Metal threads in 17th century textiles:

Art-technological Research and Characterization of Burgzand North 17 Metal Threads

Photo by Margareta Svensson.

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Abstract

English

The purpose of this research is to study the historical manufacturing methods of fine metal threads found on 17th century marine archaeological textile fragments. The research focuses on elaborately decorated textile fragments found on the Burgzand North 17 shipwreck (further to be called BZN 17 or Palmhout shipwreck), which was discovered in 2014 by a local diving club in the Burgzand North area close to the Dutch island of Texel.

The objects originate from a toiletry set, as they share similar stylistic features in the use of fabric, decorative patterns, application methods and materials of the metal threads. These objects comprise the following: a loose fragment of embroidered fabric (approx. 12x12 cm), a clutch purse (originally found containing a wooden comb), a toiletry brush, a wooden table mirror with detached decorated frontal frame, and a rectangular tablecloth. The objective of the research was to determine and explain the manufacturing methods, describe the objects' original appearance and position them in their historical context.

Literature research was conducted to investigate similar historical objects dating to the 17th century and gain information about the manufacturing methods commonly used in this period to produce the embroidered metalwork. Next, the toiletry set was thoroughly examined. Microscopy, including the aid of a Hirox digital microscope, was used to determine the main metalwork types and to document the general condition of the objects. To determine the elemental composition, cross-sections of the metalwork were analysed by scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX).

The Hirox inspection revealed that the metalwork was composed of four main types of components, round wires, rectangular wires, metal strips and metal disks. All decorative elements were attributed an illustrative 3D rendering. SEM-EDX analysis showed that the majority of the metalwork consisted of silver and sulphur with a small amount of copper and iron as a trace element. One specific decorative element, the round disk, was found to consist of a high amount of copper in the core area together with a silver outer layer. None of the samples had maintained a metallic core, and gold was detected on all surfaces. The SEM analysis also provided information about the metal surface, which made it possible to deduce that the round wires were drawn, the rectangular ones were flattened from round drawn ones and the metal strips were cut from a sheet. The round disks were most likely flattened from a coil section.

Further research is recommended to study the condition of these objects and explain the formation of certain corrosion products. Furthermore, literature research concerning the used alloys and stylistic motifs should serve to discover more about the possible origin and manufacturing period of these elaborately decorated objects.

Nederlands

Het doel van dit onderzoek is het bestuderen van historische productiemethoden van fijne metaaldraden die te vinden zijn in maritiem archeologische textielfragmenten uit de 17e eeuw. Het onderzoek richt zich op uitbundig gedecoreerde textielfragmenten die gevonden zijn in het scheepswrak van Burgzand Noord 17 (verder BZN 17 of scheepswrak van Palmhout genoemd), die in 2014 werd ontdekt door een plaatselijke duikclub in de regio Burgzand Noord, dichtbij het Nederlandse eiland Texel.

De objecten zijn afkomstig uit een set toiletartikelen, aangezien ze dezelfde stilistische kenmerken delen in het gebruik van stof, decoratieve patronen, applicatiemethoden en materialen binnen de metaaldraden. De voorwerpen bestaan uit de volgende objecten: een los fragment geborduurd weefsel (ongeveer 12x12 cm), een kleine handtas (oorspronkelijk gevonden met een houten kam erin), een gezichtspenseel, een houten tafelspiegel met een vrijstaande versierde lijst en een rechthoekig tafelkleed. Het doel van het onderzoek was om de productiemethoden vast te stellen en te verklaren, de oorspronkelijke vorm van de objecten te omschrijven en ze in hun historische context te plaatsen.

Met behulp van literatuuronderzoek werden vergelijkbare historische objecten uit de 17e eeuw onderzocht en werd informatie verkregen over de productiemethoden die in deze periode veel werden gebruikt om het geborduurde metaalwerk te produceren. Vervolgens werden de toiletartikelen grondig onderzocht. Microscopie, met behulp van een Hirox digitale microscoop, werd gebruikt om de belangrijkste soorten metaalbewerking te bepalen en de algemene staat van de objecten te documenteren. Om de elementaire samenstelling te bepalen werden dwarsdoorsneden van het metaalwerk geanalyseerd met behulp van een rasterelektronenmicroscoop met energiedispersieve röntgenspectroscopie (SEM-EDX).

Uit de Hirox-inspectie bleek dat het metaalwerk uit vier hoofdcomponenten bestond: ronde draden, rechthoekige draden, metalen stroken en metalen schijven. Alle decoratieve elementen hebben een illustratieve 3D-weergave toegewezen gekregen. SEM-EDX-analyse toonde aan dat het grootste deel van het metaalwerk uit zilver en zwavel bestond met een kleine hoeveelheid koper en ijzer als spoorelement. Eén specifiek decoratief element, de ronde schijf, bleek in het kerngebied uit een grote hoeveelheid koper te bestaan, inclusief een zilveren buitenlaag. Geen van de monsters had een metalen kern behouden en goud werd op alle oppervlakken gedetecteerd. De SEM-analyse verschafte ook informatie over het metaaloppervlak, wat het mogelijk maakte om te concluderen dat de ronde draden getrokken waren, de rechthoekige draden waren gemaakt van platgemaakt rond getrokken draad en de metalen stroken uit een plaat gesneden waren. De ronde schijven waren waarschijnlijk platgewalst van een spoelsectie.

Verder onderzoek wordt aangeraden om de staat van deze objecten te bestuderen en de vorming van bepaalde corrosieproducten te verklaren. Verder zou literatuuronderzoek naar de gebruikte legeringen en stilistische motieven helpen om meer te ontdekken over de mogelijke oorsprong en productieperiode van deze rijkversierde objecten.

1. Introduction

In 2014, a 17th century shipwreck was discovered close to the Dutch island of Texel. The numerous luxurious finds brought ashore by the local divers have offered a chance to look into the lives of the bourgeois of the time. The collection consists of artefacts of a large variety of materials and has challenged researchers in many fields to find out more about this remarkable discovery.

Among the finds is an attractive toiletry set, made of dark red silk velvet decorated with elaborate metal embroideries. Due to the relatively poor condition of the objects, their original appearance could not be easily identified. Furthermore, the lack of information about the origin of the ship complicated the dating of the artefacts. Therefore, further research was needed to complete the descriptive profile of these finds.

Apart from collecting information about the specific historical finds within the BZN 17 collection, the research aims to contribute to the existing knowledge regarding a very specific type of metalwork: *embroidered metal threads*. This is done by consulting historical manufacturing manuals and contemporary research papers in order to understand the manufacturing methods for metal threads and other decorative elements used in the embroideries. The results of the art-technological research are summarized separately and viewed in the context of the BZN 17 toiletry set.

The toiletry set consists of a clutch purse, a mirror, a toiletry brush, a loose textile fragment (possibly once part of a pincushion) and a rectangular tablecloth.[1] It is not known if any other objects were meant to be part of the ensemble. In fact, in the early stages of the research, it was even not possible to confirm that these five pieces *were* meant to form a set. The decorative embroidered patterns, however, show stylistical similarities. With virtually no exposure to light and oxygen, some parts of these objects are in a remarkably good condition and provide a chance to study how they were made, and to establish whether the manufacturing methods were the same among the five objects.

1.1. Research aim and methodology

The aim of this research is to gather information about the initial appearance of the elaborately decorated textile fragments found on BZN 17 shipwreck and to provide an overview of historical manufacturing methods for the metalwork. The research question based on this aim is presented below.

[1] The selection from the full BZN 17 collection was made based on discussions with other researchers. The criteria, when choosing the objects, was based on limited previous research and parallely conducted research by other disciplines. Further research is being carried out by Suzan Meijer (Head of Textile Conservation, RMA) and Ana Serrano (Researcher RCE).

1.1.1. Research question

What manufacturing techniques were used for producing the BZN 17 metal threads, and are these techniques similar between the five research objects?

Sub-questions:

- What metals were used?
- Can similar alloys be identified between the five objects?
- How many different thread types are present?
- Are there threads between different pieces from the same assortment?
- Which gilding methods were used?

During the course of this research, the objects were thoroughly examined, utilizing non-destructive methods such as visual inspection, microscopical analysis and detailed examination with the Hirox microscope. Additionally, samples were taken and characterized by scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX) with the purpose of describing the alloys used, the corrosion products that had formed and the microstructural characteristics.

1.2. Relevance to the field of conservation

Nowadays, museum collections all around the world contain numerous textile artefacts adorned with precious metal threads. The collection of the Rijksmuseum Amsterdam (RMA) holds fine examples of 17th century bridal gloves, adorned with colourful silk yarns and delicate metal threads.[2] The collection of the Museum of London contains embroidered mules that were worn by Queen Henrietta Maria, the wife of Charles I.[3] The Victoria and Albert Museum exhibits an early 16th century piece titled *'The Cloth of Gold'* and characterizes it as the most expensive type of textile made in Renaissance Europe. These items are visually stunning and carry a rich history as they were manufactured by highly skilled craftsmen and owned by the most illustrious members of society. Therefore, it is important to preserve these historical objects.

Conservation of metal threads is a major issue for conservators from the fields of both textiles and metals. In the museum context, objects containing metal threads are often categorized as textiles, as apart from being partly composed of natural fibres, they function as wearable items or accessories. The conservation and restoration of metal threads, however, reaches beyond a single discipline and is complicated by the coexistence of two very different materials: inorganic metal and organic textiles.

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[2] https://www.rijksmuseum.nl/nl/zoeken?p=1&ps=12&f.objectTypes.sort=bruidshandschoen&st=Objects&ii=0 Retrieved 16.06.2018

[3] http://collections.vam.ac.uk/item/O74679/pair-of-shoes-unknown/ Retrieved 22.05.2018

Cleaning is one of the most common problems relating to metal embroidered artefacts. The threads, often containing a considerable quantity of silver, tend to oxidize and thereby lose their original appearance. This is caused by atmospheric pollutants in the environment but also by silk decomposition mechanisms, releasing sulphur which accelerates sulfide formation on the metal threads.[4] In order to reverse the change in appearance caused by corrosion products, invasive treatment methods need to be used, posing a risk to the textiles in question.

For centuries, craftsmen and conservators have been searching for treatment methods that would efficiently restore metals' initial appearance without damaging the organic fibres. Evidence of the importance of the matter is provided by early historical sources, such as a publication by an Amsterdam-based embroidery master Pieter van de Lande. In 1703, he published an advertisement with advice on the maintenance of fine silver embroideries.[5] Published in 1905 by Viktor Joclét, *'Kunst- und Feinwäscherei'* provides detailed instructions for cleaning metal embroidered textiles by using milk, white wine, vinegar, honey and more.[6] Solvents and acidic solutions were used for cleaning until the 1980s, when the idea of electrochemical reduction was introduced, in which silver sulphides are reduced back to metallic silver.[7] All these aforementioned methods, showing inefficient results, have been questioned from the 1990s onwards, when invasive conservation treatments that focussed primarily on improving objects' appearance began to be condemned for their unethical approach.

More complexity is added to the task of restoring metal embroideries when the artefacts have an archaeological background. In this case, the metalwork has often fully mineralized, losing its original appearance, exhibiting microstructurally induced brittleness and becoming highly susceptible to further physical damage. For archaeological objects, chemical reactions in the material are bound to take place. In anaerobic conditions, the main silver corrosion product is silver sulphide (Ag_2S).[8] In aerobic conditions, the formation of silver chloride (AgCl) results in an increase in the object's volume, whereby the metal might undergo a full transformation into corrosion products.[9] Therefore, it is necessary for the conservator to understand the possible formation of new chemical compounds and take this into account in the treatment procedure.

1.3. Current scientific knowledge

Metal threads have received a significant amount of attention in conservation-related research. Hungarian conservation scientist Márta Járó has carried out extensive research on metal threads at the Hungarian National Museum up to the last decade. Together with Attila Tóth, they have published numerous articles about the material characterisation,

[4] Simsek, Simsek 2006: 509.
[5] De Groot 1997: 61.
[6] De Groot 1997: 62.
[7] De Groot 1997: 64.
[8] North, MacLeod 1987: 92.
[9] Marchand et al 2014: 1.

manufacturing methods and scientific analysis of metal threads over the centuries, as well focussing more specifically on threads produced in the 17th century.[10]

In addition to the work carried out in Hungary, researchers with different topic-related focusses have contributed to the field with their research. Firstly, Anna Karatzani has received a PhD degree in analytical investigation of Byzantine-Greek metal threads and has published articles on thread types and their characterisation methods. Identification methods have also been researched by Vanessa Muros, who has an extensive background in archaeology and is a co-author of an extensive article focusing on 17th to 19th century metal threads found in the Colonial Andes. Secondly, from the material point of view, renowned authors like David A. Scott, Ian MacLeod and Russell James Wanhill have investigated and described the deterioration processes of marine silver alloys, thereby creating a base for understanding the chemical changes within archaeological objects. Lastly, an extensive amount of historical and statistical research has been carried out , exemplified by a Dutch publication and conference *'Metaaldraad'* (*'metal thread'*) by the Dutch Textile Foundation[11] in 1997.

To supplement this extensive past research, other aspects of metal threads need further attention. Art-technological aspects such as alloys used, metalcraft techniques and gilding methods have not been described sufficiently. When being inventoried, materials such as gold are often falsely attributed to the objects, on the basis of the appearance of the outer layer of the metalwork.[12] "Only the determination of manufacturing techniques together with the systematic analysis of the metals or alloys used, can provide enough data to characterize the types of metal thread which decorated textiles in a given period, are characteristic of a particular workshop, craftsman, etc." Járó, Tóth 1991:181.

[10] Járó, Tóth 1991: 175-184.
[11] Stichting Textielcommissie Nederland
[12] Dye 2012: 7.

2. The shipwreck and its finds

2.1. Burgzand area

The Dutch have always been at the forefront of the maritime trade. Around 1600, the city of Amsterdam was flourishing and experiencing a rapid growth in trade, shipbuilding and industry.[13] However, even though the city had become an important trading place for goods from all over the world, the coastline of Amsterdam was for a long time unsuitable for receiving large trade ships because of its shallow waters. To solve this dilemma, the ships' cargo was frequently loaded and unloaded by the Northern coast of the Netherlands in the area that is now known as the Waddenzee (Figure 2.1).[14]

Figure 2.1. The Texel Roads marked in red. Janssonius, 1658[15]

The Texel Roads (Rede van Texel), or the Burgzand area, as it was already called in the 17th century, is thus known as an important historical harbour and anchorage for the trade ships.[16] Regardless of its relatively calm waters, many heavy storms affected the area in the 17th century; the storms sunk dozens of ships during that period. This is illustrated by the

[13] https://www.rijksmuseum.nl/en/rijksstudio/timeline-dutch-history/1600-1665-amsterdams-prosperity Retrieved 28.03.2018
[14] http://moss.nba.fi/eng/bzn-10.html
[15] https://leeuwenhoek.wordpress.com/2016/04/21/the-wadden-sea-wardrobe/
[16] Vos 2015: 29.

numerous finds reported up to this day, demonstrated in Figure 2.2 below.[17] With the completion of the Afsluitdijk in 1932, the ecosystem of the Waddenzee underwent a drastic change. Protecting the mainland from flooding, the dike also brought changes to the water flow, causing the seabed of the Burgzand area to be gradually swept away.[18] This sequence of events lead to the discovery of the BZN 17 finds.

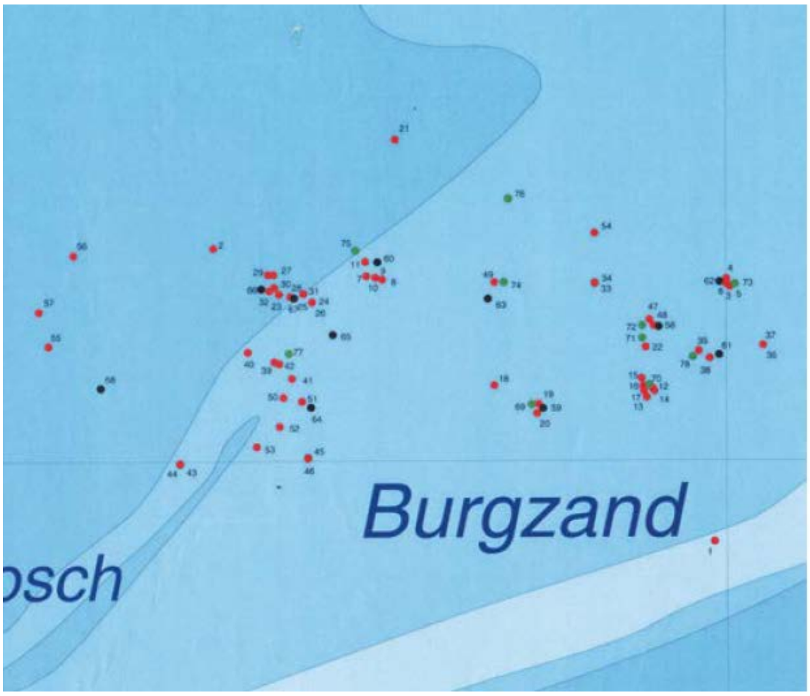

Figure 2.2. Reported finds by different divers' groups[19]

2.2. The discovery of the shipwreck

Since 2009, a local Dutch diving club had been paying repetitive visits to a shipwreck in the Burgzand North area near the Dutch island of Texel, hereafter referred to as the Burgzand North 17 (BZN 17) or Palmhout[20] shipwreck. The Burgzand North area is renowned for its high archaeological value as it contains at least 12 known shipwrecks from the 16th, 17th and 18th centuries. It has been declared a natural heritage site in the Netherlands (Rijksmonument) and was included in European research projects such as MoSS[21] and

[17] http://moss.nba.fi/eng/bzn-10.html Retrieved 10.05.2018
[18] Vos 2015: 65.
[19] Vos 2015: 29.
[20] The shipwreck was given this name because of the logs of boxwood that were found on board.
[21] MoSS (Monitoring, Safeguarding and Visualizing North-European Shipwreck Sites) is a three year shipwreck research project funded by the European Community Culture 2000 Programme. https://mass.maritime-heritage.com/burgzand-noord-17-bzn-17http://www.nmm.pl/1stCHFpdf/pdf_articles/8.1_all.pdf

MACHU[22], monitoring and protecting historical underwater sites.[23] Hence, it did not come as a surprise when, after their first diving sessions, the group reported small finds, such as tapestry fragments lying adjacent to the shipwreck.

During a crucial visit in 2014, the diving team noticed that the sand covering the well-preserved wreck had been partially swept away, revealing a large quantity of the ship's cargo. This is when the majority of the finds were uncovered and brought to land. The treasure is dated to approximately 1640 and it features numerous artefacts, including skilful metalwork and rare examples of clothing[24]. For instance, a complete silk dress (Figure 2.3), which is considered to be one of the most noteworthy marine discoveries ever made, was brought ashore.[25]

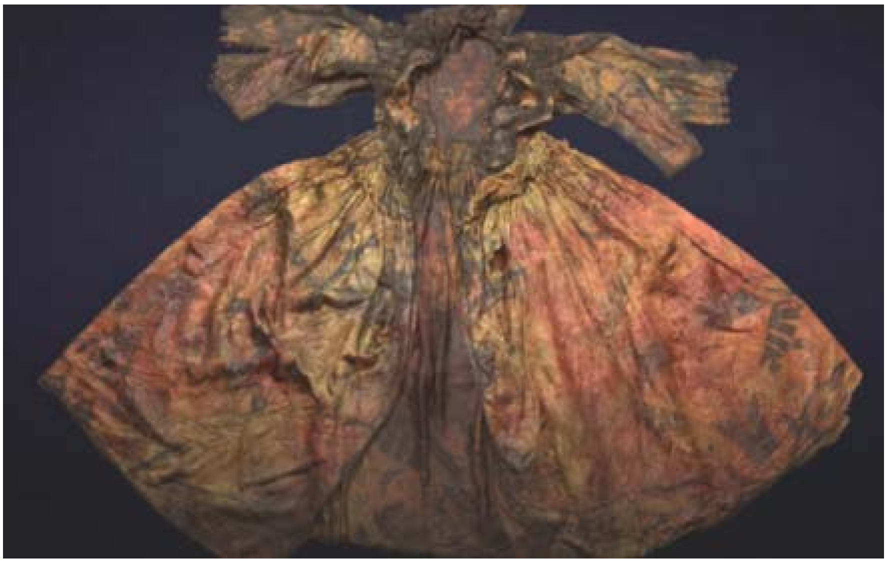

Figure 2.3. *Dress made of silk damask decorated with a floral pattern (museum Kaap Skil)*

2.3. The collection and its significance

"Because in a ship everything is preserved together – as if in a time capsule – this discovery can give great insight into the life and work of those on board and the trade relations and political situation of the time."[26]

-Will Brouwers, Museum Het Valkhof

The importance of the collection is highlighted both by its contextual and material value. The wide range of objects, ranging from day-to-day items to luxurious accessories, provides an overview of the visual aesthetics of mid-17th century European citizens and gives insight into

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22 Managing Cultural Heritage Underwater (MACHU), www.machuproject.eu.
23 https://cultureelerfgoed.nl/sites/default/files/publications/scheepswrak-burgzand-3-en-10.pdf Retrieved 01.04.2018
24 https://www.modemuze.nl/blog/textielschat-uit-zee Retrieved 02.04.2018
25 https://mass.maritime-heritage.com/burgzand-noord-17-bzn-17 Retrieved 01.04.2018
26 ibid

their customs and culture. Furthermore, these objects give researchers a chance to study historical manufacturing methods and identify the materials used. The objects consist of a wide range of materials such as leather, textiles, metals, wood, glass, earthenware and many more. The collection is currently located at Huis van Hilde, the Archaeological Depot of the Province of Noord-Holland where the objects are investigated by various institutes such as the Dutch Cultural Heritage Agency (RCE), University of Amsterdam, the Rijksmuseum and the School of Historical Dress.[27]

A large part of the collection is made up of elaborately decorated textile finds that were stored in large wooden chests. The textile fragments and nearly complete garments comprise a total of 108 loose finds. In 2016, a major inventory procedure was carried out in collaboration between the University of Amsterdam and the Dutch Cultural Heritage Agency (RCE). Marijke de Bruijne and Sjouke Telleman, postgraduate students in the Textile Conservation Department, divided the textile finds into 26 object groups and characterized each object by its material, manufacturing techniques, patterns, measurements and condition.[28]

The manufacturing methods for the textile garments are of remarkably high quality, showcasing precious materials and premium craftsmanship. Densely woven silk forms the main material component of nearly all the items found. A large number of the garments are decorated with fine metal embroidery. These thin metal wires are applied with utmost care and demonstrate the technique in its best quality. Furthermore, the collection represents a large variety of metal thread application methods. In some cases, metal strips are woven into the textiles, but in most cases the threads are applied on ready-made garments.

3. Art-technological research

This chapter provides an overview of the history and manufacturing methods relating to the metalwork of the Palmhout toiletry set. A brief overview is given of the use of metal threads in historical garments. Metal threads are divided into different types and their manufacturing methods are described as presented in literature. The research draws on historical manuscripts such as Biringuccio's *Pirotechnica* but also includes newer publications dedicated to manufacturing methods for metalwork, such as Oppi Untracht's *Jewelry concepts and technology.*

3.1. Historical background

3.1.1. Garments

The use of metal threads either in a woven or embroidered form has existed for millennia. Even though no garments decorated with metal threads originating from ancient times are

[27] https://collectie.huisvanhilde.nl/ Retrieved 15.06.2018
[28] https://www.modemuze.nl/blog/textielschat-uit-zee Retrieved 28.03.2018

physically preserved, numerous written sources provide proof of the techniques' existence. The earliest mention is found in the Old Testament Book of Exodus, originating from the period of 13-12 BC. It describes the making of the pontifical robe (ephod) worn by Aaron as follows:[29]

"And they made the ephod of gold, blue and purple, and scarlet, and fine twined linen. And they did beat the gold into thin plates, and cut it into wires, to work it in the blue, and in the purple, and in the scarlet, and in the fine linen, with cunning work." Old Testament, Exodus, 39: 2-3.

Generally, due to the materials' high cost and laborious manufacturing process, metal threads were used for liturgical garments and church decorations, or clothing and accessories for nobility.[30] Only the best fabrics were used in combination with the meticulously applied fine embroideries. The historical metal threads were manufactured solely from precious metals up to the late middle ages, when less costly embroideries from copper alloys started to be produced for lower classes of society.

3.1.2. Development of the technique

Initially, metal threads were manufactured by hammering a narrow strip of gold into foil. Hammering metal to a delicate thin leaf was already practised by Egyptian goldsmiths by the 5th millennium BC. The first physical proof of cut metal strips in combination with textiles was found in a Macedonian royal tomb in Vergina, dating to the 4th century BC. The metal strips consisted of pure gold that was hammered into a foil thickness of 0.04-0.03 mm and was then cut into strips measuring approximately 0.3-0.4 mm in width.[31]

The technique of manufacturing metal threads from gold, silver or gilt silver remained unchanged up to the 11th century. From then onwards, new ways were invented in order to decrease the threads' weight, making the embroidered garments more wearable.[32] Metal coated leather or animal membrane was cut into narrow strips for use in woven fabrics and for applications to decorations up to the 16th century. This technique subsequently began to be replaced by solid metal strips.[33] Even though metal-coated organic strips allowed the creation of relatively light and affordable garments, they also deteriorated faster and, at least in Europe, were therefore almost completely replaced by solid metal threads by the mid-16th century.[34]

By the beginning of the 16th century, another step was made in the manufacturing methods. Solid metal threads once again became predominant in the embroidered decorations. This was made possible by the introduction of gilt wire. In a book of recipes dating the latest to 1478, an unknown author refers to gilt silver wire as the 'basic material' for metal

[29] Járó 1990: 40.
[30] Muros et al. 2007: 230.
[31] Karatzani 2012: 55-65. (11.)
[32] Járó, Tóth 1991: 181.
[33] Járó 1990: 51.
[34] Járó 1990: 51.

embroideries.[35] The process implied covering a rod of silver with gold leaves that were attached to the surface by heating. These gilt rods could be drawn out into thin wire without exposing the underlying core of silver. The fine wire could then be flattened into wider strips that were spun around a fibrous core similar to the cut strips.

