ACID-ETCHING. A FORGOTTEN STORY

Triin Jerlei

Abstract This essay focuses on the early history of etching glass objects with hydrofluoric acid. In this fascinating technique, some parts of glass are covered with wax or other resistant agents and then the object is immersed in acid. The parts of the surface that have not been covered with a resistant are partially dissolved by acid, resulting in a surface less transparent and in effect similar to the result of sandblasting. It was not until the nineteenth century that the technology became increasingly popular for the mass-production of tableware, but its roots go back to the German city of Nuremberg, where in 1670 the glass engraver Heinrich Schwanhardt discovered the previously unknown substance and its use for altering glass surfaces in a novel manner.

Keywords Heinrich Schwanhardt, Joachim Sandrart, Johann Gabriel Doppelmayr, Georg Christoph Einmart the Younger, Johann Helmhack, Johann Beckmann

1 Introduction

Little is known about the early history of the etching of glass. Although some information about the inventor of the technique can be found in scientific publications, printed sources and research literature, there remain gaps in our understanding of how knowledge of the technique was communicated.[1] In contrast to the commonly-held belief that knowledge of this technique, of a newly-discovered acid that could corrode glass, was lost and then later re-discovered – we now know that this knowledge was shared, communicated, and even published. Despite the existence of, and availability of this knowledge the technique was rarely used until the mid-nineteenth century. For what reasons might the technique have been relatively neglected until the mid-nineteenth century?

This paper aims to connect the discovery of this etching technique to the wider context of glass-art and science of the seventeenth and eighteenth centuries, and to describe the transmission of knowledge from the artistic sphere to the realm of science. It also provides information on how acid-etching was received in scientific, cultural and social history. The last part studies the nineteenth century use of acid-etching to demonstrate the changes in the perception and usage of the technology. Methodologically, this research combines the methods used by history of design and material

1 For example, Dionysius Lardner claims that the secret of Schwanhardt's discovery "went with him to the grave". Lardner 1832, p. 312.

Jerlei, Triin: Acid-Etching. A Forgotten Story, in: Cremer, Annette C. (Hrsg.): Glas in der Frühen Neuzeit. Herstellung, Verwendung, Bedeutung, Analyse, Bewahrung, Heidelberg: Heidelberg University Publishing, 2022 (Höfische Kultur interdisziplinär, Bd. 6), S. 293–319. DOI: https://doi.org/10.17885/heiup.821.c14189

culture with the methods of the history of knowledge. The technology of acid-etching is analysed through information in scientific publications, as well as historical descriptions and objects that have been preserved in museums. The consulted archival sources, manuscripts and prints were provided by the Gotha Research Library (Forschungsbibliothek Gotha, Erfurt University), the National Art Library of the Victoria and Albert Museum London as well as Sheffield University Library.[2]

2 Heinrich Schwandhardt in Nuremberg

The seventeenth century was an era of several significant innovations and discoveries in glass.[3] Contemporaneous alchemists worked extensively on new recipes for glass manufacture. Amongst them, perhaps the most influential was Antonio Ludovic Neri, an Italian priest and alchemist, whose *L'Arte Vitraria* was published in 1612.[4] During the seventeenth century, Neri's work was translated into several other languages by scientists who added their own discoveries to the book. For example, Christopher Merrett translated the work into English in 1662.[5] In 1679, the German alchemist Johannes Kunckel translated Merrett's publication into German, further complementing Neri's and Merrett's achievements with his own experiments.[6] More affordable glass objects were often decorated by enamel- painting by so-called *Hausmaler* (who literally worked at home) using standardised scenes and ornaments.[7] Thus, the era is characterised by a rich and varied culture of glass-decoration, including one lesser-known invention

2 This research is indebted to the Fritz-Thyssen-Foundation for generous funding in 2018, to Gotha Research Library for providing access to their invaluable collections and to the Gotha Research Centre of University Erfurt, especially Prof. Martin Mulsow, Dr. Markus Meumann, Elisa Schaarschmidt, and my fellow researchers, Dr. Anna Tropia, Dr. Russell Palmer, Prof. Sandro Jung and others, for providing feedback and support during this research project. I would like to express my gratitude to the research group working at Justus-Liebig-University Giessen, especially to Judith Thomann, Dr. Anna-Victoria Bognár and Dr. Annette Cremer, for introducing me to the collections of Schlossmuseum Arnstadt, for fascinating exchanges of ideas and for inviting me to contribute to this wonderful publication, and to dr. Cremer for her invaluable work in editing this paper. I am extremely grateful to the Germanisches Nationalmuseum, especially to Dr. Heike Zech, Bettina Guggenmos and Annika Dix, for generously inviting me to their amazing collections, as well as to Veste Coburg. Last, but not least, I would like to thank Bamberg Staatsbibliothek, National Art Library of Victoria & Albert Museum, Rare Books Collection of the Sheffield University Library, Rita Kišonienė at Mykolas Žilinskas Art Gallery, Silvia Compaan-Vermetten at the archives of Leiden University, Victoria & Albert Museum and Aleksandr Kirpu. Finally, I would like to express my warmest gratitude to Prof. Lou Taylor from Brighton University, whose class started my interest in this topic during my MA studies.

3 Kerssenbrock-Krosigk / Horn 2001.

4 Antonio Neri 1612.

5 Antonio Neri 1662.

6 Kunckel 1679.

7 Bosch 1984, p. 11.

Figure 1. The collection of the Staatsbibliothek Bamberg holds a drawing of Heinrich and his younger brother, possibly the only image of him that has survived to this day. Unknown artist, Heinrich Schwanhardt (left, according to sources in Staatsbibliothek Bamberg) with Georg Schwanhardt the Younger, 1672. Staatsbibliothek Bamberg, Inv.-Nr. I P 231.

which is the topic of this paper. Heinrich Schwanhardt, the discoverer of hydrofluoric acid and acid-etching of glass, was a glass artist from Nuremberg, born 22nd April 1625, died 2nd October 1693 (fig. 1). While different authors praise his skill, only a small number of attributed works have been preserved to our day. His father, Georg Schwanhardt the Elder (1601–1667), had studied glass engraving under the Bohemian master Caspar Lehmann and is considered to be the father of the glass engraving school in Nuremberg. Five of Georg's children became known glass artists: in addition to Heinrich, also his younger brother Georg Schwanhardt the Younger (1640–1676) as well as the sisters Sophia (1628–1657), Susanna (1631–1669) and Maria (1636–1658). However, Heinrich was the most successful of the five siblings.

Thanks to the artist Joachim Sandrart (1606–1688) and the scientist Johann Gabriel Doppelmayr (1677–1750), two contemporaneous writers from Nuremberg, it is possible to get a fairly good overview of Schwanhardt's life and career. The first mention of Heinrich Schwanhardt's discovery was published already during his lifetime in 1675, in *Teutsche Academie* by Joachim von Sandrart. Sandrart is thorough in his treatment, mentioning not only the sons of Georg Schwanhardt the Elder, but also the three daughters, as well as Georg the Younger's wife as another reputable glass engraver. On Heinrich, he writes:

