recipe not part of the overall calculation.

4.1.2 Firing temperature

The recipe works from cone 010 to cone 06, which is 903 ˚C to 998 ˚C. (Sievers, 2023) Which was the range I was initially interested in.

4.1.3 Firing Cycle

As for the firing cycle, not many sources mention this piece of information, which might be due to its insignificance, or the consensus of using a ceramic bisque cycle. Therefore, I can't be sure of its importance and effect on the results. Nevertheless, I did find the following firing cycle:
50 – 60 ˚ C per hour, at 250 ˚ C 5-minute soak, 100 ˚ C per hour. At 1249 ˚ C 10-minute soak. (Pratt, 1999), and decided to adjust for my temperatures and use it.
It is not very different from a normal bisque firing cycle, with the small difference of soaking at 250˚ C instead of the common soak, some artists stick to at 573 ˚C, which is the temperature of quartz inversion and a critical point in ceramic firing, (refer to page 51 of this research for more information)
However, Pratt was using a different recipe, and going to unusually high temperatures, especially for Egyptian paste, therefore, for my purposes I decided to use the same cycle, firing at a lower temperature but nevertheless still soaking at my highest temperature for 10 minutes.

Due to the many variables already existing within this research I stuck to the above firing cycle and would only consider alterations if results were not satisfactory, that being said, as I already mentioned I cannot say for certain that the results would not have been successful had I tried a normal bisque firing cycle for example, instead of soaking for 5 minutes and 10 minutes at 250˚C and at my highest temperature respectively, this might be an interesting test for another time.

4.1.4 Other substitutes and variations

Table 2 shows all the different variations applied to the different recipes, where in some I substitute silica for powdered furnace glass, or colored glass, in other recipes I changed the percentages of the fluxes or ball clay and in some I even introduced a new flux.

Table 2
Table summarizing components and percentages in the recipes.

	Silica	*Soda Feldspar*	*Soda Ash*	*Sodium bi Carbonate*	*Ball clay*	*Cu_2O*	*Cr_2O_3*	*Fe_2O_3*	*MnO_2*	*Furnace glass frit*	*Colored glass frit*	*Colemanite*
A	38	38	6	6	12	2	-	-	-	-	-	-
B	38	38	6	6	12	-	2	-	-	-	-	-
C	38	38	6	6	12	-	-	2	-	-	-	-
D	-	38	6	6	12	2	-	-	-	-	38	-
E	38	38	6	6	12	-	-	-	-	-	-	-
F	38	38	6	6	12	-	-	-	2	-	-	-
G	-	38	6	6	12	-	-	-	-	38	-	-
H	-	38	6	6	12	2	-	-	-	38	-	-
I	30	38	10	10	12	2	-	-	-	-	-	-
J	38	38	12	12	-	2	-	-	-	-	-	-
K	38	38	12	12	-	-	2	-	-	-	-	-
L	38	38	12	12	-	-	-	-	2	-	-	-
M	38	38	9	9	6	2	-	-	-	-	-	-
N	38	30	13	13	6	2	-	-	-	-	-	-
O	36	36	11	11	6	2	-	-	-	-	-	-
P	36	36	12	12	4	2	-	-	-	-	-	-
Q	34	34	13	13	6	2	-	-	-	-	-	-
R	38	30	7	7	8	2	-	-	-	-	-	10
S	38	30	7	7	6	2	-	-	-	-	-	12
T	38	30	7	7	6	-	2	-	-	-	-	12
U	38	30	7	7	6	-	-	-	2	-	-	12
V	38	38	9	9	6	-	2	-	-	-	-	-

4.2 Sample preparation and process

- Raw materials are carefully weighed and mixed in their dry forms really well.
- Water is added; I was usually using 2:1 ratio, 2 parts raw materials and 1-part water, then more water is added if needed. The idea is to have a thick slurry.
- Mixture is mixed really well to make sure all raw materials dissolved in the water.
- Mixture is left for some time to “mature”, usually overnight.

- Mixture is transferred onto a plaster board for some time to dry, but since the mixture contains a lot of salts, soda ash in particular, it is somewhat corrosive and ends up eating at the plaster, therefore the plaster boards can't be reused as often as they usually are when using clay because they end up corroded (see figure 25 – 27) this step might be avoidable if less water is added.
- The mixture is now similar to clay and can be wedged and handled.
- Samples are prepared by rolling smaller pieces into balls by hand and flattened to make small disks.
- Samples are left to dry.
- Figures 28, 29, and 30 show the process of drying, and the effloresced sodium salts that are formed on the surface. Figure 28 was directly after making, figure 29 was taken after 4 days, and figure 30, was taken 5 days after making.
- Samples were then placed onto plaster and silica boards and fired on these boards, which were used instead of only kiln shelf wash for extra protection for the kilns. Later I started placing the samples directly onto these boards when drying, as to try and not handle them and agitate the efflorescence when they have dried and ready to be fired.

Figure 25
Plaster board after use, after two days. (©Nour Ali)

Figure 26
Plaster board after use, left for a few days, salts starting to accumulate. (©Nour Ali)

Figure 27
Corrosion of plaster after scrapping the accumulated salts. (©Nour Ali).

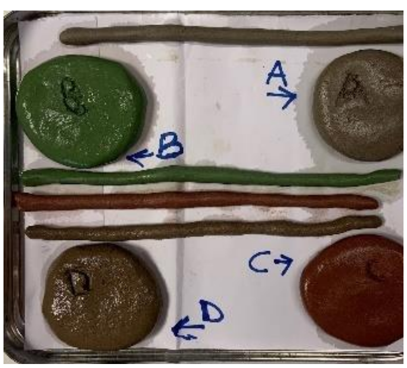


Figure 28
Samples directly after making. (©Nour Ali)

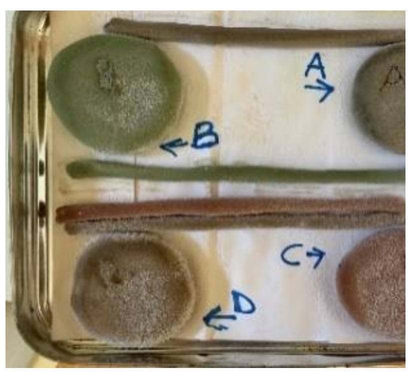


Figure 29
Four days after making. (©Nour Ali)

Figure 30
Five days after making. (©Nour Ali)

4.2.1 First firing and initial results

My first firing was at 950˚C, which is the middle point of the temperature range of my recipe. I started with samples A through H, firing the small round discs and coils of Egyptian paste, as well as brushing it on glass, (the two applications that I stuck with for all temperature testing), however at 950 ˚ C, since it is the ideal temperature for my recipe, I tried a couple extra applications, such as such as fusing glass onto the fired samples of Egyptian paste as well as trying a few of the variations on ceramics, both in greenware state and after bisque firing. Figure 31 shows the results at 950 ˚ C.

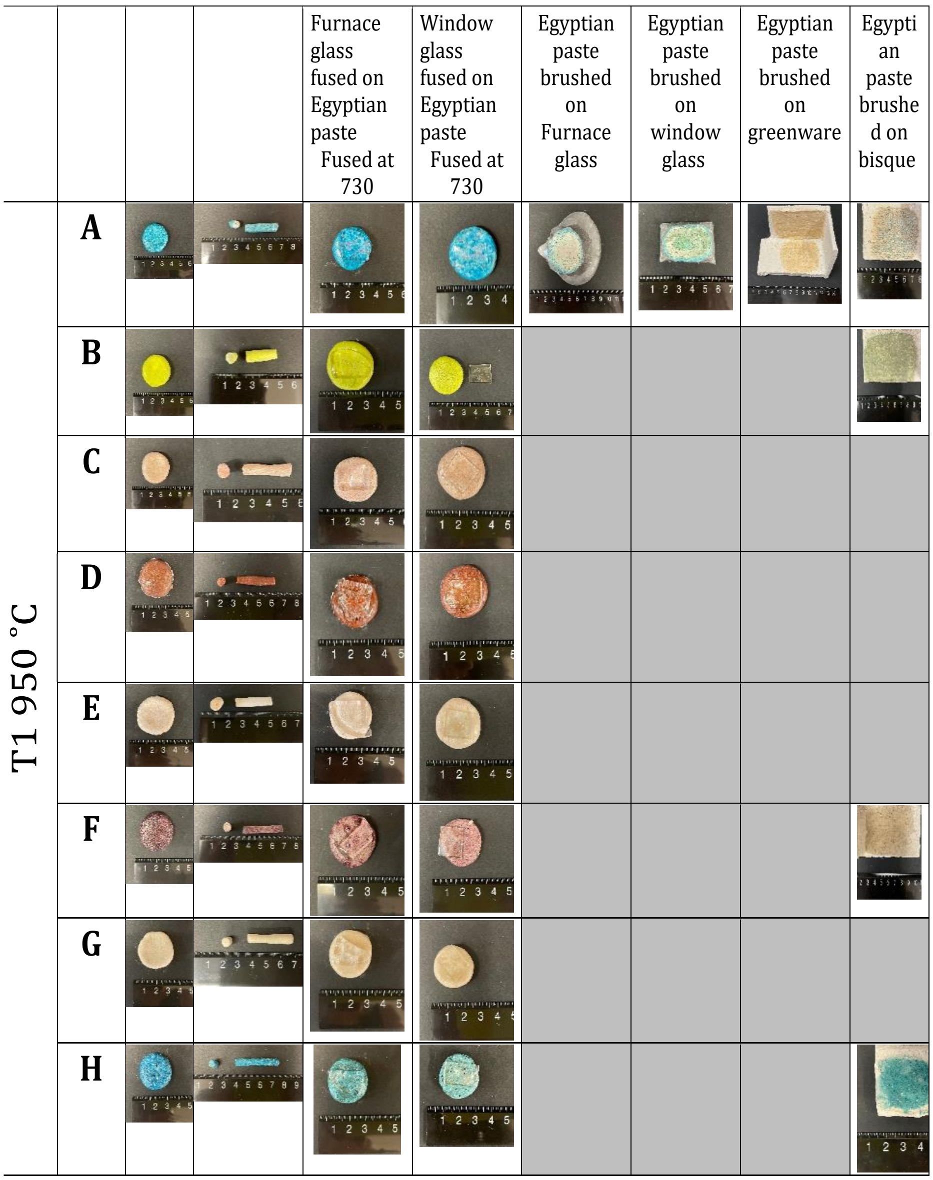


Figure 31
Results at 950 ˚ C

New samples were made to allow observation of glass and Egyptian paste tests under the polariscope to see visual levels of their compatibility, and any existent stress and strains in the glass. Figure 32 shows the new samples, only of the recipes of interest, fired at 950 ˚ C, and a thin layer of window glass, and furnace glass fused on top at 730 ˚ C.
The Egyptian paste samples in figure 32 were fired at 950 ˚ C, then a layer of window glass, and furnace glass were added and then fused at 730 ˚ C.

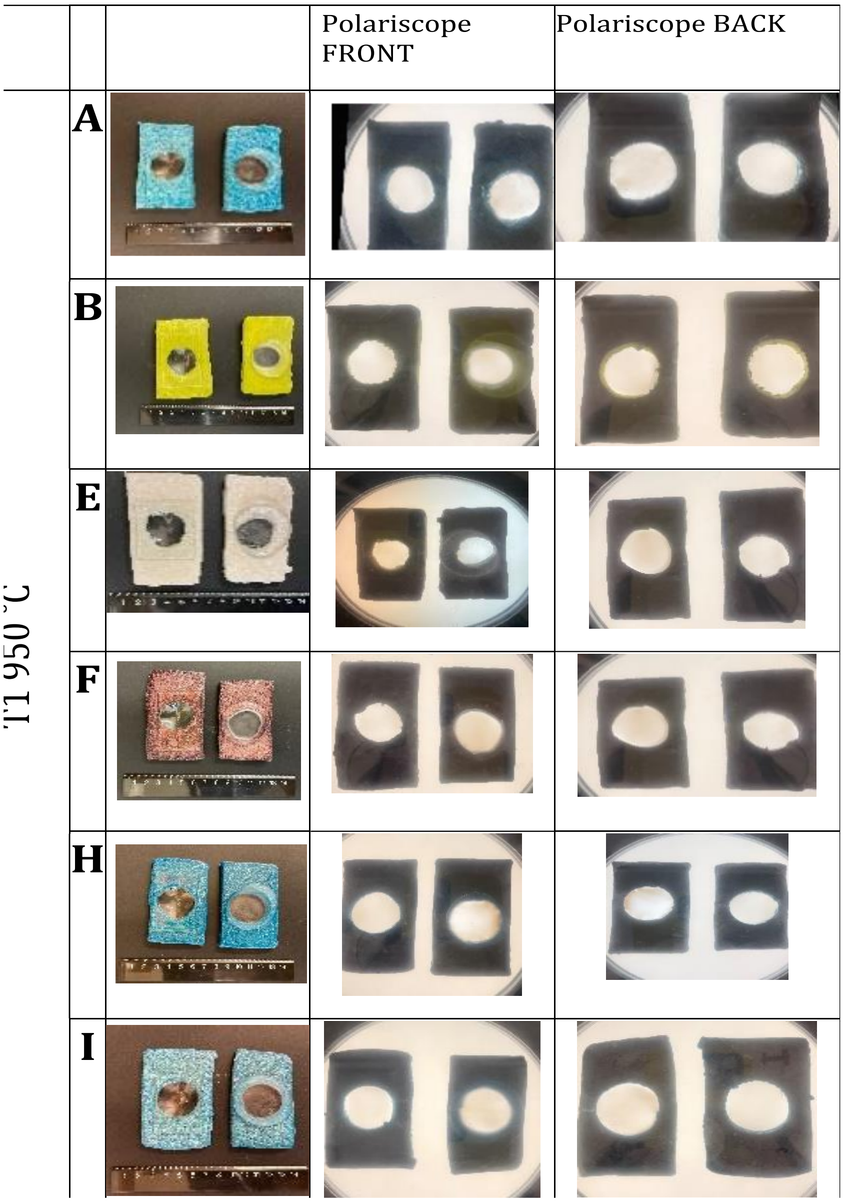


Figure 32
column 1: selected recipes fired at 950 ˚ C with a layer of fused (at 730 ˚ C) furnace glass (left) and window glass (right), column 2: samples under the polariscope from the front, column 3: samples under the polariscope from the back.