Manufacturing metal threads from gilt wires instead of cut strips had several advantages. Firstly, combining a core of a less costly metal with a thin layer of gold reduced the overall cost of the threads. Secondly, gilt wires were covered with gold on all sides, whereas for the cut strips, the core metal was exposed on multiple sides.[36] This meant that the fully gilt threads tarnished at a lower rate than the threads where silver was partially exposed. Thirdly, the procedure of wire drawing speeded up the manufacturing process significantly, enabling the production of larger quantities of metalwork. All these factors guaranteed a higher demand for the product, providing work to metalworkers, embroiderers and tradesmen.

Despite being a lucrative business, the profession posed many challenges. Firstly, the handling of precious metals implied that all regulations and laws imposed by the state had to be strictly observed. Secondly, manufacturing fine wires and applying them to garments required utmost skill from the metalworkers, weavers and embroiderers. Hence, European craftsmen had to complete a long apprenticeship before becoming entitled to a master's status and being allowed to open their personal workshop.[37]

While there is no clear evidence of the arrival of imported threads in Europe, the records about the local manufacturers and traders of precious metal threads do exist. In London, for example, the local production of fine gilt wires is believed to have started as early as the 1470s.[38] The importance of the industry in England is marked by the formation of the *Worshipful Company of Gold and Silver Wyre Drawers,* which by 1693 was incorporated by the Royal Charter, recognizing its power, legal rights and privileges.[39]

An extensive overview of the association's history is given by Horace Stewart in the book *History of the Worshipful Company of Gold and Silver Wyre-drawers: And of the Origin and Development of the Industry which the Company Represents.,* published in 1891.[40] He describes the function of the association by quoting the words from the Preamble of the Charter: *"The Trade Art and Mistery of Drawing and Flatting Gold and Silver Wyre, and Making and Spinning of Gold and Silver Thread and Stuffe within the Cities of London and Westminster, the Borrough of Southwark, and all other places within Thirty Miles distance from the same."*

[35] Járó 1997: 13.
[36] How many sides were exposed depended on if the strips were gilded on one or both sides. Additionally, the cut edges were not covered by the gilding layer.
[37] http://collections.vam.ac.uk/item/O130131/cloth-of-gold-unknown/ Retrieved 16.06.2018
[38] Dye 2012: 7.
[39] Stewart 1891: 24
[40] The full content of the book is available at https://archive.org/stream/historyofworship00stew#page/n0/mode/2up

The historical records provided in the book create a better understanding of the trade from the 15th century onwards, including visual imagery relating to the practical aspects of the craft. Figure 3.1. depicts the wire drawing procedure carried out on a long drawbench, with two ladies on the background, spinning gold. This allows to deduce that in many cases a variety of metal thread manufacturing processes were carried out under the same roof.

Figure 3.1. *Drawbench, depicted in the book by Horace Stewart*[41]

In the 17th century, there were no further significant advancements in the manufacturing methods for metal threads. In several European countries, the beginning of the century saw a decline in the amount of professionally produced metal embroidery. This happened as a result of new religious movements towards the end of the 16th century: in the Netherlands, for example, the church ceased to be the major commissioner of metal-adorned fabrics because of restricted attitudes promoted by Calvinism.[42] The rich upper-class, nevertheless, retained its interest in the elaborately decorated garments and accessories.

Figures 3.2 and 3.3 present a Dutch example of embroidered artefacts, bride's gloves made of white silk and adorned with fine metalwork dating to the the first quarter of the 17th century. As seen from these images, the decorations consist of metal elements of different shapes and sizes that are similar to the ones found on the Palmhout toiletry set. On that account, the following paragraphs introduce the different types of metalwork used in embroideries in the 17th century Europe and provide a description of the relevant production methods.

[41] Stewart 1891: 24.
[42] Stam 1997: 58.

Figures 3.2.-3.3. *Detail, metal embroidery, bride's gloves, The Netherlands, 1650s*[43]

3.2. Technical classification

Commonly used metal components in the 17th century embroideries were drawn wires, cut strips and flattened disks. Wires had either a round or a rectangular shape and they were commonly applied as purls or *cannetilles* - short lengths of springs that were sewn on the surface of the fabric. Metal strips were either flattened lengths of drawn wire or narrow strips cut from sheet metal. Both types were usually wound around a fibrous core and applied by stitching as a single strand, twisted pair or braided arrangement. Flattened disks, called spangles or *paillettes* were small round rondelles with a centre hole, often combined with a small length of purl, or other decorative elements, such as pearls and beads. Figure 3.4 below summarizes the classification types of these constructional components.

[43] Hirox images by Suzan Meijer; Rijksmuseum, Amsterdam, BK-NM-2921-A

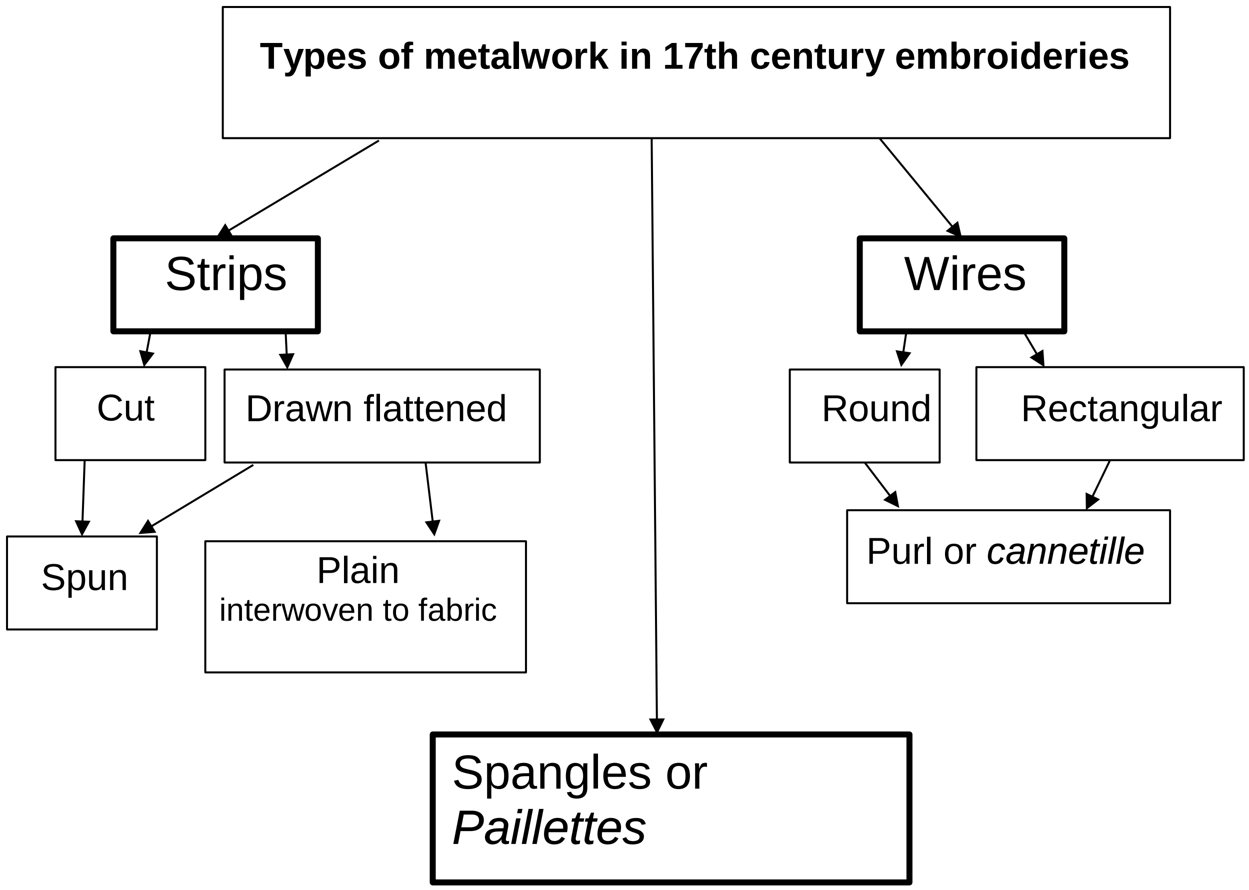


Figure 3.4. *Summary of the common metalwork components in 17th century embroideries*

3.3. Manufacturing methods

3.3.1. Principles of wire drawing

Drawing wire implies that a bar of metal is forced through a die hole that is a fraction smaller than the material's cross section. This is done by pulling the wire from its smaller cross/sectional size and not by pushing from the opposite direction. This operation is repeated as many times as necessary, each time moving on to a smaller die hole, gradually reducing the diameter of the material down to the desired size.

The drawing procedure requires getting the material into a suitable shape and metallurgical state. The rectilinear bar needs to exhibit a roughly cylindrical cross-section that is formed by forging or rolling. One end of the bar needs to be tapered, so that it can enter the die hole in a sufficient length to be gripped firmly with a pair of tongs and pulled through the die hole

(Figure 3.5).[44] As for the metallurgical considerations, heat treatment is needed prior to the drawing process to increase the alloy's ductility.

The heating process, called annealing, implies heating the metal rod either with an open flame or in a kiln, bringing the material to the temperature where recrystallisation takes place. Annealing usually has to be carried out several times throughout the wire-drawing process, as the metal loses its initial ductility during the cold deformations. It is advisable to anneal the metal after the cross-sectional area has been reduced roughly by half.[45] If annealing is not carried out in time, the material becomes brittle and breaks in the process of drawing.

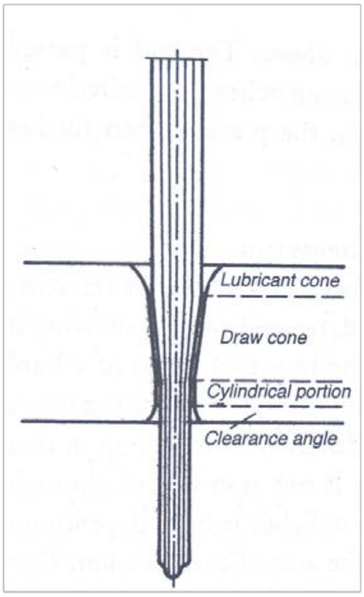


Figure 3.5. *The principle of material reduction in the wire drawing procedure*[46]

The drawing process imposes a high degree of friction on the surface of the metal. To minimise wear and passive resistant forces, lubricating substances such as waxes or soaps are applied on the surface of the wire.[47] A common procedure implies heating the wire gently and rubbing it with beeswax, resulting in a thin even layer of wax covering the surface of the metal.

[44] Brepohl 2011: 162.
[45] Brepohl 2011: 160.
[46] Brepohl 2011: 162.
[47] ibid.

3.3.2. Advancements in drawing techniques

Even though the art of drawing wire was already being practiced in antiquity, there were no significant technological advancements up to the Renaissance period.[48] According to surviving historical records, the setup for the procedure used during the Middle Ages was relatively primitive. A German mid-fifteenth century etching (Figure 3.6) depicts a daily scene in a goldsmiths' workshop. In the lower left corner, an apprentice is drawing wire by standing on a die and thereby holding it in place simply by using his body weight. Figure 3.7 shows a drawing originating from the *Mendelsches Hausbuch* dating from 1425, where the craftsman Dietrich Schockentzieher sits on a swing, pushing with his feet in order to create the necessary motion for drawing the wire.[49]

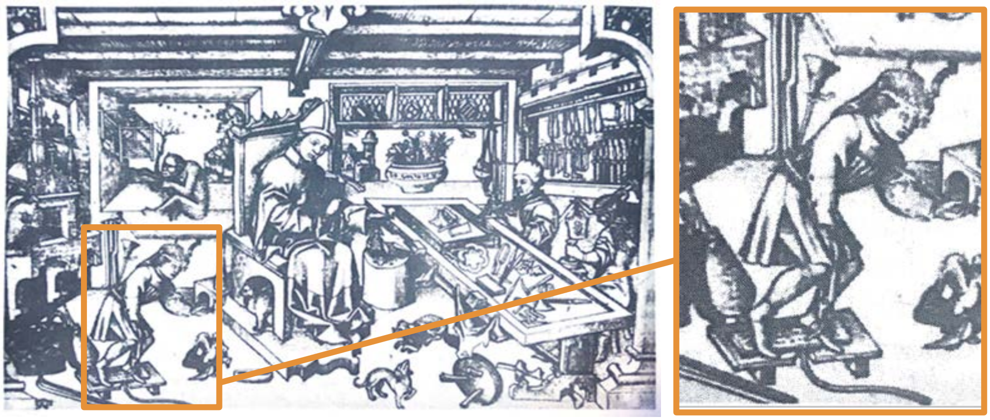


Figure 3.6. *St Eligius in his workshop, 1450-1460* [50] *Wire drawing procedure: the apprentice is drawing wire by standing on the drawplate and pulling in a vertical direction.*

[48] Bimbenet-Privat 2012: 57
[49] Bimbenet-Privat 2012: 57
[50] https://www.rijksmuseum.nl/en/collection/RP-P-OB-963 Retrieved 22-05-2018

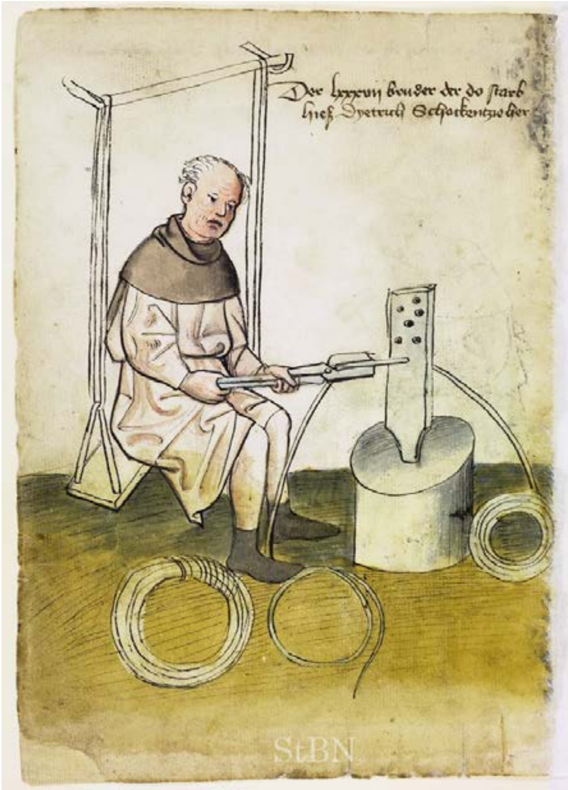


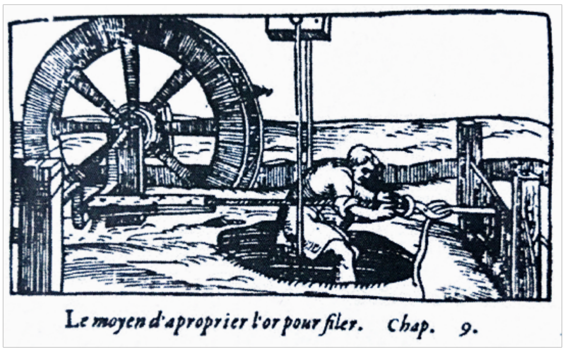
Figure 3.7. *[51] Wire-drawer using the energy of the swing to make the process less laborious.*

Undoubtedly, the 16th century brought several advancements to wire-making technology. A complete description of wire drawing is provided by the well-known Italian metallurgist Vannoccio Biringuccio. In his extensive manual on metalworking, *De la pirotechnica*, published posthumously in 1540, he divides the procedure into two stages: drawing heavy rods and thin wires. Figure 3.8 depicts the drawing process using a heavy capstan with a windlass. As shown by the engraving, the workman has to sit on a swing in order to synchronize his movements with the motion of the paddle wheel and the crankshaft. The worker's task is to maintain a steady grip on the tongs while the mechanism allows him to control the drawing process without major physical effort.

The second stage of drawing finer wires based on historical manuscripts utilizes a variety of manually controlled systems. Two of the shown mechanisms, depicted in Figure 3.9 provide increased force during the drawing process. The first one, a system functioning with a force of a screw is depicted in the right corner. The second method utilizes a belt and a small windlass. Biringuccio describes the rest of the related apparatus as follows: *In addition, a pair of large tongs with flat, serrated mouths and open legs are needed. "These should be held by a stirrup-shaped iron ring which has a hook at the foot to which is attached the end of a belt or rope, the rest of which is wrapped around the small windlass or the large one by turning. In this way the tongs close when you pull them and in that instant take hold of the tip*

[51] http://www.nuernberger-hausbuecher.de/75-Amb-2-317-40-v Retrieved 22-05-2018

of the ends of the gold or silver wire, which has been well greased with new wax and put by the craftsman into one of those holes of the drawplate."[52]



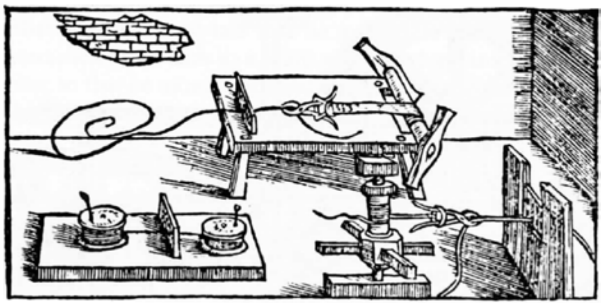


Figure 3.8-3.9. *Wire drawing, Biringuccio (left: Heavy wire drawing by the means of water power: capstan and windlass ; right: manual drawing of finer wire)* [53]

3.3.2.1. Drawbenches

Drawbenches were created to aid the process of drawing thick wire that measures over two millimeters in diameter. The equipment works by connecting the drawtongs by a belt or a chain to a to a large crank.[54] The wire drawing systems in Biringuccio's manuscripts worked based on this principle. However, the apparatus depicted there did not provide the necessary control that was needed in addition to the created force.

In 16th century Germany, great innovations were introduced to this field. The Elector of Saxony, Augustus I, commissioned an intricate piece of equipment designed especially for wire drawing. In close collaboration with a Nurnberg engineer Leonhard Danner, the Elector commissioned a device that would enable him to draw large amounts of fine precious metal wire that would then be used for jewellery or richly embroidered textiles. At that time, drawbenches were already in use, but the improvements that Danner introduced brought his design well ahead of its time.[55] Danner's revolutionary drawbench is depicted in Figure 3.10.[56]

[52] Gnudi, Biringuccio, Smith 1990: 379-380
[53] ibid
[54] Brepohl 2011: 162
[55] Bimbenet-Privat 2012: 57
[56] Danner's draw bench was unique at the time for its hidden mechanism, containing a screw mechanism. (*Bimbenet-Privat 2012: 57*)

Figure 3.10. *Drawbench, commissioned by Augustus I of Saxony, constructed by Leonhard Danner.*[57]

Similar innovations were seen also elsewhere in Europe. In France, drawbenches appear to have been rare before the mid-16th century, but they then found their way to goldsmiths' premises. Proof of this is found from inventories that were recorded after the death of a goldsmith. These documents only mentioned manual drawing equipment up to the 1550s. The first mention of the use of a drawbench in Paris originates from 1557 and is followed shortly by other similar descriptions. An example from the workshop of Claude Taubin marks the use of a mechanism for drawing gold wires together with a large pair of tongs: "*Ung engin à tirer fil d'or et une paire de grosses tenailles à tirer".*[58]

Obtaining finer wires was achieved by different means, as most drawbences did not provide enough control in handling these delicate wires. In addition, lengths of fine metal thread had to be stored on drums in order to prevent damage. Thus, a construction consisting of two manually turned drums, depicted in the left corner in Figure 3.9 and in Figures 3.11 and 3.12, was often used for the purpose. A visually similar system depicted in other historical illustrations does not show the use of a drawplate, indicating that wire is being stretched in order to reduce its thickness (Figure 3.12).[59]

[57] https://www.gettyimages.ca/detail/news-photo/the-wire-drawing-bench-of-leonhard-danner-of-nuremberg-news-photo/98452369 retrieved 16.05.2018
[58] Bimbenet-Privat 2012: 67.
[59] Bimbenet-Privat 2012: 56.

Figures 3.11-3.12. *Wire drawing and stretching, as depicted in Mendelsches Hausbuch*[60]

3.3.2.2. Rolling

Rolling is a process in which the metal's dimensions are decreased by compressive forces: the metal is passed through a pair of rollers revolving in opposite directions.[61] This procedure results in a flattened and elongated piece of metal. On the basis of existing sketches by Leonardo da Vinci, the invention of the rolling mill is attributed to that artist.[62] The first flattened wires for embroidery are believed to originate from 16th century Augsburg in Bavaria, where the technique supposedly was kept secret. As a result, the precise method used is not known.[63]

3.3.3. Metal strips

Metal strips, cut from thin sheets of metal, can be commonly found in earlier historical embroideries of the 16th century, but were gradually replaced by flattened wire strips during the next century.[64] Regardless of their wide usage throughout history, relatively little is known about the exact manufacturing methods for these threads. According to Biringuccio, a metal sheet (both single or gilded) was hammered into a very thin foil, after which it was cut into narrow strips with 'a long, flexible and sharp pair of scissors'.[65] These strips are known to have been relatively short. Járó describes examining a Roman textile from the 4th century, found in Hungary, where it was confirmed that the longest strip was only 75 millimetres long. 'Over sections about 5 mm long, the strips were wound around each other. The short segments were joined this way, probably in the course of the winding up procedure'.[66]

[60] Bimbenet-Privat 2012: 66, 56.
[61] Karatzani 2012: 55-65 (10).
[62] Scott, Podany, Considine 1994: 162.
[63] Glover 1967: 1, Karatzani 2012: 55-65 (10).
[64] Járó 1997: 5.
[65] Gnudi, Biringuccio, Smith 1990: 382.
[66] Járó 1997: 9.

3.3.3.1. Spinning

The technique of winding the thread around an organic core is considered a major milestone in the history of metal thread manufacturing, as these types of threads were easy to work with and possessed a desirable round shape that was similar to organic yarns.[67] According to current scientific knowledge, the exact origin of this technique cannot be confirmed. It is known that the technique of spinning metal strips was practiced during the late Roman period and that a spindle was used to produce either S or Z-twisted threads, as illustrated in Figure 3.13 below.[68] When an organic core was used in combination with wound metal, the fibres would normally be spun in the opposite direction to the metal strips.[69] Figure 3.14 presents equipment used for spinning in the mid-18th century. Earlier illustrations (Figure 3.1) suggest that similar equipment was also in use in the 17th century.

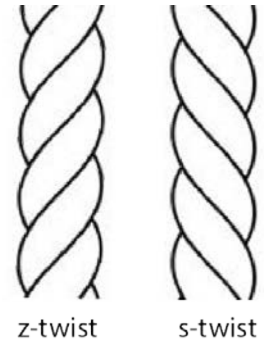


Figure 3.13. The spinning principles of S and Z-twist

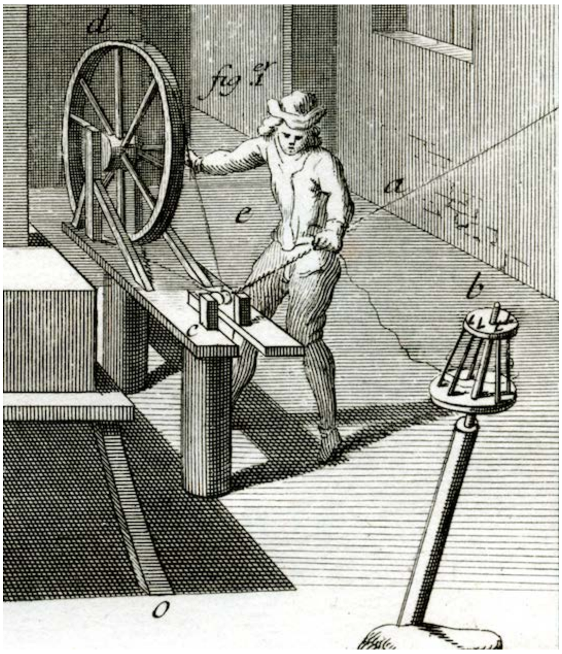


Figure 3.14. Equipment used for spinning[70]

[67] Karatzani 2012: 55-65 (3).
[68] Wild 1970: 39-40.
[69] Muros 2007: 238.
[70] Perronet 1765

3.3.4. Spangles

The spangles, yet another common decorative element of the embroideries, were commonly made by flattening a section of coiled wire. This process was relatively easy to carry out and the wires used for this purpose were often gilded. Additionally, there are records of spangles that were punched out of a metal sheet, but these are less commonly found in the later periods.[71] A method of combining spangles wirework is presented in Figure 3.15.