> "Dieser Schwanhardt hat allerhand Landschaften und ganze Städten/ unter andern auch die Stadt Nürnberg auf Glaß/ ganz correct an der proportion, und erkentlich/ nach der perspectiv hinein weichend/ gleich den gemahlten/ zuwegen gebracht/ und hierinn alle/ so vor ihm gewesen/ weit überstiegen: Ja er hat auch mit seinem subtilen Verstand das jenige/ was man bißher vor unmöglich geschätzt/ ergründet/ und ein solches corrosiv Erfindet die Kunst in das Glas zu ätzen erfunden/ dem das sonst so harte Crystalline Glaß gehorsamen/ und gleich andern Metall und Stein einwarts und erhoben sich ätzen laßen muß/ da es doch sonsten aller starken Spirituum beste Behaltnus bißhero gewesen; In welcher Kunst er erst neulich eine so vollkommene Prob gethan/ indem er vielerley Zierlichkeiten und Schriften so rein und sauber in Glas geetzet/ daß es fast unmöglich scheinet/ eine größere Vollkommenheit hierinnen zu erlangen/ wo nicht dieses Künstlers emsiges Nachsinnen und schöner Geist noch mehrere Subtilitäten ausgründet/ wie er dann allbereit vollkommene Menschen-Bilder/ theils nackend/ theils bekleidte/ auch allerhand Thiere/ Blumen und Kräuter ganz natürlich gebildet/ und es im Erheben sehr hoch gebracht hat. Sein Bruder Georg Schwanhart hat zwar auch eine gute Manier im Crystallschneiden gehabt/ ist aber durch die beschwerliche Glieder-Krankheit/ an fernerer Perfection merklich verhindert worden."[8]

Johann Gabriel Doppelmayr communicated two insights into the life of Heinrich Schwanhardt. His *Historische Nachricht von den Nürbergischen Mathematicitis und Künstlern Nürnbergs*, published in 1730, repeats many of the same facts that were iterated by Sandrart more than half a century earlier:

> "Ein Glass-Schneider, lage anfänglich denen studiis, und zugleich mit der Poesie, mit vielen Fleise ob, als aber selber nach deme eine besondere Neigung zu seines Vatters, des öfters bemeldten Georg Schwanhards, Kunst bey sich verspührte, liese er von dem Studiren ab, und begriefe bey jenem viel mehr das Glaß-schneiden mit einer grosen Begierde, hierinnen kam er, da ihme zum voraus seine Geschicklichkeit in der Zeichen- und Perspektiv-Kunst eine gar treffliche Beförderung gabe, in wenigen Jahren so weit, daß er nicht allein alle, die zuvor das Glaßschneiden getrieben, sondern auch seinen Vatter weit übertrafe. In Schrifften, absonderlich in Lateinischen auf Italiänische Manier, mit schönen Zugwercken auf Glaß zu schneiden zeigte er was extraordinaires, indeme er den besten Schreib-Künstlern, die dergleichen mit der Feder auf dem Papier darstellten, es gar bevor thate. Nach 1670 (1671?) fande er unvermuthet glücklich aus gläserne Scheiben zu ätzen, auf welchen sich der Grund matt, dabey aber jede angebrachte Schrift gantz hell ergabe, triebe auch die Kunst, um die Figuren erhoben auf die Gläser zu schneiden, am

8 Sandrart 1675, pp. 346–347.

> ersten sehr weit, gleichwie er dieses alles durch viele Proben in der That sehr rühmlich erwiesen. Starb den 2. October 1693."[9]

However, a manuscript for an unpublished second edition, held in the archives of the Germanisches Nationalmuseum in Nuremberg, paints a different and more intimate picture of Schwanhardt's life. For example, Doppelmayr claims that Schwanhardt was not very productive but had his clientele:

> "Ob nun auch schon derselbe verdienet, so lebt er doch immer zum öftesten im Mangel, denn er arbeitete nicht eher als am Sonntag und wenn er kein Geld gehabt. Da er dann seine Liebhaber wusste, zu welchen er seine angefertigten Gläser gesendet. Als zum Exempel zu dem damaligen Herrn Castellan Herrn Kressen von welchem er dann gleich bares Geld dafür empfangen."[10]

The manuscript also highlights the importance of acid-etching: "Dieser Schwanhard (als des älteren Sohn) hat im 1671 schöne Proben getan mit Scheidwasser die Glasscheiben auszuätzen und zu bringen, die Schrift erhaben geblieben."[11]

Doppelmayr's use of *Scheidwasser* instead of *Flusssäure* highlights the fact that hydrofluoric acid was little known in 1730. We can assume that as Doppelmayr avoids any discussion of the chemical components used by Schwanhardt, he probably was uninterested in the nature of the acid used and instead adopted the general term. Nevertheless, from Doppelmayr's account we can deduce that Schwanhardt was remarkably talented. If we believe Doppelmayr's manuscript, he was not as productive as many of his contemporaries, but his style was greatly appreciated at the time.

3 Acid-Etching

How did Schwanhardt, the glass engraver 'stumble' upon this discovery? Was he trying to achieve a different result or was it a conscious and informed experiment? Sandrart and Doppelmayr see Schwanhardt's discovery as an accident. While the topos of an accident in the history of science may occasionally be overused, in this case it seems unlikely that Schwanhardt was consciously trying to invent an acid that would work on glass. If we assume the invention to have been an accident, one question remains: what was the initial aim?

9 Doppelmayr 1730.

10 Manuscript by Johann Gabriel Doppelmayr found in the Germanische Nationalmuseum, Hs 108571. Quoted after: Meyer-Heisig 1963, p. 222.

11 Ibid.

Here, Neri's book presents a valuable collection of the main glass experiments known at the period. Although Kunckel's translation to German was only published in 1679, Schwanhardt's studies and his documented knowledge of languages suggest that he was possibly able to read either the Italian or the English version. Amongst Neri's experiments one in particular stands out and was the envy of the Baroque period: the *Rubinglas*, a particular bright red tone that was achieved by adding gold to the flux. In Chapter CXXIX we find a recipe for it:

> "Calcine Gold with Aqua-regis, many times, pouring the water upon it five or six times, then put this powder of Gold in earthen pans to calcine in the furnace till it become a red powder, which will be in many days, then this powder added in sufficient quantity, and by little and little, to fine Crystall glass which hath been often cast into water, will make the transparent red of a Rubie as by experience is found."[12]

In this case, the core of the experiment is to add powdered gold to a heated mixture of nitric and hydrochloric acid. Importantly, Neri also suggests that different bright-coloured stones could be used for experimenting and achieving different colours.[13] Thus, one theory for achieving the hydrochloric acid could be that Schwanhardt used bright-coloured fluorite crystals in an attempt to achieve a similarly bright-coloured glass, using the method he had read or heard being used for achieving Rubinglas – although Schwanhardt did not work in a glasshouse, to our knowledge, and thus the likelihood of it is very small. However, fluorite was relatively common in Germany and had been formally described by Georg Agricola in 1546.[14] One source even testifies that Bohemian emerald was commonly found in old pharmacies and that in this consistency it was fairly reactive.[15]

A large part of Heinrich Schwanhardt's work is arguably either missing, unattributed or in private collections. There are a number of engraved objects in various glass collections, but only one example of acid-etching. Thanks to the hospitality of the Germanisches Nationalmuseum in Nuremberg, I was able to have a closer look at the first documented and preserved object executed in this technique, a plate dating from 1686 (fig. 2). It is also the only surviving acid-etched object firmly attributed to him.[16] Written sources as shown above suggest that Schwanhardt executed numerous other objects. However, as acid-etching has not been a focus of research so far and as this technology is little known, it is probable and likely that many objects, both by Schwanhardt

12 Neri 1612; Neri 1662.

13 Neri 1662, p. 192.

14 Georg Agricola 1546, p. 466.

15 "Von diesem Flußspath besitze ich noch eine kleine Quantität, er ist durchgehendes grünlich und besteht aus lauter kleinen ausgesuchten Bruchstücken, welche durch Wärme ziemlich lebhaft leuchtend werden." Schubarth 1826, p. 247.