4.2.2 Results and observations of new samples and polariscope results,

- Most samples with furnace glass seem to show a lot of cracks.
- Window glass appeared to be a bit more compatible, with less cracks overall.
- Sample H, which is the variation with furnace glass frit instead of silica seemed to be the least compatible with the window glass sample, showing the most stress under the polariscope. - Figure 33.
- I, the recipe with the most flux and less silica seemed to have almost no cracks in the glass, and no obvious or extensive stresses or strains in the polariscope analysis. – Figure 34.

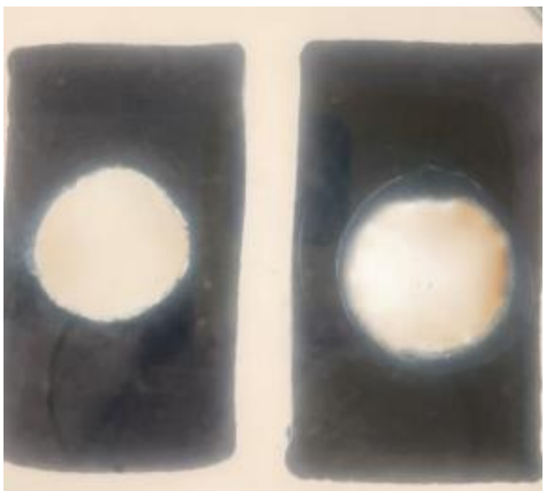


Figure 33
Sample H with window glass (left), furnace glass (right), fused on top – under the polariscope. (©Nour Ali)

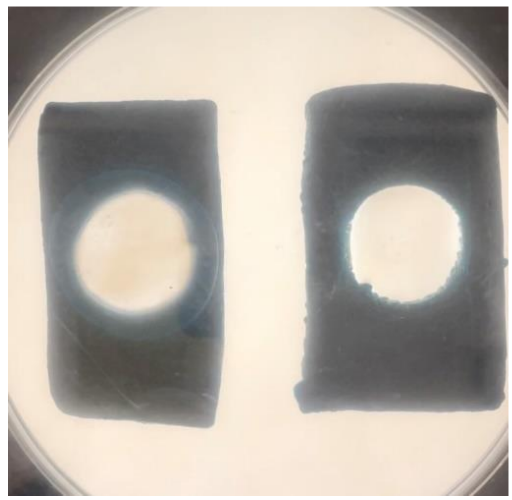


Figure 34
Sample I with window glass (left), furnace glass (right), fused on top – under the polariscope. (©Nour Ali)

I then fired samples A through H at two new temperatures, 800˚C, and 1100 ˚C which are approximately 100 degrees below the minimum temperature of 903˚C called for in the recipe, and similarly almost 100 degrees above the maximum temperature of 998 ˚C.
Figures 35 and 36 summarize the results at 800˚C - and 1100˚ C respectively.

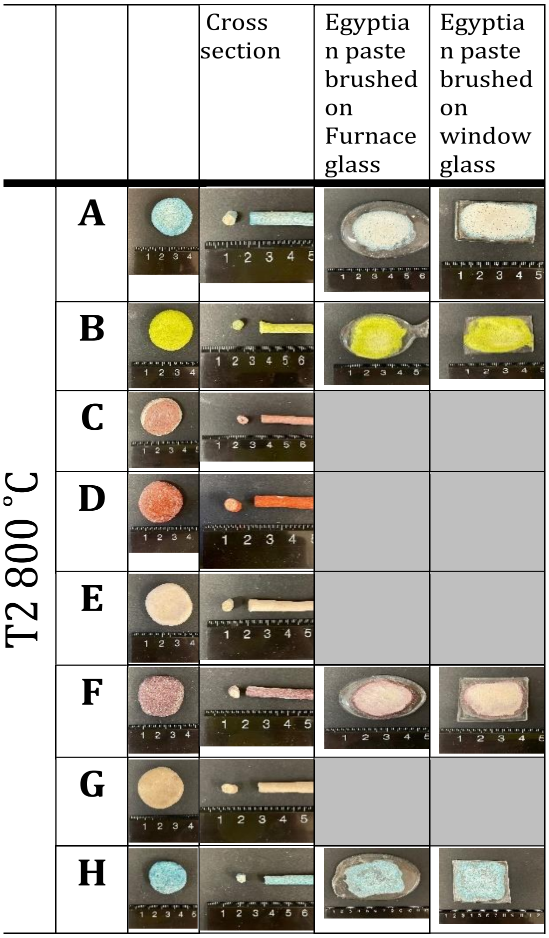


Figure 35
Samples at 800 ˚C (©Nour Ali)

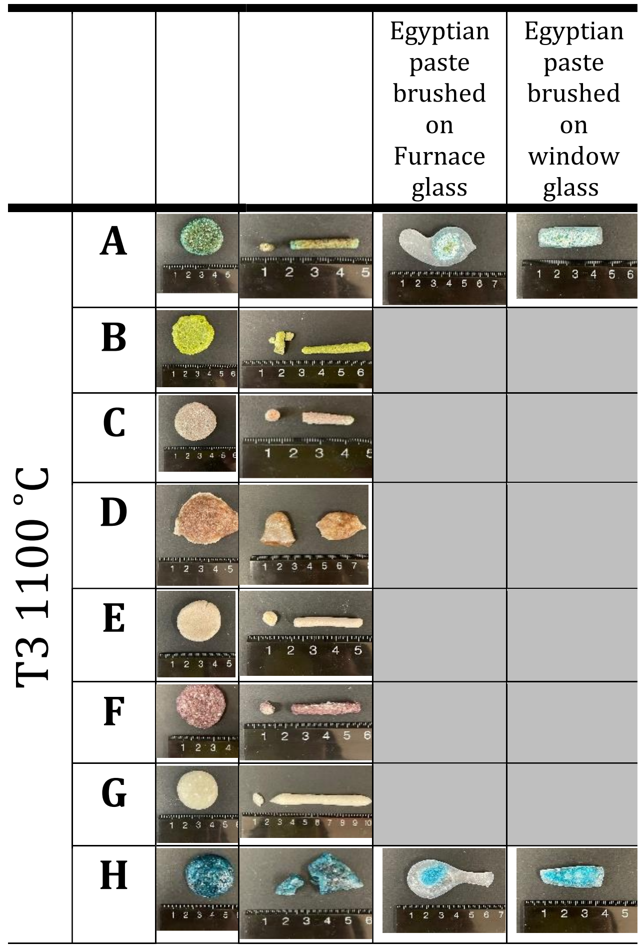


Figure 36
Samples at 1100 ˚C (©Nour Ali)

4.3 Observations

4.3.1 950 ˚C

- The reproduction of the recipe was successful. The outer layer was extremely shiny, and the body was coarse, white and gritty.
- The original recipe with the different oxides was also successful.
- The results of the Egyptian paste on the ceramics were underwhelming, and very different in appearance to the Egyptian paste on its own, as there didn't seem to be any glazed or shiny surface. They did not prove to be very interesting to me at this point and so I decided not to take this any further.
- The recipes where the silica was substituted for powdered furnace glass frit and colored glass frit produced fully vitreous bodies with no coarse, gritty, core that is standard of Egyptian paste recipe I was aiming for.
- Results of fusing glass onto Egyptian paste samples, and polariscope results,

- Most samples with furnace glass seem to show a lot of cracks.
- Window glass appeared to be a bit more compatible, with less cracks overall.
- Sample H, which is the variation with furnace glass frit instead of silica seemed to be the least compatible with the window glass sample, showing stress under the polariscope (figure 33 above)
- I, the recipe with the most flux and less silica seemed to have almost no cracks in the glass, and no obvious or extensive stresses or strains in the polariscope analysis.

- Brushing the Egyptian paste on glass produced some very interesting results, as the layer of Egyptian paste was fused onto the glass surface, and there didn't seem to be any obvious stresses and strains in the forms of cracks in the glass. Figure 37. Even under a polariscope there weren't any obvious or excessive stresses in the glasses. Figure 38. Figures 39 and 40 show recipes A and H at 950, as well their cross-section to show their core body.

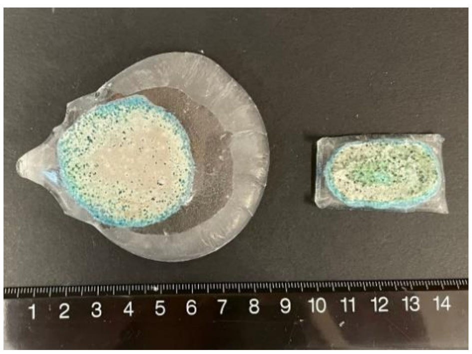


Figure 37
Recipe A, brushed on to furnace glass (left) and window glass (right) and fired at 950˚C

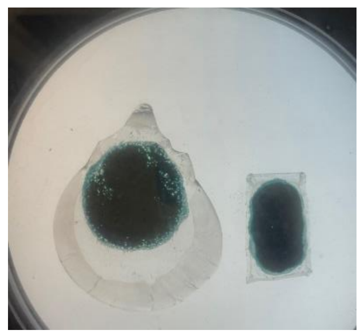


Figure 38
Samples from figure 37 under the polariscope.

.

Figure 39
Recipe A at 950 ˚C, (left) cross section (right) (©NourAli)

Figure 40
Recipe H at 950 ˚C, (left) cross section (right) (©Nour Ali)

4.3.2 800˚C

- The outer layer was less shiny and looks underfired.
  Figure 41 below show three samples of recipe A at 800 ˚C, 950 ˚C, and 1100 ˚C, respectively, side by side for comparison.
- The cross sections showed the inner body of the fired paste is in fact very similar to the samples fired at 950˚C.
- The glass brushed with the Egyptian paste was less devitrified, the Egyptian paste was also fused, with bright colors in some cases, however also lacking the shine a little bit.

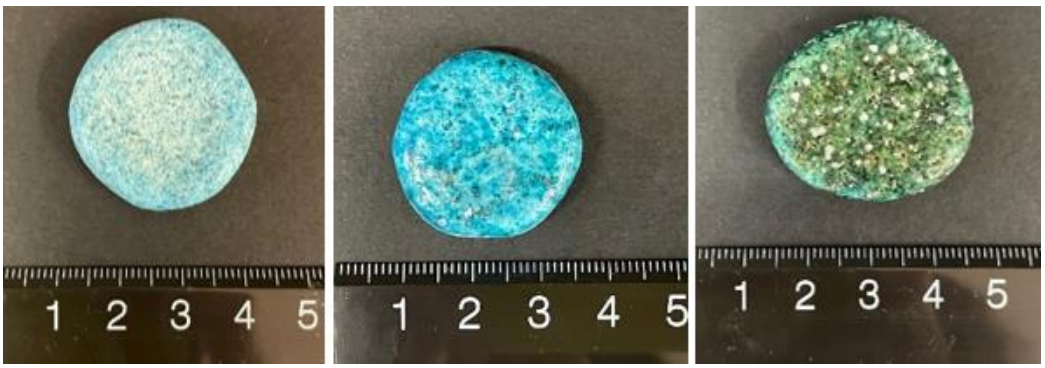


Figure 41
Recipe A at different temperatures. From left to right 800 ˚C, 950 ˚C, and 1100 ˚C. (©Nour Ali)

4.3.3 1100 ˚C

- The colors of some of the samples completely changed. Figure 41 shows the changes of color in recipe A for example.
- The textures looked bubbly, showing obvious signs of being overfired, which is to be expected. (figure 42)
- In cross section there is less of a distinction between the outer layer and the rest of the Egyptian paste body.
- The glass has completely devitrified, and some crystals appear to have formed on the surface of the paste.