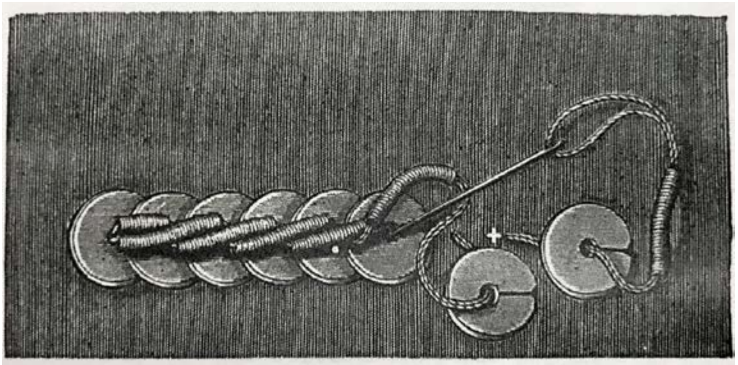


Figure 3.15. Attaching spangles.[72]

3.3.5. Gilding

Gilded silver metalwork is often encountered in 17th century embroideries. This implies that silver base material is covered with a thin layer of gold. The gilding in this period was mainly carried out by covering silver rods or sheets with gold leaf and heating them to fuse the metals onto their surfaces. This process is referred to as heat welding. Another gilding method was named fire gilding or mercury gilding. In this technique, gold amalgam [DB1] was heated and simultaneously with the evaporation of mercury, a small amount of silver was being dissolved and remaining gold deposited on the surface, resulting in the formation of a gold-silver alloy on the surface.[73] This method was utilized for larger objects and is rarely encountered in metal embroideries.

The advancements in gilding and the use of gilded metalwork in embroideries was a major step in the field but also gave rise to many ethical questions. As gilded wires were introduced, it became impossible to distinguish with the naked eye what metal was used. Gilded silver became an often-used material for metal embroideries but from the 16th century onwards, metal threads with a copper core have also been documented.[74]

Gilded or silvered copper threads were used only in embroideries commissioned by less wealthy people[75] or manufactured for theatre costumes.[76] Biringuccio, for example, in his

[71] Dye 2012: 9.
[72] "De Gracieuse" 1887: 3.
[73] Gold amalgam is an alloy of mercury and gold, usually in a paste form.
[74] Járó, Tóth 1991: 176.
[75] Járó, Tóth 1991: 181
[76] Karatzani 2012: 55-65 (6).

16th century manuscripts, refers to gilt copper wires as a ‘great fraud’.[77] In some countries, the use of these ‘false threads’ was strictly forbidden. In the Netherlands, where the embroiderers received a separate charter in 1610,[78] a discovery of this kind of fraud was said to end with burning the work and punishing both the maker and the buyer: *“Niemandt van desen Gilde en sal mogen verstouten eenich valsch gout off Silver onder het fijn te verwercken, noch gewrocht te vercopen. Op pene dat sulck werk openbaerlyck sal worden verbrandt. Ende die het gemaeckt off vercoft heeft staen tot arbitrale correctie vanden Gerechte.”* [79]

3.4. Alloys and their importance

Whatever final shape the metal will have, one always starts by casting an ingot from the desired alloying components. Pure precious metals are extremely malleable and therefore unsuitable for many purposes. In addition, delicate constructions need to withstand impact and wear. In order to make precious metals such as silver and gold more durable, other alloying components are added to fine metals prior to the melting procedure. For good workability, the alloys often combine copper with silver or gold.
Matching the alloy to a manufacturing process is crucial. Manufacturing wires implies starting from a relatively thick rod-shaped ingot, reducing it gradually to the desired thickness. When metal undergoes deformation, the grain structure of the material changes and internal stress builds up. This phenomenon is called work hardening. In order to keep metal malleable, it needs to be annealed systematically, heating it to the point where recrystallisation takes place. Producing extremely fine wires implies that the metal would remain malleable for a longer time. Mechanical actions result in work hardening of the metal, making it brittle and more likely to snap.

3.5. Summary

The following Tables 3.1-3.2 present a schematic illustration of the manufacturing methods of each metalwork element.

[77] Gnudi, Biringuccio, Smith 1990: 380.
[78] De Bodt 1991: 3.
[79] ibid.

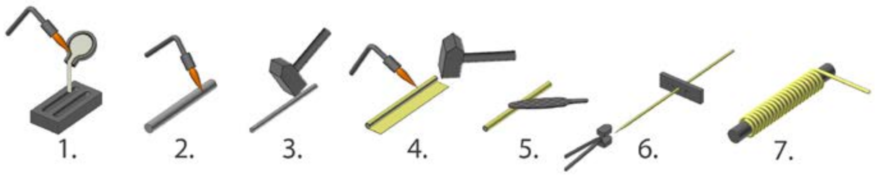
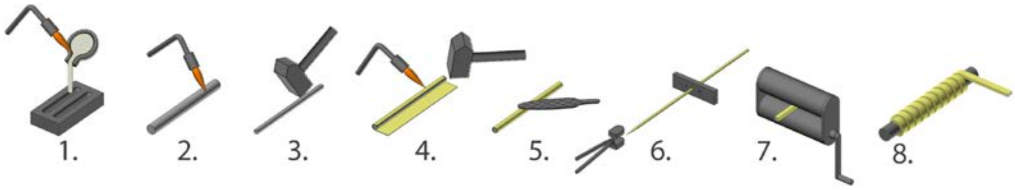
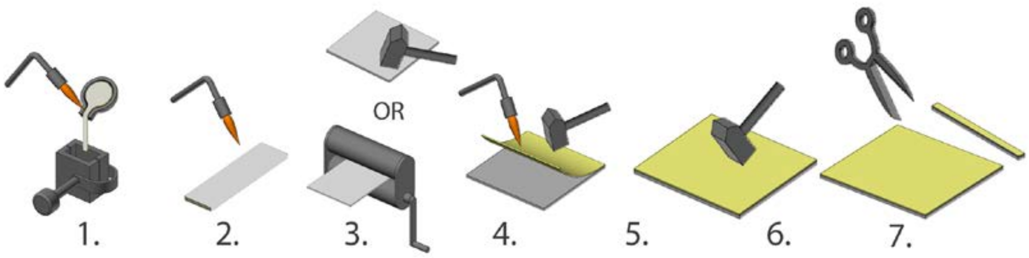
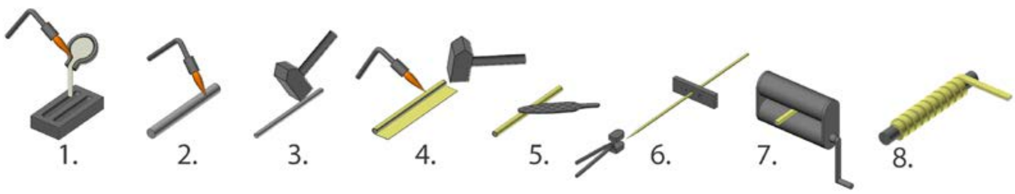
Round purls	
	1- *casting;* ***2-*** *annealing;* ***3-****hammering down;* ***4-****applying gold leaf;* ***5-****filing;* ***6-****drawing;* ***7-*** *coiling*
Flat purls	
	1- *casting;* ***2-*** *annealing;* ***3-****hammering down;* ***4-****applying gold leaf;* ***5-****filing;* ***6-****drawing;* ***7-*** *rolling* ***8-****coiling*
Cut strips	
	1- *casting;* ***2-*** *annealing;* ***3-****hammering down or rolling;* ***4-****applying gold leaf;* ***5-****hammering thinner* ***6-****cutting*
Flattened strips	
	1- *casting;* ***2-*** *annealing;* ***3-****hammering down;* ***4-****applying gold leaf;* ***5-****filing;* ***6-****drawing;* ***7-*** *flattening* ***8-****spinning*

Table 3.1. Manufacturing process of purls and metal strips.

Spangles	
	1- *casting;* ***2-*** *annealing;* ***3-****hammering down;* ***4-****applying gold leaf;* ***5-****filing;* ***6-****drawing;* ***7-*** *coiling;* ***8-****cutting into sections;* ***9-****flattening into disks*

Table 3.2. Manufacturing process of spangles.

4. Object characterization

The historical manufacturing methods in the previous chapter explained the techniques that probably were also employed for the Burgzand North toiletry set. The current chapter introduces these objects based on the visual examination. The general condition of each object is documented in writing and illustrated visually, including references to known conservation treatments, where applicable. Furthermore, the initial function of the objects, if known, is briefly discussed.

To narrow down the focus, the selection of the research objects from the full collection was made on the basis of discussions with other researchers.[80] The criteria for choosing the objects were based on limited previous research and simultaneously conducted research in other disciplines. As a result, a 17th century toiletry set, consisting of five objects, was chosen as the research topic.

4.1. Object 1 - Loose textile fragment

This loose textile fragment (inventory number 6263-116) has undergone severe degradation, but despite having lost the majority of its mineralised metal threads, the object proves useful for understanding the initial shape and application methods of the decorative elements.

[80] Simultaneously, further research is being carried out by Suzan Meijer (Head of Textile Conservation, Rijksmuseum) and Ana Serrano (Researcher Rijksdienst voor het Cultureel Erfgoed)

The rectangular piece of unlined fabric (Figure 4.1) measures approximately 13 x 15 centimetres. It is made of densely woven red silk velvet, decorated with metal threads that have been sewn onto the fabric. Its original function is unclear, as in its current state only a flat unlined piece of textile has remained, exhibiting torn edges and highly deteriorated metal embroideries.

While clearly showing similarities in its ornamental decorations, the piece was not attached to any of the other finds and cannot therefore be assumed to have been part of any of the objects. Even though Object 5 (to be described below) is missing large portions of its silk velvet components, it is unlikely that the fragment would have formed its centrepiece. Based on literature, an embroidered tablecloth was a common part of a toiletry set, but in most cases the decorations would be applied only along the edges, as the centre of the cloth was left undecorated for placing the utensils.[81]

Figure 4.1. *The front side of the loose textile fragment*[82]

Based on visual analysis and literature research, it is possible to make assumptions concerning the original function of the piece. It is likely that the textile fragment used to form part of a pincushion. As mentioned above, pincushions were commonly part of toiletry sets, as the dressing ritual often involved altering the garments (Figures 4.3 and 4.10).

[81] Information obtained during the discussions with Suzan Meijer, Head of Textile Conservation, Rijksmuseum.
[82] Photo by Margareta Svensson.

On close inspection, a long straight decorational element is seen (Figure 4.2) that is likely to have formed the bordering element of the piece, thereby setting the potential dimensional limits for the piece. Furthermore, the fact that no remaining lining can be found might indicate that the piece had been used in a filled construction. Small rectangular pincushions have often been found both physically and in illustrations. To judge from comparisons with existing objects, the scale would match existing 17th century pincushions.[83]

Figure 4.2. *Potential bordering element*[84]

Figure 4.3. *An early 19th century etching demonstration of the dressing ritual and a pincushion.* [85]

[83] Suzan Meijer, Head of Textile Conservation, Rijksmuseum, personal correspondence.
[84] Photo by Margareta Svensson.

4.2. Object 2 - Clutch purse

This object, depicted in Figures 4.4-4.6, (inventory number 623-111) was originally found containing a wooden lice comb. It is highly similar to the loose textile fragment described above. The embroidered pattern is not identical, but the same decorative elements and identical wire application methods can be found throughout the piece. Furthermore, the scale of the two pieces is similar and the application style gives reason to assume that these pieces were made by the same craftsman, using the same or similar source materials.

Unlike other objects, the edge of the clutch is adorned with a thick braided edge consisting of multiple strands. It also shows a fringed decoration that was meant to close the bag. The most remarkable difference, however, lies in the object’s condition, as the purse still retains the majority of its decorative elements. Some damaged areas on the outer layer of the fabric can be found, but the inner silk lining is fully intact and all side seams have been preserved. The front shows the greatest degradation in its lower right corner, where lining is exposed and small patches of silk velvet are missing, in several cases, together with metal embroidery. On the reverse side, the loss of fabric in the upper layer is greater, leaving the lining exposed over the whole lower left corner.

Interestingly, the metal embroidery on the front side exhibits colour differences; when the flap is opened, brighter metallic embroidered details can be seen close to the upper edge of the clutch, following the outline of the flap. This difference is mainly caused by the lack of oxygen in the mentioned area above and indicates that the bag has been stored with the flap folded over. A photo taken by the divers’ group right after bringing the piece ashore confirms that the darkening of the exposed areas had already taken place in the seabed.[86]

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[85] https://www.rijksmuseum.nl/en/collection/RP-P-2009-4158

[86] According to personal correspondence with the divers' group, Castricum, May 2018.

Figure 4.4. *Clutch purse with the flap folded open*[87]

Figure 4.5. *Clutch purse with the flap folded down*[88]

[87] Photo by Margareta Svensson
[88] Photo by Margareta Svensson

Figure 4.6. *Reverse side of the clutch*[89]

4.3. Object 3 – Brush

Figure 4.7 shows a rectangular piece of decorated fabric (inventory number 623-112). It measures approximately 16 x 7 centimetres and covers the back of a wooden brush of similar size. Like the aforementioned objects, it is made of densely woven red silk velvet, decorated with metal threads that have been applied onto the fabric.

[89] Photo by Margareta Svensson

Figure 4.7. *Brush, detached.*[90]

The embroidered pattern of this object shows strong similarities in decorative elements and wire application methods to the aforementioned two objects, and to the mirror (to be introduced below). However, certain differences can be pointed out. The pattern is scaled down in size and the metalwork application method differs from the rest of the objects in certain areas. This last observation will be discussed in further detail in Chapter 6 (Results).

The object is in fairly good condition, showing no major loss in its metalwork. However, the deposited corrosion products have altered the surface appearance significantly, forming a coarse crust over all embroidered areas.

4.4. Object 4 - Mirror

Figure 4.8 presents the decorated frame of a dressing-table mirror (inventory number 623-111), measuring approximately 30 x 25 centimetres. Two foldable panels, covered on both sides with embroidered silk velvet, are attached to the underlying wooden frame by small hinges and can be fixed in a closed position by small hooks. The mirror's embroidered motifs clearly resemble those found on the previously described objects.

The mirror has been subjected to a substantial conservation treatment and therefore was not fully examined during this research.

[90] Photo by Margareta Svensson.

Figure 4.8. *Dressing table mirror, frontal view*[91]

4.5. Object 5 - Tablecloth

The tablecloth (inventory number 6263-045), depicted in Figure 4.9, is the largest of the set, measuring about 100 x 100 centimetres. Due to its size and fragility, this object was not transported to the studio. However, loose fragments originating from the piece (inventory number 6263-035) could be brought to the studio for further research.[92]

Interestingly, the embroidery uses same type of twisted threads as the other objects, but demonstrates differences in the pattern use. The highest similarities in decorative patterns are between the tablecloth and the brush, illustrated by a bordering motif. Furthermore, Figure 4.10 shows an existing 17th century toiletry set, also containing a tablecloth, supporting the hypothesis that this object does form an *ensemble* with the other Palmhout objects.

[91] Photo by Restaura.
[92] Photo in Appendix I.

Figure 4.9. *The decorated edge of the tablecloth.*[93]

Figure 4.10. *A 17th century toiletry set, demonstrating the presence of a tablecloth among other toiletry utensils. In the collection of Fries Museum, Leeuwarden.*

[93] Photo by Margareta Svensson.

5. Methodology

5.1. Examination strategy

The five research objects were subjected to two stages of research: optical and scientific analysis. The aim or the investigations was to describe the physical characteristics of the metalwork and determine the original materials. Furthermore, the metalwork's condition was to be recorded to form a basis for future research.

The optical analysis involved preliminary inspection by eye and further microscopic investigations. This stage was followed by scientific analysis conducted in order to determine the elemental composition of the material and to get a better insight into the shape and dimensions of the fine metalwork. In addition to the non-destructive methods such as X-ray fluorescence (XRF), physical samples were taken to be examined by the Scanning Electron Microscopy/Energy-dispersive X-ray Spectroscopy (SEM-EDX).

This chapter will thus explain the considerations and the practical procedures for each research stage. The results of the analysis will be stated in the next chapter (Results*),* and, conclusively linked with further context, such as the manufacturing methods, in Chapter 7 (Discussion).

5.1.1. Visual inspection and optical microscopy

The main aim of the preliminary investigation was to differentiate various decorative elements. Considering the rarity and historical value of of the objects, this stage relied on the use of non-destructive research methods. Thus, thorough visual inspection with the naked eye and further investigation by a stereomicroscope were carried out. The equipment used was a Leica MZ7.5 stereomicroscope with Photonic A1160 light source.

On the basis of the visual inspection, preliminary object mapping was carried out, documenting the arrangement of different types of metalwork, such as round and rectangular wires, metal strips and flattened disks. Supplementary notes were made based on the condition and anomalies from the standard bulk. The selection was narrowed down to a maximum of 12 areas per object for further examination with the optical and Hirox digital microscope. The areas were chosen to represent specific threads or decoration types. Additionally, certain areas were chosen to document noteworthy phenomena relating to the condition of the objects.

While all five objects were examined visually, extensive microscopic investigation could be carried out only on four research objects (Objects 1, 2 ,3 and 4). Inspection of those four objects took place at the metal conservation studios of the University of Amsterdam and the Rijksmuseum. The tablecloth (Object 5) remained in the storage unit of the Archaeological Museum Huis van Hilde because of its delicacy and large dimensions. As less equipment was at hand at this location, the object was consequently not fully examined under the microscope. However, loose fragments belonging to the tablecloth were examined under a stereomicroscope together with the rest of the objects.

5.1.2. Hirox digital microscopy

Following the visual examination, the second investigation stage was carried out by Hirox digital microscope. The equipment used was Hirox KH-8700 with a standard zoom lens MX-2016Z / MXG-2016Z with the ACS (Auto Calibration Select) function, with a diffused lighting adapter.[94] The aim of this stage was to obtain high-resolution magnified images of all thread types and to carry out preliminary measurements of the metalwork elements. On similar grounds as described in the previous paragraph, the Hirox examination was carried out to a full extent on four objects (Objects 1-4), analysing up to 12 areas per object. The loose fragments belonging to the tablecloth (Object 5) were documented to a lesser extent.

The standard Hirox zoom lens used in the normal mode has a magnification factor of up to 160, making it possible to study the general shape and the surface characteristics of the metalwork. Due to the small scale of the embroidery, the rigid arm was chosen to achieve higher image quality. At all times, anti-vibration mode was switched on and image was taken over the locked (frozen) image. The line measurement tool was used in the magnification range of 120-160 times. Additionally, raking light was occasionally used on uneven surfaces to emphasize surface features.

5.1.3. X-ray Fluorescence

X-ray fluorescence is a well-established analytical technique and it is widely used to investigate the materials of archaeology.[95] Nevertheless, in the current context its use comes with limitations. XRF allows a qualitative assessment of elements present on the surface, but it is not possible to accurately measure the composition of the body metal.[96] The surfaces of the objects were highly corroded and were likely to contain foreign elements from the burial environment. Furthermore, elemental detection over precise areas of fine metalwork was expected to be challenging as a result of the uneven surface of the applied wires.

Hence, XRF analysis was not expected to supply reliable quantitative information on the elementary composition. Even though its non-destructive nature often makes it suitable for analysis of historical objects, XRF analysis was used here only in the early stages of the research to gain basic understanding of the materials present and the results therefore are not discussed further in detail.[97]

[94] The Hirox examination was conducted under the supervision of Ellen van Bork (UvA/Rijksmuseum and Sara Creange (Rijksmuseum).
[95] Ferretti, Miazzo and Moioli 1997: 241
[96] ibid.
[97] The results of XRF are not provided as they were not considered representative.

5.1.4. SEM-EDX

As explained in the previous paragraph, the compositional analysis of archaeological objects is challenging due to an excess of corrosion products and possible contamination from the burial environment. As surface techniques such as XRF are not able to provide accurate data, the cross-sectional areas had to be exposed in order to gather information about the chemical constituents of the metalwork components. Thus, physical samples were taken in order to be analysed by scanning electron microscopy (SEM) with energy dispersive x-ray spectroscopy (EDX).

Detecting the original alloying components played a vital role in supporting both the historical and art technological aspects of the research. It was desirable to compare the Burgzand metalwork composition to other historical objects from the same period. Furthermore, as explained in Chapter 3, the alloy has a direct relation with manufacturing techniques as its composition has a major influence on the physical properties of the material and thereby dictates certain technical processes. The elemental analysis of the body metal was therefore expected to shed light both on the manufacturing methods and on the historical context of the objects.

The secondary aim was to get a better understanding of the physical shape of the metal applications. As the majority of the surfaces were covered with bulky corrosion products, the overall form of the fine metalwork was distorted. It was expected that the corrosion products and the original core material would show up differently on the cross sections, giving better insight into the dimensions and profile shapes of the objects.

Finally, the third aim was to investigate the stratigraphy of corroded metalwork, describing the build-up of the core metal, possible gilding remains and its interface, and additional corrosion products. This information was valuable for assessing the condition of the objects and providing a starting point for future research within the field of marine conservation.

5.2. Sampling

The samples were chosen to represent different thread types and exhibit outstanding visual features such as remains of gilding layers. The main aim of the analysis of physical samples was to establish whether metal threads with different cross-sectional shapes demonstrated similar compositional features *(similar core metal, presence of gilding)* and were thus expected to have a similar original appearance. Additionally, as discussed in the previous section, examination of the cross-section of the wires, strips and rondelles was expected to shed light on the manufacturing methods. For example, studying the elemental distribution at the interface of the gilding layer and core material can help to determine the gilding technique.[98] Thus, the samples were chosen after thorough optical analysis based on the relevance to the research focus.

[98] Járó, Tóth 1991: 181.

In addition to the suitable character, an important consideration for sample removal was to minimize losses to the original material. All sampling was therefore carried out under a stereomicroscope. As the metalwork was covered with a hard mineralised crust and removal of individual wires carried the risk of breaking off larger pieces, samples were chosen from areas that had already undergone damage. In most cases, only partially dissociated fragments were sampled to ensure that the samples would originate from the chosen object areas.

In total, nine samples were analyzed.[99] Seven samples were removed from the objects. Two out of the nine samples were not attached to the object (Sample 5 and 7, Object 5). These samples, a loose strand with spun metal strips and a spangle, were picked out amongst loose fabric fragments that had detached previously during the archival procedure and were confirmed to have originated from the object.[100]

Six samples were chosen for examining the cross section of the metalwork. These samples were embedded in the resin SpeciFix 20. Considering the small size of the samples, grinding and polishing was carried out manually without using the motorized polishing wheel. During polishing, the samples were inspected under a stereomicroscope after short intervals to ensure that grinding would be halted after a desired cross-sectional area was reached.

Grinding was carried out on all six samples at a slow pace to avoid overheating or potential sample loss. Fine silicon carbide abrasive papers were used in combination with water (grit sizes 800, 1000, 1200, 4000). Polishing was carried manually on a Struers velvet disk with Struers polycrystalline diamond spray (DP-Spray 9, 6 and 1 µm accordingly) and DP lubricant. Hirox images were taken from the samples prior to SEM-EDX examination.[101]

5.3. Practical procedure

Since the material was fragile, two different sample-taking approaches were used. Loosely attached fragments were removed with weakly adhesive tape. Other samples were removed by cutting textile fibres with sharp pointed scissors and removing the metalwork sample with tweezers together with the textile fibres.

Due to the small scale and low weight of the sampled material, all specimens were embedded in two stages. In this way, maximum control was achieved over the desired orientation of the sample. SpeciFix 20 mounting resin was chosen for embedding because of its low viscosity and fast setting time: there was no danger of dissociating the sample upon pouring and it could be polished in eight hours after mixing the two components.

[99] Sample 3 is presented in Appendix II as it was highly deteriorated and the analysis results were not considered reliable.
[100] This hypothesis is confirmed by the archival documentation of Huis van Hilde, repository of the Dutch province North Holland.

5.3.1. Sample 1

Sample S1 originated from the loose fabric fragment (6263-116). It was the first sample taken and analysed by the SEM-EDX in the early stages of the research when it was not yet clear what materials were used in the embroideries. After microscopic inspection, it appeared to contain fragments of the original gilding layer.

The fragment was removed under the microscope by using adhesive tape. This sample was subjected to surface analysis and was therefore not embedded. A Hirox image of the sampling area is presented in Figure 5.1. The sample consists of the mineralised crust of corrosion products that marked the surface of two adjacent rectangular wires (Figure 5.1). The original wires were completely destroyed by the corrosion process, correspondingly resulting in a negative shape of corrosion products, indicating the interface of the remaining concretion layer and original metalwork.

Figure 5.1. *Sample S1: object 6263-116 before removal. X80, Hirox.*

5.3.2. Sample 2

Sample S2 is a section of a spun metal strip that was removed from detached textile fragments (6263-035) belonging to the tablecloth (6263-045). The sample was embedded and sectioned mechanically by manual grinding and polishing according to the methods described in the introduction to this chapter. The cross-section was exposed in order to study the alloy composition, detect possible remains of gilding and measure the thickness of the material. Figure 5.2 presents a Hirox image of the sample after polishing.