16 Germanisches Nationalmuseum, museum number GL 313.

Figure 2. Heinrich Schwanhardt, Acid-etched glass plate, 1686. Germanisches Nationalmuseum, Nürnberg, Inv.-Nr. GL 313.

and possibly by his contemporaries, have not been identified as acid-etchings and may have been overlooked in collections.

The difference between acid-etching and engraving is in the traces they leave on the surface: while engraving leaves marks of the needle or the wheel detectable, acid-etching creates a soft matt surface. Initially I assumed that Schwanhardt got the idea from copper engraving, as etching was extremely popular in the seventeenth century in general. Additionally, Doppelmayr claims in his unpublished manuscript that Schwanhardt was familiar with the celebrated copper engraver, painter, mathematician and mechanic Georg Christoph Einmart the Younger (1638–1705).[17] However, this theory is unlikely, as Schwanhardt's technique differs from that used by copper engravers in their work with nitric acid. When in traditional etching the whole surface is covered with wax or other varnish and then a pattern is scratched in it, Schwanhardt drew with varnish on a clear surface. This fact is also stressed by Beckmann, whose analysis will be further discussed in the next section.

17 Manuscript by Johann Gabriel Doppelmayr. Quoted after: Meyer-Heisig 1963, p. 222.

Figure 3. Heinrich Schwanhardt, Detail of an acid-etched glass plate, 1686. Germanisches Nationalmuseum, Nürnberg, Inv.-Nr. GL 313.

The object held by the Germanisches Nationalmuseum is a round plate with a diameter of 15 centimetres, mounted in a wooden frame. The surface has been manipulated with acid and thus appears opaque, while the glass is transparent on letters – we can assume that Schwanhardt drew the letters with wax or another agent and then manipulated the glass plate with acid. The writing is: "1686. / AVXILIVM / IESV CHRISTI / ADVENIAT." Compared to the later examples of etchings with industrially-produced acid, the acid-etched surface is slightly uneven and there are some small spots where the acid has not bitten the glass surface due to air bubbles (fig. 3). Unlike the engraved glasses of the period, where the white tone of the treated area is intense and on closer inspection reveals traces of the engraving wheel (fig. 4), acid-etched surface resembles glass covered with ice.

The meaning and choice of the inscription on the plate is still a mystery. "AVXILIVM / IESV CHRISTI / ADVENIAT," means "The help from Jesus Christ arrives". His engraved objects often feature texts in various languages, evidently inspired by different types of sources. Erich Meyer-Heisig's monograph *Der Nürnberger Glasschnitt des 17. Jahrhunderts* includes various examples from different genres. A beaker made of ruby glass, manufactured in 1696 and currently held at the Schatzkammer of the Munich Residenz, has a Cupid engraved on one side and the French inscription "Un seul me suffit" on the other.[18] Another undated glass, held at the Schlossmuseum Weimar,

18 Meyer-Heisig 1963, p. 82.

Figure 4. Heinrich Schwanhardt, Detail of an engraved glass, 1681. Germanisches Nationalmuseum, Nürnberg, Inv.-Nr. GL 315.

features a German rhyme: "An dem haben viel gefallen / dieses fast beliebet allen".[19] Doppelmayr goes so far as to praise Schwanhardt as the leading glass artist in executing different types of writing on glass:

> "Dieser Schwanhard soll auch in der Kunst, Schriften besonders im Lateinischen auf italienische Manier mit schönem Zierwerk auf Glas zu schneiden, vorzüglich geschickt gewesen sein, so daß er es dem besten Schreibkünstler bevor that."[20]

While Sandrart, Doppelmayr and later Beckmann all mention the high quality of figures on Schwanhardt's etched glass, they do not detail the precise appearance of the objects. The only written source that describes any of Schwanhardt's acid-etchings in detail is *Verein zur Beförderung des Gewerbefleißes in Preußen*, Volume 7, compiled by Ernst Ludwig Schubarth, published in Berlin in 1826. Schubarth was at the time employed as professor of chemistry at the newly founded University of Berlin; from 1828 on he also read lectures on technology.[21] Schubarth describes three round plates, made of green glass. In his words, the first two are curved like clock glasses, while the third one is flat. All three glasses have writing on them. The first one displays the same writing as the object preserved at the Germanisches Nationalmuseum, "1686.

19 Ibid., p. 83.

20 Doppelmayr 1730.

21 Wise 2018, p. 209.

AVXILIVM IESV CHRISTI ADVENIAT." The second one, similarly dated 1686 and presumably also etched by Heinrich Schwanhardt, reads: "Domine conserva nos in pace. Vivat 1686. Vivat." Unfortunately, Schubarth does not describe whether the writing on this example was in capital letters or not. Most curiously, the third, flat one, is etched later and by a different artist. His name can be derived from the inscription: "Anno 1703 den 23. Appriel ist bey den Herrn Conradt Rüssen dieses Fenster gemacht worden von Johann Helmhackh."[22]

The curious fact is that Schubarth claims that all three round plates, including the AVXILIVM, were manufactured of green glass,[23] while the plate with the identical writing, preserved presently at the Germanisches Nationalmuseum, is made of clear glass. Most likely, Schwanhardt has executed more than one copy of the round plate with an identical verse.[24] Additionally, Schubarth's documentation proves that Schwanhardt's etching was considered a valuable technical invention, as samples were considered valuable enough to be added to the collections of the Königliches Gewerbeinstitut.

The description of the third plate is perhaps the most interesting in terms of the transmission of knowledge, as it proves without a doubt that Schwanhardt's invention did not die with him, as previously assumed by historians, but was still known to glassmakers after his death. As Schubarth explains, Johann Helmhack (22 December 1679 Nuremberg – 14 May 1760 Nuremberg) was the son of the famous printmaker Abraham Helmhack (29 March 1654 Regensburg – 25 May 1724 Nuremberg). In 1692, Johann started working as a glazier and a glass painter. Similarly, his father, albeit known as a printmaker, had trained as a glassmaker with Ferdinand Walden from 1673. Unfortunately, this research was unable to find any additional details about Ferdinand Walden or whether he was based in Nuremberg. According to Schubarth, Abraham was renowned for his sundials painted on glass, optical picture lanterns and window repairs.[25] Johann probably learned the use of acid-etching from Schwanhardt, either directly or through his father. The text on the plate suggests that Johann Helmhack might have experimented with the use of acid as a way of marking the authorship of his windows.

22 Unfortunately, the current location of the objects described by Schubarth is unknown. In 1826, the objects were held in the collections of the Königliche Gewerbeakademie zu Berlin, which had opened in 1821. In 1879, the Gewerbeakademie was incorporated to the newly founded Königlich Technische Hochschule zu Berlin, presently known as Technische Universität Berlin. However, in 1943, during the Second World War, almost the entire archive of TU Berlin was destroyed in a fire and the university currently holds no objects from the former archives of the Gewerbeakademie.

23 Schubarth 1826, p. 246.

24 However, there are two other possible explanations: firstly, Schubarth might have been mistaken or he could have used faulty sources.