Figure 42
Recipe C (left) Recipe D (right) at 1100 ˚C. (©Nour Ali)

4.4 Turning point of research

After the initial firings and tests with fusing glass onto fired Egyptian paste samples, two things happened that changed the direction of my research, the first was difficulty accessing the dilatometry machine when I needed to start making changes to my recipes depending on the results generated by the dilatometry analysis, namely, the COE of the material. The second thing, and the most important one, was the results I got from brushing the Egyptian paste onto the glass. The results were very exciting to me, and held a promise of pioneering discoveries and possibilities, at least artistically speaking. Of course, this was not without its own challenges, which I will be discussing in more detail later.

4.4.1 Adjustments

I will be narrowing down the research to focus on the aspect I am most interested in for my artwork at this point, which is brushing the Egyptian paste on to glass. And to do that, I will need to create a recipe of a paste that has the characteristics of the Egyptian paste, i.e., can be molded into small forms at the minimum and give the shiny lustrous appearance of a glaze at lower temperatures.

The first step moving forward would be to start adjusting recipes to lower their firing temperatures, since glass working temperatures are lower than that of ceramics, when refiring, in kilns that is, not the actual hot working temperatures in the hot shop.

Casting usually is done at the range of 840˚C, (Halem, 1994) a considerably high temperature when reworking with glass, it is a melting and reforming temperature. While other techniques of glass working require lower temperatures, with fusing being in the range of 780 ˚C – 815 ˚C according to Halem, however this greatly depends on the type of glass being used, since in my experience, fusing can be done at lower temperatures, with 780 ˚C being the upper limit of the range and going as low as 720 ˚C. I usually prefer lower fusing temperatures, especially for clear glass to avoid devitrifying, "Devitrification: (1) The process whereby glass becomes partly crystallized as it cools (usually too slowly) from the molten state; (2) the crystals formed by this process. Devitrification can also occur on the surface as a result of unsuccessful annealing or accidental heating to a high temperature. it is not caused by chemical reaction between glass and its environment, which is known as weathering."(Whitehouse, 2006)

Therefore, my new firing temperatures would have to be 840˚C at a maximum but ideally go as low as 750 ˚C, if not lower, but at this point of the research 750 ˚C is a good starting point for ideas I want to experiment with, where the glass would not be as devitrified and still appear clear instead of milky. Lowering the melting temperature means I will need to increase the flux; however, I will need to follow the trial-and-error methodology to decide on what component or components the extra flux will have to replace and in what quantities, all the while not to jeopardize the integrity of the material and effect its characteristics and properties.

Starting with recipe I, I decided to decrease the silica by 6% and increase the soda fluxes by this amount, divided equally between the two different soda fluxes.

Then for recipes J, K, and L, I removed all the ball clay in the recipe and added the difference, divided equally, between the 2 soda fluxes.

Recipes M and U, I halved the amount of ball clay, and added the difference equally between the 2 soda fluxes.

Recipes, N, O and Q, I kept the ball clay at 6%, which is half the original amount but also tried experimenting with decreasing the silica and/or the soda feldspar and added the difference to the flux components.

Recipes R, S and T, I kept the ball clay at 6%, and decreased the soda feldspar to add colemanite as an extra source of flux.

Figure 49 shows the different recipes at 4 different temperatures for comparison. And Appendices B - E show the results of the next batch of samples at 840 ˚C, 800 ˚C, 780 ˚C, and 750 ˚C in detail.

4.4.2 Results and notable observations

The application of the material was key. When glass was applied on top of the samples, clear cracks and sign of strain was visible under the polariscope, however when the Egyptian paste variations where applied. Brushed, or molded/fused side by side to the glass there were no signs of stress or strain, in fact they seemed stable.

- I
    - Decreasing the silica by 8% to increase the flux by the same amount, did not have any obvious effect on the recipe, comparing A at 800 ˚C and I at 800 ˚C in figures 43 and 44 below, there isn’t any major difference between the two.

Figure 43
A at 800 ˚C (©Nour Ali)

Figure 44
I at 800 ˚C (©Nour Ali)

- J, K and L
  - Removing ball clay completely from the recipe and adding the difference to the fluxing components, had a major effect on results, especially with J, where the results appear to be very lustrous at 840 ˚C, and at 800 ˚C, as opposed to A at these temperatures. However, lower firing temperatures did not give the same results, the surfaces seemed "dry and rough".
  - Interestingly enough though when the same mixture is applied on to the furnace glass or window glass test samples the texture is different after firing, as opposed to its texture when fired on its own, even at lower temperatures, the texture is less grainy and rough, and the colors are brighter. (figures 45 and 46)

Figure 45
J at 750 ˚C modeled into a flat disc (©Nour Ali)

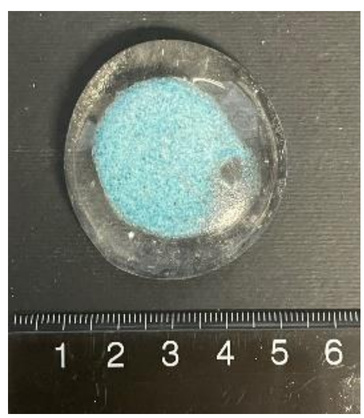


Figure 46
J at 750˚C on furnace glass (©Nour Ali)

  - Removing the ball clay made is very difficult to shape and form. The "paste" crumbled under any pressure applied to form it, the only way working with it was possible was to wet my hand and keep dipping my hands in water while working with it and trying to form it into small shapes.

- M and V
    - Decreasing ball clay by half the original quantity and adding the difference as a flux made a lot of difference when working with it, making it a lot easier to work with and shape.
    - The results of the firing at 840 and 800 were also very similar to previous results of J, where the outer surface was shiny and "glazed", but underfired at 780 ˚C and 750 ˚C. (refer to figure 49)
- N – Q
    - Decreasing Silica and soda feldspar in equal amounts to increase the flux didn't have any noticeable or different results to the previous recipes, especially at lower temperatures. On the contrary, the results at 800 ˚C where less successful, especially in Q, which had the lowest percentage of both silica and soda feldspar, refer to table 2, the sample seemed almost white with no color, which might be due to there not being enough silica in the composition despite the increase in flux. Refer to figure 49.
    - At lower temperatures, a layer of white powder was observed, which felt slimy to the touch and had a soapy texture when washed. This phenomenon is commonly observed in both glass and ceramics when additional flux, particularly alkali fluxes, are introduced into the composition. Daniel Rhodes discusses the challenges associated with adding soluble salts to clay, noting that it can lead to efflorescence or the formation of scum on the clay surface. He also mentions a layer of scum that forms on alkali glazes, which can be easily scraped off when they come out of the kiln (Daniel Rhodes, 1957). Similarly, in glass, Stephen Koob discusses a cloudy or hazy layer caused by the presence of alkali, which can result in a type of glass deterioration known as crizzling. This initial stage of crizzling is described as having a slimy, soapy feel when touched (Koob, 2006).
- R
    - Considering the findings from previous results, I made the decision to incorporate an additional non-alkali source of flux to tackle the challenges arising from an excessive amount of alkali flux. To address this, I chose to introduce colemanite, a potent flux commonly used in glazes. Colemanite contains calcium oxide and boron oxide, with the latter beginning to fuse at a relatively low temperature of 600°C (Frank Hamer, 1997). By adding colemanite, I aimed to lower the overall melting temperature of my material and potentially overcome the challenges faced with excessive alkali flux.

    - At 800 ˚C and 840 ˚C, the results were very positive, with a glazed surface, and even at 780 ˚C and 750 ˚C, the results were not unsuccessful, showing a pale color and a hint of glaze.

- S and T
    - Increasing the colemanite, by an extra 2 % from the previous recipe, which was taken from the ball clay, gave the results that I had hoped for, the color was a little deeper, and the shine a little stronger. (Figures 47 and 48 below A and S in comparison at 840 ˚C and 750 ˚C)

Figure 47
Recipe A at 840 ˚C (left) and 750 ˚C (right) (©Nour Ali)

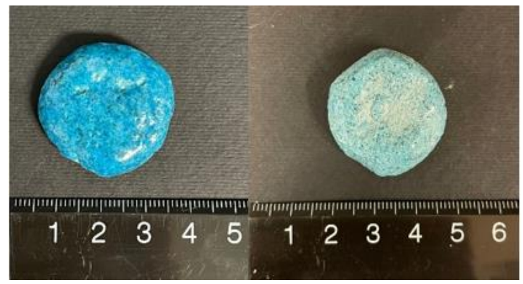
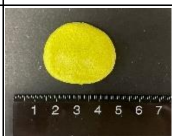
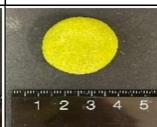
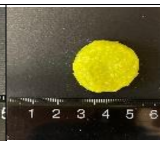
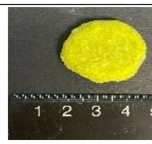
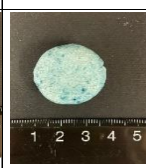


Figure 48
Recipe S at 840 ˚C (left) and 750 ˚C (right) (©Nour Ali)

While this research may not be conclusive, due to time constraints, it serves as a reasonable stopping point for this paper. The results obtained thus far will enable me to showcase them in my research exhibition. Nevertheless, these findings offer promising opportunities for future exploration, potentially leading to more robust and substantial results.

	840	800	780	750
A				
B				
C				
D				
E				
F				
G				
H				
I				
J				

K				
L				
M				
N				
O				
P				
Q				
R				
S				
T				

U				
V				

Figure 49
Recipes A - V at four different temperatures.840˚C far left, followed by 800˚C, 780˚C, and 750˚C far right (©Nour Ali)

5. Thermal and crystallinity characterization

5.1 DSC and XRD

Both Differential Scanning Calorimetry and X-Ray Diffraction analysis will be used to characterize the developed materials and give us a better understanding of its properties, structure, and thermal behavior. The two techniques complement each other with the information they will provide to help in better understanding the material.

DSC, Differential scanning Calorimetry, is a type of thermal analysis method that is used for comparative material characterization. This technique measures the difference in energy input into the sample material being tested and a reference material as a function of temperature while both materials are exposed to a controlled temperature program. (*DSC 404 F3 Pegasus*, n.d.)

XRD, “X-ray diffraction is a common technique that determine a sample's composition or crystalline structure.”(*X-Ray Diffraction (XRD) Basics and Application,* 2019) In this case I used X-ray powder diffraction, where the samples where ground into powder and each sample analyzed as a whole. This is due to access to equipment and an initial interest in analyzing the material as a whole instead of focusing on the different layers separately. The results will focus on all the material and not only on the surface.

The XRD analysis shows us if the different compositions and firing temperatures affect the crystal formations, and help us understand the crystallinity of the material, how it is changed by the changes in recipes, and how this influences its optical behavior and properties. XRD may allow us to check if we have any significant amorphous phase in the body.

5.2 Sample preparation.

Samples of three different recipes were prepared for the DSC and XRD testing. Fired samples of each recipe at two different temperatures, 750 ˚ C and 840 ˚ C, were crushed into powder using a mortar and pestle.

Recipe A, the original recipe, Recipe J, a variation with no ball clay, and recipe S, a variation including colemanite, table 2.

Recipe A is the original recipe I started with, and therefore used as a control to then compare the other two recipes and see what effects the changes in the components have on the characterization of the material.

Recipe J is the recipe lacking ball clay, which is probably closest to ancient Egyptian paste recipes, Recipe S is the closest I have gotten to achieving what I set out to do, which is to achieve the same brilliant, glazed effect but by firing at a lower temperature.

In summary, the primary objective of this study is to investigate the impact of ball clay on the material's properties, along with the influence of an additional flux, particularly a low-temperature boron oxide flux. To maintain a more controlled approach in the results and analysis, all three recipes utilized CuO as the colorant. Refer to Appendix F for the detailed method for the DSC analysis.