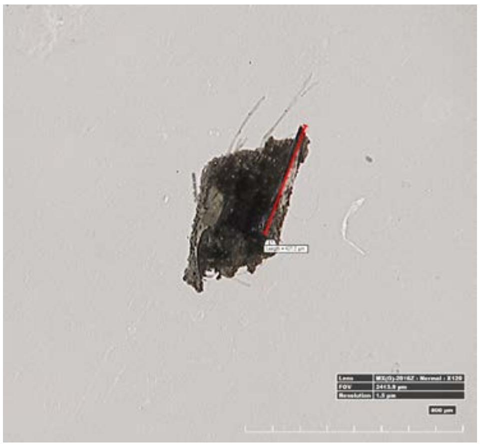


Figure 5.2. *Sample 2: flat metal strip measuring 421.2 µm in width. X120, Hirox.*

5.3.3. Sample 4

Originating from the clutch purse (6263-111), sample S4 consists of a pair of round wires covered with a crust of corrosion products. The wires were selected with attention to the orientation of the sample so that maximum precision would be achieved in exposing the correct cross-sectional area. As for previous samples, the aim was to determine the main alloy constituents and to search for possible remains of gilding. The polished cross-section of the sample is shown in Figure 5.3.

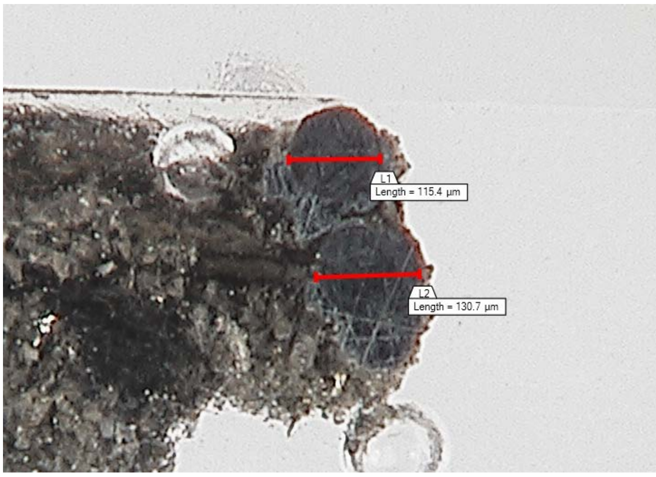


Figure 5.3. *Sample 4: round wires with an approximate diameter of 0.1 mm*

5.3.4. Sample 5

Sample 5, belonging to detached tablecloth fragments, was embedded for cross-section analysis. The sample was chosen as it was not directly attached to the piece and therefore did not cause further damage to the object. As it appeared after sectioning, the fragment was highly deteriorated. Analysis was conducted but an alternative sample from the same category was taken to give more accurate data about the alloy composition and the stratigraphy of the decorative element.

Figure 5.4. *Sample 5: paillette, cross-section.*

5.3.5. Sample 6

Sample S6 (Figure 5.5) originates from the loose fabric fragment (6263-111). It consists of a coil of flat wires. The sample was sectioned to expose the cross-sectional area of the wires. In total, eleven rectangular cross-sections can be seen. This fragment was sampled after the examination of sample 3[102], with the aim of gathering more information about the alloy composition of this wire type. The sampled material exhibited good condition, while its position on the edge of the object caused a minor visual change to the object. The sample was detached from the textile fibres by using tweezers and adhesive tape.

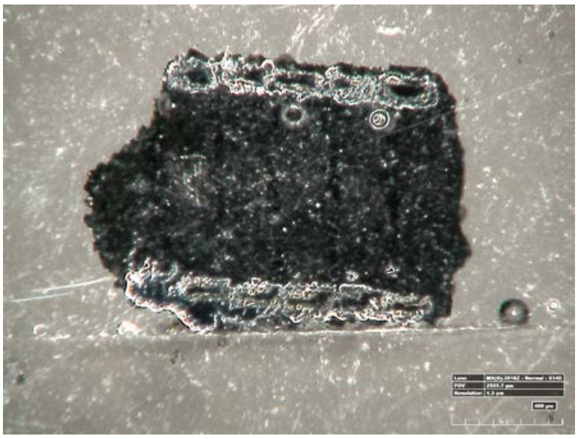


Figure 5.5. *Sample S6: coiled rectangular wires, cross-section. Hirox, X140.*

5.3.6. Sample 7

[102] Sample 3 represents the same wire type. As it was highly corroded and not considered representative, the relating results are presented in Appendix II.

Sample S7 was analysed in order to study the surface features and edge characteristics of the flat metal strips. In this case, a loose fragment (two twisted strands with spun metal strips) (6263-035) belonging to the tablecloth (6263-045) was examined at less deteriorated areas (Figure 5.6). The focus of the investigation was to take images illustrating the surface and edge characteristics and carry out elemental analysis on the edges. The main surface was scanned for potential tool marks and other significant features, and analysed for elemental composition by EDX.

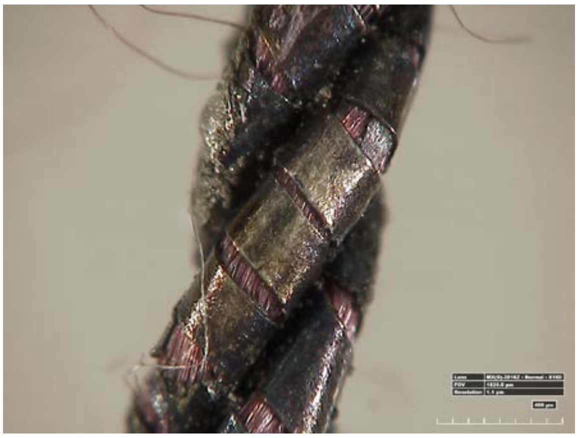


Figure 5.6. *Sample S7: spun metal strips. Hirox, X160.*

5.3.7. Sample 8

Sample S8 originates from the toiletry brush (6263-112) and was sampled from the surface of a spangle. This area was of interest due to a powdery orange substance found on several locations on the object. The goal was therefore to determine the composition of the substance. The sample was not embedded and is seen in Figure 5.7.

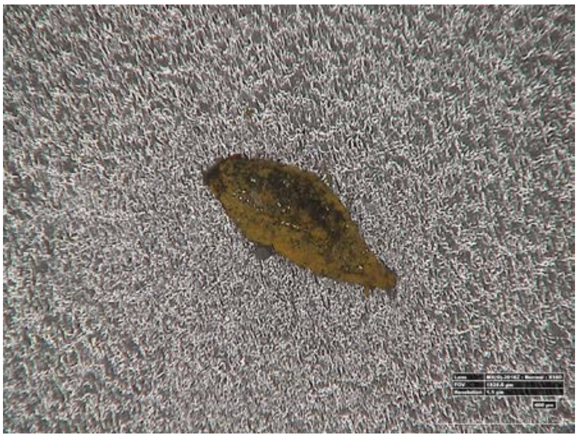


Figure 5.7. *Sample S8: spangle fragment with orange powdery substance. Hirox, X160.*

5.3.8. Sample 9

Sample S9 (Figure 5.8) is a cross section of a spangle, belonging to loose fragments of the tablecloth (6263-035). It was taken after conducting the first session of SEM-EDX, in order to further investigate the high copper content of the first analysed spangle (sample S5). The spangle was sectioned and polished in the same manner as sample S5.

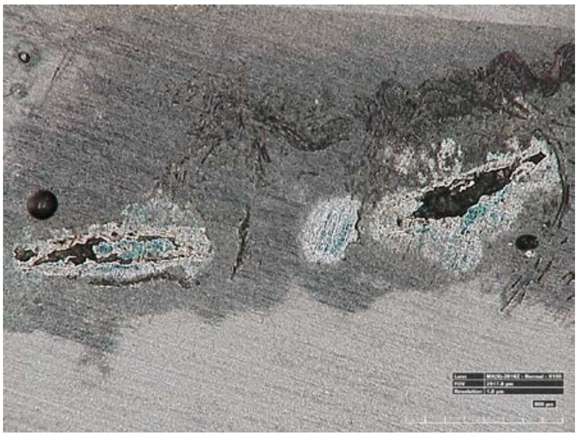


Figure 5.8. *Sample S9 : spangle. Hirox, X160.*

5.3.9. Summary of sampling

In total, nine samples were analyzed, representing all objects, except the mirror. Where possible, the samples were chosen to represent both the surface and the cross-sectional area of different metalwork types. The summary of all samples is given in Table 5.1.

Sample	Metalwork type	Object	Specification / Point of interest
S1	Rectangular wires	Loose fragment	Surface; concretion layer, possible gilding
S2	Metal strips	Tablecloth fragment	Cross-section; fragment of a spun strip
S3	Rectangular wires	Clutch purse	Cross-section; Heavily corroded, gilding
S4	Round wires	Clutch purse	Cross-section; two wires, concretion layer
S5	Spangles	Tablecloth fragment	Cross-section; Heavily corroded
S6	Rectangular wires	Loose fragment	Cross-section; coil, mild degradation
S7	Metal strips	Tablecloth fragment	Surface; mineralization, minimal deformation
S8	Spangles	Toiletry brush	Surface; Orange powdery substance
S9	Spangles	Tablecloth fragment	Cross-section; heavily corroded; copper core

Table 5.1. *Summary of samples taken.*

6. Results

The current chapter presents the results of optical examination and scientific analysis. The section *Visual analysis* contains the outcome of visual and microscopic inspection of different types of metalwork found on the five objects and presents it in the form of photos and microscopic Hirox images. The section *Analytical Research* contains results of the analysis of physical samples with SEM-EDX, which was the main scientific research method in this research. All results are discussed further in Chapter 7 - (Discussion) where previous research projects and historical sources are consulted in the context of the obtained results.

6.1. Visual analysis and microscopy

6.1.1. Metal thread types

Based on preliminary microscopical analysis aiming to define metal thread types found on the objects, the metal threads were generally found to correspond with the main metal thread types listed in literature. Table 6.1 below presents a schematic illustration of the thread types detected on the objects.

Thread type	Description
 	**Spun metal strip** with an organic core. Multiple strands are usually combined.
	**Round purl or *cannetille*** - pieces of round coiled wires attached to the fabric with organic thread.

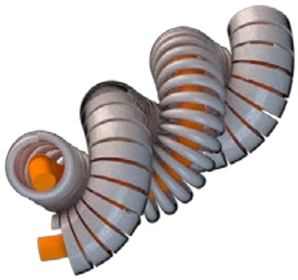
	**Flat purl or *cannetille*** - pieces of rectangular coiled wire attached to the fabric with organic thread.
	**Two purl elements** (round and rectangular), twisted.
	**Large purl of rectangular wire** *cannetille element* with twisted organic core.
	**Short pieces of round purls**, attached with organic threads.
	**Spangles or *paillettes*** - flat pieces of metal in combination with short pieces of purl (both round and rectangular wire).

Table 6.1. Types of metal thread found on BZN 17 research objects.

6.1.2. Object mapping

These visual observations served as a basis for digital mapping, carried out to aid the stylistic comparison between the five objects, visualising both similarities and differences between the decorative patterns and metal components used. All different thread types such as round and rectangular wires, flat strips and flattened disks were documented by digital mappings, designed in Adobe Illustrator CS over the existing images.

It became apparent that the decorative patterns of the set were not identical to each other but the artefacts did contain similar distinguishable decorative elements. Furthermore, these five objects showed significant similarities in the application sequence of various metal components. Figure 6.1 depicts the element that can be found as a central motif on four objects: the loose fragment, the clutch purse, the brush and the mirror. The fifth object, the tablecloth, shared similar decorative motifs with the brush and the mirror. Due to a large amount of missing fabric, it is not possible to determine whether the central pattern motive was originally found on that object.

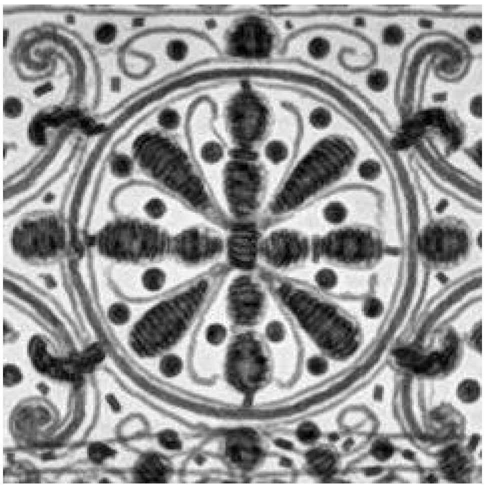


Figure 6.1. *Central decorative element occurring on four objects*[103]

Full pattern characterisation was carried out for Object 1, loose textile fragment. The object mapping is presented in Figures 6.2-6.3. The pattern is divided into eight coloured zones, each representing a certain metalwork type.[104] The digital mapping was accompanied by a legend presenting schematic renderings, modelled using 3D software (MOI3D, Autodesk 3ds Max). The renderings visualise the construction and components of each thread type (Figure 6.4).

[103] A detail from an x-ray scan. Image by Restaura conservation studio.
[104] Areas marked in white were highly damaged and metalwork detection was not possible.

Figures 6.2- 6.3. *Pattern mapping of loose textile fragment. Each colour indicates the use of a different type of metalwork.*

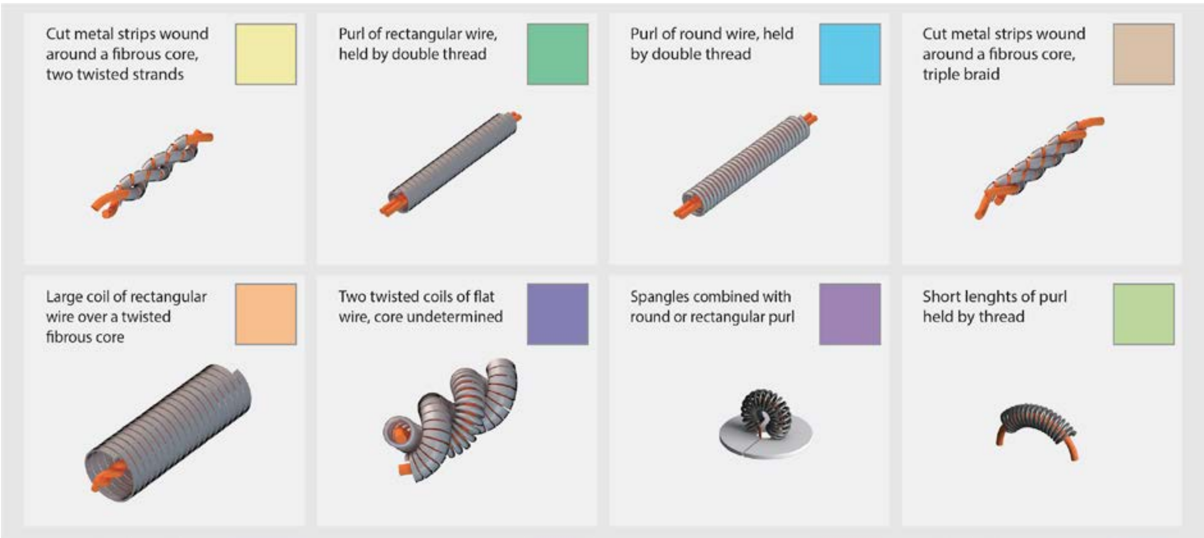


Figure 6.4. *Graphic renderings of metalwork types present on Object 1.*

6.2. Hirox

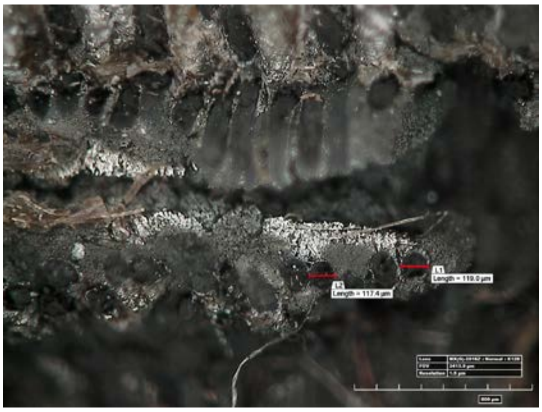
The results obtained by Hirox digital microscopy give an overview of the characteristics of the metalwork types used for the embroideries and record the general condition of the metal threads on all five objects. The same metalwork types were documented on all objects, except on the tablecloth, where metal strips and spangles were identified, but it was not clear which wire type was used for the purls. As this object remained at the storage facility, the Hirox inspection was possible only on the corresponding detached fabric fragments (6263-035).

6.2.1. Round wires

Round wires on all objects had undergone severe degradation. In several areas, the wires showed extreme brittleness and had broken off completely. These areas were used for taking measurements as the cross-sectional areas were exposed and the outline of the surface was more defined than the intact metalwork.

The wire diameter at the exposed cross-sections was measured on three objects: loose fragment, clutch and mirror. The corresponding areas on the brush (Object 3) were covered with a heavy crust and no cross-sections were accessible for measurement. The fragments of the tablecloth did not contain specimens of the round wire.

The Hirox images of the round wires on four objects are presented in Table 6.2. The measured diameters on cross-sectional areas ranged from 116-124 µm. These values are indicative as all inspected wires showed deformation due to the corrosion processes. Furthermore, the dimensions of the round wires on the brush were less precise because of the concretion layer, but general proportions of the metalwork matched other objects.

Round wires: ***Loose fragment***		
Info	***X40*** *Exposed wires split lengthways, concretion*	***X120*** *Detail, lengthways split wires, wire diameters 117 and 119 µm*

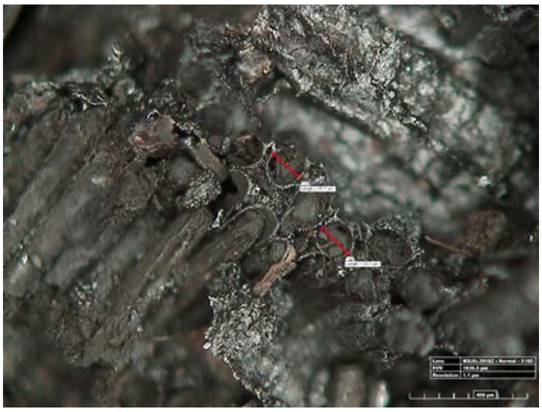
Round wires: ***Envelope clutch***		
Info	***X20*** *Less dense concretion layer, minor loss of original material*	***X40 /X100*** *Detail, exposed cross sections, wire diameters 116 and 112 µm*
Round wires: ***Brush***		
Info	***X20*** *Heavy concretion layer, irregular surface of the coils; loose sand grains*	***X80*** *Detail, heavy concretion layer, irregular surface of the coils*
Round wires: ***Mirror***		
Info	***X40*** *Severe deterioration, major loss of original metalwork*	***X160*** *Detail, split wires, exposed cross sections, wire diameters 118 and 124 µm*

Table 6.2. *Characterisation of round wires per object.*[105]

All exposed areas showed a dark grey mineralized core and several areas appeared hollow or were filled with a dark grey cotton-like substance. Apart from the dimensional similarities, the round wires on the brush appeared to have a different visual appearance. Whereas the coils on the loose fragment and purse seemed rather even, the wires on the brush had been applied in a less regular manner. No claims can be made about the method of application on the mirror because of severe deterioration.

6.2.2. Fine rectangular wires

Similar to round wires, the wires with a rectangular cross section were found on all objects except the tablecloth fragments. The coils were either covered with a bright crystalline-looking crust or showing exposed dark grey corrosion products. On close inspection, fragments with a gold-like shine were seen on the wire surfaces.

All exposed wires were mineralized and contained longitudinal crevices. In many cases, the mineralised core had delaminated or split off completely, exposing the corrosion products in the concretion layer together with gold-like patches, that mark the lower exterior surface of the original wire (Table 6.3, Rectangular wires, 160X).

Rectangular wires: ***Loose fragment***		
Info	***X20*** *Heavy deterioration: mineralised wires, remains of concretion layer*	***X120*** *Detail, longitudinal crevices, split layers, crystalline-looking concretion, width 169 µm*

[105] *All measurements are indicative. The original surface can not be located at the given magnification rate due to the concretion layer and dimensional changes caused by deterioration mechanisms.*

Rectangular wires: ***Loose fragment***		
Info	***X40*** *Nearly complete loss of original wires*	***X160*** *Detail, concretion layer, gold-like remains. widths 116 and 112 µm*
Rectangular wires: ***Envelope clutch***		
Info	***X20*** *Heavy concretion layer, compressed deposition.*	***X100*** *Detail, crystalline-looking deposition layer.*
Rectangular wires: ***Envelope clutch***		

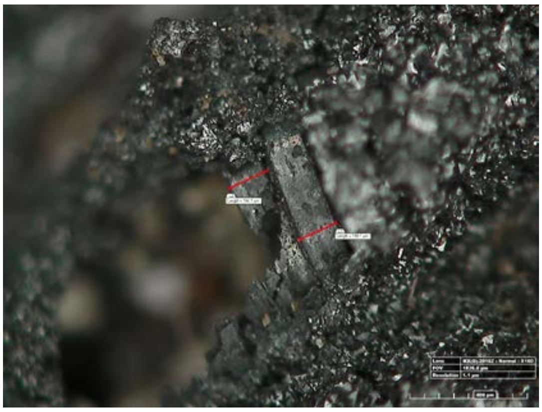
Info	***X20*** *Large coils, cross section exposed.*	***X160*** *Detail, exposed cross sections, wire width 210 and 199 µm.*
Rectangular wires: ***Brush***		
Info	***X60*** *Heavy concretion with exposed wires.*	***X160*** *Detail, exposed cross mineralised wires, wire width 144 and 139 µm.*
Rectangular wires: ***Mirror***		
Info	***X60*** *Dense concretion layer, deformation.*	***X120*** *Detail, wires, wire width 176 µm and coil diameter 707 µm.*

Table 6.3. *Characterisation of rectangular wires per object.*[106]

In addition to regular purls, rectangular wire was also used in the form of a larger coil as a central round bordering element. These areas can be seen in Table 6.3 (large coils). The wires had a visual appearance similar to those found in smaller purls, but the measurements taken at given locations indicated the use of slightly wider wires on the large coils. On the other hand, considering that the width of the rectangular wires also fluctuated within the same decorative element, an extensive measuring operation and additional scientific analysis would be needed to determine whether these wires belong to the same batch.

[106] All measurements are indicative. The original surface cannot be located at the given magnification rate due to the concretion layer and dimensional changes caused by deterioration mechanisms.

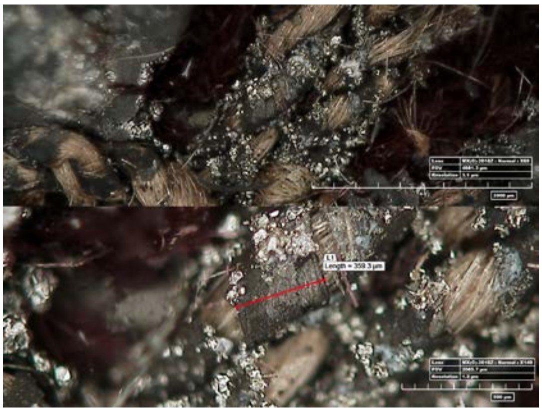
6.2.3. Metal strips

The majority of the wound metal strips had been destroyed by the corrosion process on the loose textile fragment and the mirror. The condition of these elements on all objects is presented in Table 6.4. The detached fabric fragments of the tablecloth contained strips in various conditions. On the brush, the majority of the metalwork appeared to be present, but similar to the rest of the areas, it was densely covered with a crust of corrosion products.

The clutch purse had preserved a large part of the wound strips. All components exhibited brittleness and were covered by a yellowish crystalline-looking corrosion layer, but the majority of the elements had maintained a readable form. This gave valuable insight into the original dimensions and appearance of these decorative elements.

Measurements were taken at a range of locations. All measured parts resulted in a different reading, even in areas where there was no apparent deformation. This indicated that the strips were not manufactured to an even width.

Multiple strands of spun metal strips were twisted, braided or woven. Combinations using a different number of strands can be seen in Table 6.4. This factor, however did not appear to have an independent effect on the condition of the metalwork.