25 Schubarth 1826, p. 247.

4 Acid-Etching on Different Materials

Technologies similar to acid-etching had already been developed by the fourteenth century. Medieval stained glass windows on cathedrals were produced by removing layers of coloured glass with acid to reveal a differently coloured layer underneath it. Thus, many authors have raised the question: was Schwanhardt's discovery truly new or had a similar technology been employed previously? Especially in the early twentieth century several authors presumed that any type of acid-etching must have been executed with hydrofluoric acid. Helen McCloy assumed that it was used for abrasing flash red glass.[26] John A. Knowles stated that Schwanhardt's "so-called discovery" was little more than an improvement, referring to a Renaissance Bolognese manuscript translated and published in 1849 by Mary Philadelphia Merrifield.[27] Merrifield's *Original Treatises* indeed contain a translation of what is referred to simply as Bolognese Manuscript dating back to the fifteenth century, including a description of the production of an acid that corrodes glass:

> "Take vitriol, which comes upon the walls, and make a distilled water from it, and keep it in a vessel well closed. Then take Roman vitriol and pound it well, distil it, and keep the water also in a close vessel; then take sal-ammoniac and distil it, and keep this also. When you want to use the liquor, take equal quantities of each of these waters, mix them together, and draw with the mixed liquor upon the glass, and it will be cut exactly as you like wherever it is wetted with this water."[28]

Vitriol stands for sulphuric acid, Roman vitriol is cupric sulphate and sal-ammoniac is ammonium chloride. The process described creates hydrochloric acid, a substance that was discovered by alchemist Jabir ibn Hayyan already in 800.[29] Although the solution would not work on contemporary glass, the type of glass produced before the seventeenth century would have been cut to size exactly as desired. However, the glass used by Schwanhardt is resistant to hydrochloric acid.

The difference between the types of glass and the effect that acid-etching has on them is explained in the work of Jean Haudicquer de Blancourt, originally published in French in 1697:

26 McCloy 1935, p. 4.

27 Knowles 1923, p. 47. Especially in late nineteenth century and early twentieth century publications a nationalist bias can be detected. Knowles also stresses that the secret for making ruby glass was rediscovered in 1826, although it was already common in the seventeenth century. Ibid., p. 40; See Kerssenbrock-Krosigk / Horn 2001.

28 Merrifield 1849, Vol. 2, p. 494.

29 Harvey / Rutledge 2018, p. 214.

> "But here we will take notice, that there are two Ways to make *Glass*, and that it may be made more or less fixed. That the more fixed, which is the least beautiful and the least transparent, resists every thing; no Preparation of *Mercury*, nor any Species of *Aqua-fortis*, can Dissolve it, nor the most subtle *Poisons*, or highest *Corrosives,* arrive any further than to break it. The less fixed, on the contrary, *which* is the most clear and transparent, as that of *Venice*, is less capable of Resistance, being composed of a more purified Salt: Thus it will Dissolve in the Earth, or in cold and moist Places, if there be more Salt in it proportionably than Sand, by a Separation natural to those two sorts of Matter: And *Poisons* Extracted out of *Minerals* will Dissolve it, by reason of their great cold."[30]

Here, a question arises: what exactly is the difference between the two types of glass? As Blancourt mentions Venice, I would argue that he has here referred to *cristallo*, a specific type of glass that first emerged in Murano and was renowned for its clarity. According to Marco Veritā and Sandro Zecchin, the clear colour of *cristallo* was achieved by "purifying the plant ash (by dissolving it in boiling water, filtering the solution, and then concentrating and drying it) to obtain the *sale da cristallo*, which was melted, in the proper proportion with silica sand."[31] We see that Blancourt also stresses the use of purification. In addition, Veritā and Zecchin note that this process eliminate not only the insoluble iron compounds that caused colouring impurities, but also calcium, magnesium and phosphorus compounds that are necessary for stabilising glass and avoiding environmental deterioration.[32] Therefore, *cristallo* would indeed be 'less fixed'.

Blancourt's definition additionally illustrates the relatively poor colour quality of the new type of glass, especially compared to *cristallo.* Even the best examples of engraving executed for noble patrons, arguably executed on glasses made by high quality manufactures, have a certain yellow hue, bubbles and other imperfections. This fact can be seen as a key factor for explaining the importance of different experiments with coloured glass and enamels that form the majority of Neri's work, Kunckel's and Merrett's translations and Blancourt's book. Similarly, the poor quality can arguably influence the style of contemporaneous glass engraving, where large surfaces of glass are treated, and, ultimately, Schwanhardt's use of his new (re-)discovery or improvement. One possible explanation for the popularity of different techniques that manipulate larger surfaces of glass would be a wish to hide the imperfections of glass, or to distract from the colouring that was perceived as less bright or less desirable than *cristallo.*

While Heinrich Schwanhardt's glass objects were unique in their usage of hydrofluoric acid, etching in general was used on various materials in the early modern period, mostly using nitric acid. Interestingly, this technique is especially common in

30 Haudicquer de Blancourt 1699.

31 Veritā / Zecchin 2008, p. 109.

32 Ibid.

Nuremberg and the surrounding areas, which may suggest material links between the different types of etching. However, the use of etching as a metalwork technique was not limited to printing plates. Nuremberg, along with Augsburg, held a special status as 'free imperial city', subject only to the emperor, and used this privilege to "promote goldsmithing, clock making, cabinetmaking, glass engraving, and the manufacture of parade armour and musical instruments."[33] However, a study of etching on metal reveals that acid was mainly used for smaller, insignificant details, never as the main technique. One may assume that the reason is the relative unpredictability of acid: engraving allows greater precision, as well as sharper lines. Additionally, most metalsmiths covered the entire surface with wax and then drew on its surface with a needle, instead of drawing with a resist agent and letting the acid corrode the background.

5 Transmission of Knowledge

As far as we know, the first mention of acid-etching on glass had already been published during Schwanhardt's lifetime. It is Sandrart who first claims that the invention of acid-etching dates to 1670, the year that is repeated in subsequent publications. Given that Sandrart's book was published in 1675, we can say with certainty that there must have been other objects that predate the plate in the Germanisches Nationalmuseum. However, there are no records of earlier examples. Either they were lost due to their fragility, or they have not been attributed and identified correctly. Knowledge of the invention of acid-etching seems to have been limited to Nuremberg and its immediate vicinity. In 1679, when Kunckel published his commented translation of Neri's *L'Arte Vitraria* in Frankfurt, it contained no references to acid-etching or any other type of acid affecting glass. However, as Kunckel was mainly interested in the production of glass, not its decoration, this fact is hardly surprising.

After Carl Wilhelm Scheele had discovered the process for the industrial production of hydrofluoric acid in 1771,[34] two significant, almost simultaneous publications in Germany highlight the history of the acid. In 1791, Johann Adolph Hildt wrote an article on this subject in his journal *Handlungszeitung oder wöchentliche Nachrichten von Handel, Manufakturwesen, Künsten und neuen Erfindungen*, published in Gotha. In it, he states that the acid is in fact an old German invention. Curiously, though, he does not mention Heinrich Schwanhardt, but a publication called *Sammlung von Natur- und Medicin- wie auch hierzu gehörigen Kunst- und Literatur-Geschichten so sich von 1717–26 in Schlesien und anderen Orten begeben … und als Versuch ans Licht gestellet* (often referred to as *Breslauer Sammlungen*), dating back to 1725, where the process is

33 Collins 2013, p. 261.

34 West 2014, p. 816.

described by Johann Georg Weygand.[35] Weygand states to have learned it from a certain Dr. Matthäus Pauli.[36] Just one year later, in 1792, the prolific German author Johann Beckmann dedicated an entire chapter of his *Beyträge zur Geschichte der Erfindungen* to the subject of acid-etching. In addition to mentioning the article by Weygand from 1725 in *Breslauer Sammlung*, Beckmann also refers to Heinrich Schwanhardt. He is confident that the knowledge must have been transmitted from Schwanhardt to Pauli and then onwards to Weygand, although he does not explain this theory in more detail and instead repeats Hildt.[37]

Beckmann stresses that, unlike the later methods of covering the glass with varnish and scratching the desired ornament into the surface, which then leaves a trace similar to engraving, Schwanhardt drew the figures onto the glass surface with varnish and then applied the acid to the remaining parts. According to Beckmann, a bright, smooth figure was produced upon a dim ground, which he considered to have a better effect than cut figures.[38] This description contradicts Doppelmayr's explanation; however, given that Doppelmayr only refers to the aesthetics of acid-etching and that there is no evidence that he would have actually learned the subtleties of the technique itself, we may assume that he was simply not familiar with the process of acid-etching on glass. Additionally, Schwanhardt may have experimented with different applications of acid.