5.3 Results

5.3.1 DSC

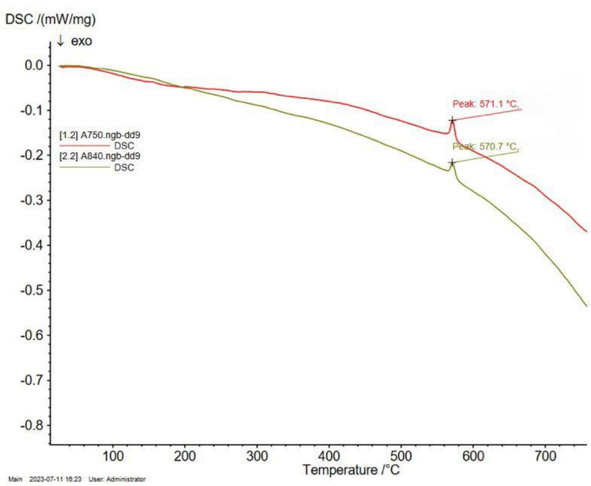


Figure 50
DSC analysis A750 and A840

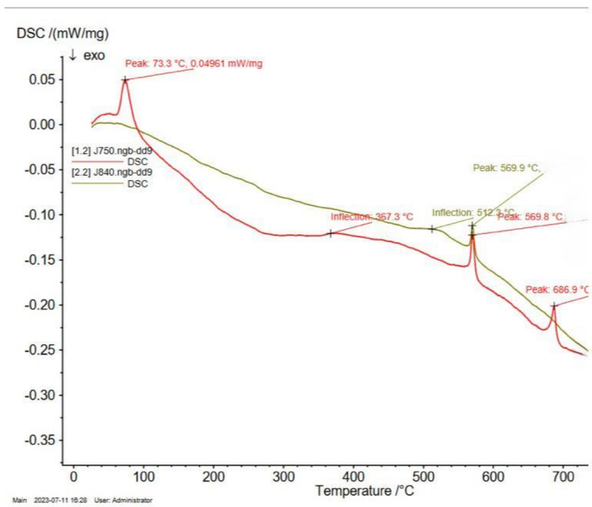


Figure 51
DSC analysis J750 and J840

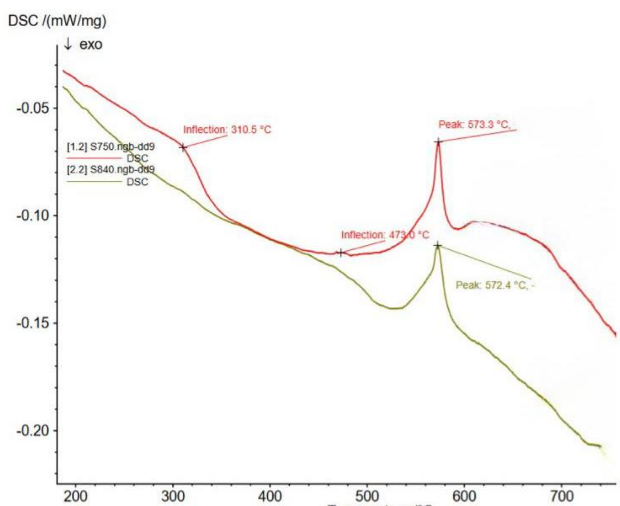


Figure 52
DSC analysis S750 and S840

5.3.2 XRD

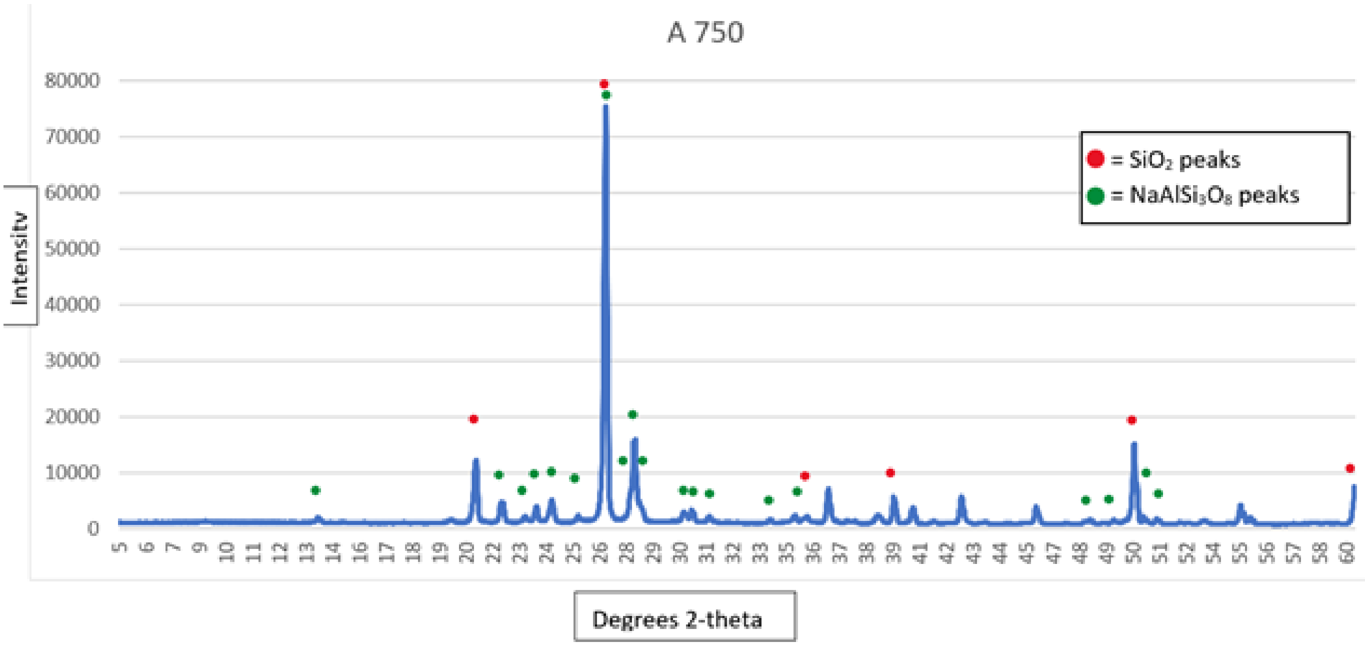


Figure 53
XRD analysis, A750

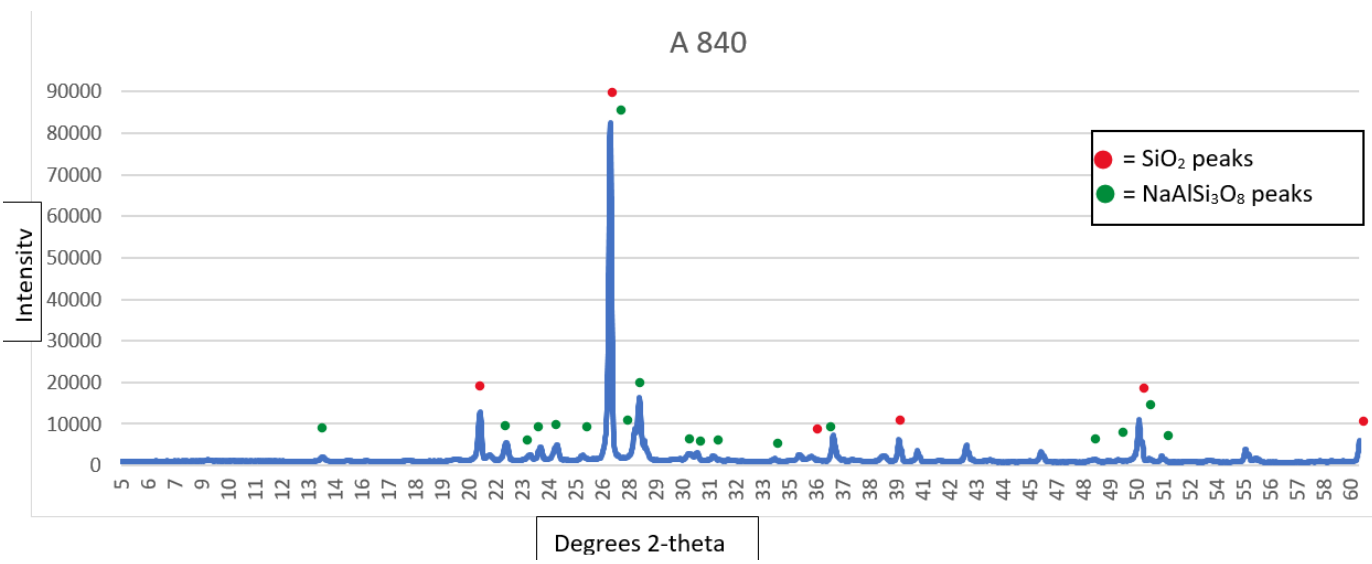


Figure 54
XRD analysis, A840

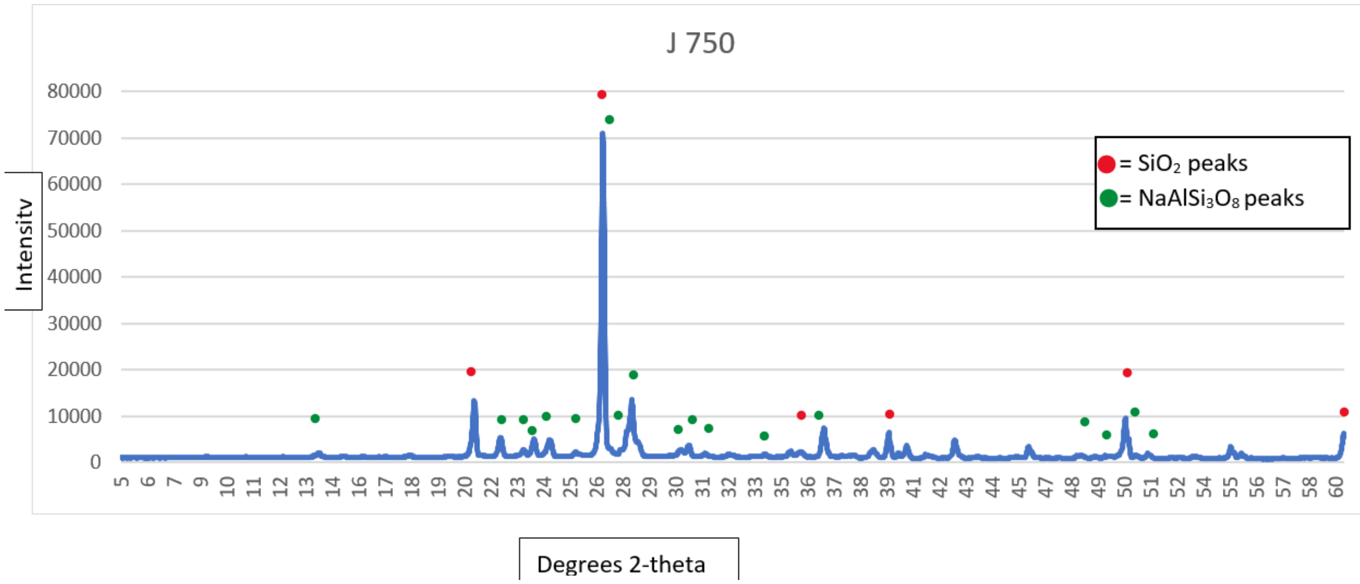


Figure 55
XRD analysis, J750

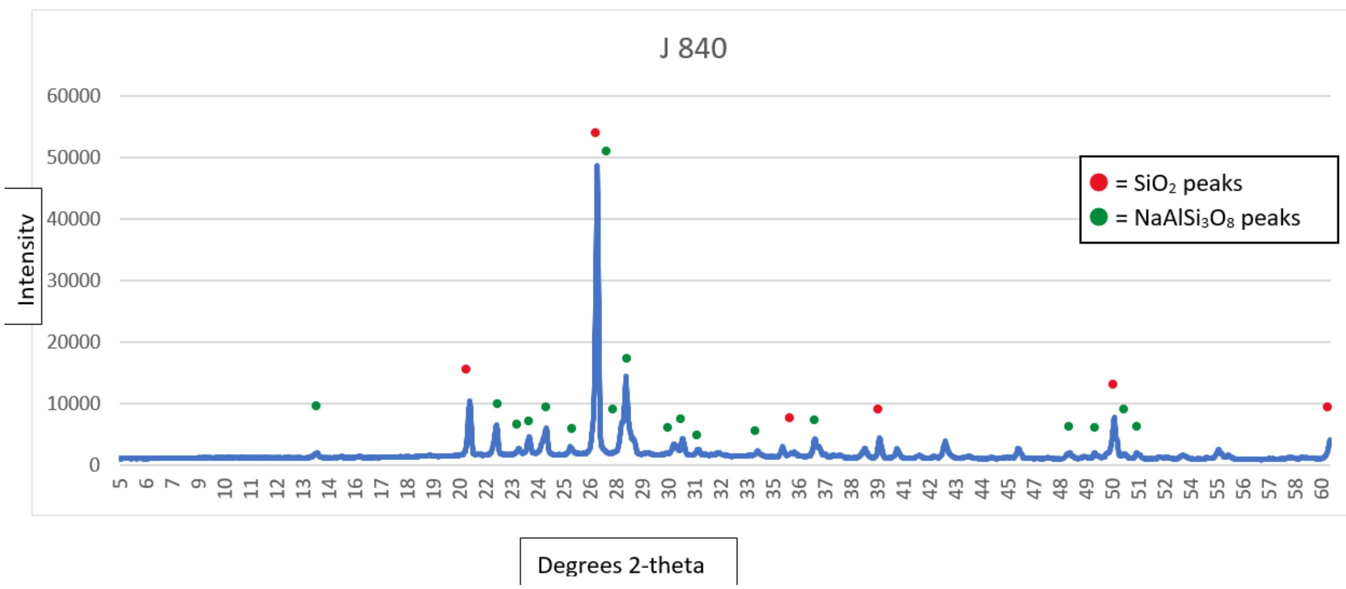


Figure 56
XRD analysis, J840

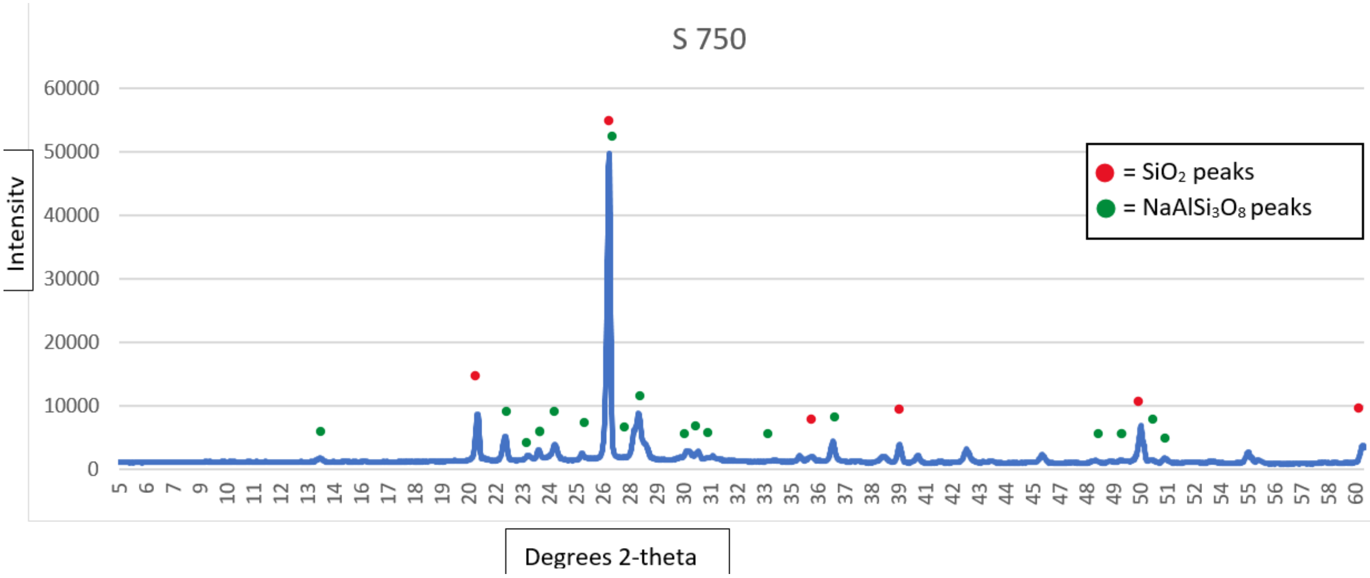


Figure 57
XRD analysis, S750

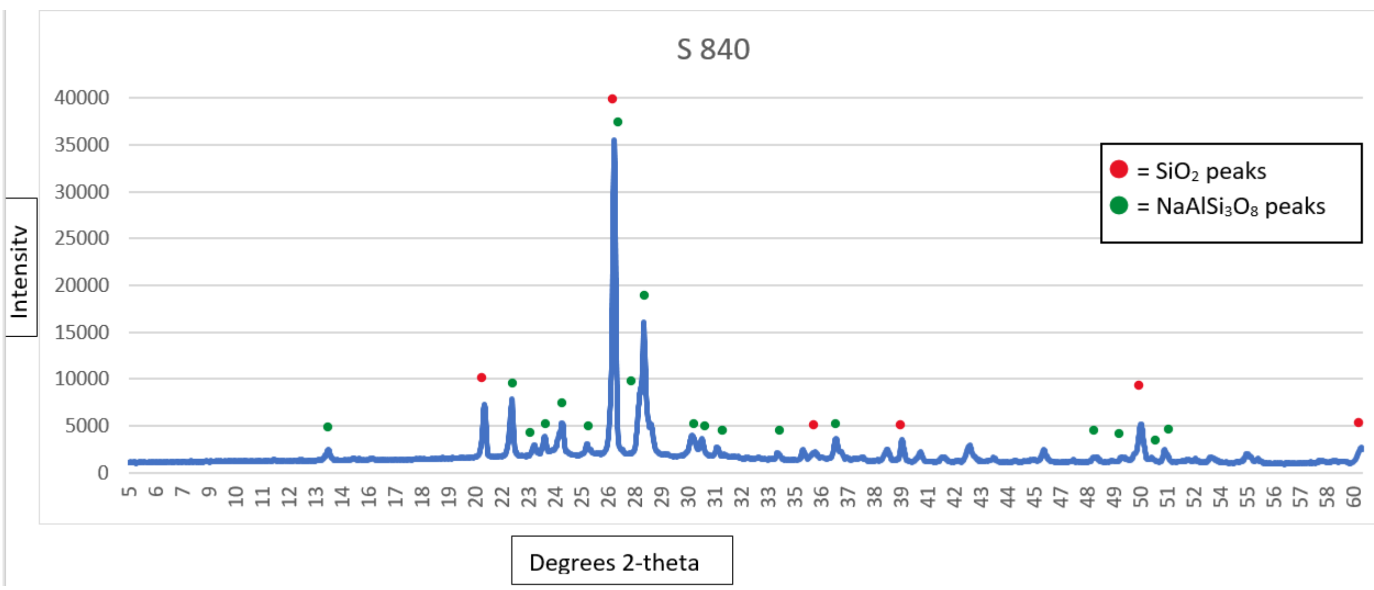


Figure 58
XRD analysis, S840

5.4 Analysis

5.4.1 DSC

The results obtained from the DSC (differential scanning calorimetry) analysis, figures 50 – 52, do not exhibit any prominent peaks, except for a significant peak observed in all samples within the temperature range of approximately 569-573°C. This temperature range aligns with the known quartz inversion range. Quartz inversion refers to the change in the crystal form and properties of quartz due to heat treatment, without altering its composition. (O'Bannon, 1984). These findings are consistent with our existing knowledge that Egyptian paste is indeed a ceramic body, exhibiting qualities unique to the quartz crystals in its composition.

Examining the components in the recipes, particularly the original recipe (A), from a ceramist's standpoint, it appears to resemble a glaze composition. It contains all essential components typically found in a glaze, which are silica, alumina, flux, and colorant. (Murfitt, 2002). And considering that glaze is essentially a glass coating, it is worth noting that the DSC results do not indicate any significant temperature changes or distinctive peaks that would be expected at lower temperatures. Such indications would be signs of glass transformation temperatures, such as Tg (glass transition temperature), which would characterize it as a glass. Glass is defined by two main characteristics: the presence of a glass transformation behavior, and the absence of a long-range, periodic atomic arrangement. Therefore, the identification of any material exhibiting this glass transformation behavior confirms its classification as glass (Shelby, 2005).

It is worth mentioning that when comparing the DSC results of sample A, which represents the original recipe with the highest proportion of ball clay and the least amount of flux, to the other two samples, J (no ball clay) and S (with colemanite), sample A exhibits a more stable curve. Although the other two samples do not show any noticeable additional peaks or changes, it is noteworthy to consider that the increased presence of ball clay in sample A may contribute to its greater stability.

5.4.2 XRD

Analyzing the results from the above graphs, figures 53 – 58, we can deduce that all samples show similar results, the peaks on the graphs show that two major crystalline structures are present, SiO_2 and $NaAlSi_3O_8$, and these two compounds are clearly evident in all the samples, the mineral names of these structures formed are Quartz and Albite, respectively.

In addition, other much less intense peaks are visible in all samples which might be linked to another compound which will need more research to identify but given the low intensity it proves to be less important at this point in the research, as well as the uncertainty of other formations due to low resolution. Both the silicon oxide and the sodium aluminum silicate peaks are intense and very evident on all samples.

Table 3
Ratios of Silicon Oxide and Sodium Aluminum Silicate peak intensities

	SiO_2 XRD peak intensity at around 26 2Θ	**$NaAlSi_3O_8$ XRD peak intensity at around 28 2Θ**	**Ratio of SiO_2 to $NaAlSi_3O_8$ formations**
A750	75367	15961	4.72
A840	80634	16073	5.02
J750	71122	13527	5.26
J840	48774	14527	3.36
S750	49705	8834	5.63
S840	35549	16130	2.20

Table 3 shows the ratios of the peak intensity for the two compounds, silicon oxide and sodium aluminum silicate, those ratios show an obvious increase in sodium aluminum silicate structures in comparison to silicon oxide structure formations at higher temperatures. They also show similar ratios among all samples at lower temperatures, suggesting that the addition of flux in J and S when compared to A doesn’t really have a significant effect on the formation of silicon oxide structures at lower temperatures.