Metal strips: ***Loose textile fragment***		
Info	***X40*** *Heavy corrosion, severe loss of original material.*	***X120*** *Detail, needle-like corrosion products, measured width 359 µm.*

Metal strips: ***Envelope clutch***		
Info	***X40*** *Less dense concretion layer, medium loss of original material.*	***X80*** *Detail, crystalline-looking corrosion products, measured widths 231 to 284 µm.*
Metal strips: ***Brush***		
Info	***X40*** *Heavy concretion layer, metal strip surface locally exposed; loose sand grains.*	***X140*** *Detail, heavy concretion layer, Exposed surface, measured width 281 µm.*
Metal strips: ***Mirror***		
Info	***X40*** *Severe deterioration, major loss of original metalwork.*	***X160*** *Detail, small segment of original metalwork, measured width 99 µm.*

Metal strips: ***Tablecloth fragment***		
Info	***X20*** *Severe deterioration, major loss of original metalwork.*	***X60*** *Concreation layer, nearly full loss of original material.*

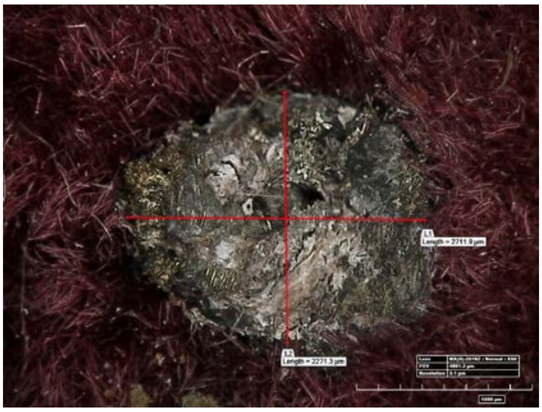
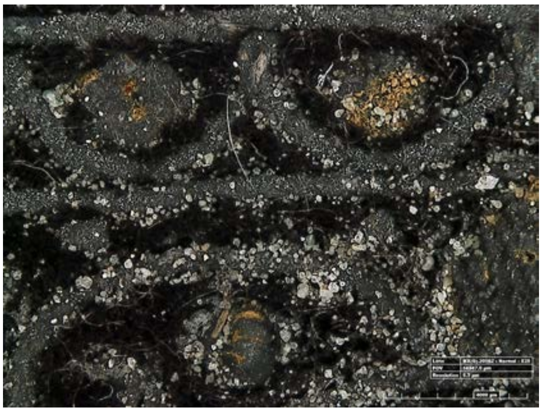
Table 6.4. *Characterisation of metal strips per object.*[107]

6.2.4. Spangles

The spangles (Table 6.5) are present on all five objects. Round, mostly heavily corroded disks are combined with small pieces of purl that resemble the previously discussed metalwork (coils of round and rectangular wire). Like the rest of the decorations, spangles as well contain both round and rectangular wire. In most cases, the spangles have undergone severe degradation, resulting in a loss of the fine purl segments. It is therefore impossible to determine the thread type on all spangles, it remains unclear whether the spangles with different purls were applied in a certain sequence.

Overall, the observed spangles showed similarities in size (approximately 2700-2800 µm. and application methods. Interestingly, the spangles on the brush (6263-112) were covered with a powdery orange substance. However, the same substance was found to a smaller extent on other areas of the object and could therefore not be directly related to the spangles.

[107] All measurements are indicative. The original surface can not be located at the given magnification rate due to the concretion layer and dimensional changes caused by deterioration mechanisms.

Spangles: **Loose textile fragment**		
Info	***X40*** *Heavy deterioration, multiple depositions. Loss of fine wires.*	***X60*** *Detail, heavy corrosion, lamination. Diameters 2271 and 2712 µm.*
Spangles: **Envelope clutch**		
Info	***X60*** *Heavy corrosion. Round wires, cross-section exposed.*	***X60*** *Rectangular wires, concretion; Gold-like remains. Diameters 2631 and 2648 µm*
Spangles: **Brush**		
Info	***X20*** *Heavy concretion layer, orange corrosion on several spangles and wire coils*	***X60*** *Detail, orange powdery corrosion, sand grains, concretion; coiled wire absent.*

Spangles: ***Brush***		
Info	***X60*** *Detail, Orange corrosion on coiled wire of the spangle; concretion.*	***X60*** *Detail, powdery orange corrosion, coiled wire absent.*
Spangles: ***Mirror***		
Info	***X60*** *Heavy concretion, spangle diameter 2789 µm, hole diameter 844 µm.*	***X140*** *Detail, Discontinuous spangle surface.*

Table 6.5. *Characterisation of spangles per object.*[108]

6.3. SEM-EDX

All samples were characterized by scanning electron microscopy-energy dispersive X-ray spectroscopy (SEM–EDX), with a primary aim of determining the material composition and observing surface features. The analysis was performed and the data interpreted by Ineke Joosten, a conservation scientist at the Cultural Heritage Agency of the Netherlands.[109] The equipment used was a NovaNanoSEM450 from FEI and an Ultradry silicon drift detector (SDD) with Pathfinder software from Thermo Scientific. The analysis were performed in high

[108] All measurements are indicative. The original surface can not be located at the given magnification rate due to the concretion layer and dimensional changes caused by deterioration mechanisms.
[109] Rijksdienst voor het Cultureel Erfgoed (RCE)

and low vacuum (50-90 pa) and an accelerating voltage of 20 keV. Backscattered electron (BSE) images were taken with the gaseous analytical detector (GAD).

6.3.1. Sample 1

Sample 1 (Figure 6.5) consisted of the mineralized conration layer that had formed around a rectangular pair of wires. The wires were completely destroyed by the corrosion process, leaving no remaining original substance other than on the interface of the remaining concretion layer. Despite the absence of the original metalwork, microscopic inspection confirmed that the remaining corrosion layer contained information about the original surface features. Therefore, the sample was analysed without being embedded.

SEM-EDX analysis showed the presence of a high amount of silver (Ag) and sulphur (S). Additionally, gold (Au) was distributed over the whole surface. The sample surface expressed the rectangular characteristics of the wire and additionally exhibited longitudinal ridges along the entire sample surface.

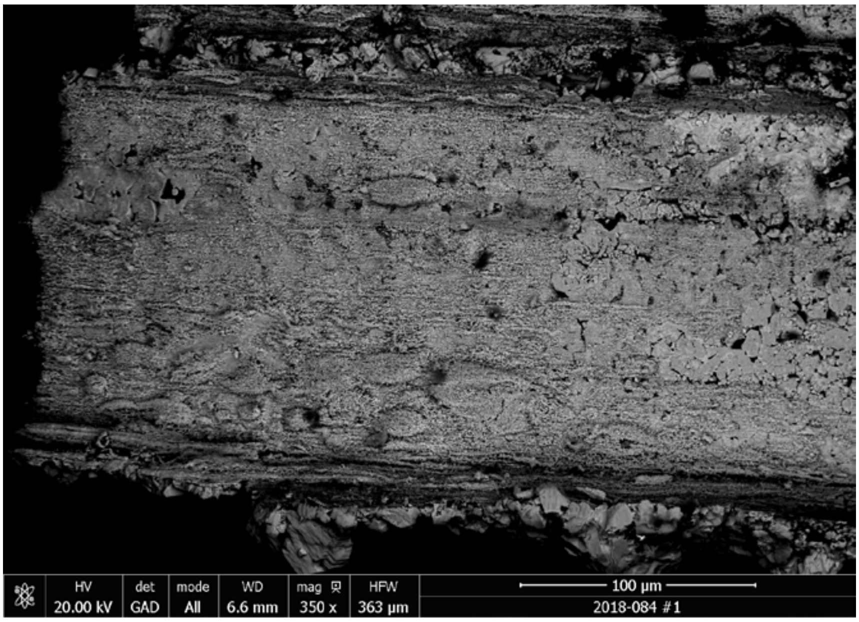
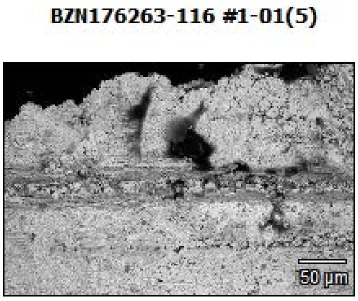


Figure 6.5. *BSE image of sample 1.*

Additionally, as seen from the elementary mapping carried out by SEM-EDX (Figures 6.6-6.7), a higher amount of gold was following the surface characteristics, being concentrated in narrow longitudinal areas.



Data Type: Atomic %
Image Resolution: 512 by 340
Image Pixel Size: 0.74 µm
Map Resolution: 512 by 340
Map Pixel Size: 0.74 µm
Acc. Voltage: 20.0 kV
Magnification: 570

Figure 6.6. *BSE image of sample 1.*

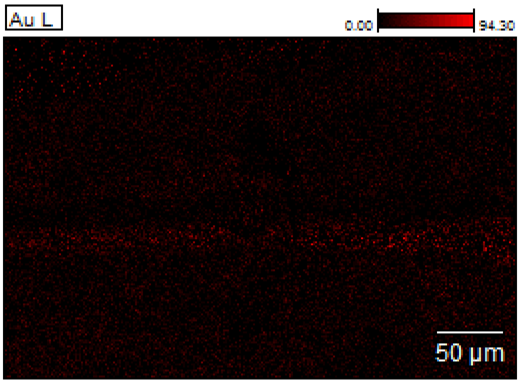


Figure 6.7. *Elemental map of sample 1, showing the distribution of gold on the surface.*

6.3.2. Sample 2

The SEM-EDX results of cross-sectional analysis of flat metal strips are shown in Figures 6.9-6.10. The main compositional constituents were silver (Ag) and sulphur (S). Gold was detected along both cross-section edges at points 2 and 4, but also further towards the centre of the sample at point 1. At point 3, no gold was found to be present. Furthermore, low amounts of copper and iron were detected at all four measured points.

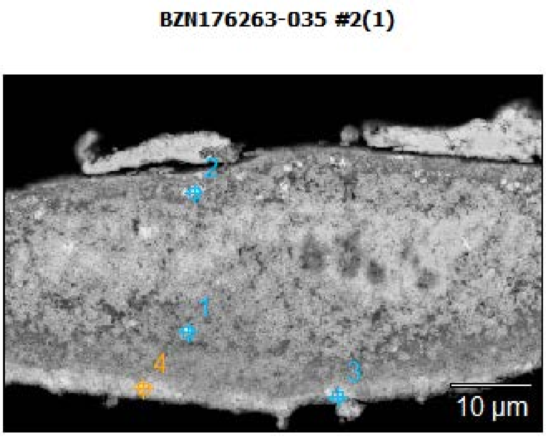


Image Name: BZN176263-035 #2(1)
Image Resolution: 512 by 340
Image Pixel Size: 0.13 µm
Acc. Voltage: 20.0 kV
Magnification: 3260

Figure 6.8. *BSE image of sample 2. The points indicate the place the analysis was performed.*

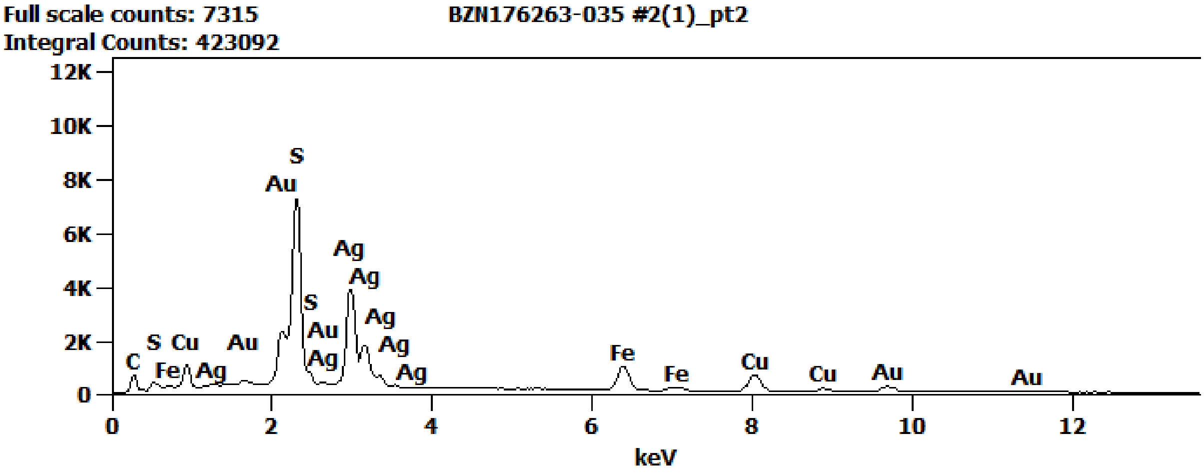


Figure 6.9. *EDX spectrum of sample 2, point 2.*

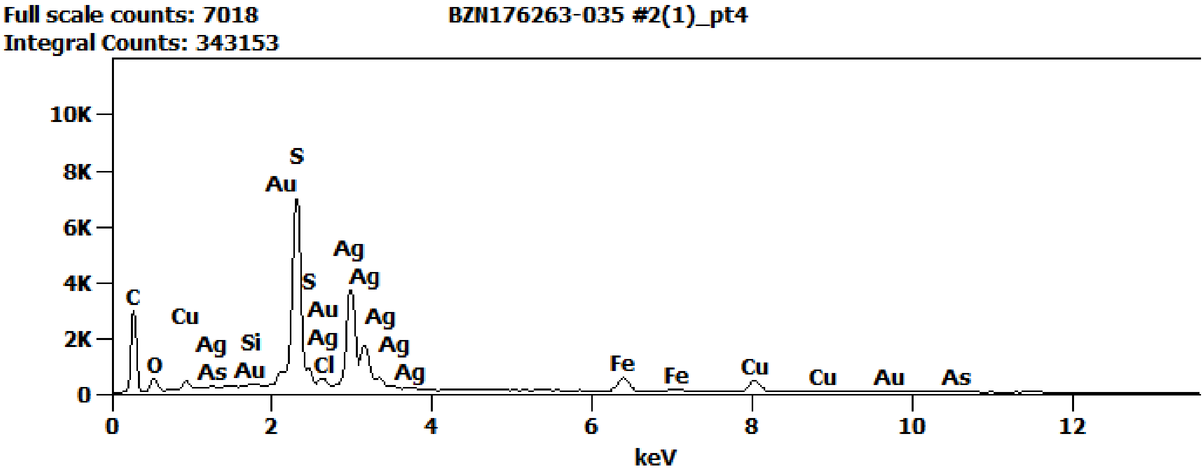


Figure 6.10. *EDX spectrum of sample 2, point 4.*

6.3.3. Sample 4

The round wires exhibited a clear outline. The bulk of corrosion products deposited on the outer surfaces was distinguishable by a denser coherent structure and a higher silver content. As seen in Figure 6.11, both cross-sections exhibit a laminated structure. Furthermore, the two cross-sections are similar in size, measuring approximately 120-140 µm.

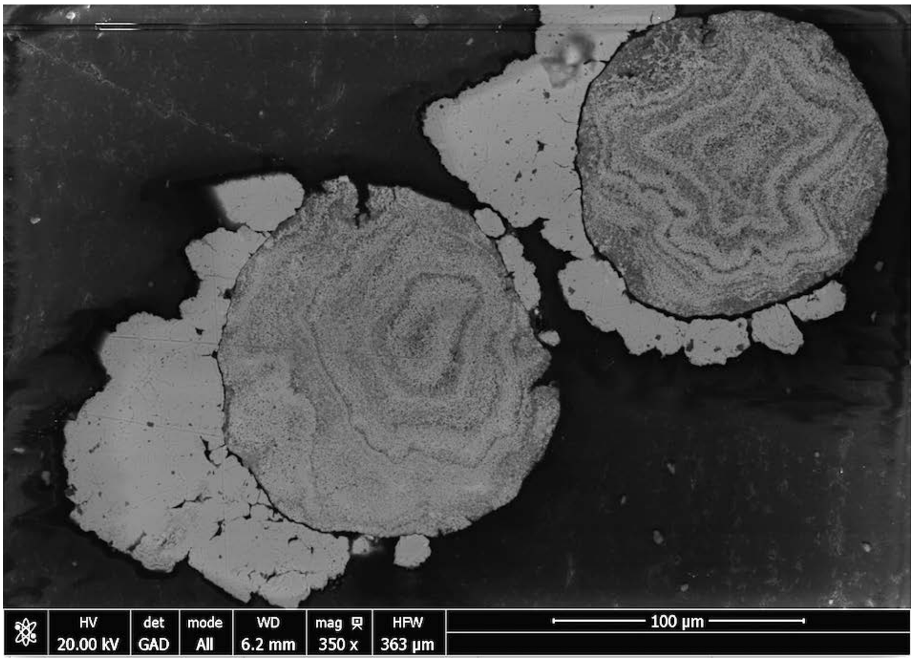


Figure 6.11. *BSE image of sample 4.*

Figures 6.12-6.16 below show the general elemental composition of the wires (Figure 6.12 area 1). Large amounts of Ag and S were detected with an addition of smaller amounts of copper and iron. To define the composition of the two alternating phases, a line scan was carried out for the cross-sectional area (For spectra, see Appendix II). The results showed that the dark grey phase was composed of higher amounts of O and Cu, whereas the light phase contained higher amounts of S and Ag. Furthermore, the surface area was analysed separately (Figure 6.14). Au was detected in the wire surface area (Point 1) and in the deposition area as well (Point 2).

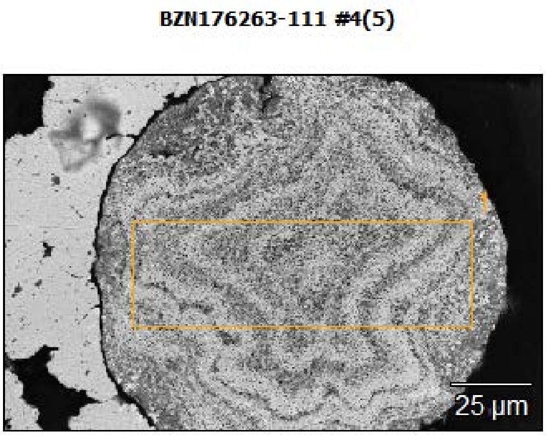


Image Name:	BZN176263-111 #4(5)
Image Resolution:	512 by 340
Image Pixel Size:	0.33 µm
Acc. Voltage:	20.0 kV
Magnification:	1304

Figure 6.12. *BSE image of sample 4. The rectangle shows the analysed area.*

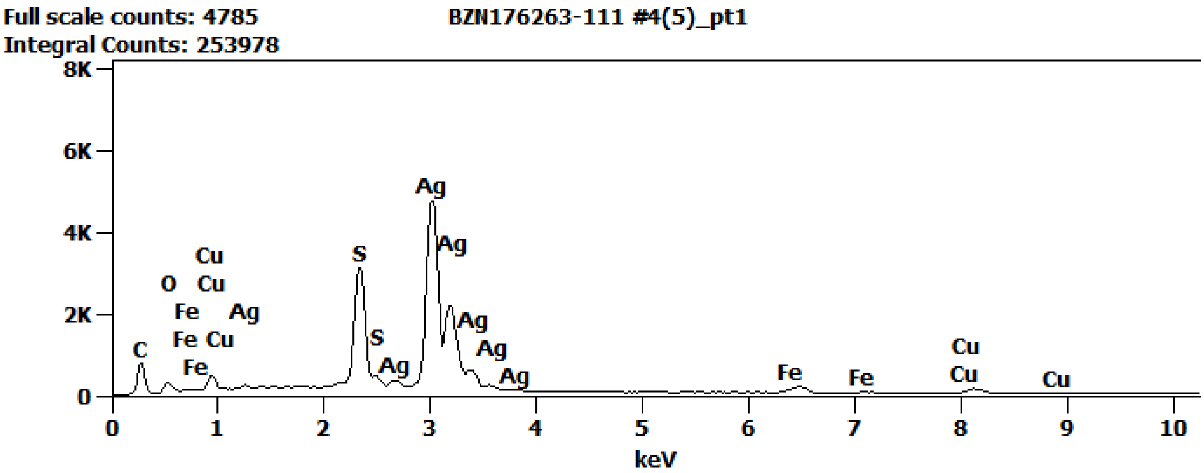


Figure 6.13. *SEM-EDX spectrum of sample 4, area 1.*

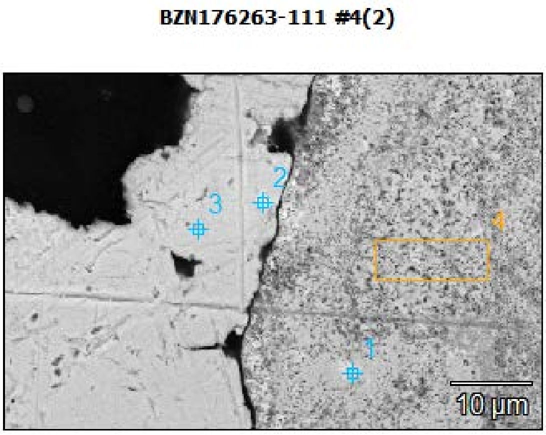


Image Name: BZN176263-111 #4(2)
Image Resolution: 512 by 340
Image Pixel Size: 0.13 µm
Acc. Voltage: 20.0 kV
Magnification: 3260

Figure 6.14. *BSE image of sample 4 (surface area analysis). The points indicate the place the analysis was performed.*

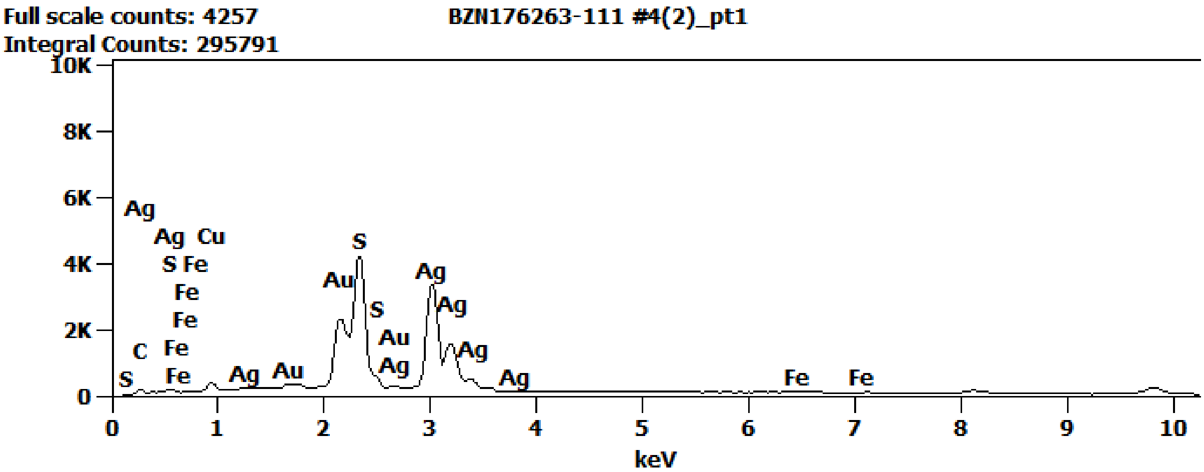


Figure 6.15. *SEM-EDX spectrum of sample 4, point 1.*

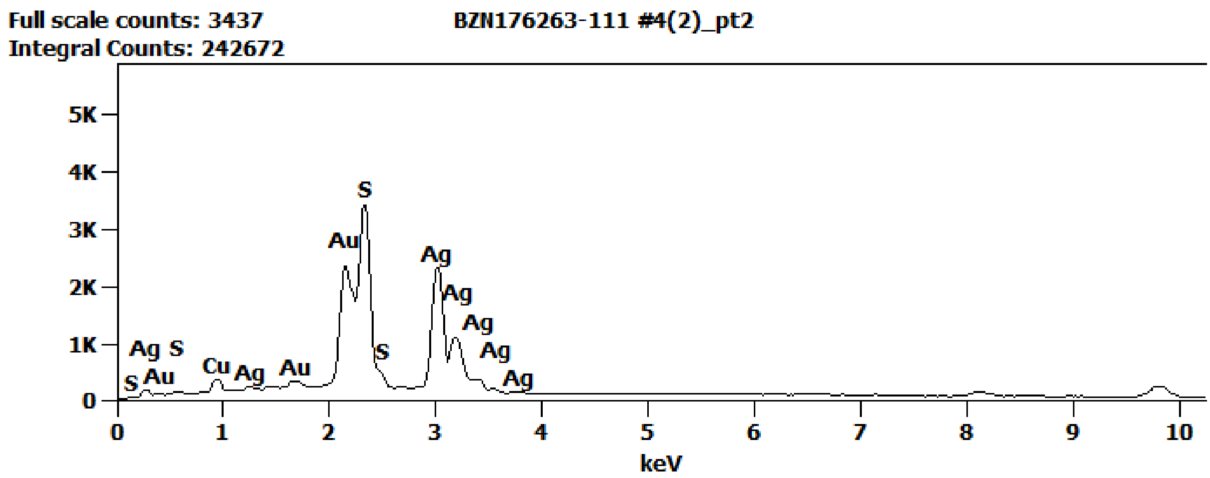


Figure 6.16. *SEM-EDX spectrum of sample 4, point 2.*

6.3.4. Sample 5

The results of the SEM-EDX analysis of the cross section of sample S5 (paillette) are shown in Figures 6.17-6.19. The SEM images in the backscattered mode reveal that the sample is composed of alternating grey and light phases. The dark areas mark the embedding resin. As seen from the spectra presented in Figures 6.18-6.19, high amounts of Cu were detected in the grey phases (points 1, 3 and 6) alongside S and lower levels of Ag. The measurement taken on the light phase (point 2) showed high amounts of Ag and S alongside a small proportion of Fe and Cu. Potential surface areas (this sample showed extensive deterioration and the surface areas were thus difficult to define) were subjected to closer inspection, and similar to other samples, Au was found to be present. (For the further spectra, see Appendix II).