Unfortunately, the type of glasses described by Beckmann as indicators of Schwanhardt's skill seem to be lost or have not been attributed to his name. Beckmann is able to separate acid-etching from engraving; he also mentions inspiring a contemporaneous specialist named Klindworth to try the same method and that he was consulting the artist M. Renard from Strasbourg, who was a manufacturer of glass thermometers.[39] It is impossible to know for sure which Klindworth Beckmann is referring to, as there is no mention of a first name; however, it is likely to be Johann Andreas Klindworth (1742–1813), a celebrated mechanic and clockmaker, who was based in Göttingen at the time.[40]

The text *Breslauer Sammlung* from 1725 as well as both publications from the 1790s do not connect acid etching to Heinrich Schwanhardt. Nonetheless it contains instructions for the production of hydrofluoric acid:

> "Wenn der Salpetergeist durch die Destillation bereits in die Vorlage herunter gegangen ist, treibt man ihn zuletzt mit starkem Feuer, und gießt ihn, wohl dephlegmirt, (weil er

35 Kanold 1725.

36 Ibid., p. 107.

37 Beckmann 1792, pp. 336–346 and pp. 546–558.

38 Ibid., p. 336.

39 Ibid., p. 549.

40 Stadtarchiv Göttingen, F 3, Nr. 8980.

> das gemeine Glas angreift) in eine waldenburgische Flasche; nachgehends schüttet man einen pulverisirten böhmischen Smaragd (welcher pulverisirt in der Wärme grün leuchtet,) darein, und setzt es wieder 24 Stunden in warmen Sand. Unterdessen nimmt man ein mit einer Lauge von allem Fette gereinigtes Glas, fasset dasselbe rings um den Rand, ungefähr einen Finger hoch, mit Wachs ein; gießt nachher das scharfe Aetzwasser darauf, daß das Glas fein gleich allenthalben bedeckt sey, und läßt es darauf eine Zeitlang stehen: so greift es alsdann das Glas an, und das mit Schwefel und Firniß gezeichnete bleibt erhaben und anaglyphisch stehen."[41]

'Waldenburg flask' in all likelihood refers to a stoneware flask manufactured around the Waldenburg area. The region was, according to Beatrix Adler, renowned for high quality stoneware.[42] The same recipe was in fact later included in Johann Georg Krünitz's *Oeconomische Encyclopädie*.[43] Translated into contemporary English, the procedure requires distilling and heating nitric acid, pouring it into a special stoneware vessel, mixing in powdered fluorite and then keeping the mixture in warm sand for 24 hours.

6 Glass and Porcelain

Let us now turn to two physicians, who most likely played a part in the transfer of knowledge from Schwanhardt as 'inventor' of acid etching in the seventeenth century to Beckmann and the development in the nineteenth century: Johann Georg Weygand and Matthäus Pauli, already mentioned above. Matthäus Pauli might have learned the technique of acid-etching from an artist: if we believe Beckmann, he was able to etch different figures, coats of arms and landscapes.[44] However, while Beckmann assumes that it was likely that Pauli and Schwanhardt met, I investigated who Johann Georg Weygand and Matthäus Pauli, who was at least thirty years older than him, were, and why Pauli was so interested in a glass technology and yet never published that invention under his own name.

41 Kanold, January 1725. pp. 107–108. English translation: "When the spiritus nitri per distilliatonem has passed into the recipient, ply it with a strong fire, and when well dephlegmated, pour it, as it corrodes ordinary glass, into a Waldenburg flask. Then throw into it a pulverized green Bohemian emerald, otherwise called *hesphorus* (which, when reduced to powder, and heated, emits in the dark a green light), and place it in warm sand for 24 hours. Take a piece of glass well cleaned, and freed from all grease by means of a ley; put a border of wax round it, about an inch in height, and cover it all over with the above acid. The longer you let it stand so much the better; and at the end of some time the glass will have corroded, and the figures which have been traced out with sulphur and varnish will appear as if raised above the pane of glass." Source of translation: Dobson 1803, pp. 118–119.

42 Adler 2005, p. 334.

43 Art. "Glas=Aetzen". In: Krünitz 1777–1858, vol. 18 (1779), p. 678.

44 Beckmann 1792, p. 550.

Matthäus Pauli (1649?–1704) was difficult to trace and his biography remains obscure. Most notably, Pauli was the physician (*Leibarzt*) of Frederick Augustus I. of Saxony, also known as August the Strong, who later became the patron of the Meissen porcelain manufacture in Dresden. Andreas Lesser has studied the life of Matthäus Pauli in his research on Albertine *Leibärzte*.[45] Similar to Beckmann's book and my own findings, Lesser is confident that Pauli played a key role in transmitting the knowledge of acid-etching between Schwanhardt and the scientific community.[46] Pauli had matriculated at Leiden University on June 8th 1669 to study medicine.[47] He completed his exams on 13th March 1671[48] and graduated on "De Scorbuto" on 27th November 1671.[49] His interest in art is suggested by the fact that his son, Johannes Georgius Pauli (d. 1736), became a notable patron of the arts in Breslau, especially to the porcelain painter Ignaz Bottengruber.[50] It is difficult to pinpoint when and where Weygand and Matthäus Pauli might have met. Weygand did not enter medical school until 1699 and Pauli passed away in Poland in 1704, thus the assumed encounter must have taken place between those dates, in all likelihood between 1702 and 1704, while Weygand was practising in Rostock.

Otherwise, little is known about Pauli and his name only occasionally emerges in biographies of Frederick Augustus I., mostly to praise his skills as a physician.[51] However, it is known that Pauli entered the prince's service in 1687 as a travelling court physician, just before the prince undertook his Grand Tour.[52] In 1689 the prince visited Nuremberg.[53] Heinrich Schwanhardt was still alive back then and had already successfully executed his acid-etchings. Thus, there are different possibilities how Pauli might have acquired the skill of acid-etching. Firstly, he might have met Schwanhardt in person and the latter might have taught Pauli how to produce hydrofluoric acid and how to use it for etching glass – although the reason why Schwanhardt would have shared his secret remains unclear. Secondly, as Helmhack's plate proves, there were other glassmakers in Nuremberg who would have been equally capable of instructing Pauli. Why a medical doctor was interested in hydrofluoric acid and its artistic effects on glass, may at first seem puzzling. It is important to note that at the time different agents in Europe, among them Frederick Augustus I of Saxony, were keen to find the recipe for porcelain. Personal doctors were generally involved in the scientific community surrounding

45 Lesser 2015.

46 Ibid., p. 269.

47 Leiden University Archives (LUA), Matrikel BD. 1, p. 555.

48 LUA, ASF 348, ASF 414.

49 Pauli 1671.

50 Cassidy-Geiger 1998, p. 245.

51 Czok 1989, p. 30.

52 Lesser 2015, p. 267.

53 Ibid.

the court. For example, it is documented that the successor of Matthäus Pauli, Jacob Bartholomäi, was trusted with the recipe for manufacturing red and white porcelain on 6th of January in 1708, soon after Böttger's discovery.[54]