Figures 59 – 61 show the different samples at the two different firing temperatures for comparison. Sample A showed the least structural change between the two different firing temperatures, which is evident in figure 59 where both samples show a lack of glossy/glazy appearance at both temperatures.

Samples J and S both show a significant decrease in ratios at higher temperatures, which indicates an increase in quartz structure formations, and is also evident in figures 60 and 61, the lower the ratio the brighter and glossier the results.

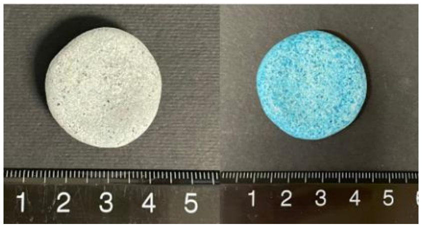


Figure 59
A 750 ˚C *(left) A 840* ˚C *(right)*
(right)
(©Nour Ali)

Figure 60
J 750 ˚C *(left) J 840* ˚C *(right)*
(©Nour Ali)

Figure 61
S 750 ˚C *(left) S 840* ˚C
(©Nour Ali)

DSC analysis shows that all the samples are in fact ceramic bodies as they show peaks at quartz inversion temperatures common in a ceramic body.

XRD analysis shows that the intensity of the quartz peaks changes with the composition. And the quantity of the silicon oxide structures formed changes with the temperature. Showing a bigger change in structure formation when flux is added, but only at higher temperatures, as is evident in the lower ratios shown in table 3.

Therefore, this leads me to think that if I were to further carry on with these changes to recipes in an effort to create the same results at lower temperatures, I would need to consider further changing the composition to maybe a different flux, or further increase the percentage of the colemanite, which is a low temperature flux, to try and achieve these structural changes in the crystalline formations at lower temperatures.

When comparing recipe A and S, figures 59 and 61 respectively, A being the starting recipe, and S, the last recipe and alteration I tried, we can see a clear difference in the two samples at the two temperatures, however when studying the results of the XRD analysis we could not find any crystals that were formed that would justify the difference in appearance.

An interesting extension to the analysis would be to conduct a nondestructive XRD analysis to inspect the two layers, the glazed surface, and the body of the material, separately to compare the characteristics of the different layers and understand what structures are forming where. Which in turn might direct us to how the compositional alterations are affecting the different layers, ideally allowing us to focus on the changes that will lead to the desired results, specifically in better understanding what crystals, if any, are forming on the surface, as opposed to the body, and resulting in the glossy effect.

6. Part two: Artistic Approach and Application

My artistic approach and process involved a lot of experimentation, driven by a sense of restlessness and curiosity. Throughout my work with this material, I constantly got new ideas and felt that the options were limitless. This is ironic considering the material's non-plastic nature, which is commonly perceived as restrictive. However, from an artistic perspective, the solution was as simple as changing the application of the material and methods of working with it.

That's why I decided to explore and test all the possible application options I could think of. While some experiments turned out to be failures, others showed great potential that I intend to utilize in the future. As a result, my artistic outcome resembles a journal of the material and its possibilities—an amalgamation of application options and potentials. None of the pieces I created are final to me; they represent different stages of my artistic research and process. These pieces served as canvases or mediums to showcase the diverse possibilities and options available.

This brings me to the underlying question of this research: How do art and science work together? Can one engage in both? The question of 'how' seems redundant at this point because without the original literature and scientific research conducted decades ago, we wouldn't have been able to reproduce Egyptian paste or possess the knowledge we now take for granted. As for the possibility of pursuing both art and science, I believe that programs like this one serve as proof that it can be done, highlighting the significance of both aspects in the creative process and, subsequently, the outcome. Understanding the material undoubtedly facilitates the development of ideas.