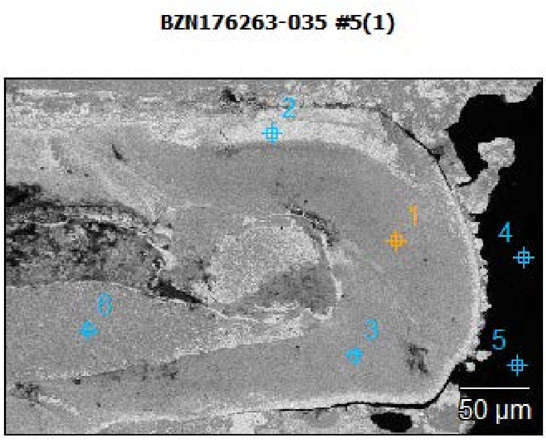


Image Name:	BZN176263-035 #2(1)
Image Resolution:	512 by 340
Image Pixel Size:	0.13 µm
Acc. Voltage:	20.0 kV
Magnification:	3260

Figure 6.17. *BSE image of sample 5. The points indicate the place the analysis was performed.*

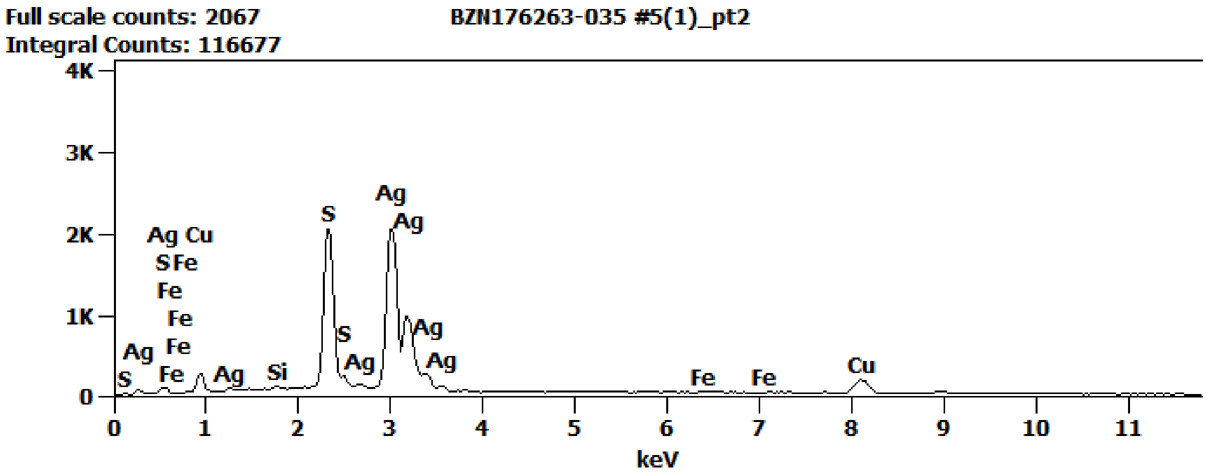


Figure 6.18. *SEM-EDX spectrum of sample 5, point 2.*

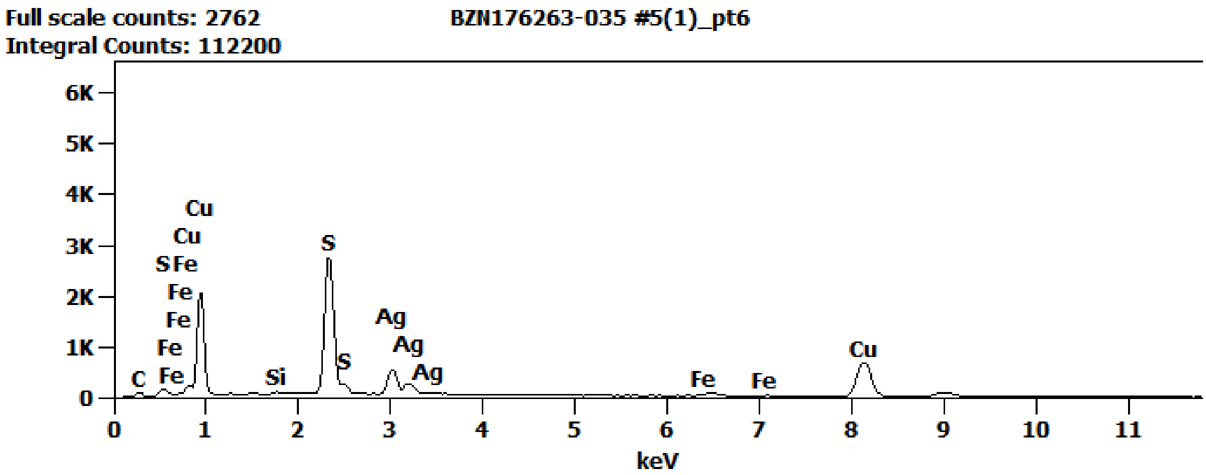


Figure 6.19. *SEM-EDX spectrum of sample 5, point 6.*

6.3.5. Sample 6

Sample 6 illustrates the shape and elemental composition of the cross-sectional area of flat wires. The markers of the original shape are seen on the BSE image on Figure 6.20. The general outline of the cross-section is rectangular and in many cases, alongside deformed portions of the wires, straight bordering areas together with original surface features, such as gilding (Figure 6.20, area 3) indicate the original shape. The pair of short sides have in all cases a rounded form and also demonstrate remains of gilding.

A clear distinction between the original core material and the deposited material is illustrated by compositional differences and dissimilar material densities. Area 1 (Figure 6.20) contains large amounts of sulphur (S) and silver (Ag), and small amounts of iron (Fe). Area 2 (Figure 6.20) shows a high amount of silver (Ag) in combination with lower amounts of sulphur (S), and no iron (Fe).

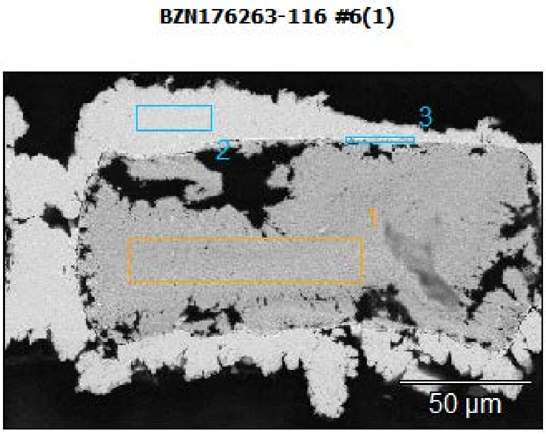


Image Name:	BZN176263-116 #6(1)
Image Resolution:	512 by 340
Image Pixel Size:	0.40 µm
Acc. Voltage:	20.0 kV
Magnification:	1059

Figure 6.20. *BSE image of sample 6 (flat wires). The rectangles indicate the points the analysis was performed.*

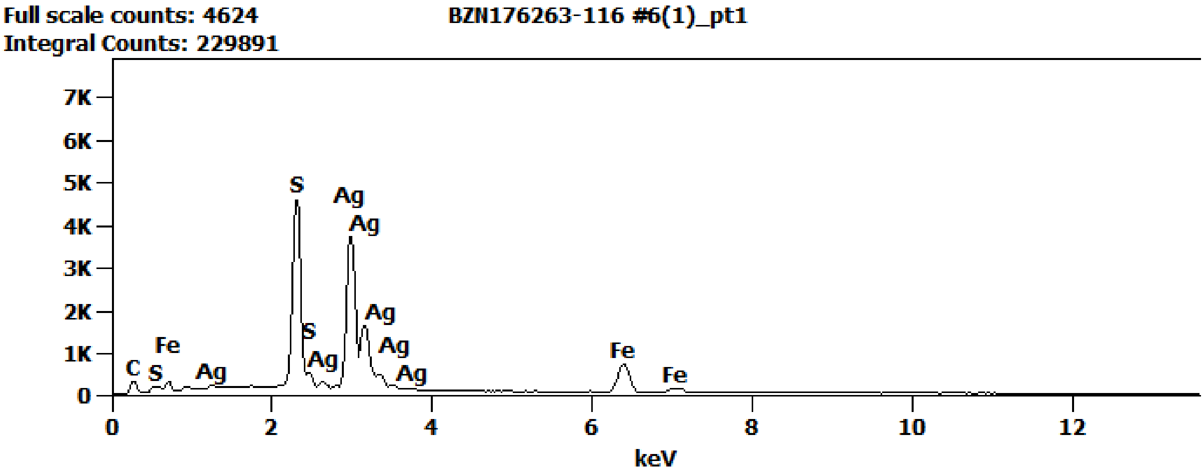


Figure 6.21. *SEM-EDX spectrum of sample 6, point 1 (general composition of the core material).*

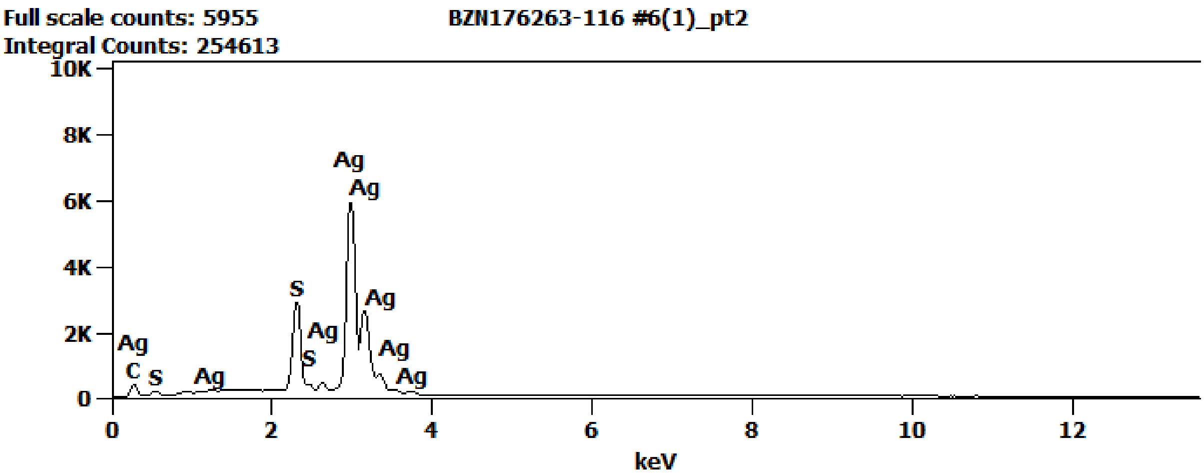


Figure 6.22. *EDX spectrum of sample 6, point 2 (general composition of the deposition layer).*

Figure 6.23 presents the magnified image of the area 3 on Figure 6.20. Gold was detected both at area 1 within the dense reposition layer and at point 2 in the wire profile area. The thickness of the gold-rich segment at area 1 measured 0.534 µm.

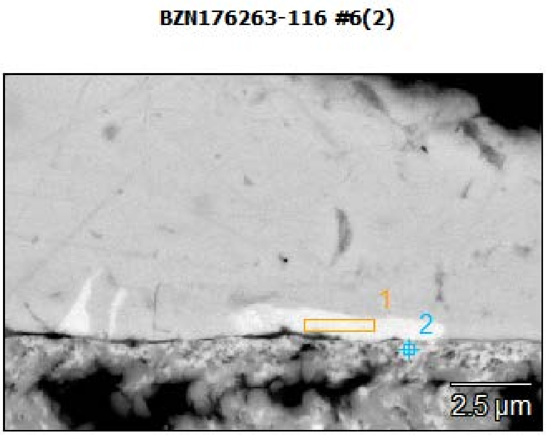


Image Name: BZN176263-116 #6(2)
Image Resolution: 512 by 340
Image Pixel Size: 0.03 µm
Acc. Voltage: 20.0 kV
Magnification: 13039

Figure 6.23. *BSE image of sample 6 (gold-rich areas). The points indicate the place the analysis was performed.*

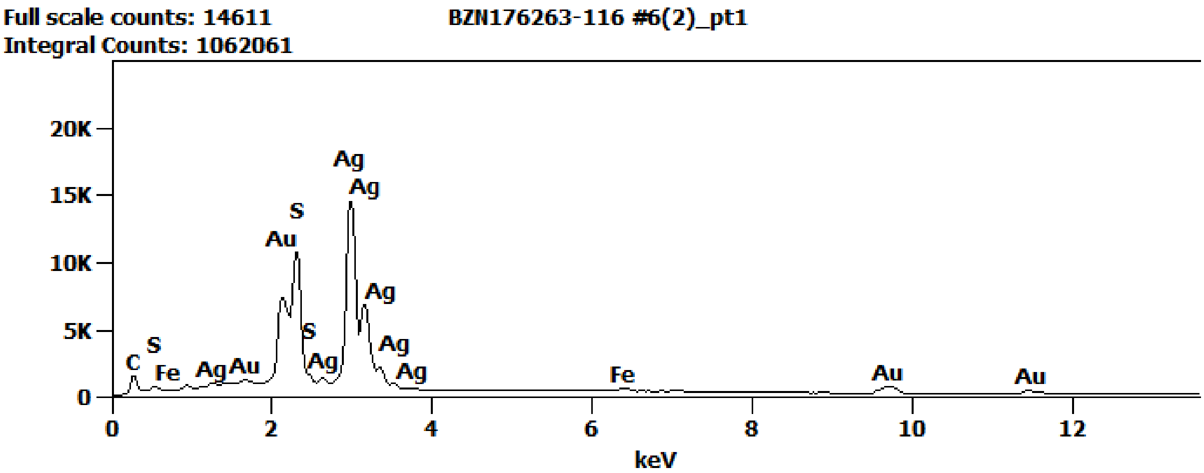


Figure 6.24. *SEM-EDX spectrum of sample 6, area 1 (gold-rich area within the deposition layer).*

6.3.6. Sample 7

Figures 6.25 and 6.26 shows characteristic surface features of the metal strips. The surface looks even and does not exhibit longitudinal crevices that were found on fine rectangular wires. Small cut-like impressions can be seen over the surface of the metalwork. The edges of the strips are well defined and exhibit rollover burrs in various locations. The majority of the surface is covered with deposition similar to other samples.

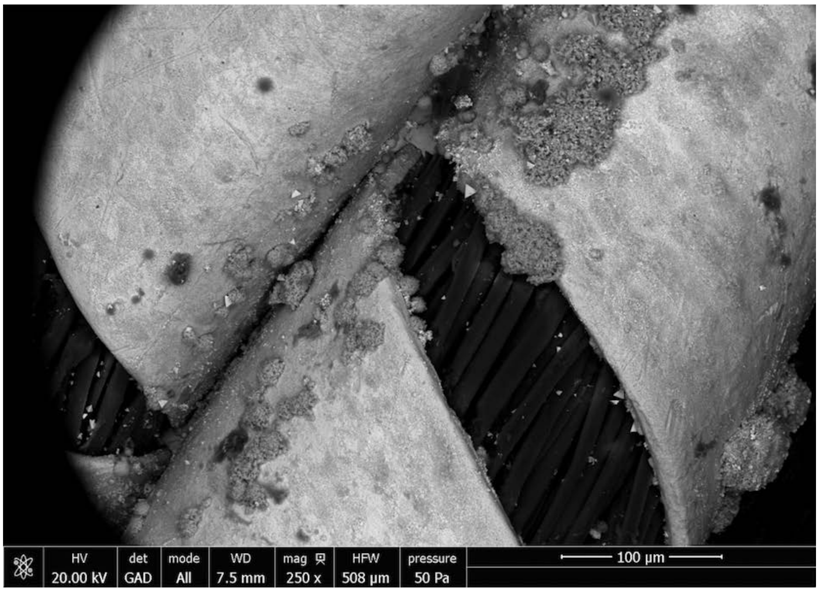


Figure 6.25. *BSE image of sample 7 (metal strips).*

Figure 6.26 presents measurements taken on the main surface area (point 1), on the edge of the strip (point 2). Interestingly, this sample contained triangular crystalline-looking particles that did not resemble any previously discussed corrosion products. Two measurements were taken at these locations (points 3 and 4).

BZN176263-035 #7(4)

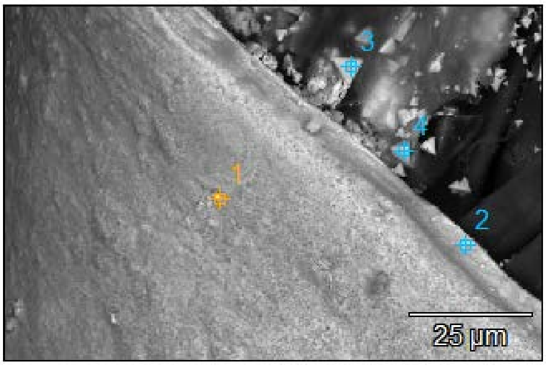


Image Name: BZN176263-035 #7(4)
Image Resolution: 512 by 340
Image Pixel Size: 0.22 µm
Acc. Voltage: 20.0 kV
Magnification: 1956

Figure 6.26. *BSE image of sample 7 (edge characteristics). The points indicate the place the analysis was performed.*

Figures 6.27 and 6.28 show that the elements detected on the main surface area were silver (Ag), copper (Cu), iron (Fe), sulphur (S), oxygen (O) and gold (Au). On the edge surface (Figure 6.26, pint 2), the same elements were detected, except gold (Au). The composition of the crystalline substance was measured at point 3, where in addition to silver and sulphur, arsenic was detected (For spectra, see Appendix II).

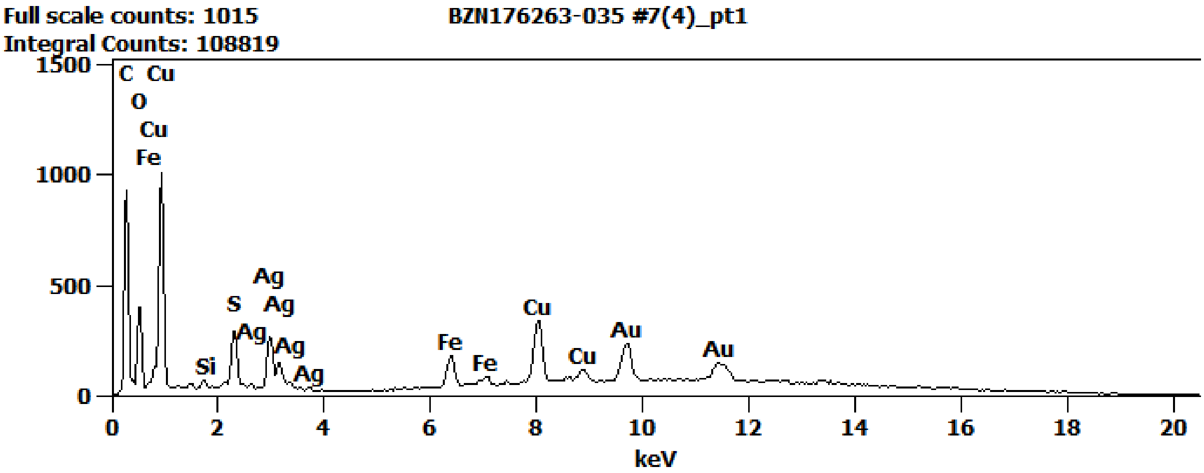


Figure 6.27. *EDX spectrum of sample 7 (flat strip), point 1 (surface).*

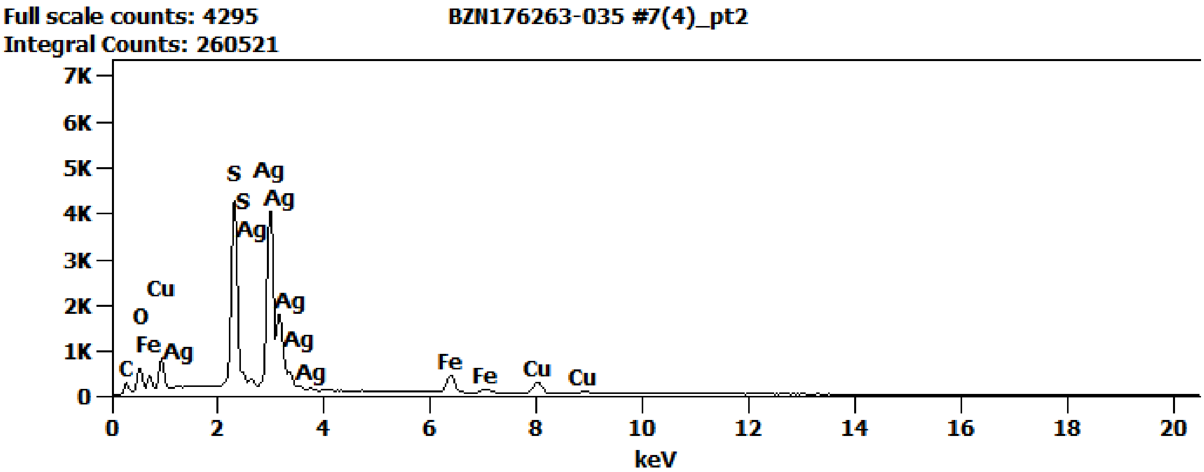


Figure 6.28. *EDX spectrum of sample 7 (flat strip); point 2 (edge).*

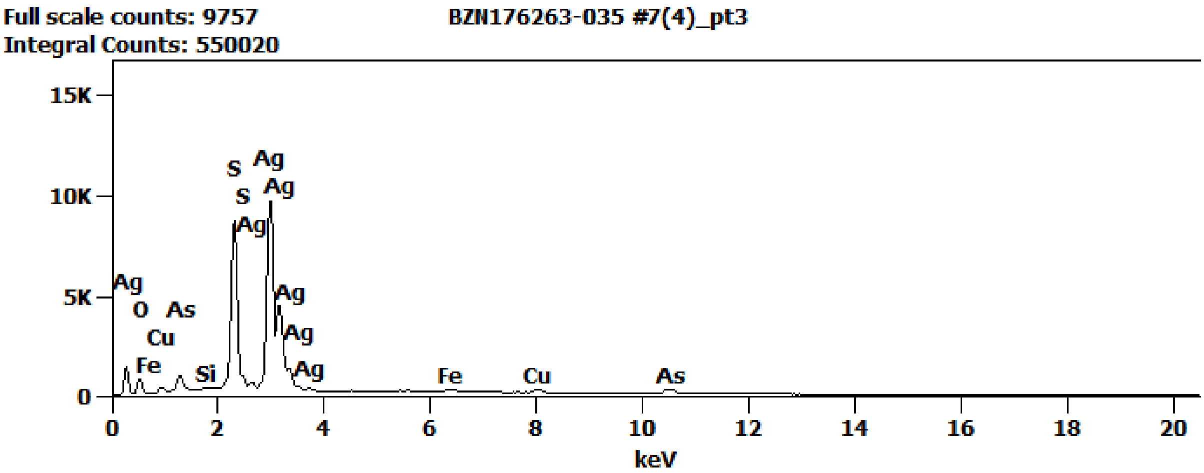


Figure 6.29. *EDX spectrum of sample 7, (flat strip) point 3 (crystalline substance).*

6.3.7. Sample 8

Figure 6.30 shows the points analysed in order to determine the composition of the orange powdery substance covering the sample surface. As seen on the spectrum (Figure 6.31), high levels of iron (Fe) and oxygen (O) were detected at points 1 and 2 in addition to lower levels of Ag, S, Cu and C.

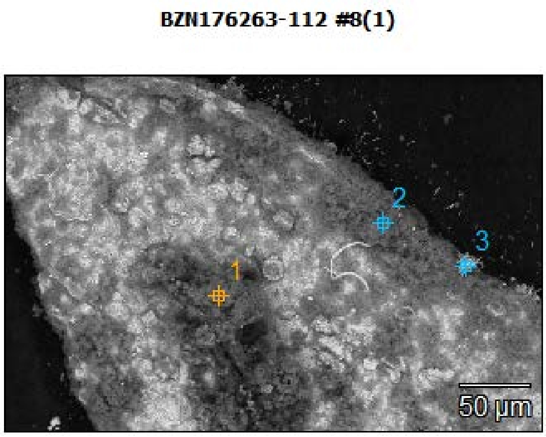


Image Name:	BZN176263-112 #8(1)
Image Resolution:	512 by 340
Image Pixel Size:	0.74 µm
Acc. Voltage:	20.0 kV
Magnification:	570

Figure 6.30. *BSE image of sample S8. The points indicate the place the analysis was performed.*

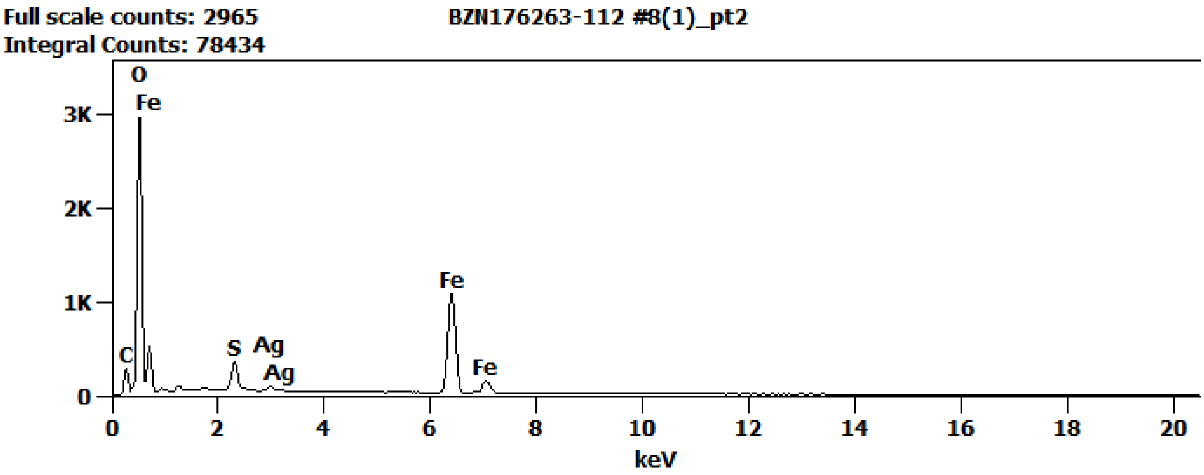


Figure 6.31. *EDX spectrum of sample 8.*

At point 3, a higher concentration of Ag was detected together with lower amounts of S, Fe and C. Additionally, in the same area, Chlorine (Cl) was found (For spectra and BSE image of the area, see Appendix II).