Johann Georg Weygand was born in Bauske, in today's Latvia, on February 6, 1680, and passed away in Golding in Courland on 20th March 1740.[55] According to the *Baltisches Biographisches Lexicon*, he studied in Königsberg between 1699 and 1702, then moved to Rostock and around 1707 to Leiden. From 1710 to 1711 he worked in Libau (Liepāja), after which he moved to Golding.[56] Weygand was prolific in the scientific community: a registry of inventions published by Johann Kanold attributes a total of 36 inventions and medical findings to his name, while mentioning that he was a physician in Golding (Kuldīga).[57]

A popular belief in Europe prior to the founding of the Meissen manufactory was that porcelain was glass treated in a specific manner.[58] According to Martin Schönfeld's findings, the famous Venetian milk glass popular since the fifteenth century had originally been a misguided attempt to discover the recipe for porcelain.[59] Before the recipe for hard-paste porcelain, similar to the one produced in China, was found in Meissen, there was already production of so-called frit porcelain in the manufactory of Saint-Cloud, opened in 1693 in the suburbs of Paris.[60] The key difference between the two types was in one of the raw materials: hard-paste porcelain is made using kaolin, a special type of mineral, while the type of porcelain originally invented in Florence and manufactured in Saint-Cloud, Rouen and Sèvres, was made by using frit instead, defined by contemporaneous dictionaries as "a calcinated mixture of sand and fluxes ready to be melted in a crucible to make glass."[61] Thus, European scientists of the late seventeenth century still believed that the materials for glass and porcelain had to be related.

Records show that the founders of Meissen were familiar with the process of porcelain making in Saint-Cloud. Ehrenfried Walther von Tschirnhaus (1651–1708), a German physicist and philosopher who was in charge of finding the recipe for porcelain in the court of Frederick Augustus I, visited Saint-Cloud in 1701, although in his writings he suggested that the manufactory would ultimately fail because of the poor quality of its products. However, Tschirnhaus did not doubt the recipe, but claimed

54 Hoffmann 1982, p. 95.

55 Gadebusch 1777, p. 212.

56 Baltisches Biographisches Lexicon Digital 2020, pp. 860–861.

57 Kanold 1725.

58 Goder 1982, p. 113.

59 Schönfeld 1998, p. 722.

60 D'Albis / Rondot 1999, p. 12.

61 Ibid.

that the reason for the inferiority of French porcelain was the large amount of salt in the composition.[62]

Meanwhile, acid-etched glass surface bears a slight similarity to porcelain. Even though Schwanhardt's method for producing acid resulted in a weak substance that was prone to form air bubbles, the translucidity of etching might have indicated to contemporaries, especially those preoccupied with finding the secret of porcelain that it was in a way related to the latter. This resemblance was also documented later; in 1775, John Hill, who was writing to a British audience about Swedish pharmacist Scheele's discovery of the recipe, notes: "This Substance seems to promise all that can be wished, without any father Mixture. For the Matter in the Neck of the Retort, when hardened, differs little from the Substance of China Ware."[63]

One possibility to explain this transmission of knowledge between the scientific and artistic fields is that descriptions detailing the technology of acid-etching, or even actual objects, reached Matthäus Pauli while he was in Nuremberg accompanying Frederick Augustus on his Grand Tour. Pauli might have met with Schwanhardt, assuming that the invention could be used to produce porcelain or that it would at least bring him closer to the goal. However, after either learning that he had been mistaken or becoming less vested in the technology for a different reason, Pauli must have shared his knowledge with Weygand, as suggested by Hildt and Beckmann.[64] So far, the use of acid-etching on glass in the early eighteenth century remains a mystery. The collection of the Schlossmuseum Arnstadt, Germany holds several objects, which may have been decorated at that time – especially one particular glass, which bears stylistic similarities to objects dating from the 1730s (fig. 5, 6).[65] Therefore, especially relying on scientific accounts of *Breslauer Sammlungen*, it can be assumed that acid-etching was already used for the decoration of glassware in the early eighteenth century.

It is likely that the aesthetic connection to porcelain might have been the reason why Tschirnhaus and through him, possibly Frederick Augustus, might have shown an interest in acid-etching. As Florian Knothe has found, Tschirnhaus's glass manufactory also produced milk glass.[66] He stresses that so-called imitation porcelain was highly popular in seventeenth and eighteenth century Europe and "flourished in tandem with true porcelain."[67] Therefore, a second explanation could be that Pauli's interest in acid-etching was in fact connected to Tschirnhaus's glass manufactory, not to Meissen

62 Cassidy-Geiger 1999, p. 97.

63 Hill 1775.

64 Hildt 1791, p. 92; Beckmann 1792, pp. 549–550.

65 I would like to once again thank Judith Thomann for discovering it and contacting me.

66 Knothe 2010, p. 203.

67 Ibid., p. 209.

Figure 5–6. Flötenglas, eighteenth century. Schlossmuseum, Arnstadt, Inv.-Nr. K-G 0473.

porcelain. However, considering that Tschirnhaus left behind a considerable amount of writings and yet did not mention acid-etching, it seems that he did not attribute great significance to it.[68]

7 Later Use of Acid-Etching in Mass Production

In 1771, a Swedish pharmacist called Carl Wilhelm Scheele discovered a new method for producing hydrofluoric acid.[69] Some experiments concerning the use of hydrofluoric acid for the treatment of glass were conducted by Andreas Sigismund Marggraf

68 Unfortunately this research was not able to use the writings of Tschirnhaus and thus the author relies on d'Albis / Rondot 1999.

69 West 2014, p. 816.

(1709–1782) and by Joseph Priestley (1733–1804), but the first thorough academic paper on this subject was published in 1788 by the French scientist Marcassus de Puymaurin (1757–1841).[70] Starting with Scheele's invention, references to Schwanhardt and Weygand begin to disappear from scientific literature and the discussion of the technology turns more to its potential use in mass production.

However, after Scheele's and Puymaurin's experiments, the use of hydrofluoric acid on glass soon became popular. The speed and extent of the transmission of the new technique is well illustrated by a glass bottle, manufactured by the Imperial Glass Factory in Saint Petersburg, Russia, currently held by Mykolas Žilinskas Art Gallery in Kaunas, Lithuania (fig. 7). The ornament includes a date, 1791, so only twenty years after Scheele's discovery. The décor appears to be drawn with hydrofluoric acid on the clear surface freehand, using a brush. Similar techniques can be found later in the nineteenth century on many glass objects intended for middle class consumption, for example German Biedermeier wine glasses or on another glass bottle held in the collections of Mykolas Žilinskas Art Gallery, manufactured by the Imperial Glass Factory in Saint Petersburg in the mid- or late nineteenth century (fig. 8). In some cases, acid etching was used in combination with other embellishment techniques. The collection of the Angermuseum in Erfurt, Germany, holds a wine glass dating from approximately 1820, which combines brilliant cut with acid etching, used to create a narrow decorative band around the glass.[71]

However, the popularity of acid-etching in the nineteenth century is mainly related to the United Kingdom. Previously, the high taxation of glass had prevented experimentation amongst glass artists and manufacturers. Glass tax was cancelled in 1845, mainly because of the influence of the entrepreneur and politician Apsley Pellatt, whose family firm had a worldwide reputation for the production of fine glassware, mainly engraving,[72] and who can be credited with the study of several ancient techniques.[73] Pellatt himself was by no means connected to acid-etching; in his book, *Curiosities of glassmaking*, published in 1849 he divided the glass decorating methods into four principal operations: blowing and making glassware by hand, pressing in moulds, pressing in moulds using machinery, and tube-drawing.[74] The first patent for etching glass was issued in London in 1853 to Emmanuel Barthelemy, Tony Petitjean and Jean-Pierre Bourquin.[75] The first major company to start experimenting with the possibilities of acid-etching

70 Thorpe 1969, p. 47.

71 Erfurt, Angermuseum, museum number 2121.

72 Cooke 1986, p. 15.

73 Wills 1976, p. 21.

74 Pellatt 1849, p. 80.

75 Klein / Lloyd 1984, p. 180.

Figure 7. Glass bottle, manufactured by the Imperial Glass Factory in Saint Petersburg, Russia in 1791. Mykolas Žilinskas Art Gallery in Kaunas, Lithuania, Inv.-Nr. Tt-13252.