However, based on my personal experience, I found it challenging to engage in both art, particularly in the traditional sense, and science simultaneously, especially within the given timeframe. Perhaps this was primarily due to the overwhelming number of options available and the restlessness I felt due to the novelty of this approach. Consequently, I shifted my focus away from the concept of a final piece. However, this shift was not a negative one. Instead, it allowed me to delve deeper, explore various possibilities, and accumulate results to showcase the wide range of options rather than limiting myself to a few final pieces. These findings will undoubtedly hold value in future projects that require them.

This research and process is no different from attending a workshop or learning a new technique that you know you'll eventually utilize, or purchasing a recipe book for future reference. Therefore, based on my personal experience, art became a process—a continuous journey of exploration and discovery. And therefore, my final exhibition will serve as a research exhibition showcasing the physical results of my discoveries and findings.

6.1 Clayze

[cleyz] 🔊

verb

clayzed, clayz·ing.

- to give a ceramic surface or coating to (a glass surface), as by the application of a substance or by fusion of the bodies.

noun

- a clay-like or ceramic material that is applied onto glass, to color, decorate, or give a ceramic finish.

- a self-glazing ceramic body derived from Egyptian paste.
  - a clay or ceramic coating.
  - the substance used to produce such a coating.

ORIGIN OF CLAYZE

from clay and glaze

Clayzing is the term I use to describe the process of applying a modified version of Egyptian paste recipes onto glass and firing it. The name "Clayze" is a wordplay on "glaze," which is derived from glass and defined as a glassy coating fired on a ceramic piece or the mixture of ingredients that is used to create the coating (O'Bannon, 1984). By combining "clay" and "glaze," Clayze represents a clay-like mixture applied to glass, just as glaze is a glass like mixture applied on clay/ceramics. I am highlighting ‘clay-like’ due to previously mentioned ongoing debate and reservations to the use of ‘faience’ and in extension ‘clay’ when referring to Egyptian paste.

Various definitions of clay exist, with some emphasizing its plasticity (Dodd, 1967), others focusing on its composition (O'Bannon, 1984), and some simply referring to it as "rock dust" and highlighting its ceramic purpose (Daniel Rhodes, 1957; Rhode, 2010). The definition I have chosen to refer to describes clay as a naturally occurring material mainly composed of fine-grained minerals, typically exhibiting plasticity when added to water and hardening when dried or fired. The plastic properties do not require specific quantification to classify a material as "clay" (Guggenheim, 1995).

On the other hand, ceramics are often defined as clay products made permanent through the application of heat, also known as the ceramic change. The term originates from the Greek word "keramos," meaning potter's clay and the ware made from it. However, ceramics also encompass non-clay refractories and various silicate products that are transformed or formed by heat. It is common for individual potters to use the term "ceramics" when they feel that "pottery" is too limiting to describe their work (Frank Hamer, 1997).

From an artistic standpoint, the distinction between clay and ceramics is not of great importance. In online forums and within the ceramic and artistic communities, Egyptian paste is sometimes referred to as a "self-glazing clay body," although we now know this to be incorrect. This discrepancy may arise from the fact that artists do not necessarily feel the need to differentiate between the two materials. However, in scientific contexts, the distinction is typically emphasized as it is of great importance.

Definitions are regularly updated to incorporate new studies and discoveries. However, these new definitions do not dismiss previous ones or widely accepted definitions.

Bray (2001) highlights the evolution of pottery and glass crafts, which have expanded their range of materials beyond naturally occurring minerals and their firing methods, incorporating additional minerals such as silicon nitride, silicon carbide, and uranium dioxide, which are not naturally occurring. Also highlighting a further change in meaning that the term "ceramics" has undergone. Previously, it referred specifically to pottery, tiles, bricks, and similar materials resulting from firing clay. However, it now encompasses a broader range of materials with refractory properties that undergo heat treatment. Another reason supporting the name "Clayze" is the interconnectedness of materials like clay, ceramics, glass, glaze, and Egyptian paste. They all belong to the same category, sharing some properties and raw materials. For instance, clay is a mixture of natural minerals that, when fired, transform into ceramics. Glaze, on the other hand, is a glassy mixture applied to ceramics as a coating. Interestingly, a low-temperature clay body can also function as a glaze at higher temperatures. By mixing this low-fire clay body with water and applying it to a stoneware surface, it can be fired to stoneware temperatures creating a glazed, glassy finish to the stoneware surface. (Rhode, 2010).

To ensure accuracy, it is important to clarify that Clayze is not necessarily composed of a clay body. However, the term is used to denote that, like clay, it undergoes ceramic transformation when fired.

6.2 Application techniques

I employed various application techniques during my experiments. These techniques included brushing or spraying the mixture onto glass, attaching slabs of the mixture onto pieces of glass, and using the paste to join two pieces of glass together. Additionally, I explored firing the mixture in plaster and silica molds while simultaneously casting glass into the mold using the ceramic pot casting technique. Furthermore, I experimented with slumping sheets of glass that had been painted with my mixtures. Since some of the application techniques might hold some similarity in appearance or application to an enamel, in that it is a painted on to glass, it is important to clarify that is indeed not an enamel as it does not possess or share the same properties and characteristics. (more details in the next section)

6.2.1 Applying onto cold glass

Applied through methods such as spraying or brushing, like applying a glaze onto ceramics. Almost like an enamel, but not quite, since it is not an enamel, nor does it share its properties. According to David Whitehouse’s definition of Enamels, an enamel is a vitreous substance consisting of finely powdered glass colored with metallic oxide, mixed with an oily agent to facilitate application onto glass with a brush and then fired at temperatures ranging 500°–700°C (Whitehouse, 2006).

Brushing the mixture onto glass leaves brush strokes and uneven surfaces which create an issue with different thicknesses which in turn creates a potential problem of coming off the glass or cracking on the surface at the thickest points, therefore using a manual sprayer, or paint atomizer, used for spraying paint or glaze was the best option, leaving a thin, even layer of the material on the glass with even coverage.

- Apply onto pre-blown glass pieces, put into pickup kiln, and flash in the glory hole to fire the ‘clayze’ and achieve a colored surface. This method is ideal for applying the current recipes on to a three-dimensional glass surface without risking deformation of the form or devitrifying of the glass. Figures 62 – 64.

- Applying onto two-dimensional glass and firing in glass kiln to fire clayze onto the glass. Figure 65.

Figure 62
Clayze applied onto pre-blown glass forms. (©Nour Ali)

Figure 63
Clayzed glass figurines before firing, showing signs of effloresced salts on the surface. (©Nour Ali)

Figure 64
Clayzed figurines after flashing in glory hole. (©Nour Ali)

Figure *65*
Clayze applied onto glass drippings and fired in glass kiln. (©Nour Ali)

6.2.2 Attaching to cold glass

This method is ideal for glass sheets, or two-dimensional forms, not different to fusing.

- Glass is already cut or formed (by glass dripping or trailing in my case) into desired forms and then the clayze mixture is added separately, in the form of modelling paste or "clay" engulfing the edges of the glass, to fuse the two materials. Figure 66.
- Using coils of Egyptian paste to attach, or glue two pieces of glass, almost like kintsugi, which is a traditional Japanese art form that involves repairing broken ceramics with gold or metallic lacquer. Rather than concealing the damage, kintsugi embraces and highlights the repaired areas, creating visible lines of gold that add a unique aesthetic to the piece. This art form emphasizes the concept of embracing imperfections and the history of the object, turning the brokenness into a celebrated part of its story. (Kemske, 2021) Figure 67.
- Applying between two sheets of glass. Figure 68.

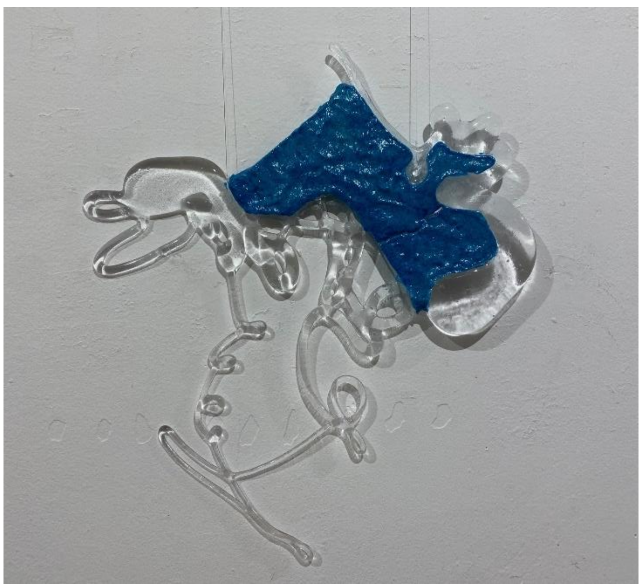


Figure 66
Clayze mixture fused onto two separate pieces of glass drippings to hold them together and accentuate the negative space by filling in with color. (©Nour Ali)

Figure 67
Coils of Clayze mixture used to glue two pieces of glass together. (©Nour Ali)

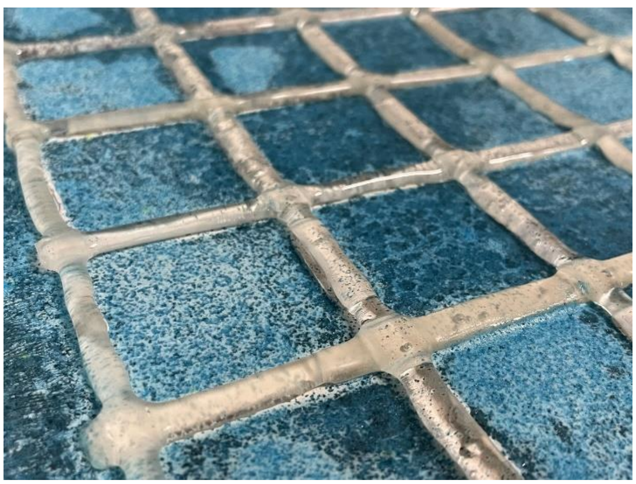


Figure 68
Clayze applied onto sheet of window glass, and strips of glass added on top and fired. Revealing the coarse body of a fired Egyptian paste trapped between the glass, while showing the colored surface on the rest of the glass sheet. (©Nour Ali)

6.2.3 Adding to hot glass

- Applying paste like I would a slip into a plaster and silica mold, as I would for slip casting, to create a thin wall and then casting glass into the mold using the ceramic pot technique, where a ceramic pot with a small hole is filled with glass and suspended on top of the plaster and silica mold which is lined either partially or fully in slabs of Egyptian paste mixture. Allowing the glass to slowly drip into the mold when it reaches the casting temperature at which point the Egyptian paste on the inside of the mold would have already reached its maximum firing temperature as well. Figure 69.

Figure 69
Glass casting into mold lined with clayze. (©Nour Ali)

A variety of recipes were utilized for different applications, selected based on the specific firing temperatures required for each technique. The selection of recipes was tailored to ensure optimal results and compatibility with the specific firing techniques employed.

In the application techniques I employed, I adopted many techniques from ceramics and glaze application methods, adapting and incorporating them for the application of clayze onto glass.

6.3 Interesting observations

It has been previously determined that the mixture lacks plasticity prior to firing. However, I have made some interesting observations that suggest the material may also lack plasticity when exposed to heat, which is unlike glaze which becomes runny and turns to liquid when exposed to heat. This observation is evident when the mixture is applied onto glass, dries, and the piece undergoes firing. If the glass substrate undergoes movement during firing, the "clayze" layer on top does not stretch or flow with the glass. As a result, it almost detaches from its original position and repositions itself on the stretched glass surface. This behavior indicates a lack of plasticity and flow in the material even when subjected to heat. Refer to figure 70, which shows the cracking in the “clayze” layer when it is slumped after it has already been fired, proving that it does not re-melt when re-fired. Another clear characteristic of ceramics. Therefore, when undertaking fusing and slumping processes, it is crucial to slump or fuse the glass into its final shape before applying the "clayze" mixture. This is because the non-plastic nature of the "clayze" prevents it from moving and adjusting along with the glass as it transforms into its desired shape. If the "clayze" layer is applied prior to slumping or fusing, it can lead to cracks or even breakage when the glass undergoes the shaping process, particularly during slumping on a mold. Thus, ensuring the glass is in its final shape before applying the "clayze" is essential to avoid such issues.

Figure 70
Cracking in Clayze layer when slumped after it has already been fired. (©Nour Ali)

6.4 Final exhibition

In my final exhibition, as mentioned previously, my intention was to showcase some of the most intriguing outcomes from my experimentation with the material. However, I consider these exhibited pieces as final ideas rather than fully finished artworks, at least from my personal perspective.