6.3.8. Sample 9

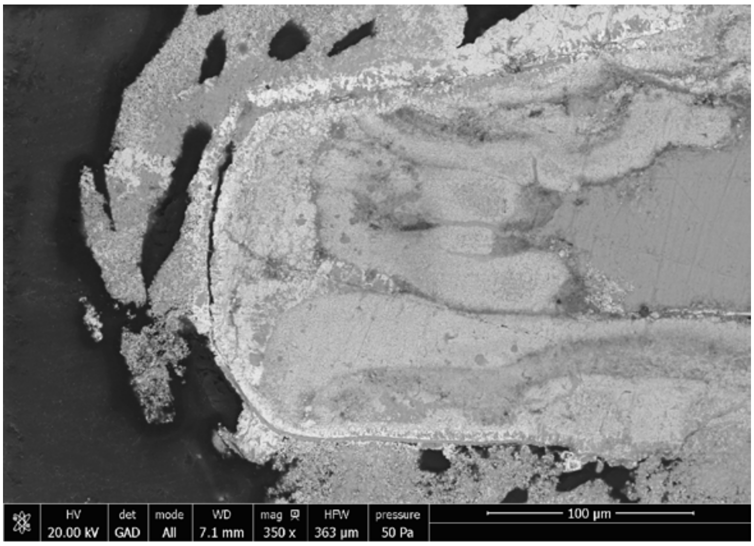
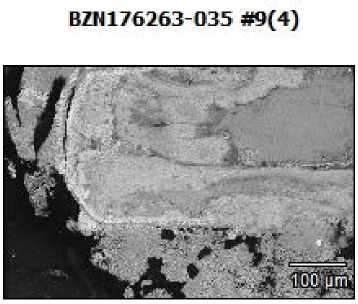


Figure 6.32. *BSE image of sample S9.*

The results of the SEM-EDX analysis of the cross section of sample S9 (paillette) are shown in Figures 6.32-6.34. Elemental mapping was carried out to visualize the distribution of elements. The mapping reveals that the sample is composed of a core with high copper content. Adjacent to the core, a silver-rich area was detected. Furthermore, gold was found in higher concentrations along the sample surface. Other minor elements found were S, Fe and Si.



Data Type: Net Counts
Image Resolution: 512 by 340
Image Pixel Size: 1.21 µm
Map Resolution: 512 by 340
Map Pixel Size: 1.21 µm
Acc. Voltage: 20.0 kV
Magnification: 350

Figure 6.33. *BSE image of sample S9.*

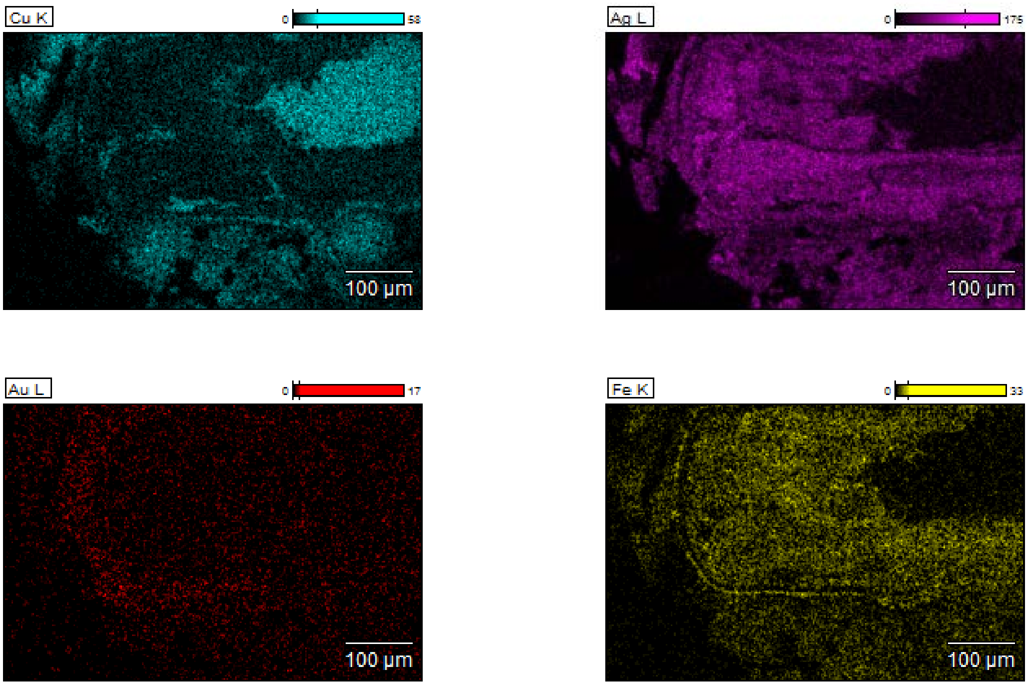


Figure 6.34. *Elemental mapping of sample S9, showing the distribution of Cu, Ag, Au and Fe.*

6.4. Summary of results

6.4.1. Appearance

Optical observation demonstrated that similar metalwork was present on all objects, with some exceptions for the tablecloth. The common elements were fine round and rectangular wires, metal strips and spangles. Purls were present on the tablecloth but further research would be needed to determine the shape of the wire. On the detached fragments of the tablecloth, only spangles and metal sprips were detected.

The condition of all objects was different. The clutch showed the best condition, whereas the loose textile fragment and the mirror had lost the majority of the metalwork. The tablecloth had lost a large proportion of the silk velvet together with the metal ornamentation and the remaining metalwork also showed significant losses. The brush had maintained most of the original elements; however, it was covered with the heaviest concretion layer of all the objects. In addition, the application of round wire purls differed from other objects by their uneven surface.

6.4.2. Chemical composition

All sampled metalwork except the spangle, showed similarities in their chemical composition. At the core of the metalwork, large amounts of silver (Ag) and sulphur (S) were found with a small addition of copper and iron. The core of the spangle contained high amounts of copper (Cu) and sulphur (S) alongside low amounts of Ag and Fe. Furthermore, gold (Au) was found to be present on all samples, with a higher concentration on the surface areas. The areas outside the core showed a high concentration of silver (Ag). Finally, one sample expressed high levels of iron (Fe) in combination with oxygen (O) and chloride (Cl), and on one sample out of eight, arsenic (As) was found[110].

7. Discussion

Determining the use of tools and manufacturing techniques of historical objects is a complex procedure. When it comes to shaping metals, different production methods might result in a similar, if not identical, end result in appearance. For example, on the basis of visual inspection alone, it can be difficult to tell the difference between cast or wrought metal artefacts. Thorough analytical examination techniques offer better insights into such complex situations. Microscopic inspection and microstructural analysis are especially useful, providing information about toolmarks or microstructural patterns referring to specific processing methods.

In this research project, scientific analysis combined with visual inspection have provided valuable information about the manufacturing methods used for the embroideries of the BZN 17 toiletry set. The next section will summarize the results in the context of literature research.

[110] The reasons of the presence of arsenic needs more research. 'Arsenic is commonly found in sulfide-bearing mineral deposits; especially with gold mineralization.' However, 'arsenosulfides, orpiment (As_2S_3), and realgar (AsS/As_4S_4) were in ancient times commonly used as a pigments and dyes (golden yellow and red accordingly)'.(Flora 2015)

7.1. Manufacturing methods for the BZN metalwork

7.1.1. Wires and strips

The embroideries of the Palmhout toiletry set are mainly composed of fine metal wires in round or rectangular form. Historically speaking, the manufacturing methods for the round wires have not undergone significant changes. It is likely for the Palmhout threads as well that cast ingots were hammered into rods and then drawn through a series of dieholes to reduce the material to the desired dimensions, as discussed in Chapter 3 (Art-technological research). Round wires showed longitudinal crevices on the surface that are likely to correspond to marks left by a drawplate hole.

The rectangular wires are likely to have been made by flattening round wires. As seen from the SEM image of the sample S6 cross section (Figure 6.20, Chapter 6), the short sides of the wire show a rounded outline. These bulging edges result from compression. If a drawplate with rectangular holes had been used (as often done nowadays), the profile would exhibit an outline where all four sides appear straight. There are longitudinal crevices running along the wire surface, but these are likely related to the toolmarks from the first stages, before the flattening procedure. Flattening of these wires was most likely carried out by rolling. The wire, held under tension while passing through the rolling mill, can be easily flattened to the desired width. As all wires of this type exhibit similar width and thickness, hammering can be ruled out as a possible method as it would result in uneven shapes and surfaces.

The metal strips described by samples S2 and S7, however, exhibit a significantly different manufacturing method than that for rectangular wires. There is evidence that these elements were cut from thin metal sheets. Firstly, the edges of the strips are burred and the width varies greatly. Secondly, the surface of the metal strips appears smooth, exhibiting small irregular dents and cuts that indicate rolling or hammering rather than drawing. Lastly, no gold was found on the edges during the SEM-EDX analysis, further supporting the argument for cutting.

The preference for using cut strips instead of flattened wires remains puzzling to conservators and art historians. Manufacturing of metal strips is much more complicated than producing flattened wires, as described in Chapter 3 (Manufacturing methods). However, it is not unusual that both types were used simultaneously. Járó describes a horse-cloth from the 16th century originating from Hungary or Spain that demonstrated the use of both types of metalwork on the same object.[111]

7.1.2. Spangles

As discussed in Chapter 3 (Art-technological research), spangles or paillettes are small disk-shaped decorative elements that were often made of flattened wires and less frequently punched out of a flat metal sheet. Slightly rounded sides and discontinuous surfaces give a reason to conclude that the spangles of the Palmhout toiletry set were made of flattened

[111] Járó 1997: 13

sections of coiled wire. Moreover, if the spangles had been punched, the gilding would not stretch over the top and bottom surfaces, as seen on sample S9.

Interestingly, the spangles demonstrated visual and compositional differences when compared to other metalwork of the toiletry set. During initial optical observation, a colour difference between the deposition layers (Figures 7.1-7.2) raised questions about possible alloy variances. This hypothesis was confirmed by the SEM-EDX analysis of the sampled spangles where EDX spectra revealed significantly high amounts of copper (see spectra of samples S5 and S9 in Chapter 6, Results).

Figures 7.1-7.2. *The colour difference between spangles and the rest of the metalwork (clutch purse, 6263-111, Hirox)*

The elemental mapping in Figure 6.34 (Chapter 6, Results) shows the elemental distribution. Thus, the core of the original wire was copper, covered with a relatively thick layer of silver and finally gilded. The use of this type of material is mentioned in several articles. However, it is significant that gilded silver was used together with elements of less precious metals on the same object. As mentioned earlier in Chapter 3 (Art-technological research), the use of non-precious metals in combination with gilding was strictly regulated, if not forbidden. This finding encourages to carry out further research on other similar historical objects, where, based merely on visual observation, different decorative elements might be assigned false materials.

7.1.3. Gilding

As discussed in Chapter 3 (Art-technological research), historical sources state that several different gilding methods were used in the 17th century. Even though the precise manufacturing methods of Palmhout wires remain unknown, the analysis of the remaining interface suggests that the method of heat welding was used on all metalwork types.

Biringuccio refers to both sheet and wire preparation methods where a thin layer of solid gold is applied either to a well-cleaned rod or sheet surface and the tightly packed metals are then heated for the fusion to take place.[112] The analysis of sample S6 (fine rectangular wires) gives evidence of the gold-rich area along the wire surface. The detected dense gold-rich area preserved in the deposition layer, which follows the cross-section outline and in its compactness, allows to suggest that the gilding was applied in the early stages on a thick silver rod and was made uniform by means of the drawing procedure. These drawn gilt wires would have then been used either in a round form or flattened by pressing, as discussed earlier in this chapter.

Manufacturing methods for gilded metal sheets have also been covered in literature, although the procedure remains less clear than that for preparing the wires. Several sources suggest that thin duplex metal sheets were manufactured solely by hammering. Considering the approximate thickness (0.05 mm) measured on sample S2, it is difficult to imagine how was it possible to achieve an even surface by this method without tearing the metal. That being said, it can be noted that gold was also detected at seemingly random locations on the interior surface of the cross sample. This could be a sign of transferring the gold further in the lattice by uneven deformation caused by hammering. However, more research is needed to clarify whether this gold residue is due to heat welding or rather to migration of gold ions during deterioration processes.

Another common gilding method used up to the late 19th century is fire gilding, which foresaw applying mercury-gold amalgam paste to the surface of a less expensive metal and heating it until the mercury had evaporated. However, as no mercury was found on the embroidered metalwork (mercury was detected only on the gilded brass hinges of the mirror by XRF analysis[113]), amalgam gilding methods can be ruled out. This is not surprising as amalgam paste would result in a relatively uneven layer of gilding when applied to smaller surfaces, such as a rod of silver. These thickened areas, in turn, would hinder the further manufacturing procedures such as drawing thin wire.

The fact that hardly any intact layers of gilding were preserved on the BZN 17 finds is not unexpected. Firstly, in marine burial conditions such as those in the Dutch Waddenzee, where the seabed is highly active,[114] the objects are expected to be subject to abrasion. But more importantly, it is the influence of underlying less noble metals that have a deteriorating effect on the gilding layers. When silver sulphides begin to form beneath gilding, the layer of gold is physically pushed off.[115] If this happened prior to the formation of the deposition layer, the only remaining marker of gilding would be the gold-rich diffusion in the outer layers of the metalwork.

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[112] Gnudi, Biringuccio, Smith 1990: 382.
[113] Personal correspondence with Arie Pappot. May 2018.
[114] Vos 2015: 30.
[115] Hallebeek 1997: 82.

7.2. Degradation processes

7.2.1. Corrosion layers on marine silver

From the conservation point of view, corrosion layers have a high significance. Archaeological finds have in most cases undergone a significant chemical and physical change. When treating these objects with the aim to improve their visual appearance, it is necessary to have a deep understanding of the stratigraphy of corrosion layers, as they often retain the original surface details of the artefact.[116]

The condition of a silver marine finding depends on many factors. The characteristics of the object such as its dimensions and microstructural features have an influence on the corrosion rate. Where larger objects are found with a metallic core preserved,, smaller objects under the same conditions may have become fully mineralized. Furthermore, the exact burial conditions undoubtedly affect the state of the objects. Even though marine objects are usually not exposed to an extensive amount of oxygen,[117] factors such as extent of water movement, microorganisms, water and seabed composition, and position of objects in relation to other shipwreck components affect corrosion of marine metal.[118]

The buildup of the corrosion layers on silver artefacts has been analysed in numerous cases. In the 1970s, the Maritime Archaeology department of the Western Australian Museum carried out excavation work on four shipwrecks of the Dutch East India Company: Batavia, Vergulde Draek, Zuytdorp and an unidentified wreck, which sank in1629, 1656, 1712 and 1810 respectively. During the project, several thousands silver coins were inspected and treated.[119] The coins were found in very different states, some still containing a metallic core while others did not. This study provides a conclusive overview of the different corrosion layers detected.

A typical silver coin from the WA Museum collection consisted of a central core of uncorroded silver. The surrounding corrosion layer consisted of silver chloride AgCl (cerargyrite), a mixed silver chloride-bromide, and silver sulphide Ag_2S (argentite). The corrosion layer was covered with a concretion layer that consisted of shell fragments, sand grains, copper compounds and iron from surrounding objects from the wreck and large amounts of silver sulphides. In other cases, local conditions had resulted in the accumulation of crystalline metallic silver in the corrosion layer.[120] A diagram presenting the general stratigraphy of corrosion layers is presented in Figure 7.3.

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[116] North, MacLeod 1987: 92.
[117] Exposure to of oxygen has an accelerated effect on corrosion, especially for archaeological objects.
[118] North, MacLeod 1987: 68.
[119] MacLeod, North 1979: 65-170
[120] MacLeod, North 1979: 65-170

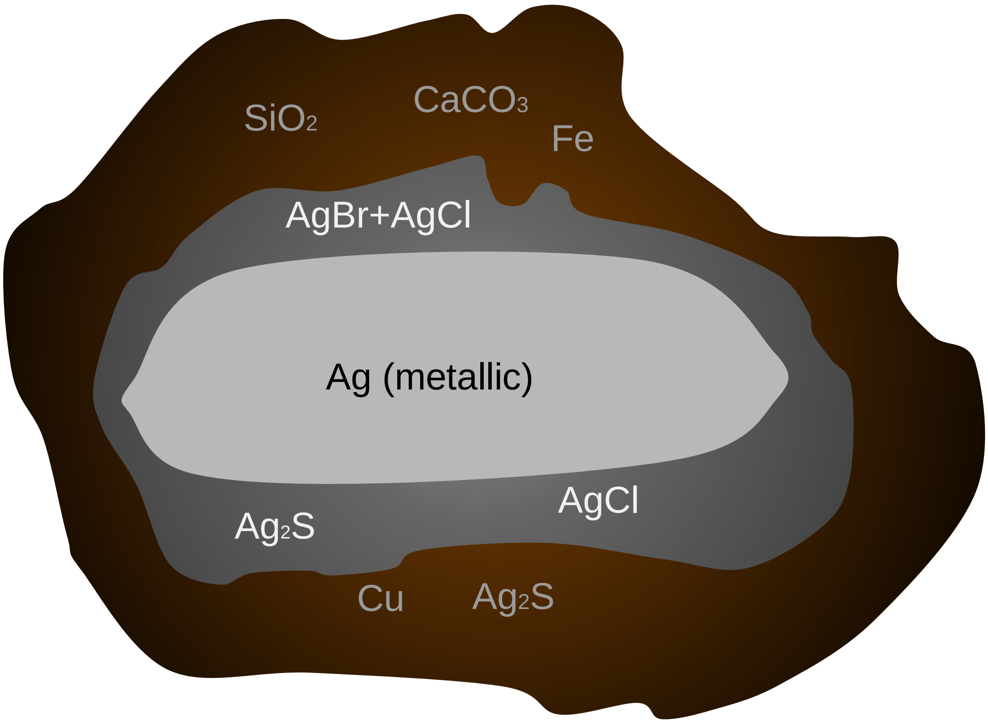


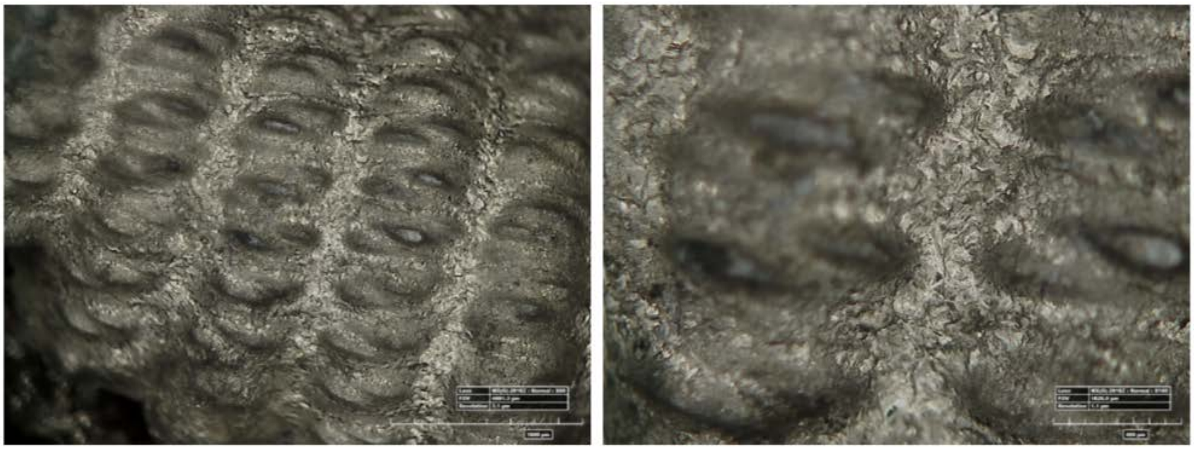
Figure 7.3. *Common build-up of corrosion layers on maritime silver.*

7.2.1.1. Redeposition phenomenon

All five objects of the Palmhout toiletry set share a common feature: the wires are partially covered by a bright dense crust that looks metallic on visual observation. On some objects, these areas are larger and easily noticeable, while on other objects the layer surface looks rougher and shows a uniform smooth crust only on smaller areas, and then only on microscopic inspection.

The clutch (Object 2) exhibits large areas that have retained the shape of the underlying metal decorations, but resemble a shaped sheet of metal rather than individual freestanding wires (Figures 7.4-7.5). On closer inspection, a coarse crystalline-looking material can be seen alongside higher surface areas where this material has been densely compressed (Figures 7.6-7.7). The marks on the higher areas indicate that pressure by direct contact with another object was applied to the surface.

Figures 7.4-7.5. *Redeposition phenomena*



Figures 7.6-7.7. *Redeposition phenomena, close-up of the crystalline-looking material.*

A pair of round wires belonging to the clutch purse, examined by SEM-EDX, shows a bulk of corrosion products with a high silver content (Figure 6.14, Chapter 6). In fact, the silver content appears even slightly higher than in the remaining wire cross-sections. It is possible that, similar to the WA Museum finds mentioned earlier in this chapter, this layer consists of a later redeposited layer of metallic silver that degraded in a later stage in comparison to the original material. As the BZN 17 collection includes numerous large silver artifacts, it is possible that this bulky deposition layer originates from the adjacent objects rather than the fine wires themselves.

7.2.1.1.1. Deposition of iron

Similar to the described deposition of silver, other foreign elements are commonly found on the surface of marine findings. This was demonstrated by orange powdery corrosion products found primarily on object 3, the brush. It was determined by SEM-EDX that this substance contained mainly iron and oxygen. Table 6.5 in Chapter 6 (Results) shows that the iron deposition products had precipitated mainly onto the round flat surfaces of the spangles but also found their way into smaller areas between the wires. This discovery is not surprising, as according to literature, the iron found on marine objects normally originates from corroding artefacts nearby. [121] Further research should investigate whether the higher copper content of the spangles, as stated earlier in Chapter 6 (Results) plays a role in the accumulation of the iron deposition mainly on these metalwork components.

7.2.2. Material properties and degradation

In addition to understanding the burial environment, the microstructure and metallurgical state of the objects play an important role in the degradation processes. For instance, if the metalwork is not annealed after final mechanical working, accelerated corrosion takes place in the microstructural areas that experienced high strain.[122] [123] In the case of drawn wires, the compressive forces result in a crystal orientation that runs parallel to the wires longitudinal axis. This method results in an even coherent microstructure compared to forged wires, where the compression is uneven and the microstructure irregular.[124] The less uniform microstructure speeds up the corrosion, a phenomenon which could be one of the factors resulting in the widespread loss of the metal strips on the objects of the toiletry set.

Microstructural corrosion is also influenced by the alloying components. For instance, interdendritic and segregation band corrosion occur due to the segregation of copper during the solidification process that, regardless of further deformation of the grain structure during manufacturing procedures, remains characteristic to the initial distribution of elements in the silver matrix during alloy formation. In this case, preferential corrosion on the grain boundaries is likely to take place.[125] This phenomenon can also be observed on the Palmhout objects. SEM-EDX analysis of sample S4, the round wire cross-section (Figure 7.8), provides an image of the elemental segregation. Darker grey phases are copper-oxygen rich areas whereas the alternating light grey phases within the round cross-section are silver and sulphur rich. In these circumstances, preferential corrosion could develop along the longitudinal copper-rich areas. This would split the wires, as seen in Figures 7.9-7.10.

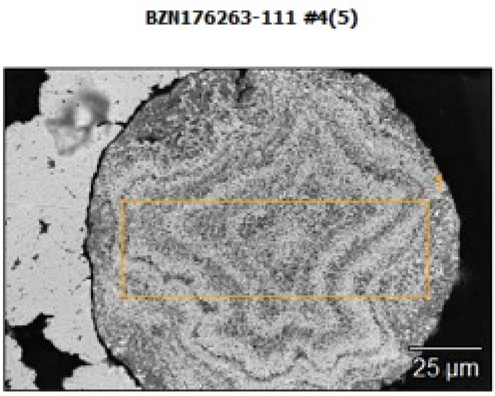


Figure 7.8. *BSE image of sample S4, demonstrating the elemental segregation phenomena.*

[121] North, MacLeod 1987: 92
[122] Work hardening and annealing is further discussed in Chapter 3 (Manufacturing methods)
[123] Wanhill 1993: 13.
[124] Untracht 2011: 150.
[125] North, MacLeod 1987: 92.

Figure 7.9-7.10. *Hirox images of splitting round wire.*

7.2.3. Further research

With the research carried out within this project, there is room for further studies to be conducted. Firstly, this research paper does not go into depth on the issue of corrosion. This area, being a major research topic on its own, is inevitable when considering the treatment options for the BZN 17 toiletry set in the future. Secondly, apart from the material perspective, further stylistic research into the 17th century embroidered artefacts could be carried out. In addition to recording the objects' function and origin, a database with the classification and categorisation of commonly occurring pattern motifs would provide useful information to link artefacts stylistically.