Figure 8. Glass bottle, manufactured by the Imperial Glass Factory in Saint Petersburg, Russia, during the reign of Catherine II. and Alexander III. (1845–1894). Mykolas Žilinskas Art Gallery in Kaunas, Lithuania, Inv.-Nr. Tt-12636.

was Richardson's in Stourbridge, in the 1850s. It was Benjamin Richardson who took out another one of the first patents to etch glass, in 1857.[76] From there, the technique became increasingly popular. Wills attributes the popularity of acid-etching in Victorian Britain to its comparative cheapness and novelty: even a relatively unskilled workforce could produce ornaments with a more delicate outline than could have been achieved using other methods.[77] John Northwood from Stourbridge manufactured a special, "lathe-like machine" for the use of etching. As stated by Wills: "With its use, borders of Greek Key, interlacing circles and similar running patterns were executed by men and women operatives after brief training."[78] Objects were coated with wax into which a needle automatically cut the pattern. Then, objects were placed in a bath of acid.

76 Vose 1975, p. 183.

77 Wills 1976, p. 40.

78 Ibid., p. 41.

Figure 9. Émile Gallé, Vase "Oakleaf", manufactured by the Gallé Glassworks c. 1895. Victoria & Albert Museum, London, Inv.-Nr. 9449.

The height of popularity came with the advent of *Art Nouveau*, especially in the works of Emile Gallé (fig. 9). For Gallé, there was no dominating technique in glasswork, as virtually all of his creations are combinations of different processes. Until 1884, Gallé refused to use acid-etching as a decorative process altogether, declaring it useless to the artistic effects he aimed to achieve.[79] In his opinion, acid "does not think nor add anything to the model"; however, he was willing to admit that that it "tames some glasses in its own way".[80] It was not until 1889 when Gallé started to use acid-etching also for the decoration of the surface, not just as a way of preparing the glass; he mostly used etching as a means to give the glass a somewhat raw appearance.[81] One of the main reasons for Gallé to turn to the technique he had previously looked down upon was money: acid-etching was relatively cheap and therefore allowed him to mass-produce inexpensive ranges of commercial glassware.[82]

One of the main uses for acid-etching was the production of cameo glass, a traditional technique that had been in use ever since the antiquity. Traditionally, a thin layer of different coloured glass was applied on the initial object; then, the glass was hand-carved so that the remaining parts of the top layer would form the ornament. Gallé used acid to get rid of the unwanted parts of the top layer; he was by no means the inventor

79 Gallé 1908, p. 107.

80 Ibid., p. 346.

81 Bloch-Dermant 1980, p. 108.

82 Duncan / De Bartha 1984, p. 131.

of this technique, as it was widely used at the time, although not with such skill. Another way acid was employed in Gallé's workshops was for giving certain areas of the object a matt finish, thereby increasing the contrast between different parts of design. However, it must be stressed that despite all this, etching was not considered as worthy as many other techniques, as its results were not considered to be a display of artistic efforts. As the process's main purpose was commercial, not artistic, most pieces were of average quality and sold at relatively low prices.[83]

8 Conclusion. Why Was Acid-Etching Forgotten until the Nineteenth Century?

Although my research has shown that acid-etching, as (re-)invented by Heinrich Schwanhardt, was relatively well-known and invoked the interest of many significant scientists of the time, the technique appears to have been largely ignored by the Saxon court. The possible connections between Weygand, Pauli, Tschirnhaus and acid-etching remain pure speculation. Although Tschirnhaus left behind a significant body of writings, this research has not been able to discover any references to acid-etching within his letters. Therefore, instead of discussing the importance of this technology, one might ask: why did this later significant discovery gain so little interest in the late seventeenth and early eighteenth century? If Matthäus Pauli was aware of this technique and thus this knowledge would have been available to Tschirnhaus, a man with many interests, why did the latter obviously disregard it, as there is no evidence of hydrofluoric acid being used or even mentioned by him?

Here, the analysis of the objects made by Schwanhardt in 1686 and by Helmhack in 1703 may shed some light on the suspected usages for acid-etching. Although Sandrart mentions that Schwanhardt was able to draw "wonderful figures" with his new discovery, the only figurative designs of which we have evidence preserved until this day are texts. Furthermore, the abovementioned glass plate in the Germanisches Nationalmuseum is the only preserved example of a finished glass object by Schwanhardt which employed etching by hydrofluoric acid. Although Helmhack's use of etching suggests that the glassmakers and artists of Nuremberg were aware of this technique, there are no examples of any other famous contemporaneous glass artist employing it. Instead, the only other object of which there are verifiable accounts in Schubarth's *Verein* appears to employ acid-etching to facilitate signing windows, with seemingly no artistic aspirations.

Another potential reason might have been the aesthetic quality of the finished surfaces. The background of the plate in the collection of the Germanisches Nationalmuseum

83 Ibid., p. 133.

is not evenly matte, but the small bubbles formed in the relatively unreliable process of manufacturing hydrofluoric acid have created a number of small clear spots. Considering the small size of details typically present on the skilled examples of Baroque glass, acid might have potentially been too unreliable for local glass artists to be used on more complex objects. With regard to mass production of simpler objects, the manufacturing process of the acid, as described in *Breslauer Sammlung*, was time-consuming and only allowed the production of small quantities. Hence, the technology remained a curiosity, fascinating mainly historians of technology and chemistry.

9 Bibliography

9.1 Archival Sources

Göttingen, Stadtarchiv Göttingen
F 3, Nr. 8980.

Leiden, Leiden University Archives (LUA)
ASF 348.
ASF 414.
Matrikel BD. 1, S. 555.

9.2 Published Sources

Agricola 1546: Georg Agricola: De ortu & causis subterraneorum Lib. V. De natura eorum quæ effluunt ex terra Lib. IIII. De natura fossilium Lib. X. De ueteribus & nouis metallis Lib. II. Bermannus, siue De re metallica Dialogus. Interpretatio Germanica uocum rei metallicæ, addito Indice fœcundissimo. Basel 1546.

Beckmann 1792: Johann Beckmann: Beyträge zur Geschichte der Erfindungen, vol. 3. Leipzig 1792.

Dobson 1803: Thomas Dobson: Supplement to Encyclopædia. Or, A Dictionary of Arts, Sciences, and Miscellaneous Literature. Philadelphia 1803.

Doppelmayr 1730: Johann Gabriel Doppelmayr: Historische Nachricht von dem Nürnbergischen Mathematicis und Künstlern Nürnbergs. Nürnberg 1730.

Gadebusch 1777: Friederich Konrad Gadebusch:

Gallé 1908: Émile Gallé: Écrits pour l'art. Paris 1908.