There were three primary factors that influenced this approach. Firstly, the sense of restlessness and curiosity while exploring this material, which I mentioned earlier, fueled my excitement in exploring new possibilities and executing novel ideas. Some of these ideas I consider to be revolutionary in their concept and potential, while others require further investigation and refinement. My focus during this process was more on the artistic journey itself rather than achieving a definitive set of finished artworks.

The second, and what might seem as a rather naive factor, which influenced my artistic intention and focus was the realization that I would be leaving soon after the exhibition. This limited time frame made it challenging to manage the logistical aspects of handling and preserving final pieces. Packing, storing, and shipping artworks would have added additional stress and complications. Subconsciously, this realization also pushed me more towards a decision to prioritize exploring various techniques and accumulating as much knowledge as possible. I intend to unpack and utilize this knowledge when I am more settled in a new physical space and can dedicate myself to further pursuing my artistic practice. As I already mentioned, that while this reasoning might seem a bit simplistic, it is a valid one, that in my opinion sheds light on constant issues that artists and makers go through daily, the planning, logistics and the financial burden of making work with an uncertain future.

However, the third, and perhaps the most significant, factor was that during the course of writing my thesis and curating my exhibition, I found myself grappling with profound questions regarding the essence and significance of my ‘art’-making, especially against the backdrop of an uncertain world, particularly in the context of Lebanon and its ongoing struggles. The weight of doubts and uncertainties about the relevance of creating art in the face of such hardships led me to initially hesitate in labeling my work as art—an act that seemed like a privilege amidst the stark realities many were enduring. This hesitancy, at times misconstrued as avoidance, may have been rooted in a form of survivor's guilt.

The journey into research and experimentation, yielding exciting and tangible results, proved to be a liberating experience. The successful merging of ceramics and glass. Embracing experimentation became a tool for introspection, reigniting my passion and instilling a profound sense of purpose in contributing to the evolving narrative of art.

This introspection led me to a pivotal juncture where I had to decide whether to take the conventional route of labeling my work as art, leaving its valuation to the subjective judgment of viewers, or adhering to what I believed to be of utmost importance—the innovative merit inherent in my creative process. Recognizing the two-fold nature of labeling as art, I acknowledged its potential to initiate a conversation about the work's value within an artistic narrative. However, my priority remained on highlighting the innovative techniques applied, redirecting the focus from categorization to the transformative power of the artistic process.

In contemplating the essence of art making, its significance, and the value ascribed through language and explanations, the existential role of labels became evident. The question arose: does an artistic narrative enhance the value of the artwork in comparison to emphasizing the experiments, the process, and the results? In my experience, particularly in this case, the artistic language does not necessarily add value to the maker.

Consequently, I deliberately chose an alternative approach, foregrounding the innovative merit in each creation. By challenging viewers to engage with my work on both aesthetic and intellectual levels, I aimed to elevate the discourse surrounding my art. This approach invites contemplation on the transformative power of innovation, steering away from the simplicity of categorization and encouraging a nuanced understanding of its intrinsic value.

Throughout this entire creative process, I made numerous conscious and subconscious decisions regarding which glass pieces to use for my experiments, in what context to use them and how to present them in my final exhibition. These glass pieces were all crafted during my year of working with hot glass, showcasing a different facet of my artistic journey.

The drippings, for instance, embody my, and everyone else’s for that matter, fascination with hot glass - capturing the spontaneous and transient moments while freezing time. Working with the material in the moment taught me to control movements to create the desired lines and shapes, even amidst the chaos of hot glass. Combining two separate pieces of drippings, however, and filling the negative spaces with the clayze mixture allowed for a more deliberate and thoughtful artistic process, where the clayze adds color, texture, and intention to the random lines of convenience.

On the other hand, the glass figurines served as a practice in honing my glass-blowing technique. Selecting to clayze and group them together for the final exhibition was a conscious decision, as they evoked the ancient Egyptian funerary figurines, famously known to be made of Egyptian paste, Figure 71. I wanted to add my own spin to these renowned Egyptian paste figurines through employing these new discoveries and my unique method of applying the material through clayzing.

Figure 71
Egyptian paste Funerary figurines at the British Museum (©Nour Ali)

6.5 Results and conclusion

Based on the extensive experimentation and testing conducted thus far, I can confidently state that when applying the Egyptian paste variation onto glass, these two materials appear to be stable in their respective states.

This raises broader questions about the compatibility of two materials in general and whether it is an absolute concept. In this case, the method and process of application play a significant role in determining the success or failure of the results. Regarding the application of the Egyptian paste variation onto glass, I can confidently assert that these two materials demonstrate stability, even when attaching the two materials at the edges, they continue to relay stability. However, the same cannot be said when attempting the reverse process, such as applying glass onto the Egyptian paste samples. However, to definitively establish compatibility, additional testing would be necessary.

Having considered the aforementioned factors, I firmly believe that this entire process has been a success on multiple levels. Namely, the successful fusion of ceramics and glass, a longstanding quest that has been accomplished through this exploration, albeit within specific parameters and conditions. As ironic as it is, that the solution would lie in Egyptian paste, the link, and steppingstone, from ceramics to glass.

In summary, regardless of my role as an artist, maker, or investigator, and whether my endeavors involved creating art or conducting experiments, I believe that the diverse applications of Egyptian paste, as presented in this paper, constitute the true artistic value. This perspective holds irrespective of a narrative that might have diverted attention from what I consider most crucial, potentially steering the conversation in a different direction.

6.6 Remaining curiosities and Next steps

Based on the current research findings, it is evident that the stability of the two materials when applied in a specific manner has been established. However, their overall compatibility remains uncertain. Therefore, further testing is necessary to assess compatibility. Coefficient of Expansion (COE) testing is crucial as it provides insights into the material's rates of expansion and contraction when exposed to heat. Additionally, viscosity testing is essential to understand the material's flow behavior in response to temperature changes. Considering the shrinkage percentage of the material can also be helpful in understanding its properties, enabling a comparison with glass and ceramics. This comprehensive understanding of the material will facilitate informed claims regarding its compatibility with other materials.

There are still lingering questions and possibilities that pique my curiosity regarding this material. One primary curiosity revolves around the potential for achieving more vibrant colors at the intended firing temperature of 750˚C. Exploring the possibility of lowering the firing temperature range to around 700˚C, which is more conducive when working with fused glass, is also an intriguing extension worth considering. It is noteworthy that most research and recipes pertaining to Egyptian paste do not explicitly mention the firing atmosphere, assuming an implicit understanding that an oxidation atmosphere is employed. However, it would be interesting to experiment with different recipes and the various oxides in a reduction firing. This exploration is driven by a sense of curiosity, aiming to observe how the material would react under different conditions.

These remaining curiosities present exciting avenues for further experimentation and exploration, offering a wider firing range and the potential for enhanced color outcomes at different temperatures as well as expanding our understanding of the material's behavior in alternative firing atmospheres.

References

Barber, E. A. (1906). *Tin Enameled Pottery: Maiolica, Delft, and Other Stanniferous Faience*. Museum.

Bray, C. (2001). *Dictionary of glass: Materials and techniques*. London : A & C Black ; Philadelphia : University of Pennsylvania Press. http://archive.org/details/dictionaryofglas0000bray

Cloonan, M. (2014). *Egyptian Paste: Building Sculpturally with Color*. Pottery Making Illustrated. https://ceramicartsnetwork.org/daily/article/Egyptian-Paste-Building-Sculpturally-with-Color

Dodd, A. E. (Arthur E. (1967). *Dictionary of ceramics:* London, Newnes. http://archive.org/details/dictionaryofcera0000unse

DSC 404 F3 Pegasus. (n.d.). NETZSCH - Analyzing and Testing. Leading in Thermal Analysis, Rheology and Fire Testing. Retrieved July 13, 2023, from https://analyzing-testing.netzsch.com/en/products/differential-scanning-calorimeter-dsc-differential-thermal-analyzer-dta/dsc-404-f3-pegasus

Gilberg, M. (1997). Alfred Lucas: Egypt's Sherlock Holmes. *Journal of the American Institute for Conservation*, *36*(1), 31–48. https://doi.org/10.2307/3180082

Glazy.org. (2015, July). Glazy Ceramic Glaze and Pottery Recipes. https://glazy.org/materials/15119

Halem, H. (1994). *Glass notes: A reference for the studio glass artist*. Kent, Ohio : Halem Studios. http://archive.org/details/glassnotesrefere0000hale

Hopper, R. (2015, March). Egyptian Paste. *Pottery Making Illustrated*. https://ceramicartsnetwork.org/docs/default-source/uploadedfiles/wp-content/uploads/2015/03/egyptianpaste.pdf

Hyman, S. (1976, June). Making Egyptian Paste. *Ceramic Review*, *39*, 4–5.

IAN SHAW-PAUL NICHOLSON. (1995). *THE BRITISH MUSEUM DICTIONARY OF ANCIENT EGYPT BY IAN SHAW PAUL NICHOLSON*. http://archive.org/details/THEBRITISHMUSEUMDICTIONARYOFANCIENTEGYPTBYIANSHAWPAULNICHOLSON

Jamieson, A. (2003). Egyptian Faience. *Ceramics Technical, Vol. 17*. https://www.academia.edu/15359522/Egyptian_Faience

Kemske, B. (2021). *Kintsugi: The Poetic Mend*. Herbert Press.

Kingery, W. D., & Vandiver, P. B. (1986). *Ceramic masterpieces: Art, structure, and technology*. Free Press ; Collier Macmillan.

Lundstrom, B. (1994). *Glass fusing*. Colton, OR : Vitreous Group. http://archive.org/details/glassfusing0000lund_u2m7

Matin, M., & Matin, M. (2012). Egyptian faience glazing by the cementation method part 1: An investigation of the glazing powder composition and glazing mechanism. *Journal of Archaeological Science*, *39*(3), 763–776. https://doi.org/10.1016/j.jas.2011.11.013

Medici, T., Lima, A., de Matos, A. P., & Vilarigues, M. (2014). O papel dos materiais geológicos no estudo de proveniência de vidros. *APEQ*.

Nicholson, P. (2009). *Faience Technology*.

Nicholson, P. T., & Shaw, I. (2000). *Ancient Egyptian Materials and Technology*. Cambridge University Press.

Nigrosh, L. I. (1980). *Low fire: Other ways to work in clay*. Davis Publications.

Noble, J. (1969). The Technique of Egyptian Faïence. *American Journal of Archaeology*, *73*, 435–439. https://doi.org/10.2307/503999

Noble, J. V. (1969). The Technique of Egyptian Faïence. *American Journal of Archaeology*, *73*(4), 435–439. https://doi.org/10.2307/503999

O'Bannon, L. S. (1984). *Dictionary of ceramic science and engineering*. New York : Plenum Press. http://archive.org/details/dictionaryofcera0000oban

Pradell, T., & Molera, J. (2020). Ceramic technology. How to characterise ceramic glazes. *Archaeological and Anthropological Sciences*, *12*(8), 189. https://doi.org/10.1007/s12520-020-01136-9

Pratt, B. (2016). *Little Rugged Vessel* [Egyptian Faience].

Pratt, B. (1999, June). Chaos and Calm. *Ceramic Review*, *177*. https://www.ceramicreview.com/issues/ceramic-review-issue-177/

Rogers, B. (1995). Feldspar: What Is It? Where Does It Come From? What Do I Need to Know About Using It? In *A Collection of Papers Presented at the 1994 Ceramic Manufacturers and Suppliers Worskhop: Ceramic Engineering and Science Proceedings* (pp. 211–214). John Wiley & Sons, Ltd. https://doi.org/10.1002/9780470314708.ch40

Sievers, M. (2023, April 19). *What is the Orton Cone Chart? | Skutt Ceramics*. Kilns | Ceramic Pottery Kiln, Glass Kiln, Pottery Wheels | Skutt. https://skutt.com/what-is-the-orton-cone-chart/

Sparavigna, A. C., & di Torino. (2014). *Philica front page Ancient Technologies: The Egyptian Sintered-Quartz Ceramics Search About Philica Take the tour*. *426*.