Another interesting topic for further research concerns manufacturing methods. Even though much is known about certain techniques, such as gilding and production of wires, much is still unknown about the method of manufacturing cut metal strips for embroidering. For example, the intended use of the cutting tools such as the ‘long flexible pair of scissors’ described in Biringuccio's manuscripts remains unclear. Furthermore, there is insufficient information on the techniques for overlapping the strips to extend them to the required length during spinning. An attempt to reconstruct the procedure of making and extending metal strips, taking into account the existing historical manuals, could shed valuable light on this matter.

8. Conclusion

The Burgzand North 17 finds have provided an extraordinary opportunity to study highly appealing historical objects. On the other hand, these shipwreck finds pose challenges to conservators looking for the best possible ways to preserve these objects. With the current research, it was possible to shed light on these questions. Thanks to the opportunity to of take samples of the metalwork, it was possible to detect the original metalwork's materials. Since the metalwork was covered by a crust of corrosion products, this information would have remained unknown if only surface analysis techniques had been used. The metalwork, found to consist mainly of gilt silver, fits in the 17th century context. The employed techniques, such as thin round drawn wires, flattened wires, cut metal strips and flat spangles, can all be found on embroidered garments from the same period.

As some techniques such as cutting the strips and flattening metal into thin large sheets are not widely covered in literature, more research into these topics is needed. Further research projects would benefit from a reconstruction studying the cutting tools and procedure and should utilise analytical methods such as SEM-EDX to analyse tool marks and surface characteristics and compare these to historical objects.

For conservators, the issue of preserving and treating delicate metal threads will still remain formidable. When two essentially different materials, textiles and metal, are combined, they are bound to affect each other, potentially resulting in an accelerated degradation process. As most conventional treatment options within each discipline rule each other out, the role of ethical considerations in conservation strategies will surely increase.

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Appendix I

Additional images

Figure I.1. *The tablecloth (Object 5) in its full size.*

Figure I.2. *The loose fragments (6263-035) belonging to the tablecloth (Object 5).*

Additional Hirox

Due to large file size, Hirox images are attached separately as digital files. Printouts will be included in the physical version of the thesis, accessible at the University of Amsterdam.

Appendix II

Additional SEM-EDX

Sample S3, a section of a single flat wire belonging to the clutch purse (6263-111) was chosen despite being heavily degraded, as it was believed to contain multiple fragments of the original gilding (Figure II.1). The sample was embedded and sectioned. The cross-section, measuring approximately 78 x 215 µm, is shown on a Hirox image (Figure II.2).

Figure II.1 - II.2. *Sample 3: flat wire prior to embedding and after polishing. (Dinolite X100, Hirox X160).*

Sample 3, the cross section of flat wire, did not show a homogenous core. Measurements were taken at different areas, confirming the presence of similar elements compared to previous samples: silver (Ag), sulphur (S), copper and gold at one measured point. No apparent gilding layer was detected on the sample.

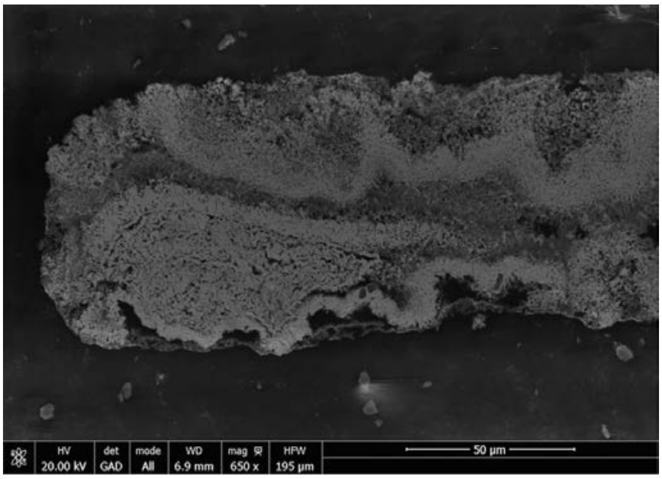


Figure II.3. *BSE image of sample 3.*

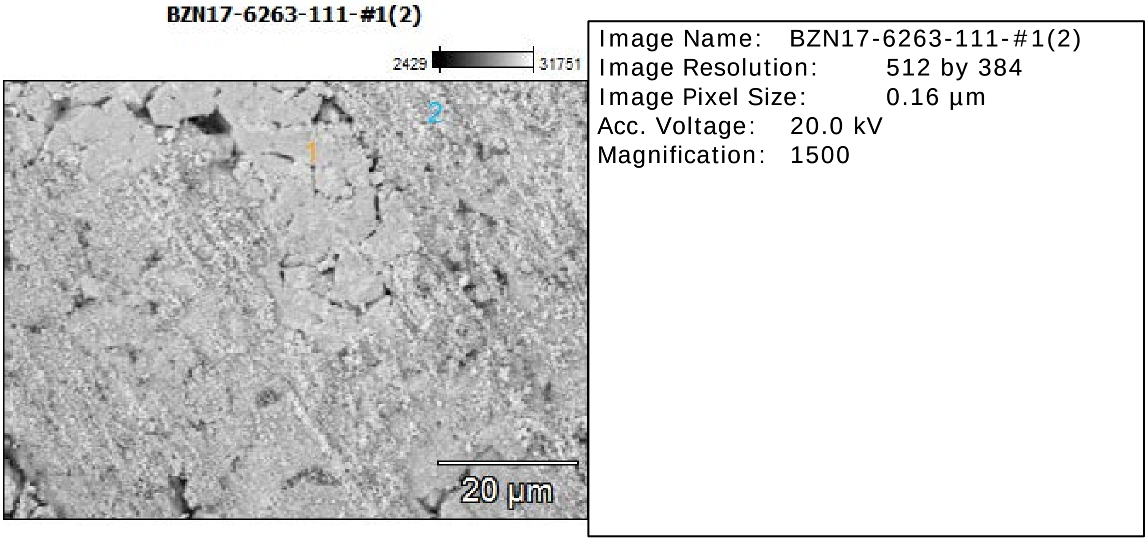


Figure II.4. *BSE image of sample 1. The points indicate the place the analysis was performed.*

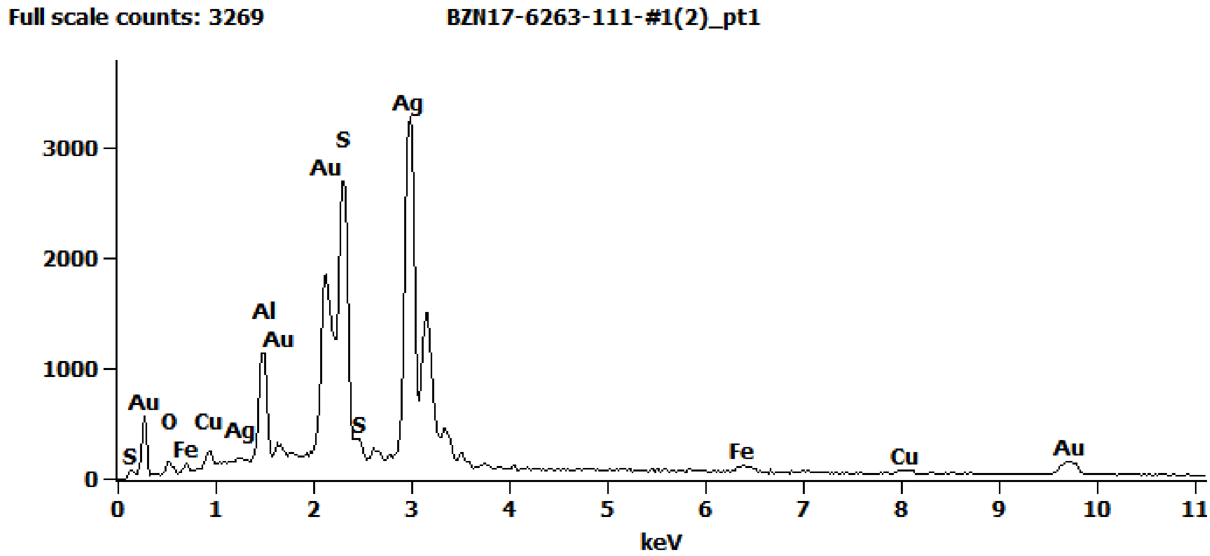


Figure II.5. *SEM-EDX spectrum of sample 1, point 1 (mineralized corrosion layer, flat wires).*

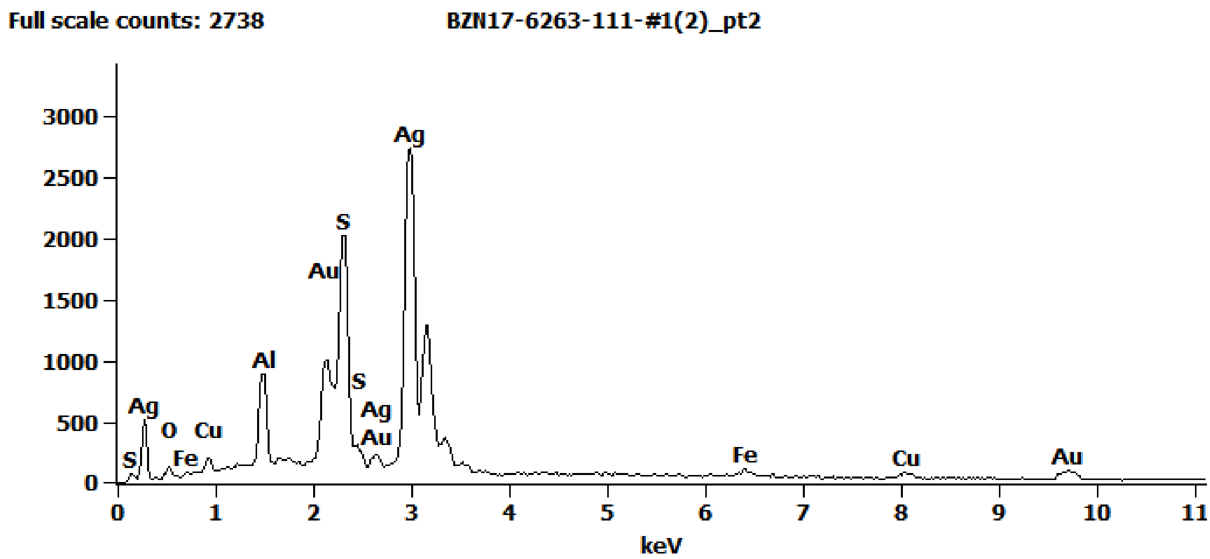
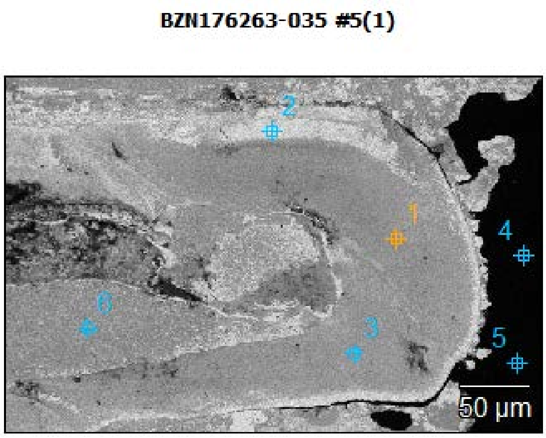


Figure II.6. *SEM-EDX spectrum of sample 1, point 2 (mineralized corrosion layer, flat wires).*



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Magnification: 3260

Figure II.7. *BSE image of sample 5. The points indicate the place the analysis was performed.*

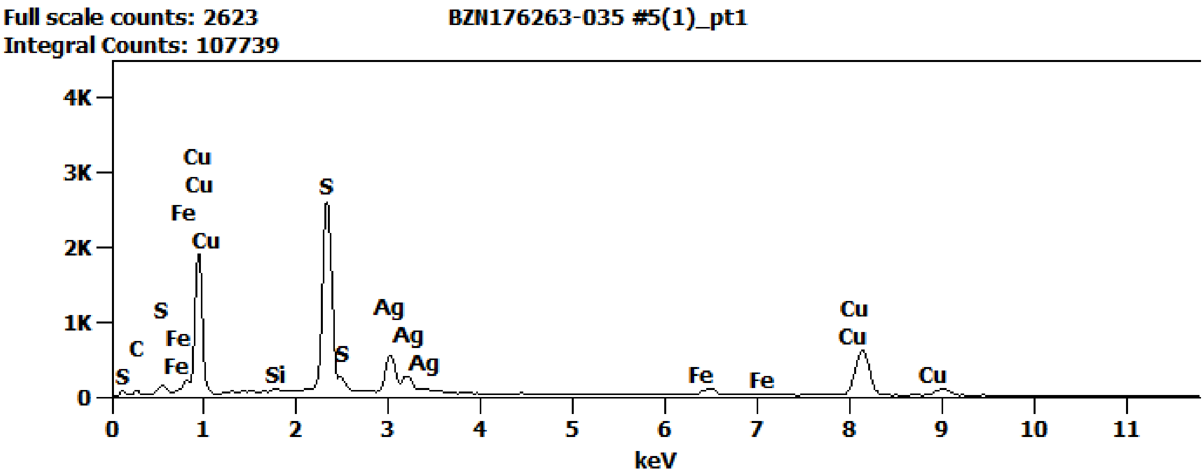
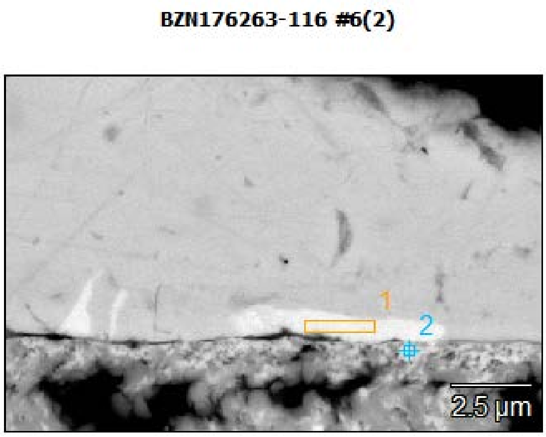


Figure II.8. *SEM-EDX spectrum of sample 5, point 1.*



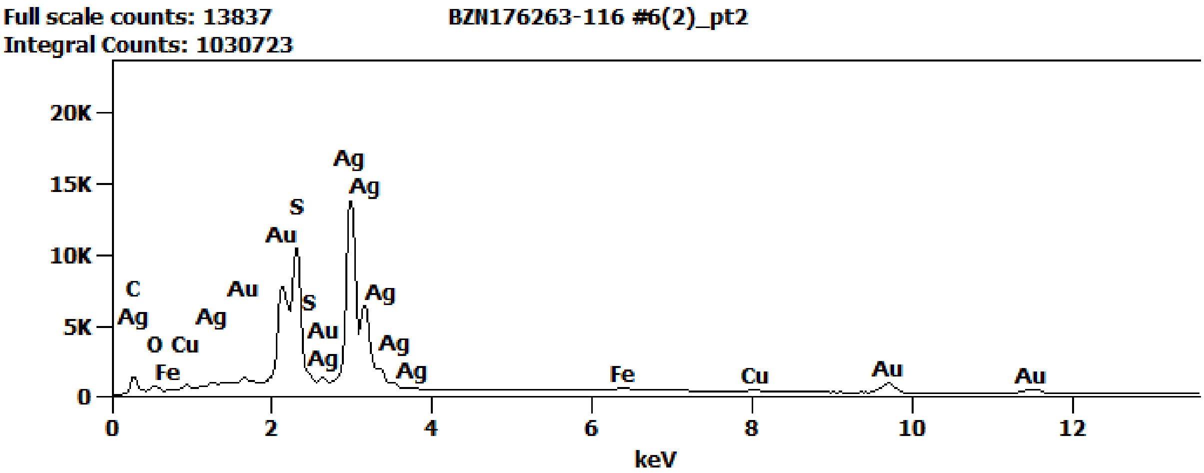
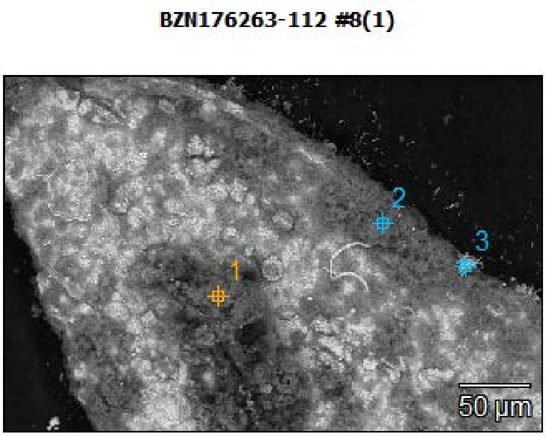


Figure II.9. *EDX spectrum of sample 6, point 2 (gold-rich area within the wire cross-section).*



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Magnification: 570

Figure II.10. *BSE image of sample S8. The points indicate the place the analysis was performed.*

Image Name: BZN176263-112 #8(2)
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Acc. Voltage: 20.0 kV
Magnification: 2445

Figure II.11. *BSE image of sample S8.*

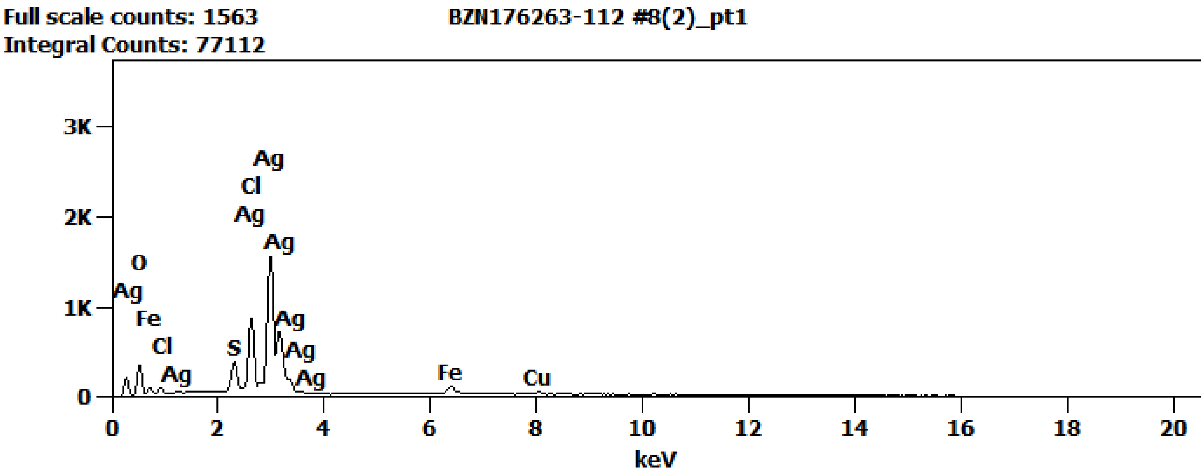

Figure II.12. *EDX spectrum of sample 8.*

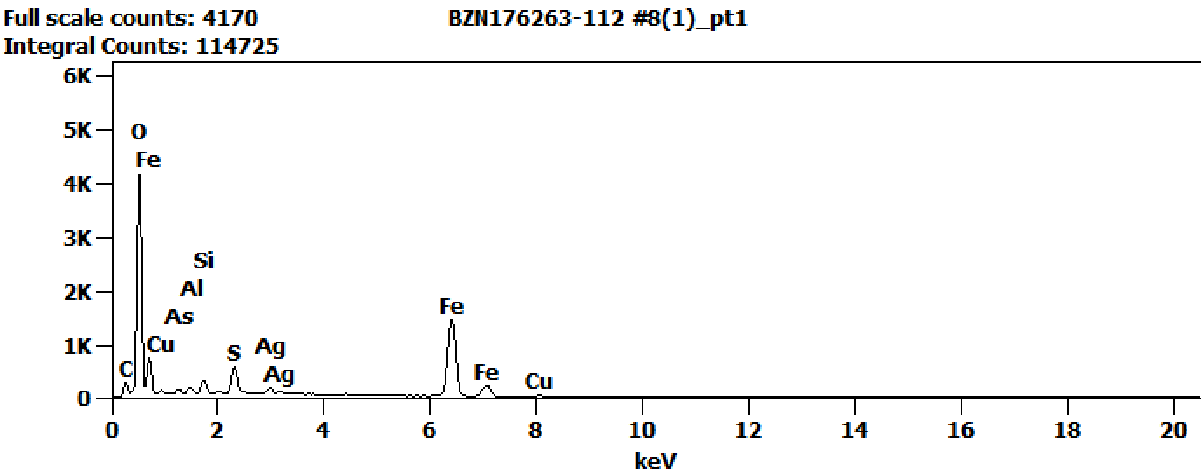

Figure II.13. *EDX spectrum of sample 8.*

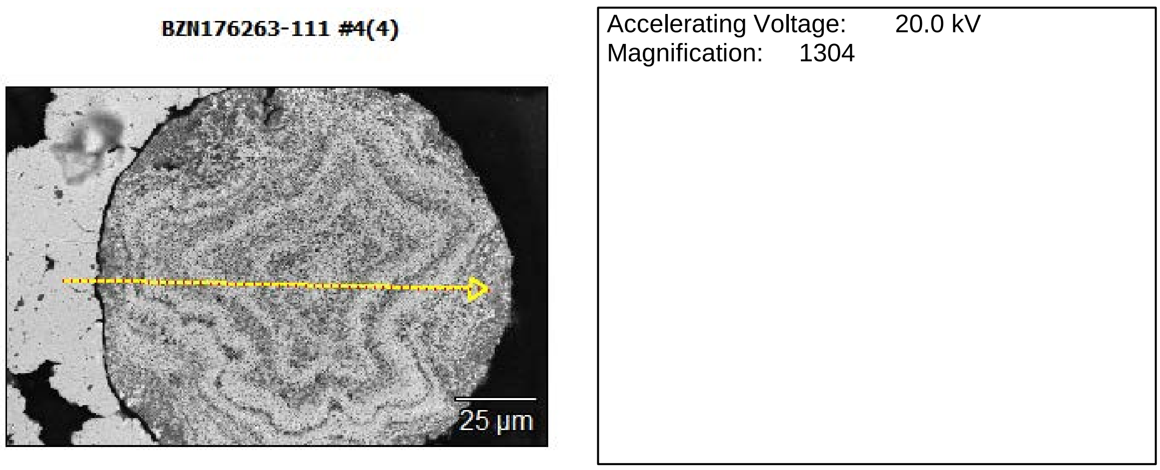

Figure II.13. *BSE image of sample 4.*

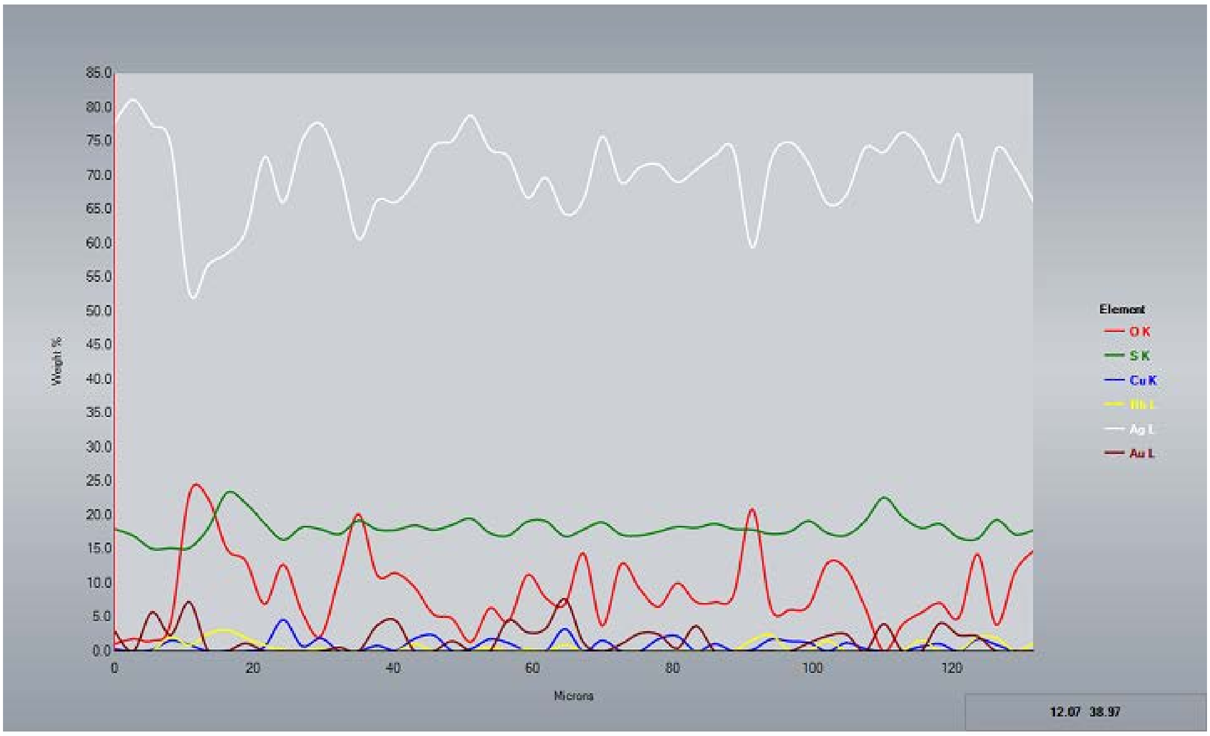

Figure II.14. *Sample 4, line scan results.*