Haudicquer de Blancourt 1699: Jean Haudicquer de Blancourt: The Art of Glass. Shewing How to Make All Sorts of Glass, Crystal and Enamel, Likewise the Making of Pearls, Precious Stones, China and Looking-Glasses. To Which Is Added, the

Method of Painting on Glass and Enameling: Also How to Extract the Colours from Minerals, Metals, Herbs […]. S.l 1699.
Hildt 1791: Johann Adolph Hildt: Handlungszeitung oder wöchentliche Nachrichten von Handel, Manufakturwesen, Künsten und neuen Erfindungen. Gotha 1791.
Hill 1775: John Hill: Enquiries into the Nature of a New Mineral Acid, Discovered in Sweden; And of the Stone from Which It Is Obtained […]. London 1775.
Kanold 1725: Johann Kanold: Sammlung von Natur- und Medicin- wie auch hierzu gehörigen Kunst- und Literatur-Geschichten so sich von 1717–26 in Schlesien und anderen Orten begeben […]. Breslau 1725, under: https://books.google.ee/books?id=YGRVAAAAcAAJ&pg=PA1&hl=et&source=gbs_selected_pages&cad=2#v=onepage&q&f=false [29.03.2021].
Krünitz 1773–1858: Johann Georg Krünitz: Oekonomische Encyklopädie oder allgemeines System der Staats- Stadt- Haus- und Landwirthschaft in alphabetischer Ordnung. 242 vols., Berlin 1773–1858, under: http://www.kruenitz.uni-trier.de/ [29.03.2021].
Kunckel 1679: Johann Kunckel: Ars Vitraria Experimentalis. Oder Vollkommene Glasmacher-Kunst […]. Frankfurt 1679.
Lardner 1832: Dionysius Lardner u. a.: A Treatise on the Progressive Improvement and Present State of the Manufacture of Porcelain and Glass. [The Cabinet Cyclopaedia]. London 1832.
Neri 1612: Antonio Neri: L'Arte Vetraria distinta in Libri Sette. Florence 1612.
Neri 1662: Antonio Neri: The Art of Glass. Wherein are Shown the Wayes to Make and Colour Glass, Pastes, Enamels, Lakes, and Other Curiosities. Written in Italian by Antonio Neri, and Translated into English. London 1662.
Pauli 1671: Matthäus Pauli: Dissertatio medica inauguralis de scorbuto … Lugduni Batavorum. Apud viduam & haeredes Johannis Elsevirii, 1671. Leiden University Library Special Collections 1671.
Pellatt 1849: Apsley Pellatt: Curiosities of Glass Making. With Details of the Processes and Productions of Ancient and Modern Ornamental Glass Manufacture. London 1849.
Sandrart 1675: Joachim von Sandrart: Teutsche Academie, II, 3. Nürnberg 1675.
Schubarth 1826: Ernst Ludwig Schubarth: Verein zur Beförderung des Gewerbefleißes, vol. 7. Berlin 1826.

9.3 List of References

Adler 2005: Beatrix Adler: Early Stoneware Steins from the Les Paul Collection. A Survey of All German Stoneware Centers from 1500 to 1850. Dillingen 2005.
Baltisches Biographisches Lexikon 2020: Baltisches Biographisches Lexikon Digital, ed. by Baltische Historische Kommission. Berlin 2020.

Bloch-Dermant 1980: Janine Bloch-Dermant: The Art of French Glass 1860–1914. London 1980.

Bosch 1984: Helmut Bosch: Die Nürnberger Hausmaler. München 1984.

Cassidy-Geiger 1998: Maureen Cassidy-Geiger: The Porcelain Decoration of Ignaz Bottengruber. In: Metropolitan Museum Journal 33 (1998), pp. 245–262.

Cassidy-Geiger 1999: Maureen Cassidy-Geiger: Meissen and Saint-Cloud, Dresden and Paris: Royal and Lesser Connections and Parallels. In: Antoine d'Albis / Bertrand Rondot (eds.): Discovering the Secrets of Soft-Paste Porcelain at Saint-Cloud. New Haven 1999, pp. 97–111.

Collins 2013: Jeffrey Collins: Europe 1600–1750. In: Pat Kirkham / Susan Weber (eds.): History of Design. New Haven and London 2013, pp. 230–267.

Cooke 1986: Frederick Cooke: Glass. Twentieth Century Design. London 1986.

Czok 1989: Karl Czok: Am Hofe Augusts des Starken. Leipzig 1989.

d'Albis / Rondot 1999: Antoine d'Albis / Bertrand Rondot (eds.): Discovering the Secrets of Soft-Paste Porcelain at Saint-Cloud. New Haven 1999.

Duncan / De Bartha 1984: Alastair Duncan / Georges De Bartha: Glass by Gallé. London 1984.

Goder 1982: Willy Goder u. a.: Die technische Entwicklung von Böttgersteinzeug und Böttgerporzellan. In: Rolf Sonnemann (ed.): Johann Friedrich Böttger. Die Erfindung des europäischen Porzellans. Leipzig 1982, pp. 99–127.

Harvey / Rutledge 2018: Dexter Harvey / Nicky Rutledge: Industrial Chemistry. Waltham Abbey 2018.

Hoffmann 1982: Klaus Hoffmann: Johann Friedrich Böttger – Stationen seines Lebens. In: Rolf Sonnemann (ed.): Johann Friedrich Böttger. Die Erfindung des europäischen Porzellans. Leipzig 1982, pp. 71–98.

Kerssenbrock-Krosigk / Horn 2001: Dedo von Kerssenbrock-Krosigk / Ingo Horn: Rubinglas des ausgehenden 17. und 18. Jahrhunderts. Mainz 2001.

Klein / Lloyd 1984: Dan Klein / Ward Lloyd. The History of Glass. London 1984.

Knothe 2010: Florian Knothe: East meets West. Cross-Cultural Influences in Glassmaking in the 18th and 19th Centuries. In: Journal of Glass Studies (2010), pp. 201–216.

Knowles 1923: John A. Knowles: Forgeries of Ancient Stained Glass. Methods of Their Production and Detection. In: Journal of the Royal Society of Arts 72/ 3707 (1923), pp. 38–56.

Lesser 2015: Andreas Lesser: Die albertinischen Leibärzte vor 1700 und ihre verwandtschaftlichen Beziehungen zu Ärzten und Apothekern. Petersberg 2015.

McCloy 1935: Helen McCloy: A Lost Art Re-Born. Recent Developments in American Stained Glass. In: Parnassus 7/ 3 (1935), pp. 4–6.

Merrifield 1849: Mary Philadelphia Merrifield: Original Treatises. Dating from the XIIth to the XVIIIth Centuries, [o]n the Arts of Painting, in Oil, Miniature, Mosaic, and on Glass. Of Gilding, Dyeing, and the Preparation of Colours and Artificial Gems [...], vol. 2. S. l. 1849.

Heisig 1963: Erich Meyer-Heisig: Der Nürnberger Glasschnitt des 17. Jahrhunderts. Nürnberg 1963.

Schönfeld 1998: Martin Schönfeld: Was There a Western Inventor of Porcelain? In: Technology and Culture 39/ 4 (1998), pp. 716–727.

Spiegl 1976: Walter Spiegl: Böhmische Gläser. München 1976.

Thorpe 1969: William Arnold Thorpe: History of English and Irish Glass. S. l. 1969.

Veritā / Zecchin 2008: Marco Veritā / Sandro Zecchin: Scientific Investigation of a Venetian Polychrome Goblet of the 16th Century. In: Journal of Glass Studies (2008), pp. 105–115.

Vose 1975: Ruth Hurst Vose: Glass. The Connoisseur Illustrated Guides. London 1975.

West 2014: John B. West: Carl Wilhelm Scheele, the Discoverer of Oxygen, and a Very Productive Chemist. In: American Journal of Physiology. Lung Cellular and Molecular Physiology 307/ 11 (2014), pp. 811–816.

Wills 1976: Geoffrey Wills: Victorian Glass. London 1976.

Wise 2018: M. Norton Wise: Aesthetics, Industry, and Science. Hermann von Helmholtz and the Berlin Physical Society. Chicago 2018.

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