Tajeddin, Z. (2014). *Egyptian Faience; Ancient Making Methods and Consideration of Technical Challenges in Sculptural Practice* [Degree of Doctor of Philosophy, University of Westminster]. file:///C:/Users/35191/Downloads/Egyptian_faience_ancient_making_methods.pdf

Thixotropic definition and meaning | Collins English Dictionary. (2023, July 10). https://www.collinsdictionary.com/dictionary/english/thixotropic

Tite, M. S., Freestone, I. C., & Bimson, M. (1983). EGYPTIAN FAIENCE: AN INVESTIGATION OF THE METHODS OF PRODUCTION. *Archaeometry*, *25*(1), 17–27. https://doi.org/10.1111/j.1475-4754.1983.tb00658.x

Tite, M., Shortland, A., & Paynter, S. (2002). The Beginnings of Vitreous Materials in the Near East and Egypt. *Accounts of Chemical Research*, *35*(8), 585–593. https://doi.org/10.1021/ar000204k

Whitehouse, D. (2006). *Glass: A pocket dictionary of terms commonly used to describe glass and glassmaking*. Corning, N.Y. : Corning Museum of Glass. http://archive.org/details/glasspocketdicti0000whit

Wypych, G. (2016). 2—FILLERS – ORIGIN, CHEMICAL COMPOSITION, PROPERTIES, AND MORPHOLOGY. In G. Wypych (Ed.), *Handbook of Fillers (Fourth Edition)* (pp. 13–266). ChemTec Publishing. https://doi.org/10.1016/B978-1-895198-91-1.50004-X

X-ray diffraction (XRD) basics and application. (2019, April 14). Chemistry LibreTexts. https://chem.libretexts.org/Courses/Franklin_and_Marshall_College/Introduction_to_Materials_Characterization__CHM_412_Collaborative_Text/Diffraction_Techniques/X-ray_diffraction_(XRD)_basics_and_application

Appendices

Appendix A

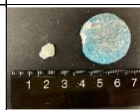
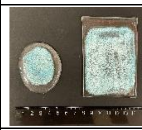
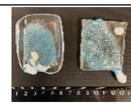
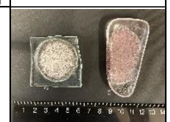
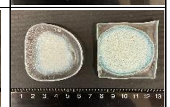
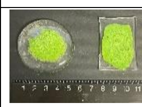
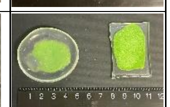
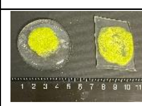
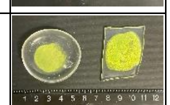
Table 4

Different compositions of samples.

A	Silica 38 Soda Feldspar 38 Ball clay 12 Soda Ash 6 Sodium bicarbonate 6 Cu 2
B	Silica 38 Soda Feldspar 38 Ball clay 12 Soda Ash 6 Sodium bicarbonate 6 Cr 2
C	Silica 38 Soda Feldspar 38 Ball clay 12 Soda Ash 6 Sodium bicarbonate 6 Fe 2
D	Coloured glass 38 Soda Feldspar 38 Ball clay 12 Soda Ash 6 Sodium bicarbonate 6
E	Silica 38 Soda Feldspar 38 Ball clay 12 Soda Ash 6 Sodium bicarbonate 6
F	Silica 38 Soda Feldspar 38 Ball clay 12 Soda Ash 6 Sodium bicarbonate 6 Mn 2
G	Furnace glass powder 38 Soda Feldspar 38 Ball clay 12 Soda Ash 6 Sodium bicarbonate 6
H	Furnace glass powder 38 Soda Feldspar 38 Ball clay 12 Soda Ash 6 Sodium bicarbonate 6 Cu 2
I	Silica 30 Soda Feldspar 38 Ball clay 12 Soda Ash 10 Sodium bicarbonate 10 Cu 2
J	Silica 38 Soda Feldspar 38 Ball clay 0 Soda Ash 12 Sodium bicarbonate 12 Cu 2
K	Silica 38 Soda Feldspar 38 Ball clay 0 Soda Ash 12 Sodium bicarbonate 12 Cr 2
L	Silica 38 Soda Feldspar 38 Ball clay 0 Soda Ash 12 Sodium bicarbonate 12 Mn 2
M	Silica 38 Soda Feldspar 38 Ball clay 6 Soda Ash 9 Sodium bicarbonate 9 Cu 2
N	Silica 38 Soda Feldspar 30 Ball clay 6 Soda Ash 13 Sodium bicarbonate 13 Cu 2
O	Silica 36 Soda Feldspar 36 Ball clay 6 Soda Ash 11 Sodium bicarbonate 11 Cu 2
P	Silica 36 Soda Feldspar 36 Ball clay 4 Soda Ash 12 Sodium bicarbonate 12 Cu 2
Q	Silica 34 Soda Feldspar 34 Ball clay 6 Soda Ash 13 Sodium bicarbonate 13 Cu 2
R	Silica 38 Soda Feldspar 30 Ball clay 8 Soda Ash 7 Sodium bicarbonate 7 Colemanite 10 Cu 2
S	Silica 38 Soda Feldspar 30 Ball clay 6 Soda Ash 7 Sodium bicarbonate 7 Colemanite 12 Cu 2
T	Silica 38 Soda Feldspar 30 Ball clay 6 Soda Ash 7 Sodium bicarbonate 7 Colemanite 12 Cr 2
U	Silica 38 Soda Feldspar 30 Ball clay 6 Soda Ash 7 Sodium bicarbonate 7 Colemanite 12 Mn 2
V	Silica 38 Soda Feldspar 38 Ball clay 6 Soda Ash 9 Sodium bicarbonate 9 Cr 2

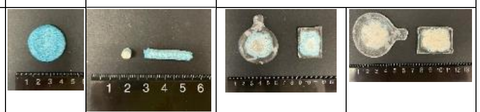
Appendix B

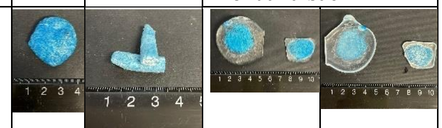
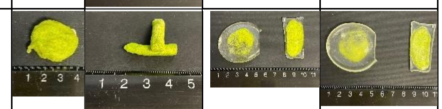
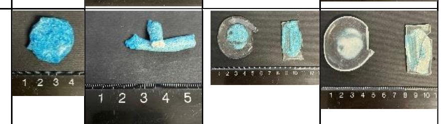
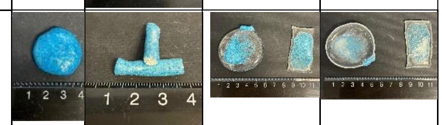
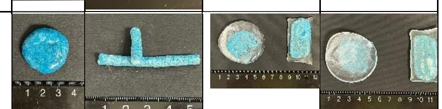
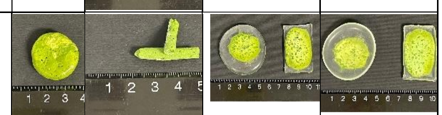
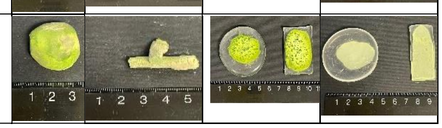
Recipes I – V fired at 800˚C.

			Cross section	Egyptian paste brushed on furnace glass(left) and window glass. (right) Front and back	
T2 800 °C	**I**				
	J				
	K				
	L				
	M				
	R				
	S				
	T				
	U				
	V				

Appendix C

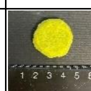
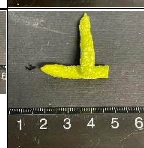
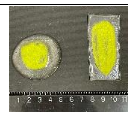
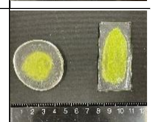
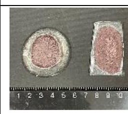
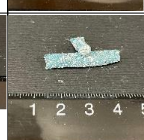
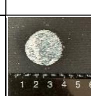
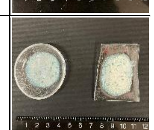
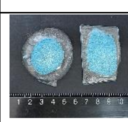
Recipes A – V fired at 840˚C.

			Cross section	Egyptian paste brushed on furnace glass(left) and window glass. (right) Front and back	
T4 840 °C	**A**				
	B				
	C				
	D				
	E				
	F				
	G				
	H				

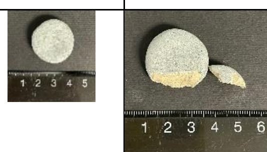
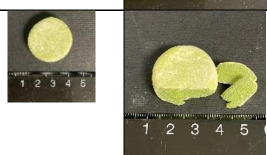
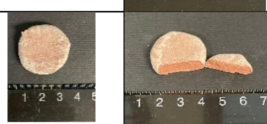
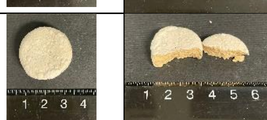
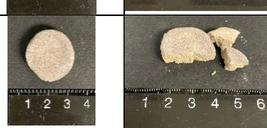
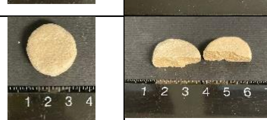
		Cross section	Egyptian paste brushed on furnace glass(left) and window glass. (right) Front and back	
J				
K				
M				
N				
S				
T				
V				

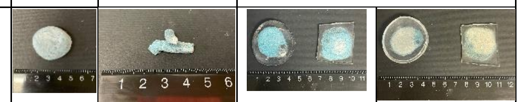
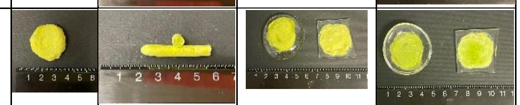
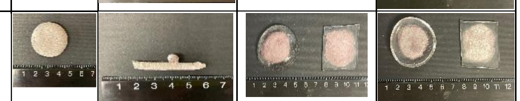
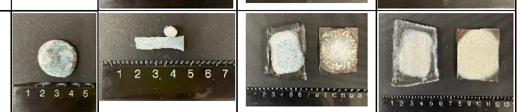
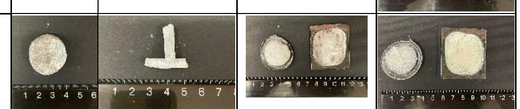
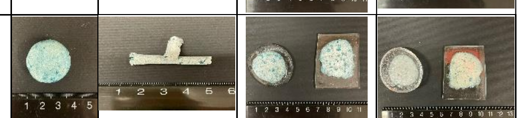
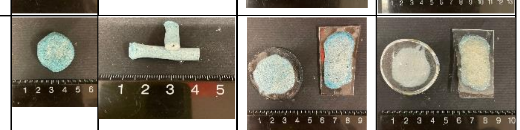
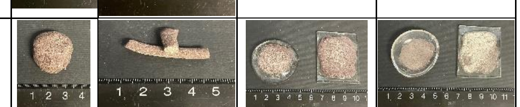
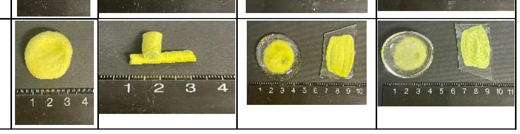
Appendix D

Recipes J – S fired at 780˚C.

				Egyptian paste brushed on furnace glass(left) and window glass. (right) Front and back	
T5 780 °C	J				
	K				
	L				
	M				
	N				
	O				
	P				
	Q				
	R				
	S				

Appendix E
Recipes A – V fired at 750˚C.

			Cross section
T6 750 °C	A		
	B		
	C		
	D		
	E		
	F		
	G		
	H		
	I		

			Cross section	Egyptian paste brushed on furnace glass(left) and window glass. (right) Front and back	
T6 750 °C	J				
	K				
	L				
	M				
	N				
	O				
	P				
	Q				
	R				
	S				
	T				
	U				
	V				

Appendix F

DSC analysis method.

1. The DSC 404 F3 Pegasus was used.
2. 2 platinum crucibles are prepared, one for the sample and one for our reference material.
3. The reference material used was alumina due to its properties and knowing that it wont react at the temperature we are going to, which is 1100 degrees C.
4. The weight of each crucible is recorded, then in one alumina is added and weighed, and in the other one the sample is added and weighed as well.
5. The 2 crucibles are put into a tiny chamber, called the sample carrier and enclosed in a protective tube.
6. Nitrogen gas is used for the firing, therefore the gas outlet is checked and turned on.
7. The program is started.
8. When the firing is done, (around 2 hours), and the machine has cooled back to room temperature, (also around 2 hours), the sample crucible is removed and put in a solution of low concentration Hydrochloric acid to clean.
9. The reference crucible, alumina, and be reused a few times since it is unaffected.
10. The previous steps are repeated for each of our 6 samples.

The analysis is first run with only alumina to create a baseline.

Correction = baseline

Reference = alumina

Sample = Egyptian paste

Table 5 shows the weights of crucibles, samples, and reference.

Table 5

Weights of the different samples, crucibles, and reference.

Sample	Reference crucible weight (g)	Reference crucible weight with Alumina (g)	Sample crucible weight (g)	Sample crucible with sample (g)
A 750	0.172	0.041	0.179	0.041
A 840	0.172	0.041	0.179	0.043
J 750	0.172	0.041	0.179	0.040
J 840	0.172	0.041	0.171	0.049
S 750	0.172	0.041	0.172	0.055
S 840	0.172	0.041	0.179	0.051

NOVA SCHOOL OF SCIENCE & TECHNOLOGY
b a belas-artes ulisboa

NEW DISCOVERIES IN USES AND APPLICATION OF EGYPTIAN PASTE IN THE ARTS

NOUR ALI

⟨2023⟩